



This electronic version (PDF) was scanned by the International Telecommunication Union (ITU) Library & Archives Service from an original paper document in the ITU Library & Archives collections.

La présente version électronique (PDF) a été numérisée par le Service de la bibliothèque et des archives de l'Union internationale des télécommunications (UIT) à partir d'un document papier original des collections de ce service.

Esta versión electrónica (PDF) ha sido escaneada por el Servicio de Biblioteca y Archivos de la Unión Internacional de Telecomunicaciones (UIT) a partir de un documento impreso original de las colecciones del Servicio de Biblioteca y Archivos de la UIT.

(ITU) للاتصالات الدولي الاتحاد في والمحفوظات المكتبة قسم أجراه الضوئي بالمسح تصوير نتاج (PDF) الإلكترونية النسخة هذه والمحفوظات المكتبة قسم في المتوفرة الوثائق ضمن أصلية ورقية وثيقة من نقلًا.

此电子版（PDF版本）由国际电信联盟（ITU）图书馆和档案室利用存于该处的纸质文件扫描提供。

Настоящий электронный вариант (PDF) был подготовлен в библиотечно-архивной службе Международного союза электросвязи путем сканирования исходного документа в бумажной форме из библиотечно-архивной службы МСЭ.



INTERNATIONAL TELECOMMUNICATION UNION

CCIR

INTERNATIONAL
RADIO CONSULTATIVE
COMMITTEE

RECOMMENDATIONS AND REPORTS OF THE CCIR, 1982

(ALSO QUESTIONS, STUDY PROGRAMMES,
RESOLUTIONS, OPINIONS AND DECISIONS)

XVth PLENARY ASSEMBLY
GENEVA, 1982

VOLUME X — PART 1

BROADCASTING SERVICE (SOUND)



Geneva, 1982



INTERNATIONAL TELECOMMUNICATION UNION

CCIR

INTERNATIONAL
RADIO CONSULTATIVE
COMMITTEE

RECOMMENDATIONS AND REPORTS OF THE CCIR, 1982

(ALSO QUESTIONS, STUDY PROGRAMMES,
RESOLUTIONS, OPINIONS AND DECISIONS)

XVth PLENARY ASSEMBLY
GENEVA, 1982

VOLUME X — PART 1

BROADCASTING SERVICE (SOUND)



Geneva, 1982

ISBN 92 61 01481 x

**PLAN OF VOLUMES I TO XIV
XVTH PLENARY ASSEMBLY OF THE CCIR**

(Geneva, 1982)

VOLUME I	Spectrum utilization and monitoring.
VOLUME II	Space research and radioastronomy.
VOLUME III	Fixed service at frequencies below about 30 MHz.
VOLUME IV-1	Fixed-satellite service.
VOLUME IV/IX-2	Frequency sharing and coordination between systems in the fixed-satellite service and radio-relay systems.
VOLUME V	Propagation in non-ionized media.
VOLUME VI	Propagation in ionized media.
VOLUME VII	Standard frequencies and time signals.
VOLUME VIII	Mobile services.
VOLUME IX-1	Fixed service using radio-relay systems.
VOLUME X-1	Broadcasting service (sound).
VOLUME X/XI-2	Broadcasting-satellite service (sound and television).
VOLUME XI-1	Broadcasting service (television).
VOLUME XII	Transmission of sound broadcasting and television signals over long distances (CMTT).
VOLUME XIII	Vocabulary (CMV).
VOLUME XIV-1	Information concerning the XVth Plenary Assembly: Minutes of the Plenary Sessions. Administrative texts. Structure of the CCIR. Lists of CCIR texts.
VOLUME XIV-2	Alphabetical index of technical terms appearing in Volumes I to XIII.

All references within the texts to CCIR Recommendations, Reports, Resolutions, Opinions, Decisions, Questions and Study Programmes refer to the 1982 edition, unless otherwise noted; i.e., only the basic number is shown.

DISTRIBUTION OF TEXTS OF THE XVTH PLENARY ASSEMBLY OF THE CCIR IN VOLUMES I TO XIV

Volumes I to XIV, XVth Plenary Assembly, contain all the valid texts of the CCIR and succeed those of the XIVth Plenary Assembly, Kyoto, 1978.

1. Recommendations, Reports, Resolutions, Opinions, Decisions

1.1 *Numbering of these texts*

Recommendations, Reports, Resolutions and Opinions are numbered according to the system in force since the Xth Plenary Assembly.

In conformity with the decisions of the XIth Plenary Assembly, when one of these texts is modified, it retains its number to which is added a dash and a figure indicating how many revisions have been made. For example: Recommendation 253 indicates the original text is still current; Recommendation 253-1 indicates that the current text has been once modified from the original. Recommendation 253-2 indicates that there have been two successive modifications of the original text, and so on. Within the text of Recommendations, Reports, Resolutions, Opinions and Decisions, however, reference is made only to the basic number (for example Recommendation 253). Such a reference should be interpreted as a reference to the latest version of the text, unless otherwise indicated.

The tables which follow show only the original numbering of the current texts, without any indication of successive modifications that may have occurred. For further information about this numbering scheme, please refer to Volume XIV-1.

1.2 *Recommendations*

Number	Volume	Number	Volume	Number	Volume
48, 49	X-1	374-376	VII	485, 486	VII
80	X-1	377-379	I	487-494	VIII
100	I	380-393	IX-1	496	VIII
106	III	395-405	IX-1	497	IX-1
139, 140	X-1	406	IV/IX-2	498, 499	X-1
162	III	407-412	X-1	500, 501	XI-1
182	I	414-416	X-1	502-505	XII
205	X-1	417, 418	XI-1	508	I
214-216	X-1	419	XI-1	509-511	II
218, 219	VIII	422, 423	VIII	513-517	II
239	I	428	VIII	518-520	III
240	III	430, 431	XIII	521-524	IV-1
246	III	433	I	525-530	V
257	VIII	434, 435	VI	531-534	VI
265, 266	XI-1	436	III	535-538	VII
268	IX-1	439	VIII	539-550	VIII
270	IX-1	441	VIII	552-554	VIII
275, 276	IX-1	443	I	555-557	IX-1
283	IX-1	444	IX-1	558	IV-1
290	IX-1	445	I	559-564	X-1
302	IX-1	446	IV-1	565	XI-1
305, 306	IX-1	447	X-1	566	X/XI-2
310, 311	V	450	X-1	567-572	XII
313	VI	452, 453	V	573, 574	XIII
314	II	454-456	III	575	I
326-329	I	457, 458	VII	576-578	II
331, 332	I	460	VII	579, 580	IV-1
335, 336	III	461	XIII	581	V
337	I	463	IX-1	582, 583	VII
338, 339	III	464-466	IV-1	584-591	VIII
341	V	467, 468	X-1	592-596	IX-1
342-349	III	469-472	XI-1	597-599	X-1
352-354	IV-1	473, 474	XII	600	X/XI-2
355-359	IV/IX-2	475, 476	VIII	601, 602	XI-1
362-364	II	478	VIII	603-606	XII
367	II	479	II	607, 608	XIII
368-370	V	480	III		
371-373	VI	481-484	IV-1		

IV

1.3 Reports

Number	Volume	Number	Volume	Number	Volume
19	III	363, 364	VII	581	VIII
32	X-1	368, 369	I	584, 585	VIII
93	VIII	371, 372	I	587-589	VIII
106, 107	III	374-376	IX-1	599	VIII
109	III	378-380	IX-1	607	IX-1
111	III	382	IV/IX-2	610	IX-1
122	XI-1	383-385	IV-1	612-615	IX-1
137	IX-1	386-388	IV/IX-2	616, 617	X-1
176, 177	III	390, 391	IV-1	619, 620	X-1
179	I	393	IV/IX-2	622	X-1
181	I	395, 396	II	623	XII
183	III	401	X-1	624-626	XI-1
184	I	404, 405	XI-1	628, 629	XI-1
195	III	409	XI-1	630	XI-1
196	I	411, 412	XII	631-634	X/XI-2
197	III	419, 420	I	635-637	XII
200, 201	III	422	I	639	XII
203	III	430-432	VI	642, 643	XII
204-208	IV-1	434-437	III	646-648	XII
209	IV/IX-2	439	VII	651-668	I
212	IV-1	443-445	IX-1	670, 671	I
214	IV-1	448, 449	IV/IX-2	672-685	II
215	X/XI-2	451	IV-1	687, 688	II
222	II	453-455	IV-1	690	II
224	II	456	II	692-697	II
226	II	457, 458	X-1	699, 700	II
227-229	V	461	X-1	701-705	III
236	V	463-465	X-1	706-713	IV-1
238, 239	V	468	X-1	714-724	V
249-251	VI	468	XI-1	725-729	VI
252	VI(1)	469	XI-1	730-732	VII
253-255	VI	472	X-1	735-738	VII
258-260	VI	473	X/XI-2	739-749	VIII
262, 263	VI	476-478	XI-1	751, 752	VIII
265, 266	VI	481-485	XI-1	754	VIII
267	VII	488	XII	758	VIII
270, 271	VII	491	XII	760-775	VIII
272, 273	I	493	XII	778	VIII
275-280	I	496, 497	XII	779-789	IX-1
284-289	IX-1	499-501	VIII	790-793	IV/IX-2
292, 293	X-1	509	VIII	794-800	X-1
294	XI-1	516	X-1	801-806	XI-1
299-304	X-1	518	VII	807-812	X/XI-2
306	XI-1	519-526	I	814	X/XI-2
311-313	XI-1	528	I	815-823	XII
314	XII	530	I	825-842	I
319	VIII	532-534	I	843-854	II
322	VI(1)	535, 536	II	855-865	III
324-326	I	538-541	II	866-875	IV-1
327	III	542	VIII	876, 877	IV/IX-2
329	III	543-546	II	878-885	V
336	V	548	II	886-895	VI
338	V	549-551	III	896-898	VII
340	VI(1)	552-561	IV-1	899-929	VIII
342	VI	562-565	V	930-942	IX-1
345	III	567	V	943-950	X-1
347	III	569	V	951-955	X/XI-2
349	III	571	VI	956-964	XI-1
352-357	III	574, 575	VI	965-970	XII
358	VIII	576-580	VII	971	XIII

(1) Published separately.

1.3.1 Note concerning Reports

The individual footnote "Adopted unanimously" has been dropped from each Report. Reports in this volume have been adopted unanimously except in cases where reservations have been made which will appear as individual footnotes.

1.4 Resolutions

Number	Volume	Number	Volume	Number	Volume
4	VI	39	XIV-1	71	I
14	VII	44	I	72, 73	V
15	I	61	XIV-1	74, 75	VI
20	VIII	62	I	76	X-1
23	XIII	63	VI	77	XIV-1
24	XIV-1	64	X-1	78	XIII
26, 27	XIV-1	66	XIII	79-87	XIV-1
33	XIV-1	67-70	XIV-1		

1.5 Opinions

Number	Volume	Number	Volume	Number	Volume
2	I	41	XII	64	I
11	I	42, 43	VIII	65	XIV-1
13, 14	IX-1	45, 46	VI	66	III
15, 16	X-1	49	VIII	67-69	VI
22, 23	VI	50	IX-1	70-72	VII
26-28	VII	51	X-1	73	VIII
32	I	56	IV-1	74	X-1
35	I	59	X-1	75	XI-1
38	XI-1	60	XI-1	76	XIII
40	XI-1	61-63	XIV-1	77-81	XIV-1

1.6 Decisions

Number	Volume	Number	Volume	Number	Volume
2	IV-1	28, 29	VII	47-49	VIII
3-5	V	32	VIII	50	V
6	VI	33	XI-1	51	X/XI-2
9-11	VI	36	VI	52	X-1
18	XII	39-40	X-1	53, 54	I
19	XIII	41, 42	XI-1	55	IX-1
21	VI	43, 44	X/XI-2	56	I
27	I	45	III		

1.6.1 Note concerning Decisions

Since Decisions were adopted by Study Groups, use was made of the expression “Study Group . . . , Considering” and the expression “Unanimously decides”, replaced by “Decides”.

2. Questions and Study Programmes

2.1 Text numbering

2.1.1 Questions

Questions are numbered in a different series for each Study Group: where applicable a dash and a figure added after the number of the Question indicate successive modifications. The number of a Question is completed by an *Arabic figure indicating the relevant Study Group*. For example:

- Question 1/10 would indicate a Question of Study Group 10 with its text in the original state;
- Question 1-1/10 would indicate a Question of Study Group 10, whose text has been once modified from the original: Question 1-2/10 would be a Question of Study Group 10, whose text has had two successive modifications.

2.1.2 *Study Programmes*

Study Programmes are numbered to indicate the Question from which they are derived if any, the number being completed by a capital letter which is used to distinguish several Study Programmes which derive from the same Question. The part of the Study Programme number which indicates the Question from which it is derived makes no mention of any possible revision of that Question, but refers to the current text of the Question as printed in this Volume.

Examples:

- Study Programme 1A/10, which would indicate that the current text is the original version of the text of the first Study Programme deriving from Question 1/10;
- Study Programme 1C/10, which would indicate that the current text is the original version of the text of the third Study Programme deriving from Question 1/10;
- Study Programme 1A-1/10, would indicate that the current text has been once modified from the original, and that it is the first Study Programme of those deriving from Question 1/10.

It should be noted that a Study Programme may be adopted without it having been derived from a Question; in such a case it is simply given a sequential number analogous to those of other Study Programmes of the Study Group, except that on reference to the list of relevant Questions it will be found that no Question exists corresponding to that number.

References to Questions and Study Programmes within the text are made to the basic number as well as for other CCIR texts.

2.2 *Arrangement of Questions and Study Programmes*

The plan shown on page II indicates the Volume in which the texts of each Study Group are to be found, and so reference to this information will enable the text of any desired Question or Study Programme to be located.

VOLUME X

BROADCASTING SERVICE (SOUND)

(Study Group 10)

TABLE OF CONTENTS

	Page
Plan of Volumes I to XIV, XVth Plenary Assembly of the CCIR	II
Distribution of texts of the XVth Plenary Assembly of the CCIR in Volume I to XIV	III
Table of contents	VII
Index of texts deleted	XIII
Numerical index of texts	XV
Index of other CCIR texts of concern for the broadcasting service (sound)	XVII
Terms of reference of Study Group 10 and Introduction by the Chairman of Study Group 10	XXIII

Section 10A-1 – Amplitude-modulation sound broadcasting in bands 5 (LF), 6 (MF) and 7 (HF)

Rec. 447-2	Signal-to-interference ratios in sound broadcasting. <i>Definitions</i>	1
Rec. 560-1	Radio-frequency protection ratios in LF, MF and HF broadcasting	2
Report 794-1	Protection ratios in LF, MF and HF broadcasting	4
Rec. 559-1	Objective measurement of radio-frequency protection ratios in LF, MF and HF broadcasting	18
Report 457-2	Necessary bandwidth of emission in LF, MF and HF sound broadcasting	27
Rec. 597	Channel spacing for sound broadcasting in band 7 (HF)	32
Report 616-2	Practical aspects of MF broadcasting coverage	33
Rec. 598	Factors influencing the limits of amplitude-modulation sound-broadcasting coverage in band 6 (MF)	40
Rec. 561-1	Definitions of radiation in LF and MF broadcasting bands	57
Rec. 499-2	Definitions of specific field strengths and coverage area in LF, MF, HF and VHF sound broadcasting	59
Report 619	Sky-wave reception in LF, MF and HF broadcasting	61
Rec. 410	Multiple frequency use per programme in HF broadcasting	62
Rec. 411-2	Fading allowances in HF broadcasting	62
Rec. 498-1	Ionospheric cross-modulation in the LF and MF broadcasting bands	63
Report 461	Reduction of sky-wave in MF broadcasting	70
Report 516-2	Field strength resulting from several electromagnetic fields	71
Report 945	Methods for the assessment of multiple interference	75
Report 458-3	Characteristics of systems in LF, MF and HF broadcasting	83
Rec. 205-2	Synchronized transmitters in HF broadcasting	94
Report 299-3	Compatible single-sideband transmission in sound broadcasting	95
Report 401-4	Transmitting antennas in LF and MF broadcasting	99
Report 32-4	Transmitting antennas in HF broadcasting	106
Rec. 80-1	Directional antennas in HF broadcasting	109
Rec. 414	Presentation of antenna diagrams	109

VIII

	Page
Report 943	Protection of LF-MF sound-broadcasting stations against lightning 110
Report 617-2	Sound-broadcasting receivers and receiving antennas. <i>Principal characteristics for frequency planning purposes</i> 111

Section 10A-2 – Sound broadcasting in the Tropical Zone

Rec. 48-1	Choice of frequency for sound broadcasting in the Tropical Zone 117
Rec. 49	Choice of transmitter site and type of antenna for sound broadcasting in the Tropical Zone 117
Rec. 216-2	Protection ratio for sound broadcasting in the Tropical Zone 118
Report 303-2	Determination of the effects of atmospheric noise on the grade of reception in the Tropical Zone 118
Report 302-1	Interference to sound broadcasting in the shared bands in the Tropical Zone 120
Report 304-1	Fading characteristics for sound broadcasting in the Tropical Zone 130
Rec. 215-2	Maximum transmitter powers for broadcasting in the Tropical Zone 145
Rec. 214-2	Limitation of the power of transmitters in the Tropical Zone to avoid interference in the bands shared with broadcasting in the Tropical Zone 146
Rec. 139-1	Transmitting antennas for sound broadcasting in the Tropical Zone 147
Report 301-3	Transmitting antennas for sound broadcasting in the Tropical Zone 148
Rec. 140-1	Receiving antennas for sound-broadcasting reception in the Tropical Zone 153
Rec. 415-1	Minimum performance specifications for low-cost sound-broadcasting receivers 153
Rec. 416-1	Minimum performance specifications for low-cost sound-broadcasting receivers for community listening 156
Report 472-1	Single-sideband reception for re-broadcasting applications within the Tropical Zone. <i>Reduction of fading effects</i> 158

Section 10B – Frequency-modulation sound broadcasting in bands 8 (VHF) and 9 (UHF)

Report 944	Theoretical network planning 161
Report 946	Frequency-planning constraints on FM sound broadcasting in band 8 (VHF) 174
Report 947	Radio-frequency protection ratio required by FM sound broadcasting in the band between 87.5 MHz and 108 MHz against interference from D/SECAM television transmissions 176
Report 796-1	Determination of radio-frequency protection ratio for frequency-modulation sound broadcasting 179
Report 464-3	Polarization of emissions in frequency-modulation broadcasting in band 8 (VHF) 181
Report 122-3	Advantages to be gained by using orthogonal wave polarizations in the planning of broadcasting services in bands 8 (VHF) and 9 (UHF). <i>Sound and television</i> 185
Rec. 412-3	Planning standards for FM sound broadcasting at VHF 186
Rec. 450-1	Transmission standards for FM sound broadcasting at VHF 190
Report 300-5	Stereophonic broadcasting 192

Rec. 467	Technical characteristics to be checked for frequency-modulation stereophonic broadcasting. <i>Pilot-tone system</i>	198
Report 620	Compatibility of a monophonic signal obtained from a stereophonic source	199
Report 463-3	Transmission of several sound programmes or other signals with a single transmitter in frequency-modulation sound broadcasting	199
Rec. 599	Directivity of antennas for the reception of sound broadcasting in band 8 (VHF)	205
Report 795-1	Transmission of two or more sound programmes or information channels in television .	205

Section 10C — Audio-frequency characteristics of sound-broadcasting signals

Rec. 562-1	Subjective assessment of sound quality	215
Report 292-5	Measurement of programme level in sound broadcasting	218
Report 465-3	Determination of the subjective loudness of a broadcasting programme	221
Rec. 468-3	Measurement of audio-frequency noise voltage level in sound broadcasting	223
Report 798-1	Simulated programme signals	229
Report 293-5	Audio-frequency parameters for the stereophonic transmission and reproduction of sound. <i>Principal audio-frequency characteristics</i>	230
Report 797-1	Determination of the acoustical properties of control rooms and high-quality listening rooms in broadcasting	236
Report 948	Digital audio techniques for studios and quality measurement	241
Report 949	Sampling frequency for digital sound signals in broadcasting studios	242
Report 799-1	Subjective assessment of quality of sound in broadcasting using digital techniques	243
Report 953	Digital coding for the emission of high-quality sound signals in satellite broadcasting (15 kHz nominal bandwidth). [This text may be found in Part 2 of Vol. X and XI.] . . .	244

Section 10D — Recording of sound programmes

Rec. 407-2	International exchange of recorded sound programmes	245
Rec. 408-4	Standards of sound recording on magnetic tape for the international exchange of programmes	245
Report 800	Standards of sound recording on magnetic tape for the international exchange of programmes. <i>Recording-duplicating chain for the production of sound programmes</i>	247
Report 622-2	Sound recording on magnetic tape for the international exchange of programmes. <i>Use of special section for checking the technical parameters of stereophonic tapes</i>	248
Report 950	Digital recording of audio signals	249
Rec. 564	Use of magnetic tape cartridges and cassettes for sound broadcasting	250
Rec. 563	Measurement of the characteristics of sound signals recorded on magnetic tape	250
Rec. 409-3	Measurement of wow and flutter in recording equipment and in sound reproduction . .	251
Report 468-2	Methods of synchronizing various recording and reproducing systems. [This report is published in Volume XI.]	251

Section 10E — Broadcasting service (sound) using satellites. [The texts will be found in Part 2 of Vol. X and XI.]

Questions and Study Programmes, Resolutions, Opinions and Decisions

Question 44/10	LF, MF and HF sound broadcasting	253
Study Programme 44A/10	Protection ratios in LF, MF and HF broadcasting	254

	Page
Study Programme 44B/10 Minimum usable field strength in LF, MF and HF broadcasting	255
Study Programme 44C/10 Sky-wave reception in LF, MF and HF broadcasting	256
Study Programme 44D/10 Reduction of sky-wave in MF broadcasting	256
Study Programme 44E/10 Ionospheric cross-modulation — Limitation of radiated power in LF and MF broadcasting	257
Study Programme 44F/10 Coverage in LF, MF and HF broadcasting	257
Study Programme 44G/10 Transmitting antennas in LF and MF broadcasting	258
Study Programme 44H/10 Directional antennas in HF broadcasting	258
Study Programme 44J/10 Transmission of supplementary information in amplitude modulation sound broadcasting	259
Study Programme 44K/10 Single-sideband (SSB) system for broadcasting (HF)	259
Study Programme 44L/10 Synchronized transmitters in HF sound broadcasting	260
Study Programme 44M/10 Compatibility between the MF sound-broadcasting service and other services using the same band	260
Question 45/10 Sound broadcasting in the Tropical Zone	261
Study Programme 45A/10 Short-distance broadcasting in band 7 (HF) in the Tropical Zone	261
Study Programme 45B/10 Fading characteristics of sound broadcasting in the Tropical Zone	262
Study Programme 45C/10 Single-sideband reception for reduction of fading effects for re-broadcast applications within the Tropical Zone	263
Study Programme 45D/10 Determination of the effects of atmospheric noise on the grade of reception in the Tropical Zone	264
Study Programme 45E/10 Interference from other services to sound broadcasting in the Tropical Zone	264
Study Programme 45F/10 Transmitting antennas for sound broadcasting in the Tropical Zone	265
Question 46/10 Frequency-modulation sound broadcasting in band 8 (VHF)	266
Study Programme 46A/10 The use of compandor systems in frequency-modulation sound broadcasting	266
Study Programme 46B/10 Modulation level control in frequency-modulation sound broadcasting	267
Study Programme 46C/10 Polarization of emissions in FM sound broadcasting	268
Study Programme 46D/10 Stereophonic or multi-dimensional sound in frequency-modulation sound broadcasting	268
Study Programme 46E/10 Compatibility of a monophonic signal obtained from a stereophonic source	269
Study Programme 46F/10 Techniques for checking the essential characteristics of frequency-modulation stereophonic broadcasting	270
Study Programme 46G/10 Transmission of several programmes with a single transmitter in FM sound broadcasting	270
Study Programme 46H/10 Transmission of supplementary information with a single transmitter in frequency-modulation sound broadcasting	271
Study Programme 46J/10 Compatibility between VHF sound broadcasting, television and other services using the same band or adjacent bands	272

Study Programme 46K/10	Sound broadcasting in band 8 (VHF) in the Tropical Zone	272
Study Programme 46L/10	Technical bases for planning of frequency-modulation sound broadcasting in band 8 (VHF)	273
Study Programme 46M/10	Minimum usable field strength for sound broadcasting in band 8 (VHF)	273
Question 47/10	Transmission of sound and information signals accompanying the video signal in a television channel	274
Study Programme 47A/10	Transmission of two or more sound programmes and/or information channels in television	274
Study Programme 47B/10	Standards for the transmission of several sound signals in one television channel in terrestrial or satellite broadcasting	275
Question 48/10	Protection of sound-broadcasting stations against lightning	276
Question 49/10	Receivers and receiving antennas for sound broadcasting	277
Question 50/10	Audio-frequency characteristics of broadcasting signals	277
Study Programme 50A/10	Determination of the subjective loudness of a broadcasting programme	278
Study Programme 50B/10	Measurement and control of subjective loudness in broadcasting	278
Study Programme 50C/10	Subjective assessment of sound quality in broadcasting	279
Study Programme 50D/10	Determination of the acoustical properties of control rooms and high quality listening rooms in broadcasting	280
Study Programme 50E/10	Parameters and tolerance limits for the technical quality of programmes intended for international exchange	280
Question 51/10	Standards for digital techniques for sound in broadcasting	281
Study Programme 51A/10	Subjective assessment of sound quality in broadcasting using digital techniques	282
Study Programme 51B/10	Digital audio coding standards	282
Study Programme 51C/10	Digital coding in broadcasting for emission of sound signals	283
Study Programme 51D/10	Multiplexing methods for the emission of digital sound signals in broadcasting	284
Study Programme 51E/10	Methods of modulation for the emission of digital sound signals in broadcasting	284
Question 52/10	Recording of sound-broadcasting programmes for international exchange	285
Study Programme 52A/10	Standards of sound recording for the international exchange of programmes	285
Study Programme 52B/10	Sound recording using digital modulation	285
Study Programme 52C/10	Standards for automatic programming of sound-broadcasting stations. <i>Cue signals and track formats</i>	286
Question 53/10	Methods of synchronizing various recording and reproducing systems	286
Resolution 64	Determination of the noise level for sound broadcasting in the Tropical Zone	287
Resolution 76	Presentation of antenna diagrams	287
Opinion 15-3	Broadcasting in the 26 MHz band	288
Opinion 16-2	Organizations qualified to take action on sound and television recording	289
Opinion 51	Study of digital techniques by CCIR Study Groups and the CMTT	289
Opinion 59	Simulated programme signals	290
Opinion 74	Facilities for the interconnection of sound-broadcasting receivers and associated equipment	290

XII

	Page
Decision 39-1 Sound broadcasting in band 7 (HF)	291
Decision 40-1 Parameters and tolerance limits for the technical quality of programmes intended for international exchange	292
Decision 52 Reference sound-broadcasting receivers for planning purposes. (<i>AM and FM modulation</i>)	293
 Alphabetical Index of key words and terms of Vol. X	 295

**INDEX OF TEXTS WHICH HAVE BEEN DELETED AT THE END
OF THE STUDY PERIOD 1978-1982**

(In order to facilitate the retrieval of a given text, the page No. of Volume X of the XIVth Plenary Assembly, Kyoto 1978, is indicated.)

Text	Title	Page No. Vol. X (Kyoto, 1978)
Report 305-4	Calculation of field strength for sound broadcasting in the Tropical Zone	148
Report 400-3	Coverage in MF broadcasting	18
Question 28-1/10	Calculation of the field strength for a sound-broadcasting transmitter in the Tropical Zone	199
Opinion 58	Method of calculating the field strength of a sound-broadcasting transmitter in the Tropical Zone	210
Decision 38	FM sound broadcasting in band 8 (VHF) (This Decision is not mentioned in the Volume of the XIVth Plenary Assembly, Kyoto, 1978, and only appears in the Conclusions of the Interim Meeting of Study Group 10, Geneva, 1980, page 163.)	

Note. — During the study period 1978-1982, the Study Group undertook a radical rearrangement of the Questions and Study Programmes attributed to it. Some Questions were transformed into Study Programmes, others maintained or modified. Similarly, a number of Study Programmes were modified, new ones were drafted and some were transferred from one Question to another. The detailed changes are indicated at the foot of each Question or Study Programme presented to the Plenary Assembly for approval.

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

NUMERICAL INDEX OF TEXTS

	Page
SECTION 10A-1: Amplitude-modulation sound broadcasting in bands 5 (LF), 6 (MF) and 7 (HF)	1
SECTION 10A-2: Sound broadcasting in the Tropical Zone	117
SECTION 10B: Frequency-modulation sound broadcasting in bands 8 (VHF) and 9 (UHF)	161
SECTION 10C: Audio frequency characteristics of sound broadcasting signals	215
SECTION 10D: Recording of sound programmes	245
SECTION 10E: Broadcasting service (sound) using satellites	253

RECOMMENDATIONS	Section	Page	REPORTS	Section	Page
Rec. 48-1	10A-2	117	Report 32-4	10A-1	106
Rec. 49	10A-2	117	Report 122-3	10B	185
Rec. 80-1	10A-1	109	Report 292-5	10C	218
Rec. 139-1	10A-2	147	Report 293-5	10C	230
Rec. 140-1	10A-2	153	Report 299-3	10A-1	95
Rec. 205-2	10A-1	94	Report 300-5	10B	192
Rec. 214-2	10A-2	146	Report 301-3	10A-2	148
Rec. 215-2	10A-2	145	Report 302-1	10A-2	120
Rec. 216-2	10A-2	118	Report 303-2	10A-2	118
Rec. 407-2	10D	245	Report 304-1	10A-2	130
Rec. 408-4	10D	245	Report 401-4	10A-1	99
Rec. 409-3	10D	251	Report 457-2	10A-1	27
Rec. 410	10A-1	62	Report 458-3	10A-1	83
Rec. 411-2	10A-1	62	Report 461	10A-1	70
Rec. 412-3	10B	186	Report 463-3	10B	199
Rec. 414	10A-1	109	Report 464-3	10B	181
Rec. 415-1	10A-2	153	Report 465-3	10C	221
Rec. 416-1	10A-2	156	Report 468-2	10D	251
Rec. 447-2	10A-1	1	Report 472-1	10A-2	158
Rec. 450-1	10B	190	Report 516-2	10A-1	71
Rec. 467	10B	198	Report 616-2	10A-1	33
Rec. 468-3	10C	223	Report 617-2	10A-1	111
Rec. 498-1	10A-1	63	Report 619	10A-1	61
Rec. 499-2	10A-1	59	Report 620	10B	199
Rec. 559-1	10A-1	18	Report 622-2	10D	248
Rec. 560-1	10A-1	2	Report 794-1	10A-1	4
Rec. 561-1	10A-1	57	Report 795-1	10B	205
Rec. 562-1	10C	215	Report 796-1	10B	179
Rec. 563	10D	250	Report 797-1	10C	236
Rec. 564	10D	250	Report 798-1	10C	229
Rec. 597	10A-1	32	Report 799-1	10C	243
Rec. 598	10A-1	40	Report 800	10D	247
Rec. 599	10B	205	Report 943	10A-1	110

REPORTS	Section	Page	REPORTS	Section	Page
Report 944	10B	161	Report 948	10C	241
Report 945	10A-1	75	Report 949	10C	242
Report 946	10B	174	Report 950	10D	249
Report 947	10B	176	Report 953	10C	244

Note. – Questions, Study Programmes, Resolutions, Opinions and Decisions which already appear in numerical order in the table of contents, are not reproduced in this index.

**INDEX OF THE TEXTS PUBLISHED IN OTHER VOLUMES BUT
CONTAINING INFORMATION OF INTEREST
TO BROADCASTING SERVICE (SOUND)**

Text	Title	Volume
Report 657	Statistical model for the determination of band sharing criteria	I
Report 829	Calculation of the probability of interference	I
Report 659	RF-protection ratios between the FM broadcasting service and the land mobile service	I
Report 670	Worldwide minimum external noise levels, 0.1 Hz to 100 GHz	I
Recommendation 379	Identification of radio stations	I
Report 280	Identification of radio stations	I
Recommendation 328	Spectra and bandwidths of emissions	I
Report 181	Frequency tolerance of transmitters	I
Recommendation 329	Spurious emissions	I
Recommendation 331	Noise and sensitivity of receivers	I
Report 840	Degradation of maximum usable sensitivity of frequency modulation receivers operating in non-linear conditions	I
Recommendation 332	Selectivity of receivers	I
Recommendation 239	Spurious emissions from sound and television broadcast receivers	I
Report 664	Review of band utilization of frequencies from about 40 to 3 000 GHz	I
Report 841	Spectrum management and computer aided techniques	I
Question 18/1	System design for maximizing the efficiency and utility of spectrum use	I
Question 34/1	Identification of radio stations	I
Question 44/1	System models for the evaluation of compatibility in spectrum use	I
Question 45/1	Technical criteria for frequency sharing	I
Question 58/1	Frequency sharing between various services	I
Question 62/1	Lightning protection of radio equipment	I
Decision 56	Transfer of technology	I
Report 546	Space systems technology in the space research service: Attitude control technology	II
Report 675	Radiation diagrams of antennas at space research earth stations for use in interference studies	II
Report 676	Shaped beam antennas	II
Report 844	Potential interference between deep-space telecommunication and fixed-satellite and broadcasting-satellite systems in harmonically related bands	II

XVIII

Text	Title	Volume
Recommendation 363	Space operation systems. Frequencies, bandwidths and protection criteria	II
Report 396	Maintenance telemetering, tracking and telecommand for developmental and operational satellites. Possibilities of frequency sharing between earth-satellite telemetering or telecommand links and terrestrial services	II
Report 847	Data relay satellites. Sharing with other services in bands 9 and 10	II
Recommendation 364	Telecommunication links for manned and unmanned near-Earth research satellites. Frequencies, bandwidths and criteria for protection from interference	II
Recommendation 578	Protection criteria and sharing considerations relating to deep-space research	II
Report 685	Protection criteria and sharing considerations relating to deep-space research	II
Report 224	Interference protection criteria for the radioastronomy service	II
Recommendation 517	Protection of the radioastronomy service from transmitters in adjacent bands	II
Report 697	Interference to the radioastronomy service from transmitters in other bands	II
Study Programme 15C/2	Protection of telecommunication equipment from radio-frequency radiation from space research earth stations	II
Question 18/2	Protection criteria for systems providing space operation functions	II
Question 19	Spurious emissions radiated from and received by stations of space services	II
Report 859	Frequency sharing between services below 30 MHz	III
Question 32/3	Frequency sharing between services below 30 MHz	III
Opinion 66	Frequency sharing between services below 30 MHz	III
Report 561	Feeder links to space stations in the broadcasting-satellite service	IV
Report 712	Factors concerning the protection of fixed-satellite earth stations operating in adjacent frequency band allocations against unwanted emissions from broadcasting satellites operating in frequency bands around 12 GHz	IV
Report 873	An analysis of the interference from the broadcasting-satellite service of one region into the fixed-satellite service of another region around 12 GHz	IV
Report 874	Frequency sharing between the inter-satellite service when used by the fixed-satellite service and other space services	IV
Study Programme 2K/4	Feeder links for the space stations in the broadcasting-satellite service	IV
Study Programme 2T/4	Frequency sharing between the fixed-satellite service and the broadcasting-satellite service	IV
Question 25/4	Unwanted emissions radiated from and received by earth stations and space stations of the fixed-satellite service	IV

Text	Title	Volume
Question 26/4	Provision of feeder links between fixed-earth stations and space stations of various services in frequency bands allocated to the fixed-satellite service	IV
Recommendation 368	Ground-wave propagation curves for frequencies between 10 kHz and 30 MHz	V
Report 717	World atlas of ground conductivities	V
Report 719	Attenuation by atmospheric gases	V
Report 720	Radio emission from natural sources above about 50 MHz	V
Report 721	Attenuation by hydrometeors; in particular precipitation, and other atmospheric particles	V
Report 722	Cross-polarization due to the atmosphere	V
Report 723	Worst-month statistics	V
Recommendation 370	VHF and UHF propagation curves for the frequency range from 30 MHz to 1000 MHz. <i>Broadcasting services</i>	V
Report 239	Propagation statistics required for broadcasting services using the frequency range 30 to 1000 MHz	V
Report 228	Measurement of field strength for VHF (metric) and UHF (decimetric) broadcast services, including television	V
Report 562	Propagation data required for terrestrial broadcasting in the frequency bands above 10 GHz	V
Recommendation 530	Propagation data required for the design of tropospheric-scatter trans-horizon radio-relay systems, terrestrial line-of-sight radio-relay systems, and Earth-space telecommunication systems	V
Report 564	Propagation data required for space telecommunication systems	V
Report 565	Propagation data for broadcasting from satellites	V
Recommendation 452	Propagation data required for the evaluation of interference within and between the space and terrestrial services and for the calculation of coordination distances	V
Report 569	The evaluation of propagation factors in interference problems between stations on the surface of the Earth at frequencies above about 0.5 GHz	V
Report 724	Propagation data required for the evaluation of coordination distance in the frequency range 1 to 40 GHz	V
Report 885	Propagation data required for evaluating interference between stations in space and those on the surface of the Earth	V
Recommendation 373	Definitions of maximum transmission frequencies	VI
Report 892	Computation of reliability for HF radio systems	VI
Recommendation 532	Ionospheric modification by high power transmissions	VI
Report 574	Ionospheric cross-modulation	VI
Report 728	Ionospheric modification by high power HF transmissions	VI
Report 894	Propagation prediction methods for high frequency broadcasting	VI

Text	Title	Volume
Study Programme 28D/6	Propagation factors affecting the sharing of the radio-frequency spectrum between terrestrial systems involving ionospheric propagation	VI
Study Programme 28F/6	Ionospheric effects caused by high-power transmissions	VI
Study Programme 29D/6	Noise levels expected in the frequency band 535 to 1705 kHz within Region 2	VI
Study Programme 31C/6	Method for calculating sky-wave field strength in connection with MF broadcasting for application in ITU Region 2	VI
Resolution 75	HF sky-wave field-strength prediction method for use at the WARC for HF broadcasting	VI
Report 927	General considerations relative to harmful interference from the viewpoint of the aeronautical mobile services	VIII
Recommendation 591	Compatibility between the broadcast service in the band of about 87–108 MHz and the aeronautical services in the band 108–136 MHz	VIII
Report 929	Compatibility between the broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–136 MHz	VIII
Question 56/8	Frequency sharing between services in the band 4–30 MHz	VIII
Question 60/8	Broadcasting and aeronautical radionavigation services in the LF bands. <i>Interference between regions</i>	VIII
Question 61/8	Compatibility between the broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–136 MHz	VIII
Recommendation 402	The preferred characteristics of a single sound channel simultaneously transmitted with a television signal on an analogue radio-relay system	IX
Report 789	Protection of terrestrial line-of-sight radio-relay systems against interference from the broadcasting-satellite service in the band 11.7–12.75 GHz	IX
Report 941	Protection of terrestrial line-of-sight radio-relay systems against interference from the broadcasting-satellite service (sound) in the band 1427–1530 MHz	IX
Report 958	Possibilities for incorporating the sound information in the video signal in terrestrial television	XI
Recommendation 469	Standards for the international exchange of television programmes on magnetic tape	XI
Question 15/11	Automatic monitoring of television stations	XI
Question 29/11	Broadcasting of still pictures and other information intended for the public using a television or narrow-band channel	XI
Study Programme 29D/11	Specifications for a programme delivery service	XI
Study Programme 29E/11	Specifications for a new “audiography” broadcasting service	XI
Study Programme 29F/11	Transmission aspects concerning broadcasting of still picture television signals using a television or narrow-band channel	XI

Text	Title	Volume
Question 35/11	Synchronization necessary for the satisfactory reception of sound and picture signals	XI
Question 38/11	Protection of television broadcasting stations against lightning	XI
Question 39/11	Frequency sharing between the broadcasting service (television) and the fixed and mobile services below 1 GHz	XI
Question 40/11	Methods of synchronizing various recording and reproducing systems	XI
Report 503	Performance characteristics of narrow-bandwidth sound-programme circuits. <i>Circuits of medium quality for monophonic transmission</i>	XII
Recommendation 504	Performance characteristics of 10 kHz-type sound-programme circuits	XII
Recommendation 505	Characteristics of 15 kHz-type sound-programme circuits. <i>Circuits for high-quality monophonic and stereophonic transmissions</i>	XII
Report 496	Circuits for high-quality monophonic and stereophonic transmissions	XII
Recommendation 571	A conventional test signal simulating sound-programme signals for measuring interference in other channels	XII
Report 497	A conventional test signal simulating sound-programme signals for measuring interference in other channels	XII
Report 820	Relative values of sound-programme signal levels established with the vu-meter and with a peak-programme meter	XII
Report 648	Digital sound-programme transmission impairments and methods of protection against them	XII
Question 18/CMTT	Standards for digital system for the transmission of sound-programme signals over long distances	XII
Study Programme 18A/CMTT	Standards for the digital transmission of sound-programme signals	XII
Study Programme 19A/CMTT	Method for the subjective assessment of impairment due to the characteristics of sound-programme transmission systems	XII
Opinion 41	Bandwidths of sound programme circuits	XII
Recommendation 573	Radiocommunication vocabulary	XIII
Report 971	General terminology of telecommunications. <i>Terms common to CCIR and CCITT</i>	XIII
Recommendation 607	Terms and abbreviations for information quantities in telecommunications	XIII
Recommendation 431	Nomenclature of the frequency and wavelength bands used in telecommunications	XIII
Recommendation 574	Logarithmic quantities and units	XIII
Resolution 66	Terms and definitions	XIII
Decision 19	Terms and definitions	XIII

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

BROADCASTING SERVICE (SOUND)

STUDY GROUP 10

Terms of reference:

To study:

- technical aspects of the broadcasting service and the broadcasting-satellite service when these services are used for sound;
- the special problems of broadcasting in the Tropical Zone, taking into account the standards required for good quality service; interference in the shared bands; power required for an acceptable service; design of suitable transmitting antennas; receiving equipment; optimum conditions for utilization of the frequency bands and other associated questions;
- standards for audio-frequency equipment, including recording, to facilitate the international exchange of programmes.

1978-1982 *Chairman:* C. TERZANI (Italy)
Vice-Chairmen: S. N. MITRA (India) (to 1980)
 H. EDEN (Federal Republic of Germany) (from 1980)
 O. P. KHUSHU (India) (from 1980)

1982-1986 *Chairman:* C. TERZANI (Italy)
Vice-Chairmen: H. EDEN (Federal Republic of Germany)
 O. P. KHUSHU (India)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP 10

1. Organization of work

During the period 1978-1982, Study Group 10 held its Interim Meeting at Geneva from 29 September to 16 October 1980 and its Final Meeting at Geneva from 21 September to 8 October 1981 under the chairmanship of Mr. C. Terzani (Italy).

The Interim and Final Meetings were attended by 175 and 217 delegates respectively from the telecommunication administrations of 31 (37) countries, from 14 recognized private operating agencies, from 4 (5) international organizations and from two scientific or industrial organizations.

Following the resignation of the Vice-Chairman, Mr. S. N. Mitra (India) and having regard to the heavy workload assigned to Study Group 10 by the WARC-79 and to the many ITU conferences concerned with sound broadcasting, Study Group 10 recommended that the XVth CCIR Plenary Assembly should increase the number of the Group's Vice-Chairmen to two. In the meantime, the Study Group elected Mr. H. Eden (Federal Republic of Germany) and Mr. O. P. Khushu (India) Vice-Chairmen on an interim basis.

Study Group 10 decided to amend the order of the sections in Volume X to bring it into line with its working structure.

These sections are the following:

- *Section 10A-1:* Amplitude-modulation sound broadcasting in bands 5 (LF), 6 (MF) and 7 (HF).
- *Section 10A-2:* Sound broadcasting in the Tropical Zone.
- *Section 10B:* Frequency-modulation sound broadcasting in bands 8 (VHF) and 9 (UHF).
- *Section 10C:* Audio-frequency characteristics of sound broadcasting signals.
- *Section 10D:* Recording of sound programmes.
- *Section 10E:* Broadcasting service (sound) using satellites.

2. Texts resulting from the above activities

Following the order in which the texts are reproduced in Volume X, we have first listed the Recommendations and Reports, arranged according to the subject treated, and thereafter the Questions, Study Programmes, Resolutions, Opinions and finally the Decisions. The texts concerning the broadcasting-satellite service appear in Volume X and XI, Part 2.

2.1 *Amplitude-modulation sound broadcasting*

Recommendations 447, 560 and Report 794, concerning protection ratios, were updated; more particularly a text on carrier phase locking in synchronized networks was inserted in Report 794.

Recommendation 559 was amended by the addition of data on objective measurements of the RF protection ratios and in Recommendation 561 a definition of equivalent monopole-radiated power on a short vertical antenna, approved by the WARC-79, was added.

Report 457 was amended in the part concerning the necessary bandwidth of emission in HF broadcasting and a new Recommendation on HF channel spacing was prepared.

The Report concerning the factors influencing MF coverage was converted into a Recommendation and Report 616 on the practical aspects of coverage was amended.

Amendments were also made to Report 499 concerning specific field strengths and Report 516 on addition of field strengths.

Report 458 was rearranged by the inclusion of the specifications and results from experiments with SSB systems in HF broadcasting.

Recommendation 205 was amended by the addition of a note concerning synchronized HF emissions and the updating of the definitions of service area and coverage area in accordance with texts approved by the CMV (Joint CCIR/CCITT Study Group for Vocabulary).

Amendments were made to Reports 401 and 32, particularly with regard to HF antennas.

A new Report was drafted concerning protection against lightning; this will be transmitted to Study Group 1, which will prepare a CCIR Recommendation on the subject, taking into account contributions received by the various Study Groups concerned.

Additional values of average receiver characteristics were added to Report 617.

2.2 *Sound broadcasting in the Tropical Zone*

The Study Group made certain small changes in the Recommendations on broadcasting in the Tropical Zone and added bibliographical references to several Reports.

2.3 *Frequency-modulation sound broadcasting*

A new Report on the planning of theoretical networks, a new Report on the constraints in the planning of frequencies in band 8 and two new Reports on the evaluation of multiple interference and on the protection ratios between FM sound broadcasting and D/SECAM television signals were drafted.

Amendments were made to Report 796 on the determination of protection ratios, Report 464 on the polarization of emissions by the inclusion of test results for reception in cars with different polarizations and Report 122 on the advantages deriving from the use of orthogonal polarization.

This last Report is published in Volume XI; since it also concerns sound broadcasting and is very brief, Study Group 10 decided that it would also be published in Volume X on an exceptional basis pending the preparation of a separate Report for sound broadcasting in the next study period. Those interested solely in sound broadcasting will thus find all the necessary information in a single volume.

Recommendation 412 on planning standards for FM sound broadcasting was amended by the introduction of uniform 100 kHz spacing between channels in both the monophonic and stereophonic services. Recommendation 450 on systems for frequency-modulation stereophonic broadcasting was amended to indicate the position of additional carriers.

Study Group 10 also added the characteristics of certain surround-sound systems in Report 300 and additional information on systems for the simultaneous transmission of several sound programmes or other signals in Report 463.

A new Recommendation was drafted on receiving antenna directivity in VHF sound broadcasting which supplements the Recommendation concerning television antennas in Volume XI; in Report 795 additional data were added for the transmission of several sound channels or other television signals on two systems which are in operation.

2.4 *Audio-frequency characteristics of sound broadcasting signals*

An amendment was made to the paragraph in Recommendation 562 concerning the assessment of the quality of recordings; amendments were also made in Report 292 on the measurement of modulation levels; Report 293 on audio-frequency characteristics; Report 465 on the determination of subjective loudness.

Further, in Recommendation 468, particulars were added concerning the weighting network for the measurement of audio-frequency noise, an extension of the Annex concerning unweighted measurement and a new Annex on a constant weighting network to obtain greater precision in the measurement method.

The title of Report 797 is changed to "Determination of the acoustical properties of control rooms and high-quality listening rooms in broadcasting", and certain points were added to the specifications of control rooms and to listening conditions, particularly in small rooms which do not present optimum characteristics; minor amendments were made to Report 798 on simulated programme signals and the title of Report 799 was changed to "Subjective assessment of quality of sound in broadcasting using digital techniques"; in this Report the conclusion was added that a 15 kHz bandwidth was of adequate quality having regard to the listener's hearing ability.

Two new Reports on digital techniques were prepared. They concern quality measurements in studios and the sampling frequency of 48 kHz for applications in broadcasting studios and for television sound, including the recording of sound on tape recorders and video tape recorders.

Study Group 10 would like this last Report to be converted into a Recommendation at the next study period.

2.5 *Recording of sound programmes*

As for sound recording, Recommendation 408 was amended by the addition of the hypothetical recording-duplicating reference chain; Report 622 (Sound recording on magnetic tape for the international exchange of programmes) was amended to incorporate certain changes in the operating practices of the International Radio and Television Organization (OIRT); Report 468 (Methods of synchronizing various recording and reproducing systems) was amended to take account of a proposal for the use of a 6.25 mm sound tape with two stereophonic tracks and one narrow centre track used for the time code.

Study Group 10 decided that this Report will be transferred to Volume XI, with only the title and a reference left in Volume X.

Further, a new Report on the digital recording of sound signals, which describes an experimental prototype instrument, was prepared.

Study Group 10 also proposed a list of texts on recording to be submitted to the IEC and took note of a draft booklet on recording techniques for the developing countries.

2.6 *Broadcasting service (sound) using satellites*

Advances in broadcasting-satellite techniques have led to major changes in existing texts.

Thirteen existing Reports on satellite broadcasting were updated and a new Recommendation and 5 new Reports were drafted.

The new Reports concern satellite sound broadcasting for portable and mobile receivers, multiplexing methods for the transmission of several digital sound signals and data, digital coding for the transmission of high quality sound signals and the technical characteristics of feeder links for broadcasting satellites. This last-named Report deals very fully with the various aspects of feeder links, but certain of these aspects still require a great deal of study.

2.7 *Questions, Study Programmes, Resolutions and Opinions*

Questions and Study Programmes of Study Group 10 were so rearranged that all texts dealing with one subject are included in the same Question and they are arranged in the order in which the subject matter is set out in Volume X. There are thus 12 Questions and 54 Study Programmes.

References to the relevant Resolutions and Recommendations of the WARC-79 were included in existing Questions, and new Questions and Study Programmes were prepared in response to the Resolutions and Recommendations proposing new studies.

These texts consist of three new Questions on: broadcasting of audio signals accompanying the video signal, protection against lightning and methods of synchronizing recording systems, and also five new Study Programmes on single sideband systems in HF broadcasting, synchronized HF broadcasting transmitters, compatibility between MF broadcasting and other services, the use of companders in frequency modulation sound broadcasting and on the minimum usable field strength in the VHF band.

Questions 59 and 60, which were approved by correspondence during the 1978-1982 period and deal with the compatibility between VHF sound broadcasting and other services and the technical foundations for the planning of VHF sound broadcasting, were converted into Study Programmes 46J/10 and 46L/10 respectively.

As regards broadcasting satellites, the texts and the numbering of Questions and Study Programmes in Study Groups 10 and 11 were brought into line and a new Study Programme was added on telecommand, tracking and telemetry signals and on maintenance signals.

A new Resolution relates to the presentation of the antenna diagrams which will be published in the new edition of the CCIR Handbook. In order to take the future development of new services associated with sound broadcasting into account, an Opinion was drafted asking the IEC to consider the standardization of facilities for the interconnection of sound broadcasting receivers and associated equipment for the use of the signals for these new services.

3. Decisions and Interim Working Parties (IWP)

Study Group 10 disbanded IWP 10/3, which had been established in order to prepare part of the CCIR Report for the Regional Administrative MF Broadcasting Conference (Region 2).

The text drafted by IWP 10/3 was transmitted to the first session of this Conference, which was held at Buenos Aires in March 1980.

IWP 10/4, established by Decision 38 at the Interim Meeting, under the chairmanship of Mr. J. Burgstaller (Austria) to prepare the technical bases for the 1st Session for technical preparation, Regional Administrative Conference for FM sound broadcasting in the VHF band (Region 1 and certain countries concerned in Region 3) (CARR-1-82), held a meeting at Geneva in March 1981 and met also during the Final Meeting of Study Group 10.

The Working Party drafted a Report which follows the Conference's agenda published in Resolution No. 852 of the ITU Administrative Council and comprises 6 chapters dealing with definitions, broadcasting and planning standards, VHF propagation, technical bases for planning, sharing with television and compatibility with other services.

This Report was unanimously approved by Study Group 10 and transmitted to the first session of CARR-1-82.

IWP 10/4, having thus completed its work, was disbanded and Decision 38 was cancelled.

IWP 10/5 was established by Decision 39 at the Interim Meeting under the chairmanship of Professor J. J. Geluk (Netherlands) to prepare the technical bases required for the planning of the HF bands allocated to broadcasting.

The Working Party held a meeting at Geneva in July 1981 and met again during the Final Meeting of Study Group 10, when it prepared a Report containing the characteristics of HF DSB and SSB broadcasting systems and the data required for HF broadcasting. Two annexes deal with a planning procedure and the calculation of the reliability of HF radio systems.

Study Group 10 took note of this Report and amended Decision 39 to enable IWP 10/5 to continue its work up to a date four months before the next meeting of the Study Group, to which the Final Report will be submitted. In accordance with the decisions of the XVth Plenary Assembly, the relevant texts, as approved by Study Group 10 at its Interim Meeting, 1983, will be transmitted to the Conference by the Director as a CCIR contribution.

IWP 10/6 was established by Decision 40 at the Interim Meeting under the chairmanship of Mr. G. Gilchrist (United Kingdom) to study the characteristics and tolerance limits applicable to the technical quality of programmes intended for international exchange.

The Working Party held its first meeting during the Final Meeting of Study Group 10 and prepared a report and a questionnaire in order to obtain, by correspondence, the additional information required for the preparation, during the next study period, of a Recommendation coming within its terms of reference.

By Decision 52, Study Group 10 established IWP 10/7 under the chairmanship of Mr. M. Schneider (Switzerland) to identify and define the characteristics of the sound broadcasting receivers necessary for planning purposes and to prepare the performance specifications for amplitude and frequency modulation reference receivers.

IWP 10-11/1 was established by Decision 43 at the Interim Meeting of Study Groups 10 and 11 under the chairmanship of Mr. J. F. Arnaud (France) to study the use of the geostationary-satellite orbit and the planning of space services utilizing it; this study is intended for the preparation of WARC-85 to the extent that the subject matter of this Conference concerns Study Groups 10 and 11.

IWP 10-11/1 held a meeting at Geneva in May 1981 and met a second time during the Final Meetings of the above Study Groups.

Study Groups 10 and 11 took note of the Report of IWP 10-11/1 which contains three chapters dealing respectively with feeder links, planning and the sharing of frequencies with other services. They decided that the Working Party should continue to operate in order to complete and update the Report for presentation at the next Interim Meetings to be held in 1983.

Study Groups 10 and 11 accordingly amended Decision 43.

IWP 10-11/2 was established by Decision 44 at the Interim Meetings of Study Groups 10 and 11 under the chairmanship of Dr. C. A. Siocos (Canada) to study the technical questions relating to the Regional Administrative Radio Conference for the Planning of the Broadcasting-Satellite Service in Region 2.

The Working Party held a meeting at Ottawa in April-May 1981 and met again during the Final Meetings of Study Groups 10 and 11.

These Study Groups took note of the Report of IWP 10-11/2, which contains an introduction by the Chairman and a discussion of terminology, propagation factors, the technology of broadcasting-satellite systems, the bases of planning, sharing of frequencies and a conclusion, and they decided that the Report should be completed before the end of 1981.

Study Groups 10 and 11 considered that this Report should be integrated with the results of the studies made by other Study Groups concerned and proposed that the XVth Plenary Assembly should adopt a Resolution convening, in July 1982, a special joint meeting of Study Groups 4, 5, 9, 10 and 11 in order to prepare the CCIR Report for the Regional Administrative Radio Conference for the Planning of the Broadcasting-Satellite Service in Region 2.

By Decision 51, Study Groups 10 and 11 established IWP 10-11/3 under the chairmanship of Mr. Måkitalo (Sweden) to study unified standards for the insertion of several sound channels in a terrestrial or satellite television channel.

4. Collaboration with other Study Groups

Study Groups 10 and 11 transmitted to IWP PLEN./3, 12 documents concerning the activities of this Working Party at the Interim Meetings and 19 documents relating to the Final Meetings.

Study Groups 10 and 11 transmitted to Study Group 4 the section of the Report on feeder links for broadcasting satellites concerning the sharing of frequencies, which comes within the competence of Study Group 4.

Study Groups 10 and 11 took note of the Report of Mr. J. F. Arnaud, Rapporteur in Study Group 4 and IWP 4/1 and reconfirmed him in that office.

Study Group 10 also took note of the Report by Professor S. Borodich (U.S.S.R.), who had been appointed Rapporteur in IWP 5/4, and of that Working Party's Final Report concerning the division of the world into regions with a view to the allocation of frequency bands.

Study Group 6 informed Study Group 10 that the main parts of Report 305 (Kyoto, 1978) on propagation in the Tropical Zone had been transferred to Report 571. Report 305, which had earlier been transferred from Study Group 10 to Study Group 6, had been cancelled. A reference to Report 571 will be inserted in Volume X.

Study Group 6 appointed Mr. Bradley (United Kingdom) and Mr. Al Babbain (Saudi Arabia) experts in IWP 10/5.

Study Group 10 took note of the report by Mr. A. Witham, Rapporteur in Study Group 8, and more particularly of the need to define criteria for compatibility between VHF sound broadcasting and the aeronautical radionavigation service in the adjacent upper band.

Study Group 8 appointed Mr. Karjalainen (Finland) expert in IWP 10/4.

Study Group 10 took note of the verbal report by Mr. F. Angeli (Italy), Rapporteur in IWP 11/3 and appointed Mr. V. Del Duce (Italy) expert in IWP 11/5, dealing with the protection ratios in colour television.

Study Group 11 appointed Professor Kedjersky (Poland) Rapporteur in IWP 10/4.

Cooperation between Study Group 10 and the CMTT on digital techniques is continuing by contacts between the Chairmen of IWP CMTT/1 and Working Party 10-C.

5. Problems concerning the developing countries

The work of Study Group 10 is of particular interest to the developing countries in view of the importance of sound broadcasting for the information and education of the people in those countries.

As regards amplitude modulation broadcasting, the developing countries are particularly interested in the texts relating to broadcasting in the Tropical Zone, in which several of them are situated.

As for the recording of sound broadcasting programmes, Recommendation 408 (Standards of sound recording on magnetic tape for the international exchange of programmes), with the amendments made, concerns the developing countries, but their attention is quite particularly drawn to the decision adopted by Study Groups 10 and 11 concerning the publication of a CCIR booklet on recording, intended for the developing countries.

This booklet contains an introduction on the tasks of the CCIR, a section on the standardization of tape and film for programme exchange and a section on the CCIR texts concerning sound and television recording on film and magnetic tape.

As regards broadcasting satellites, a subject of particular interest to the developing countries is the problem of sound broadcasting between a satellite and portable or mobile receivers, which is dealt with in a new Report.

The attention of the developing countries was also drawn to the importance of the Interim Working Parties for the preparation of the forthcoming ITU conferences. Although it may be thought that they are particularly interested in texts offering guidance in the selection and use of equipment, Study Group 10 would certainly find it easier to contribute to the solution of problems concerning the developing countries if they took a more active part in its work so as to focus attention on problems of particular interest to them.

At the meeting of the Plan Committee for Latin America in Buenos Aires on 28 October 1981, the Chairman of Study Group 10 gave a lecture on the problems peculiar to the sound and television broadcasting service in order to familiarize the developing countries with the results of the work of Study Groups 10 and 11.

6. Guidelines for the work to be carried out

Apart from the updating of a large number of texts and the rearrangement of Questions and Study Programmes, the study period 1978-1982 was marked by the preparation of the technical bases required for future ITU conferences following the Resolutions and Recommendations of WARC-79.

Study Group 10 therefore established the IWPs needed for these studies and approved or noted, as appropriate, the results of their work.

During the 1982-1986 study period, Study Group 10 will continue to update the existing texts by deleting obsolete parts and converting, wherever possible, the Reports into Recommendations or Annexes to Recommendations dealing with the same subject.

The study of the technical bases in preparation for the forthcoming radio conferences also constitutes an important part of the activities in this study period.

These studies will be conducted on the basis of the Questions and Study Programmes of Study Group 10, with the assistance of the existing Interim Working Parties. In particular, special attention must be paid to the establishment and updating of the technical bases for the planning of the HF bands allocated to broadcasting, taking into account Resolution 85 of the XVth Plenary Assembly, Question 44/10, Decision 39 and the work of IWP 10/5, and to the preparation of the WARC-ORB 85/87, taking into account Questions 1/10 and 11, 2/10 and 11, Decision 43 and the work of IWP 10-11/1.

A number of other important studies for which a solution is required during the 1982-1986 period are those concerning specifications for an SSB sound broadcasting system, parameters for the planning of SSB transmitter networks and problems involved in bringing them into service, all of which come under Question 44/10; compatibility between sound broadcasting stations and stations of other services sharing the same band or operating in adjacent bands, under Questions 44/10, 45/10, 46/10, 47/10 and 1/10 and 11; unified standards for the insertion of several sound channels in a terrestrial or satellite television channel, which are particularly urgent in terms of planned broadcasting satellites, taking into account Decision 51 and Questions 47/10, 51/10 and 2/10 and 11; digital techniques, particularly with regard to the choice of the digital sound sampling frequency for studio applications, in connection with Question 51/10; standards for satellite sound broadcasting and the characteristics of feeder links to broadcasting satellites, in connection with Questions 1/10 and 11 and 2/10 and 11; as well as the problems concerning the developing countries.

Study Group 10, on the basis of the contributions it receives during the current study period, will draft texts on the studies listed above which, together with other subjects within its terms of reference, are intended to form the bases for future sound broadcasting applications and for the deliberations of conferences with a view to improving spectrum utilization.

SECTION 10-A1: AMPLITUDE-MODULATION SOUND BROADCASTING IN BANDS 5 (LF),
6 (MF) and 7 (HF)

Recommendations and Reports

RECOMMENDATION 447-2 *

SIGNAL-TO-INTERFERENCE RATIOS IN SOUND BROADCASTING

Definitions

(Question 44/10, Study Programme 44A/10)

(1966–1978–1982)

The CCIR

UNANIMOUSLY RECOMMENDS

that, when considering problems of interference in sound broadcasting, the following definitions should be used:

1. *The audio-frequency (AF) signal-to-interference ratio* is the ratio (expressed in dB) between the values of the voltage of the wanted signal and the voltage of the interference, measured under specified conditions, at the audio-frequency output of the receiver.

This ratio corresponds closely to the difference in volume of sound (expressed in dB) between the wanted programme and the interference.

2. *The audio-frequency (AF) protection ratio* is the agreed minimum value of the audio-frequency signal-to-interference ratio considered necessary to achieve a subjectively defined reception quality.

This ratio may have different values according to the type of service desired.

3. *The radio-frequency (RF) wanted-to-interfering signal ratio* is the ratio (expressed in dB) between the values of the radio-frequency voltage of the wanted signal and the interfering signal, measured at the input of the receiver under specified conditions.

For example, in the case of amplitude-modulation wanted and interfering transmissions (carrier with double sideband), the chosen values will be the effective radio-frequency voltages that correspond to the wanted and interfering carriers.

4. *The radio-frequency (RF) protection ratio* is the value of the radio-frequency wanted-to-interfering signal ratio that enables, under specified conditions, the audio-frequency protection ratio to be obtained at the output of a receiver.

The specified conditions include such diverse parameters as: spacing Δf of the wanted and interfering carrier, emission characteristics (type of modulation, modulation depth, frequency deviation, carrier frequency tolerance, etc.), A.F. signal characteristics (bandwidth, dynamic compression, etc.), receiver input level as well as the receiver characteristics (selectivity and susceptibility to cross-modulation, etc.).

* This Recommendation should be brought to the attention of the CMV.

RECOMMENDATION 560-1 *

RADIO-FREQUENCY PROTECTION RATIOS IN LF, MF AND HF BROADCASTING

(Question 44/10, Study Programme 44A/10)

(1978-1982)

The CCIR

UNANIMOUSLY RECOMMENDS

that the radio-frequency protection ratios for sound broadcasting in bands 5 (LF), 6 (MF), and 7 (HF) as given in §§ 1 and 2 should be applied.

1. Radio-frequency protection ratio in bands 5 (LF) and 6 (MF)

The radio-frequency protection ratio (as defined in Recommendation 447), for co-channel transmissions (± 50 Hz) should be 40 dB when both the wanted and the unwanted signals are stable (ground-wave).

When the wanted signal is stable and the unwanted signal fluctuates (including short-term fluctuations), the radio-frequency protection ratio should be 40 dB at the reference time (see Annex I to Recommendation 435) for at least 50% of the nights of the year. This protection ratio corresponds to the ratio of the wanted field strength and the annual median value of the hourly medians of the interfering field strength at the reference time.

The protection so defined is provided:

- for 50% of the nights at the reference time;
- for more than 50% of the nights at times other than the reference time;
- for 100% of the days during daylight hours.

The radio-frequency protection ratio values specified above will permit a service of excellent reception quality. For planning purposes, however, lower values may be required. In this respect, proposals have been made by some countries and organizations (see Report 794).

Note 1. – The minimum usable field strength to which this protection ratio of 40 dB applies varies in the different regions and with frequency. Within the European zone, this minimum is of the order of 1 mV/m.

Note 2. – In the United States of America, when the wanted and unwanted signals are stable (ground-wave), the radio-frequency protection ratio for co-channel transmissions is 26 dB. When the unwanted signal is fluctuating (sky-wave), the same protection ratio is applied for 90% of the nights of the year, computed for the second hour after sunset. The minimum usable field strength is either 100 or 500 μ V/m, depending upon the class of service.

2. Relative radio-frequency protection ratio curves in bands 5 (LF), 6 (MF) and 7 (HF)

The relative radio-frequency protection ratio is the difference, expressed in decibels, between the protection ratio when the carriers of the wanted and unwanted transmitters have a frequency difference of Δf (Hz or kHz) and the protection ratio when the carriers of these transmitters have the same frequency.

Once a value for the co-channel radio-frequency protection ratio (which is equal to the audio-frequency protection ratio) has been determined, then the radio-frequency protection ratio, expressed as a function of the carrier-frequency spacing, is given by the curves of Fig. 1 (see also Annex I):

- curve A, when a limited degree of modulation compression is applied at the transmitter input, such as in good quality transmissions, and when the bandwidth of the audio-frequency modulating signal is of the order of 10 kHz;
- curve B, when a high degree of modulation compression (at least 10 dB greater than in the preceding case) is applied by means of an automatic device and when the bandwidth of the audio-frequency modulating signal is of the order of 10 kHz;
- curve C, when a limited degree of modulation compression (as in the case of curve A) is applied and when the bandwidth of the audio-frequency modulating signal is of the order of 4.5 kHz;
- curve D, when a high degree of modulation compression (as in the case of curve B) is applied by means of an automatic device and when the bandwidth of the audio-frequency modulating signal is of the order of 4.5 kHz.

* Further information is given in Report 794.

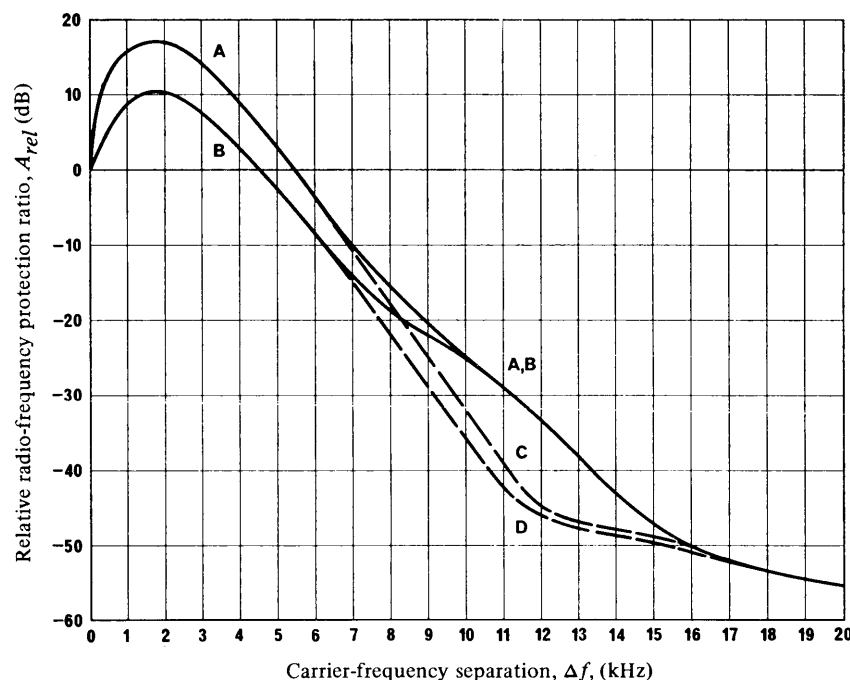


FIGURE 1 – *Relative value of the radio-frequency protection ratio as a function of the carrier-frequency separation*

The curves A, B, C and D (see also Annex I) are valid only when the wanted and unwanted transmissions are compressed to the same extent. They have been obtained mainly from measurements and calculations with a reference receiver representative of good quality receivers used for reception in bands 5 (LF) and 6 (MF). The overall frequency response curve of the European Broadcasting Union (EBU) reference receiver used passes through -3 dB, -24 dB and -59 dB at 2 kHz, 5 kHz and 10 kHz, respectively, [Petke, 1973].

ANNEX I

The shape of the relative radio-frequency protection ratio curves depends on the receiver selectivity, on the bandwidth of the audio-frequency modulating signal, and also on the ratio of the energy of the carrier and of the sidebands. This latter phenomenon is most important between 250 Hz and 5 kHz approximately, where the disturbance is essentially due to the whistle produced by the carrier-frequency beat. The shape of the curves in Fig. 1 therefore depends on the average modulation depth and on the dynamic compression of the modulation signals.

Curve A represents average values derived from calculations and from tests made with various receivers mainly designed for reception in band 5 (LF) and band 6 (MF), with modulation compression typical of that currently applied in the studios, i.e. with compression permitting a maximum dynamic range of at least 30 dB.

Curve B applies to the use of compression, as applied by an automatic device, of at least 10 dB higher than in the preceding case.

Both curves A and B, as distinct from curves C and D, apply to a bandwidth of the audio-frequency modulating signal of the order of 10 kHz.

Curves C and D apply to the use of compression of the same order of magnitude as in the cases of curves A and B, respectively. The bandwidth of the audio-frequency modulating signal, is, however, restricted to about 4.5 kHz. This degree of bandwidth limitation reduces interference from adjacent channels without, in practice, leading to any significant degradation of the reception quality.

It should be noted that, in some circumstances, listeners are able to reduce the interfering effect of an unwanted transmission, spaced by more than approximately 3 kHz, by adjusting their receivers (slight detuning, selectivity control, tone control, etc.). Under these conditions, the curves of Fig. 1 are no longer applicable for spacings of more than about 3 kHz. However, the practice of detuning leads to distortion and cannot be used when two interfering emissions of approximately equal strength are present, on both sides of the wanted carrier frequency. Moreover, many receivers are not equipped with a selectivity control or tone control.

Note 1. — In addition to the relative radio-frequency protection ratios given in this Recommendation there are other factors of importance in determining optimum frequency spacings (see Question 44/10).

Note 2. — Caution should be exercised when relative values of radio-frequency protection ratio beyond -50 dB are obtained from the curves because, in practice, non-linear distortion originating in the transmitter may lead to poorer protection than indicated.

ANNEX II

Presentation of experimental results

Whenever possible, the results of measurements of the radio-frequency protection ratio between two broadcast signals should be presented in terms of the following characteristics and parameters:

- type of modulation,
- separation, between the carrier-frequencies (kHz) (this should lie between 0 and at least 10 kHz),
- modulation depth of both signals,
- occupied bandwidth,
- modulation processing (compression and pre-emphasis),
- type of the programmes of the wanted and unwanted signals,
- characteristics of fading if present,
- radio-frequency input voltage of the wanted signal (the radio-frequency input voltage should be chosen in such a way that the protection ratios are not significantly affected by non-linearities within the radio-frequency and intermediate frequency stages of the receiver),
- passband of the receiver before demodulation,
- overall response curve at audio-frequencies of the receiver, including the loudspeaker,
- the grade of listener satisfaction aimed at and the statistical distribution of such grades,
- the measuring method (subjective or objective).

REFERENCES

PETKE, G. [October, 1973] Determination by calculation of the RF protection ratio for AM transmission systems. *EBU Rev. (Tech.)*, **141**, 227-234.

REPORT 794-1 *

PROTECTION RATIOS IN LF, MF AND HF BROADCASTING

(Question 44/10, Study Programme 44A/10)

(1978-1982)

1. Introduction

This Report is a summary of the information available on the subject of protection ratios for amplitude-modulation sound-broadcasting services.

The protection ratios quoted refer, in all cases, to the ratios at the input to the receiver, no account having been taken of the effect of using directional receiving antennas.

Agreed values of protection ratios are essential for the solution of frequency assignment problems in amplitude-modulation sound broadcasting. Moreover, they may serve as basic reference data for the evaluation of the relative merits and the effectiveness to be expected with various amplitude-modulation transmission systems.

* This Report gives information additional to Recommendations 559 and 560.

Protection ratios depend on a multiple of parameters, among which transmission standards and receiver characteristics play an important role. Apart from technical factors there are others of a physiological and a psychological nature which have to be respected. It is, therefore, extraordinarily difficult to determine generally agreed values of protection ratios, even if both the transmission standards and the receiver characteristics are given.

A large amount of research work has been carried out since the beginning of broadcasting; this Report, however, is confined to results obtained since 1948.

It is well known that the radio-frequency protection ratios for transmitters working in the same channel can be improved considerably by synchronizing techniques, thereby increasing the effective service areas of these transmitters (see also Report 616). Actual values for these protection ratios depend on various factors, including the synchronization method (see § 7). A value of 8 dB was laid down at the Regional Administrative LF/MF Broadcasting Conference for Regions 1 and 3 [ITU, 1975].

2. Audio-frequency protection ratio

The audio-frequency protection ratio is the agreed minimum value of the audio signal-to-interference ratio considered necessary to achieve a subjectively defined reception quality (see Recommendation 447).

This ratio may have different values according to the type of service desired. It depends greatly on the type of the wanted and the unwanted programme. It is essential, therefore, to carry out a considerable amount of subjective listening tests, before a minimum value of the audio signal-to-interference ratio can be agreed upon.

It must clearly be stated that, due to physiological and psychological effects, it is completely impossible to fix reasonable values of the audio-frequency protection ratio by methods other than subjective tests.

3. Radio-frequency protection ratio

The radio-frequency protection ratio is the value of the radio-frequency wanted-to-interfering signal ratio that enables, under specified conditions, the audio-frequency protection ratio to be obtained at the output of a receiver.

These specified conditions include:

- the frequency spacing between the wanted and the interfering carrier;
- the characteristics of emission (type of modulation, modulation depth, dynamic compression, bandwidth of emission, harmonic distortion, tolerance on carrier frequency permitted by the Radio Regulations, etc.);
- the receiver characteristics (selectivity, susceptibility to non-linearities depending, for instance, on the receiver input voltage, etc.).

The radio-frequency protection ratio may, thus, be determined by means of subjective tests, as in the case of the audio-frequency protection ratio. When proceeding in this way the number of parameters to be taken into account and, hence, the amount of work to be done, will prove to be far greater than in the preceding case. Comparable results can only be obtained if the test conditions are rather similar.

However, the assessment of radio-frequency protection ratios can be considerably facilitated, once the audio-frequency protection ratio has been determined. Due to the fact that the majority of physiological and psychological effects only influence the audio-frequency protection ratio, it is possible to derive, under specified technical conditions and for a given value of the audio-frequency protection ratio, values of radio-frequency protection ratios, either by objective measuring methods or by graphical, [Parreaux, 1972] or numerical, [Petke, 1973; Gröschel, 1971] methods (see Recommendation 559).

It must be emphasised that the last mentioned three methods for the establishment of radio-frequency protection ratios, are based on the same basic ideas. They should lead, therefore, in principle, to the same results and, in fact, they do so, if the three methods are used with sufficiently high precision.

The lack of suitably reliable values for radio-frequency protection ratios in the past was mainly a consequence of the very complicated relationship between the radio-frequency protection ratio and the overall amplitude/frequency response of the receivers. The latter depends on the selectivity of the radio-frequency and the intermediate-frequency stages, the selectivity of the demodulator and the amplitude/frequency response of the audio-frequency stages. This difficulty has been partly overcome as a consequence of the establishment of the objective two-signal measuring method. This method, although quite reliable, has proved to be too complicated for general use, for example, by receiver manufacturers.

Numerical methods previously mentioned may however, be used to relate data on receiver selectivity characteristics, as provided by the receiver manufacturers, to values of radio-frequency protection ratio. Although the calculations are complicated and need electronic aids, they make possible, (in contrast to the objective measuring method), the determination of the overall frequency response of the receiver for a given radio-frequency protection ratio curve.

4. General principle of non-subjective methods

All non-subjective methods assume the use of standardized conditions at both the transmitting and the receiving end of the transmission system, as described in Recommendation 559.

In all interference problems, there are two different types of annoyance:

- the cross-talk from the interfering channel into the wanted channel, caused by modulation, and
- the beat-note produced by both carriers.

The beat-note predominates in annoyance when the carrier-frequency separation is between about 0.25 kHz and 5 kHz, at least for the majority of receivers in use.

5. Data available on protection ratios

Generally agreed values of radio-frequency protection ratios are given in Recommendation 560. Report 457 deals with the effect of a limitation of the bandwidth of emission on radio-frequency protection ratios. The information given in these texts refers explicitly or, in the case of § 2 of Recommendation 560, mainly to amplitude-modulation sound broadcasting in bands 5 (LF) and 6 (MF). Further information on protection ratios may be found in [Belger and von Rautenfeld, 1958; Liedtke, 1965]. Additional data for broadcasting in band 7 (HF) are contained in Recommendation 411. The curves reproduced in Report 302 represent data at present available on the subject of Study Programme 45E/10 and refer principally to the protection ratios required to provide an acceptable broadcasting service in the Tropical Zone in the shared bands.

5.1 Radio-frequency protection ratios for ground-wave services

5.1.1 Stable wanted and interfering signals (ground-wave signal interfered with by another ground-wave signal)

In Recommendation 560, a value of 40 dB is given for use in bands 5 (LF) and 6 (MF) for co-channel transmissions.

With this value of radio-frequency protection ratio a high quality of reception is possible. For planning purposes, however, it may be necessary to adopt lower values. This problem has been studied by the EBU [CCIR, 1970-74a] and in Japan [CCIR, 1970-74b]. The values that have been proposed are 30 dB and 26 dB, respectively, and in fact, a value of 30 dB was agreed upon by the Regional Administrative LF/MF Conference for Regions 1 and 3.

Relative values of radio-frequency protection ratios as a function of the separation between the carrier frequencies of the wanted and the interfering signal are given in the form of curves in § 2 of Recommendation 560. These curves are based partly on measurements made in accordance with the objective two-signal method of measurement and partly on computations (see Recommendation 559).

The influence of dynamic compression and audio-frequency bandwidth limitation can also be seen from these curves. It should be noted, however, that the full improvement in protection resulting from bandwidth limitation can only be obtained when the non-linearity of the transmitter is small.

5.1.2 Stable wanted and fluctuating interfering signal [Belger et al., 1965]

5.1.2.1 Short-term fading

Short-term fading of the interfering signal modifies the character of the disturbance felt by the listener: if, for a given audio-frequency signal-to-interference ratio, the interfering signal is made to fluctuate, the disturbance is subjectively felt to be more severe. [CCIR, 1963-66a, b and c] indicate that, to obtain the same degree of satisfaction to the listener, the protection must be increased by about 5 dB in the latter case.

In Recommendation 560, the value for short-term fading has been incorporated in the radio-frequency protection ratio.

5.1.2.2 Long-term field-strength variations

A formula permitting the determination of the ratio between a stable wanted and a fluctuating unwanted field strength (see Annex I to Recommendation 435) is:

$$R = E_{ou} - E_{on} + L_t \quad (1)$$

where

R : is the ratio (dB) of the two field strengths at time t hours relative to the sunrise or sunset reference times as appropriate, for 50% of the nights of a year;

E_{ou} : is the field strength (dB rel. 1 $\mu\text{V}/\text{m}$) of the ground-wave of the wanted signal;

E_{on} : is the annual median value of the ionospheric field strength (dB rel. 1 $\mu\text{V}/\text{m}$) of the unwanted signal at the reference time (see Annex I to Recommendation 435);

L_t : is the hourly loss factor (dB) which shows the average of the annual median hourly variations at the time t in hours relative to the sunrise or sunset reference times, as appropriate. These are taken at the ground at the mid-path position for path lengths shorter than 2000 km and at 750 km from the terminal where the sun sets last or rises first for longer paths. Values of L_t are given in Fig. 3 of Recommendation 435.

To ensure protection corresponding to a protection ratio of A (dB), the condition

$$A \leq R \quad (2)$$

must be satisfied.

Since the field strength exceeded for 10% of the total time on a series of nights, during short periods centred on a specific hour is:

- 8 dB greater in band 5,
- 10 dB greater in band 6,

than the values $E_{on} - L_i$ given above, the wanted-to-interfering signal ratio $R(90)$ exceeded during 90% of the nights of a year is lower by an equal number of decibels.

5.2 *Radio-frequency protection ratios for sky-wave services*

A characteristic of the sky-wave service, especially when reception is being made with envelope detectors, is that propagation effects usually bring about a degradation of the received signal quality, for example, distortion in the case of selective fading. Because of this fact, it is considered that lower values of protection ratios should be applied to a sky-wave service as compared with a ground-wave service, the precise values depending upon whether the service is a primary one, as for broadcasting in band 7 (HF), or a secondary one, as for broadcasting in bands 5 (LF) and 6 (MF), where the primary service is provided by the ground-wave.

In Recommendation 560, no value is recommended for use when the service is provided by the sky-wave.

5.2.1 *Bands 5 (LF) and 6 (MF)*

As a result of the studies carried out by the EBU [CCIR, 1970-74a], in bands 5 (LF) and 6 (MF), a co-channel RF protection-ratio value of 27 dB has been proposed and in fact adopted, by the Regional Administrative LF/MF Conference for Regions 1 and 3.

5.2.2 *Band 7 (HF)*

In band 7 (HF) following the studies carried out in India [CCIR, 1978-82a], the USA, and U.S.S.R. and in the EBU, the radio-frequency protection ratio to be used for co-channel transmission (± 10 Hz, see Note) should be in the range of 27-40 dB for steady state conditions.

Note. — The permissible difference in carrier frequencies in band 7 (HF) can be as high as 600 Hz and is applicable to transmitters working at 20 MHz until January 1990 according to Appendix 7 of the Radio Regulations. After this date, this value applies only to transmitters of 10 kW power or less. For all other transmitters, the permissible frequency tolerance will be 10 Hz.

For planning purposes, a minimum value of 27 dB for stable conditions and a frequency difference of ≤ 100 Hz between the carriers is proposed.

A fading allowance of 10 dB should be added to this value if the stable condition protection ratio is to be achieved for greater than 90% of the time during short-term Rayleigh fading conditions. Moreover an additional factor needs to be added to ensure that the proper allowances are made for long-term fading.

Further studies are required to define the allowances needed to take account of various percentages of time availability and to establish the appropriate percentage of time for which the steady state protection ratio is to be achieved for services in band 7 (HF).

5.2.3 *Conclusion*

However, only a restricted amount of information is at present available on this aspect of broadcasting and administrations are strongly urged to carry out further studies.

5.3 *Measurement results*

Measurement of protection ratios for stable signals were carried out in the U.S.S.R. [CCIR, 1978-82b]. The following quality criteria were used as the basis of an experiment:

- perceptibility of interference in the background of the wanted programme,
- tolerance to interference while listening to the wanted speech programme.

Quantitative assessment using these criteria were made in the Soviet Union by a number of experts subjectively assessing an agreement between a given fragment of the programme and a predetermined criterion.

The results obtained in the experiment show the subjective assessment value K as a function of the absolute protection ratio A at a given performance criterion m , i.e.

$$K = \varphi_m(A)_0$$

and each of these relationships complies with a set of parameter combinations listed in § 5.3.2. The value of K denotes the proportion of the experts who found the interference tolerable; for example, when $K = 0.9$, 90% of the experts found the interference tolerable.

While processing the results of the experiment, a calculation of errors for all test points was carried out and these errors amounted to an average of 8.1%; this corresponds to an accuracy of 0.9 dB at the test point $K = 0.5$.

The results of measurement are given in Figs. 1, 2, 3 and in Table I.

5.3.1 Co-channel protection ratios

Figure 1 shows the results of the co-channel protection ratio measurements. Curve A represents the wanted speech programme with a wide dynamic range (recitation), curve B corresponds to the wanted speech programme, information, news, etc., with a small dynamic range (using clipping of the wide dynamic range of programme), and finally curve C corresponds to the wanted music programme with a small dynamic range (modern dance music). The interfering programme was modern dance music. Each of these curves has been plotted for different receiver passbands. The shaded parts in Fig. 1 correspond to a change of passband from wide to narrow.

Relative interference insusceptibility, as a function of protection ratio, has been obtained for the worst case, when the wanted and interfering programmes are broadcast in one language with a wide dynamic range without any band constraints and the voices are similar in tone colour. These results are shown in broken lines in Fig. 1 and Fig. 2.

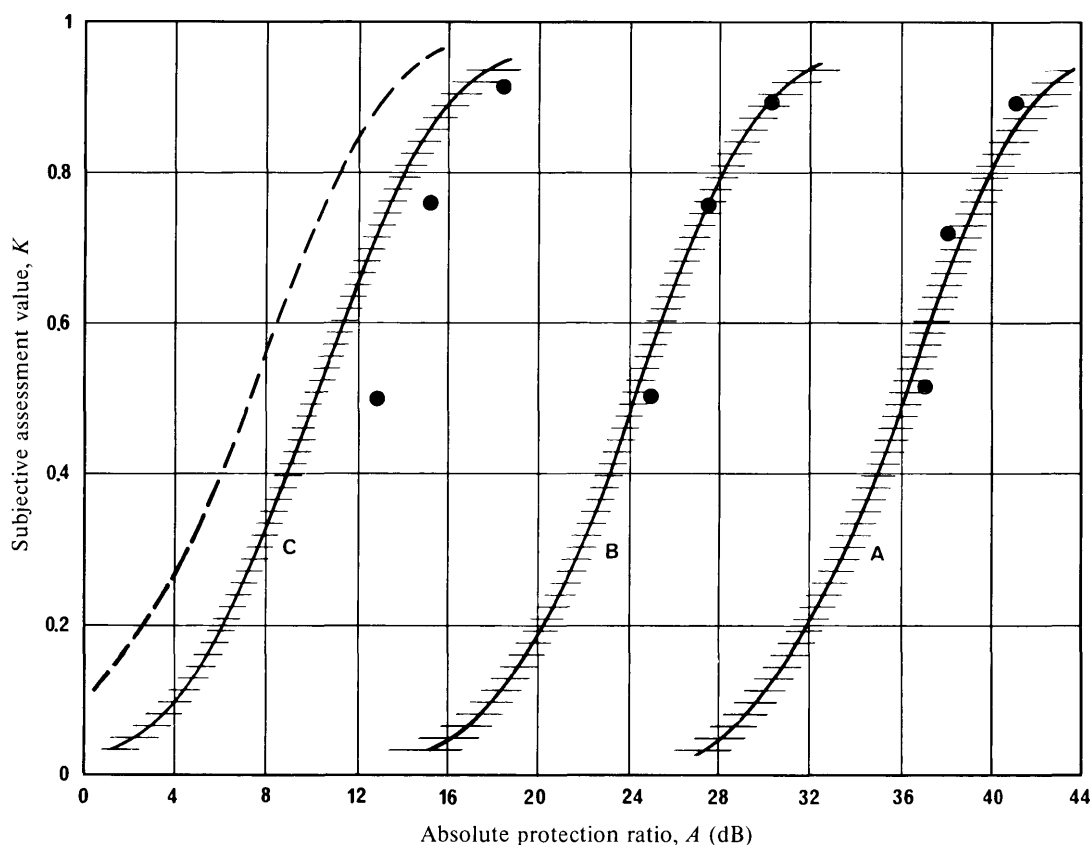


FIGURE 1 – Co-channel protection ratio measurements

- : measured values
- — : worst case, wanted and interfering programmes broadcast in one language with wide dynamic range, no band constraints and voices similar in tone colour
- Curves A: wanted speech programme with wide dynamique range
- B: wanted speech programme with small dynamique range
- C: wanted music programme with small dynamique range

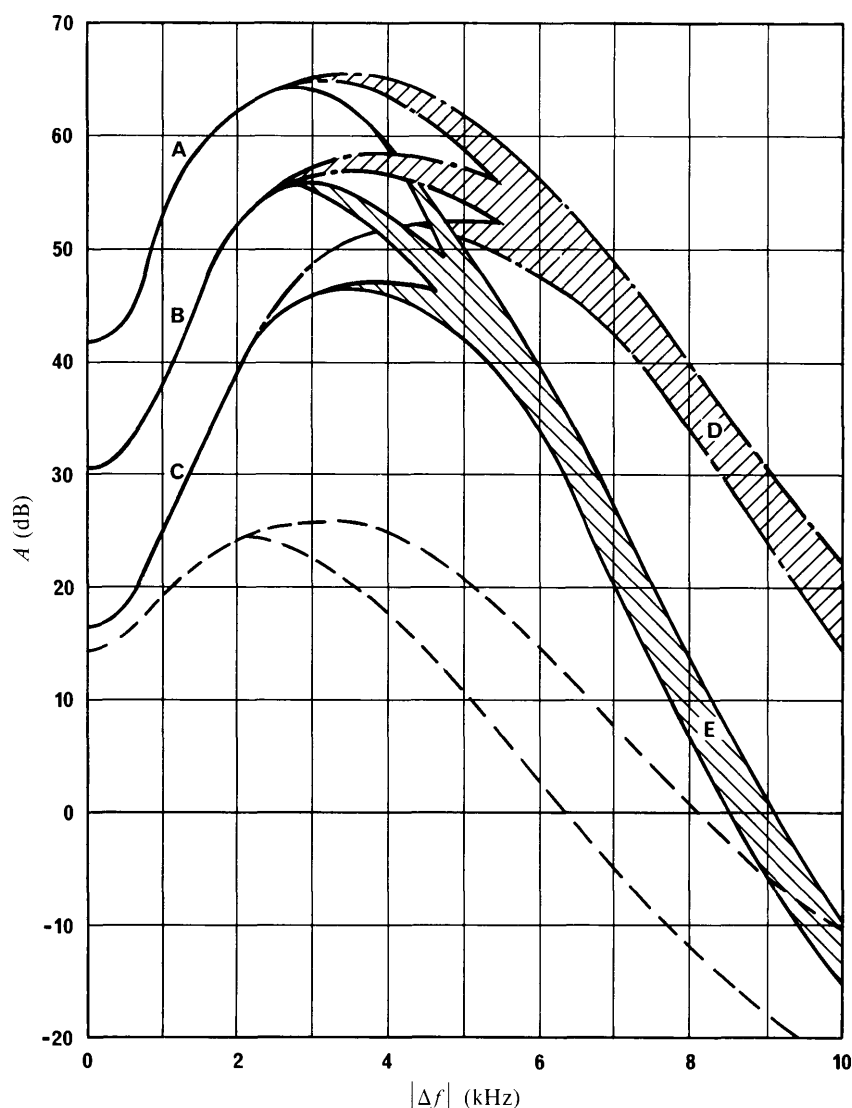


FIGURE 2 – Protection ratio as a function of carrier spacing

— — — : worst case, wanted and interfering programmes broadcast in one language with wide dynamic range, no band constraints and voice similar in tone colour

Curves A: wanted speech programme with wide dynamique range
 B: wanted speech programme with small dynamique range
 C: wanted music programme with small dynamique range
 D: wideband
 E: narrowband

5.3.2 Protection ratio as a function of frequency spacing

On the basis of the functions $K = \varphi_m(A)$ obtained in the experiment, values of protection ratio as a function of the wanted and interfering carrier-frequency spacing, $A = \psi_m(\Delta f)$, have been derived for $K = 0.9$, i.e. for the case when the specified part of the programme was found to meet the predetermined criterion in the opinion of 90% of the experts.

Figure 2 shows the above relations. The curves A, B and C represent the same conditions as those described in § 5.3.1. Shaded parts of the curves correspond to the scatter determined by the receiver passband. Figure 3 gives the receiver selectivity curves $S(F)$, where the shaded parts indicate the dispersion of curves $S(F)$ for receivers of different classes. Also shown in Fig. 3 is the selectivity curve of the EBU MBF receiver (see Recommendation 560).

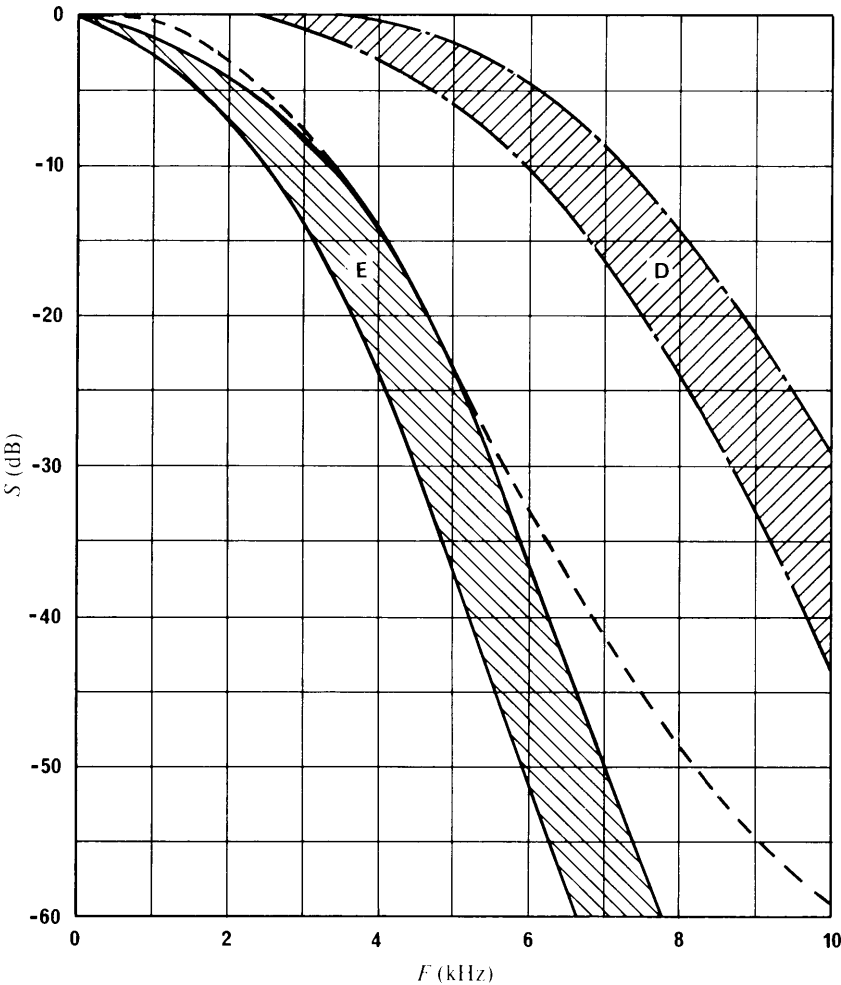


FIGURE 3 – Receiver selectivity curves

--- : EBU MBF receiver
Courbes D: wideband
E : narrowband

5.3.3 Effect of modulating signal bandwidth on protection ratios

At this stage of the experiment, the modulating frequency bandwidths of both the wanted and interfering signals were limited using two identical switched filters with the cut-off frequencies $F = 10$ kHz, 6.8 kHz and 3.4 kHz and with frequency response slopes of 90 dB/decade. Interference imperceptibility was taken as the quality criterion. Experimental results for the highest-class receiver “Symphony 003” are summarized in Table I.

TABLE I

Carrier frequency spacing, Δf (kHz)	Wanted programme	Protection ratio (dB) at F (kHz)		
		10	6.8	3.4
0	{ Speech Music	42	43	42
		16	15	14
5	{ Speech Music	62	62	63
		54	52	56
10	{ Speech Music	12	16	11
		9	11	10

As can be seen from the results in Table I, a change of modulating frequency bandwidths has no pronounced effect on protection ratios. This can be accounted for by the relatively small number of high frequency components in the spectrum of the modulation signals used.

5.4 *Result of receiver measurements*

Objective measurements of radio-frequency protection ratios have been carried out in Japan. Seven current protection MF/HF sound broadcasting receivers in the medium and low cost range were used and the measurements were made in the MF band and two of the HF bands. The average values of protection ratio obtained implied that up to 5 dB more protection was needed than that given by curve C of Fig. 1 in Recommendation 560 for a frequency spacing of 9 kHz [CCIR, 1978-82c].

6. **Subjective assessment of the quality of reception**

Statistical and subjective tests were carried out in the U.S.S.R. on the effects of distortion and interference in a broadcast channel.

The tests were performed using a statistically based subjective method, using special equipment which enabled a comparison to be made between an undistorted sound programme and a second programme, into which predetermined levels of distortion had been injected.

The object of these experiments was to determine the perceptibility of distortion and the following groups of listeners participated:

- qualified experts (sound-broadcasting producers),
- observers without special musical education and without training in the observation of distortion.

The results of these experiments were published in the form of graphs, showing the percentage of perceptibility as a function of the level of the distortion or interference injected.

All these tests were made on the basis of a large amount of statistical data. The correctness of the data obtained was checked by the methods of mathematical statistics. The results were given in terms of:

- linear distortion of different types (at various levels and for different frequency ranges),
- non-linear distortion (cubic, quadratic and “central cut-off” types),
- background noise (sinusoidal),
- white noise.

A comparison of the reception quality determined by the objective method or subjective tests shows differences in the necessary protection ratio. This difference may reach 10 dB for a frequency spacing of 9 kHz [CCIR, 1974-78a].

Some similar subjective listening tests were performed in Japan in 1973 from which the conclusion was drawn that a radio-frequency protection ratio of 26 dB satisfies about 66.7% of the listeners.

7. **Radio-frequency protection ratios for synchronized broadcasting transmitters**

7.1 *Investigations carried out in the U.S.S.R.*

These investigations were carried out to determine values of signal-to-interference ratio applicable to reception of transmissions from synchronized transmitter groups comprising two or three transmitters. Both phase and frequency methods of synchronization were considered.

7.1.1 *Explanation of the term “radio-frequency protection ratio”*

The term “protection ratio” in this context means the ratio of the field strength of the strongest signal from one of the transmitters in the synchronized group to the resultant field strength of the remaining transmitters in the same group.

7.1.2 *Determination of the protection ratio*

For the purpose of determining the protection ratio, use was made of a statistical method based on subjective impressions of reception quality from a transmitter in a synchronized group, compared with reception quality of a single non-synchronized transmitter station. Twenty-six experts were employed – all of whom were technical and scientific broadcasting staff.

Protection ratio values for non-fading signals were determined under laboratory conditions and later verified under operational conditions.

For fading signals only operational tests using a synchronized network were carried out.

For all these tests the depth of maximum modulation was 90%.

7.1.3 Results of investigations

Figure 4 shows the variations in protection ratio as a function of the phase shift between the carriers of two stations during day-time in the absence of fading. The parameter used in these curves is the percentage of experts who rate the total signal as being at least satisfactory. It will be seen from this figure that, to satisfy 90% of the listeners, the protection ratio for a network consisting of two synchronized stations for reception without fading was 4 dB.

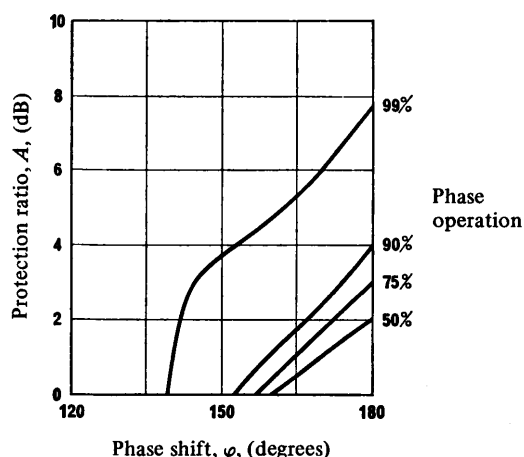


FIGURE 4 – Quality of speech and music transmissions as a function of the phase difference between the carriers of two stations (non-fading conditions)

Figure 5 shows the variation in protection ratio as a function of the difference in frequency between two synchronized transmitters for the percentage of experts who found the reception quality to be satisfactory. This figure shows that, for non-fading signals with two synchronized transmitters and a protection ratio of 4 dB, it is necessary to have a synchronization accurate to 0.015 to 0.02 Hz, to satisfy 90% of listeners. With a frequency difference of 0.1 Hz the protection ratio has to be increased to 6 dB.

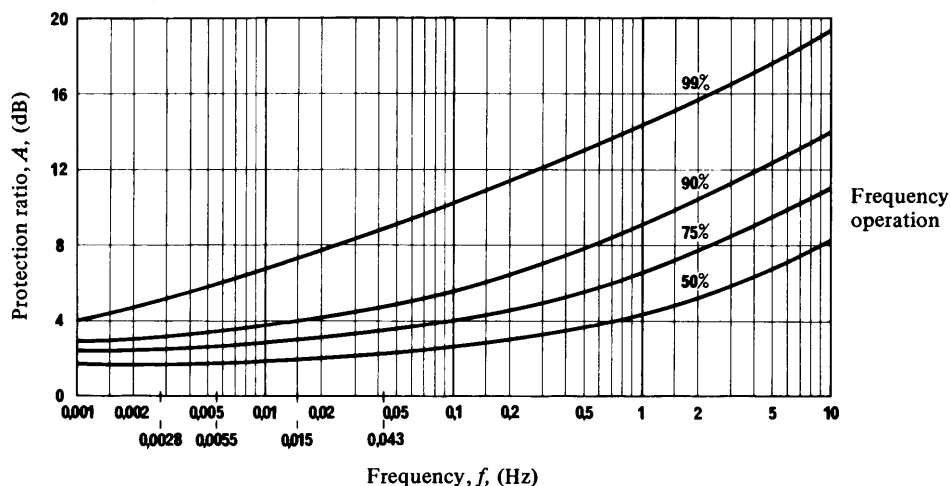


FIGURE 5 – Quality of speech and music transmissions as a function of carrier synchronization accuracy of two stations (non-fading conditions)

Figure 6 contains similar curves for phase synchronization operation of three transmitters. To satisfy 90% of the listeners the protection ratio should not be less than 3.1 dB. (The standard value is 4 dB.)

It is concluded that when reception is affected by fading it will be necessary to increase the protection ratio to 7 or 8 dB in the case of two synchronized transmitters, and to 6 dB in the case of three transmitters.

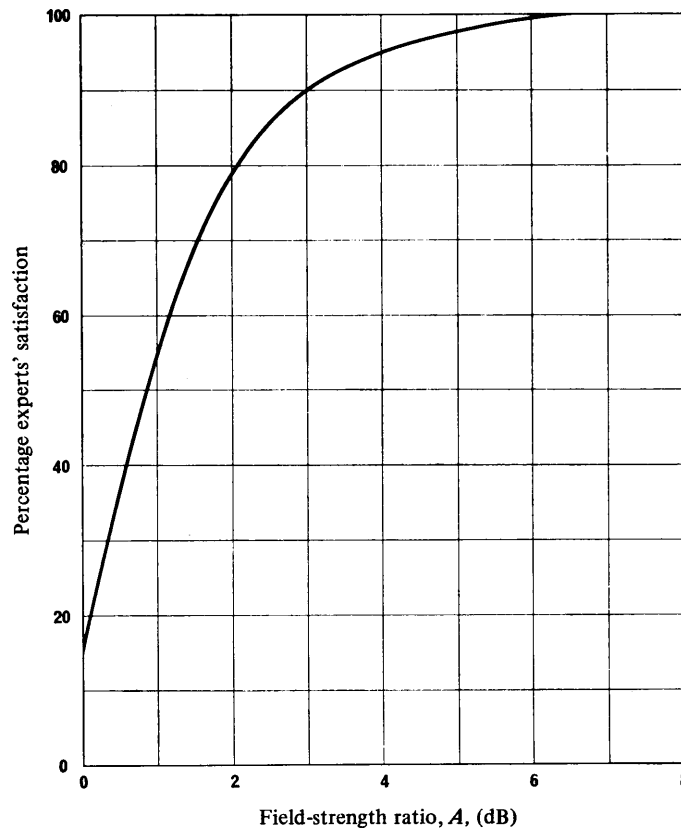


FIGURE 6 – *Quality of speech reception and of music transmissions as a function of the field-strength ratios of three transmitters synchronized in phase*

7.2 Investigations carried out within the EBU

Synchronizing techniques as developed up to 1964 (and in most cases still in use) in several countries, notably, Austria, France, Federal Republic of Germany, Italy, Netherlands, Norway, Sweden, United Kingdom, Australia and the United States of America, are described in [EBU, 1974] which contains an extensive bibliography, as well as a survey of the theoretical basis of these techniques.

7.3 Investigations carried out within the OIRT

In [Augustin and Schulze, 1973], it was found that it is possible to simulate all the essential effects of synchronized or non-synchronized common channel systems (same programme) in practice, by a model. Such a model, a block diagram of which is shown in Fig. 7, was developed by the Rundfunk- und Fernsehtechnisches Zentralamt of the Deutsche Post, Berlin. That model offers both economical and operational advantages, when carrying out studies on reception problems in the area, where the ground waves of synchronized transmitters interfere; i.e., without taking into account ionospheric fading effects.

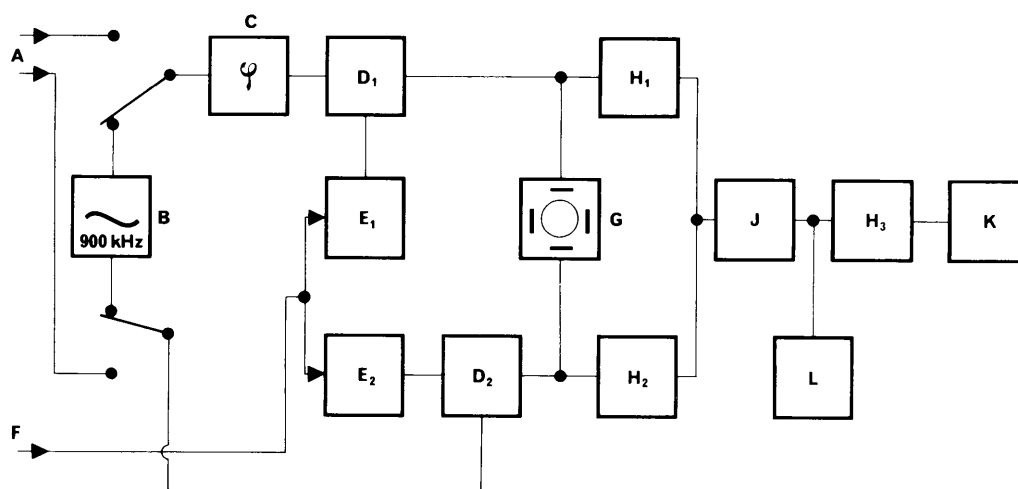


FIGURE 7 – Schematic arrangement of common-channel model

<i>A</i>	: External oscillator	<i>G</i>	: Oscilloscope
<i>B</i>	: Frequency standard (900 kHz)	<i>H₁, H₂, H₃</i>	: Level adjustment
<i>C</i>	: Phase hifter	<i>J</i>	: Adding network
<i>D₁, D₂</i>	: Transmitters	<i>K</i>	: Receiver
<i>E₁, E₂</i>	: Audio-frequency delay line	<i>L</i>	: Level indicator
<i>F</i>	: Modulation		

When using the above-mentioned model system, it is possible to study synchronized or non-synchronized common channel systems in the laboratory. In particular it has been found that the following measures are suitable [Augustin and Schulze, 1973]. If the carrier frequencies differ by only about 0.1 Hz and if the delay times of the sound signals between the studio and the transmitters of this system have been equalized, the following advantages then result:

- decrease of the interference zone to almost zero, and
- decrease of the selective fading effects, so that only amplitude fading effects still remain, which are entirely compensated for by the automatic gain control of the receiver, without unacceptable distortions.

In conclusion, it can be said that these effects permit a protection ratio of 0 dB for day-time reception.

These theoretical results have been confirmed in field tests by using two transmitters of 20 kW operating in band 6 (MF) with a spacing of about 80 km.

7.4 Investigations carried out in the United Kingdom

7.4.1 Equalization of modulation delay

Laboratory tests conducted by the BBC [Whyte, 1976] to study the effect of modulation delay in a common-channel, same-programme system gave the results shown in Table II applicable to two carriers, with the order of 0.1 Hz frequency difference, modulated by a music programme. The impairment was slightly less severe when using a speech programme.

Given the field-strength contours for a two-transmitter situation the results of Table II can be used to assess the improvement to daytime reception that modulation-delay equalization could provide over any affected region. In most cases, improvement is gained over the greatest area if the modulation delays are equated at the point where the equal-field-strength locus crosses the straight line joining the two transmitters. It may be preferable, however, to equate the modulation delays at some other point, for example, near a highly populated part of the affected region, in order to improve daytime reception for the greatest number of listeners.

TABLE II

Carrier-amplitude ratio (dB)	Subjective grade of impairment exceeded for 10% of the time for modulation-delay inequality of:(1)					
	0	30 μ s	50 μ s	84 μ s	250 μ s	1 ms
0	4	3	2	1	1	1
3	5	5	4.5	2.5	1	1
6	5	5	5	5	3.5	2
9	5	5	5	5	5	5

(1) 5-grade subjective impairment scale (Recommendation 562).

A nine-months field trial between the BBC medium wave transmitters (1214 kHz) at Brookmans Park (50 kW, directional antenna) and Droitwich (30 kW, omni-directional antenna), which are 145 km apart, largely confirmed the results of Table II and showed the arrangement to be practicable and stable and to impose very little demand operationally. The trial revealed the following practical aspects:

- It was found practicable to achieve and maintain phase equalization to within $\pm 30^\circ$ over the modulation band 50 Hz to 4 kHz at the chosen receiving point.
- After inserting the phase equalization, the residual distortion was nevertheless still significant in practice, in regions where the two field strengths differed by less than 1.5 dB; in other words, a protection ratio of 1.5 dB is still required for good reception.

7.4.2 Carrier phase locking

A system of carrier phase locking has been introduced in the United Kingdom [Millard *et al.*, 1979] for three common frequency transmitters on 200 kHz. The transmitters in question are situated in Droitwich in the centre of England, at Westerglen near Edinburgh and at Burghead in north-east Scotland. The phase locking is used in conjunction with audio delay equalization (see § 7.4.1) so that the signals received in the approximately equal field strength areas between adjacent stations (i.e. between Droitwich and Westerglen and between Westerglen and Burghead) are maintained with carriers in phase and with the timings of the modulation envelopes equalized. Furthermore, the three transmitters are driven with rubidium standard units of high frequency stability. In the critical areas, therefore, the standing wave patterns remain fixed and distortion is minimized and a stable, unvarying situation is provided for listeners. Receivers with ferrite-rod antennas may experience poor reception only on or near lines joining the transmitters. Elsewhere the magnetic fields act in different directions and do not cancel [Knight, 1980].

Experience to date indicates that the system is providing a good nationwide service.

Consideration is being given to the application of the technique to MF broadcasting.

8. Protection ratios in AM SSB sound broadcasting

A study was carried out in the People's Republic of Poland on the improvements in protection ratio that can be obtained when replacing the DSB system with an SSB system, without simultaneously reducing the channel separation [CCIR, 1974-78b].

The results showed that even in an SSB set whose RF and IF amplifiers do not differ from those used in simple DSB receivers, the adjacent-channel interference caused to the wanted signal is considerably reduced. The following improvement values are always referred to the protection ratio established for cases where both the wanted and the interfering transmitter operate with two sidebands, each of them 4.5 kHz wide (see Fig. 8a).

The improvement obtained in cases where both the wanted and the interfering transmitter operate with SSB (upper) (see Fig. 8c) is on average:

- 29 dB and 39 dB, respectively, for the first adjacent lower channel and the first adjacent upper channel;
- 29 dB and 34 dB, respectively, for the second adjacent lower channel and the second adjacent upper channel.

In cases where the DSB transmitter causes interference to an SSB signal (see Fig. 8d), the following improvement is obtained:

- 29 dB and 12 dB, respectively, for the first adjacent lower channel and the first adjacent upper channel;
- 22 dB for the second adjacent lower channel.

In the opposite case, where the SSB transmitter causes interference to the DSB signal (see Fig. 8b), the following improvement is obtained:

- 4 dB for the first adjacent upper channel;
- 9 dB and 19 dB, respectively, for the second adjacent lower channel and the second adjacent upper channel.

The protection ratios obtained when the SSB receivers have the same IF bandwidth as the DSB receivers do not depend on the type of transmission used by the wanted and interfering transmitters.

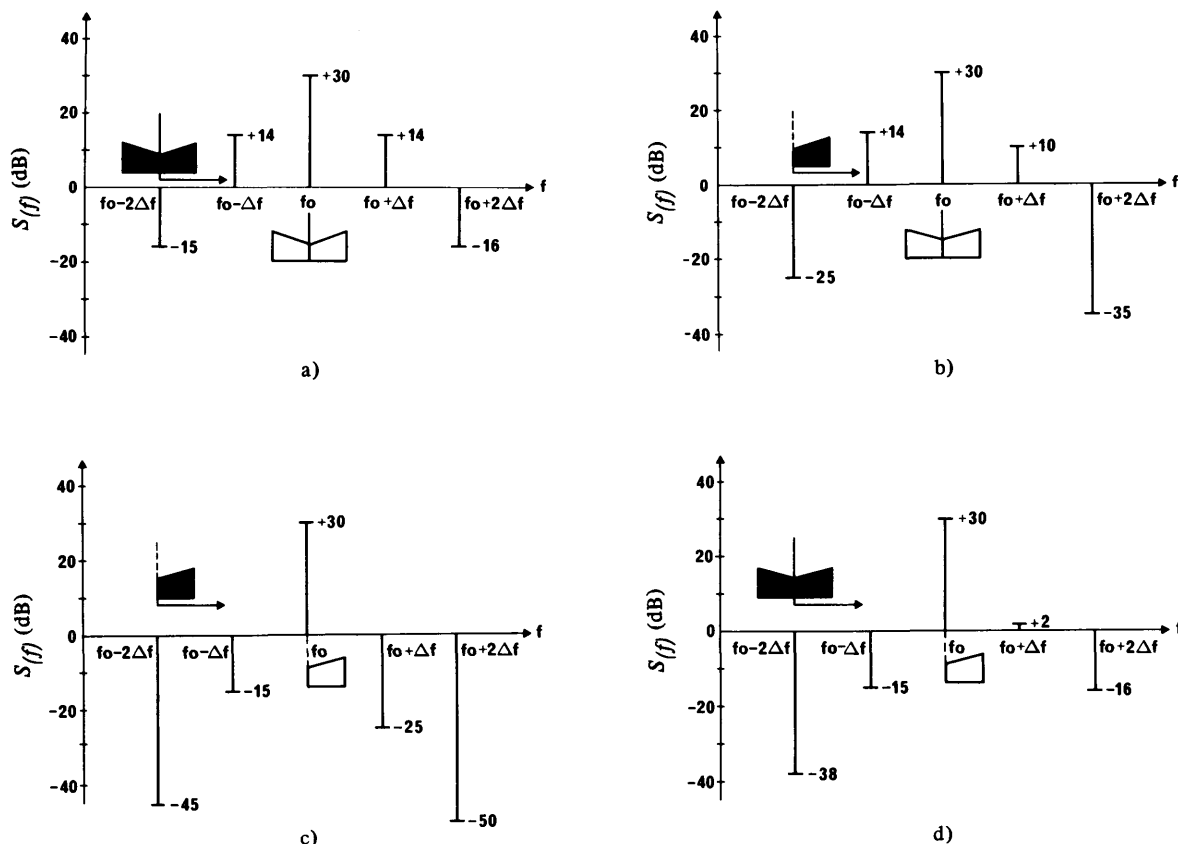


FIGURE 8 – Improvement in protection ratio, $S(f)$ resulting from the use of single sideband modulation

- (a) DSB signal interfered with by a DSB emission
- (b) DSB signal interfered with by an SSB emission
- (c) SSB signal interfered with by an SSB emission
- (d) SSB signal interfered with by a DSB emission

□ : wanted signal

■ : interfering signal

REFERENCES

- AUGUSTIN, E. and SCHULZE, R. [1973] Probleme des Gleichwellenrundfunks: ein optimales Gleichwellensystem (Problems of synchronized broadcasting transmissions: An optimum system of synchronized transmitters). *Techn. Mitt. RFZ*, **4**, 95-97.
- BELGER, E. and VON RAUTENFELD, F. [1958] Der erforderliche Gleichkanal- und Nachbarkanal-Störabstand beim amplitudenmodulierten Tonrundfunk (The protection ratios required for common channels and adjacent channels in amplitude-modulated sound broadcasting). *Rundfunktechn. Mitt.*, **2**, 172-177.
- BELGER, E., VON RAUTENFELD, F. and VOGT, K. [April, 1965] The wanted-to-interfering signal ratio required with an interfering signal fluctuating in time, in amplitude-modulation sound broadcasting. *EBU Rev. Tech.*, Part A, **90**, 69-72.
- EBU [1974] Synchronization groups of transmitters in LF and MF broadcasting. Doc. Tech. No. 3210.
- GRÖSCHEL, G. [1971] Out-of-band radiation and its influence on the adjacent channel with amplitude-modulated sound broadcasting. *Nachrichtentechn. Fachber.*, **41**, 41-49.
- ITU [1975] Final Acts of the Regional Administrative LF/MF Broadcasting Conference for Regions 1 and 3, Geneva, Switzerland.
- KNIGHT, P. [1980] Reception of phase-locked LF and MF transmissions by receivers having ferrite-rod antennas. *Electron. Lett.*, Vol. 16, **1**, 40.
- LIEDTKE, G. R. [April, 1965] The effect of receiver characteristics and radiated bandwidth on the RF wanted-to-interfering signal ratio in amplitude-modulation sound broadcasting. *EBU Rev. Tech.*, Part A, **90**, 65-68.
- MILLARD, G. H., THODAY, R. D. C. and PRICE, H. M. [1979] Synchronization of the Radio-4 (United Kingdom) transmitter chain on 200 kHz. BBC Research Report 1979/27.
- PARREAUX, D. [August, 1972] A graphical method of determining protection ratios in the case of LF and MF amplitude-modulated transmissions. *EBU Rev. Tech.*, **134**, 163-167.
- PETKE, G. [October, 1973] Determination by calculation of the RF protection ratio for AM transmission systems. *EBU Rev. Tech.*, **141**, 227-234.
- WHYTHER, D. J. [1976] Reduction of mush-area distortion in common-frequency MF transmitter networks. BBC Research Report 1976/5.

CCIR Documents

- [1963-66]: **a.** X/5 (EBU); **b.** X/31 (Germany (Federal Republic of)); **c.** X/36 (France).
- [1970-74]: **a.** 10/266 (EBU); **b.** 10/286 (Japan).
- [1974-78]: **a.** 10/324 (U.S.S.R.); **b.** 10/343 (People's Rep. of Poland).
- [1978-82]: **a.** 10/245 (India); **b.** 10/209 (Rev. 1) (U.S.S.R.); **c.** 10/184 (Japan).

BIBLIOGRAPHY

- BACHMUTOVA, N. I., PYLAEVA, Z. D., TISHIN, S. A. and YAMPOLSKAYA, N. G. [1975] Protection ratios in LF/MF European broadcasting networks. *Elektrosviaz*, **7**, 22-24.
- KOKOREV, A. V. [1976] Choice of adjacent channel protection ratios for LF/MF broadcasting systems. *NIIR Proc.*, **4**.
- KOKOREV, A. V. and SHLÜGER, I. S. [1977] Protection ratios in band 7 (HF). *Elektrosviaz*, **10**, 33-38.
- SHAMSHIN, V. A. and SHLÜGER, I. S. [October, 1975] Adjacent channel protection ratios for LF/MF sound broadcasting (150-1605 kHz). *Telecomm. J.*, Vol. 42, **X**, 606-607.

CCIR Documents

- [1963-66]: X/4 + Add. 1 (Germany (Federal Republic of)).

RECOMMENDATION 559-1 *

**OBJECTIVE MEASUREMENT OF RADIO-FREQUENCY PROTECTION RATIOS
IN LF, MF AND HF BROADCASTING**

(Question 44/10, Study Programme 44A/10)

(1978–1982)

The CCIR,

CONSIDERING

- (a) that the radio-frequency protection ratio is directly related to the audio-frequency protection ratio (see Recommendation 447);
- (b) that this relationship depends on a number of technical parameters, as there are:
 - the frequency separation between the wanted and unwanted carriers;
 - the bandwidths of the transmitter and the receiver;
 - the rate-of-cut of the band-limiting filters at the transmitting and receiving end;
 - the type and depth of modulation;
 - the spectral energy distribution of the modulation signal;
 - the dynamic compression;
 - the pre-emphasis and de-emphasis characteristics, if any;
 - the out-of-band radiation of the transmitter;
 - the amplitude/frequency response of the human ear, which can be simulated by the weighting network of the measuring instrument, (see Recommendation 468);
 - the amplitude of the receiver input voltage,

UNANIMOUSLY RECOMMENDS

that, once an audio-frequency protection ratio has been agreed upon, one of the following objective two-signal methods should be used for the determination of radio-frequency protection ratios in amplitude-modulation sound broadcasting.

1. Objective measuring method

1.1 Principle

The objective method is essentially a two-signal method which consists in modulating successively, with a given modulation depth, the wanted and the interfering transmitter by a standard colour noise signal, the spectral amplitude distribution of which corresponds to modern dance music programmes.

The interference effect is measured at the audio-frequency output of the receiver by means of a standardized instrument (see § 1.2). The reference value used to define the audio-frequency signal-to-interference ratio is that which is measured at the audio-frequency output of the receiver with the same instrument, when the wanted transmitter is modulated with the “coloured” noise, while the unwanted transmitter is switched off.

1.2 Output measurement

For measuring the wanted and interfering signals at the output of the receiver, a standardized instrument is to be used. This includes a network for weighting the subjective interference effect of different interfering frequencies in accordance with Recommendation 468 and a voltmeter portion for r.m.s. measurements. **

* Further information is given in Report 794.

** The use of an r.m.s. rather than a quasi-peak meter as given in Recommendation 468 permits more accurate account to be taken of the beat-note predominant with closer frequency spacings and all other effects. This conclusion was drawn from the excellent agreement between the values of radio-frequency protection ratio obtained, either using the objective two-signal method, or from subjective listening tests for all values of frequency spacing.

1.3 *Noise signal for modulating the signal generators*

Two conditions must be fulfilled by the standardized signal to simulate programme modulation:

- its spectral constitution must correspond to that of a representative broadcast programme;
- its dynamic range must be so small as to result in a constant unequivocal reading on the instrument.

The amplitude distribution of modern dance music was taken as a basis, as it is a type of programme with a considerable proportion of high audio-frequencies, which occur most frequently. However, the dynamic range of this type of programme is too wide and does not fulfil, therefore, the second requirement mentioned above. A signal which is appropriate for this purpose is a standardized coloured noise signal, the spectral amplitude distribution of which is fairly close to that of modern dance music (see curve A of Fig. 2, which is measured using one-third octave filters). *

This standardized coloured noise signal may be obtained from a “white-noise” generator by means of a passive filter circuit as shown in Fig. 3. The frequency-response characteristic of this filter is reproduced as curve B of Fig. 2. (It should be noted that the difference between curves A and B of Fig. 2 is due to the fact that curve A is based on measurements with “one-third octave” filters which pass greater amounts of energy as the bandwidth of the filter increases with frequency.

The spectrum beyond the required bandwidth of the standardized coloured noise should be restricted by a low-pass filter having a cut-off frequency and a slope such that the bandwidth of the modulating signal is approximately equal to half the standardized bandwidth of emission. The audio-frequency amplitude/frequency characteristic of the modulating stage of the signal generator shall not vary by more than 2 dB up to the cut-off frequency of the low-pass filter.

1.4 *Measuring arrangements*

Figure 1 shows a schematic diagram of the measuring arrangements, in which the elements of fundamental importance are drawn in thick outlines. The other elements are measuring and control devices which are required for putting the investigations into practice, or for facilitating them.

1.5 *Depth of modulation of the test transmitters*

The depth of modulation of the wanted or interfering signals is determined by the following procedure. The signal generator is first modulated to a depth of 50% with a sinusoidal tone at 1 kHz from the generator A, adjusted by means of the attenuator B and verified by oscilloscope S at the radio-frequency outputs of modulators H or L, and the required audio-frequency voltage is measured at the modulator inputs (switch U) by means of the instrument R. The amplitude of the noise signal (C + D), which is measured with the same measuring instrument R, should then be adjusted (by means of the attenuator E) to read 6 dB lower than the value obtained with the sinusoidal signal; provided that the instrument has a time constant of 200 ms. This corresponds to a depth of modulation of 50% measured with a programme meter with quasi-peak indication. Deeper modulation is not appropriate, because, on account of its very small dynamic range, the noise would have a more disturbing effect than any real programme.

1.6 *Audio-frequency signal-to-interference ratio*

The signal generator (wanted signal) (G + H + J) modulated with noise according to §§ 1.3 and 1.5 produces a signal at the audio-frequency output of the receiver under test Q, which represents, measured with the instrument R, the reference level “zero”. The noise modulation is then transferred by means of the switch U, from the audio-frequency input of the modulator H of the signal generator (wanted signal) to the audio-frequency input of the modulator L of the signal generator (interfering signal). After suppression of the modulation of the wanted signal, the radio-frequency level of the interfering signal generator (K + L + M) is then adjusted so that the unwanted voltage, as measured by means of the instrument R at the receiver output, results in the required audio-frequency signal-to-interference ratio; for example, 20, 30 or 40 dB below the reference value.

1.7 *The radio-frequency level of the wanted signal at the receiver input*

The radio-frequency output voltage of the wanted-signal generator (G + H + J) should be, to begin with, as small as possible, so that only linear receiver characteristics enter into the measurement. The level of the unmodulated signal generator should, however, be chosen high enough for the noise voltage (mostly the inherent noise of the receiver), measured at the audio-frequency output of the receiver, to lie at least 3 dB below the noise voltage in the presence of the modulated interfering signal according to § 1.6. The radio-frequency output of the signal generator (G + H + J) should then be increased in steps to include the non-linear characteristics of the receiver (cross-modulation).

* Recommendation 571 proposes a different coloured noise signal. The use of that signal instead of the one proposed in this Recommendation would lead to different relative values of the radio-frequency protection ratio which would only be justified if the characteristics of a typical programme signal would better be simulated by the coloured noise of Recommendation 571. (See Report 798.)

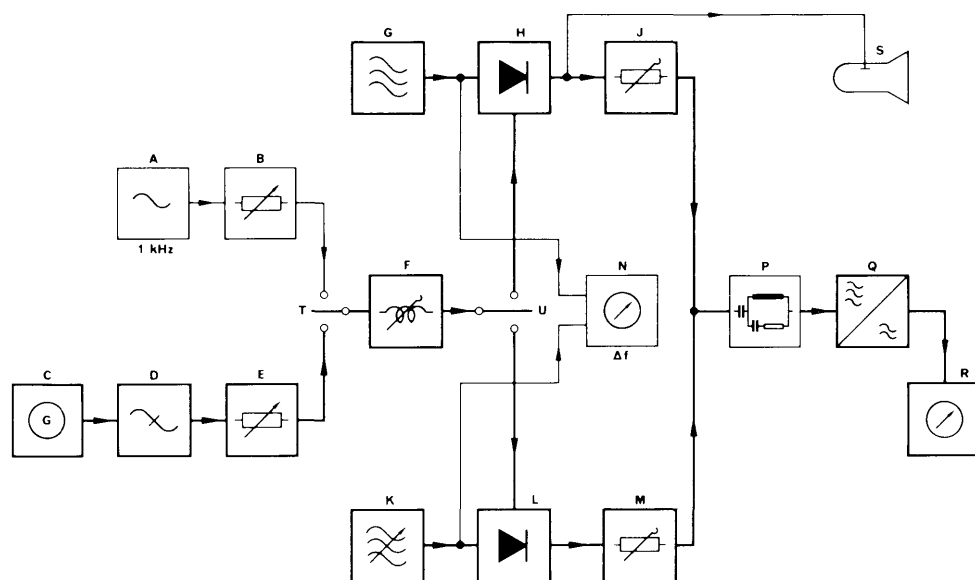


FIGURE 1 – Schematic of the measuring apparatus

A:	1 kHz audio-frequency generator (for calibration of the depth of modulation)	M:	calibrated attenuator
B:	calibrated attenuator	N:	frequency meter for measuring the frequency difference between signal generators G and K
C:	noise generator	P:	artificial antenna (according to Recommendation 331)
D:	noise-shaping filter (see Fig. 3)	Q:	receiver under test
E:	calibrated attenuator	R:	r.m.s. instrument including a weighting network in accordance with Recommendation 468
F:	low-pass filter	S:	oscilloscope (for monitoring purposes)
G:	signal generator (wanted signal)	T:	selector switch for the modulation (1 kHz tone or standardized noise signal)
H:	modulator	U:	change-over switch for the modulation (signal generator G or K)
J:	calibrated attenuator		
K:	signal generator (interfering signal)		
L:	modulator		

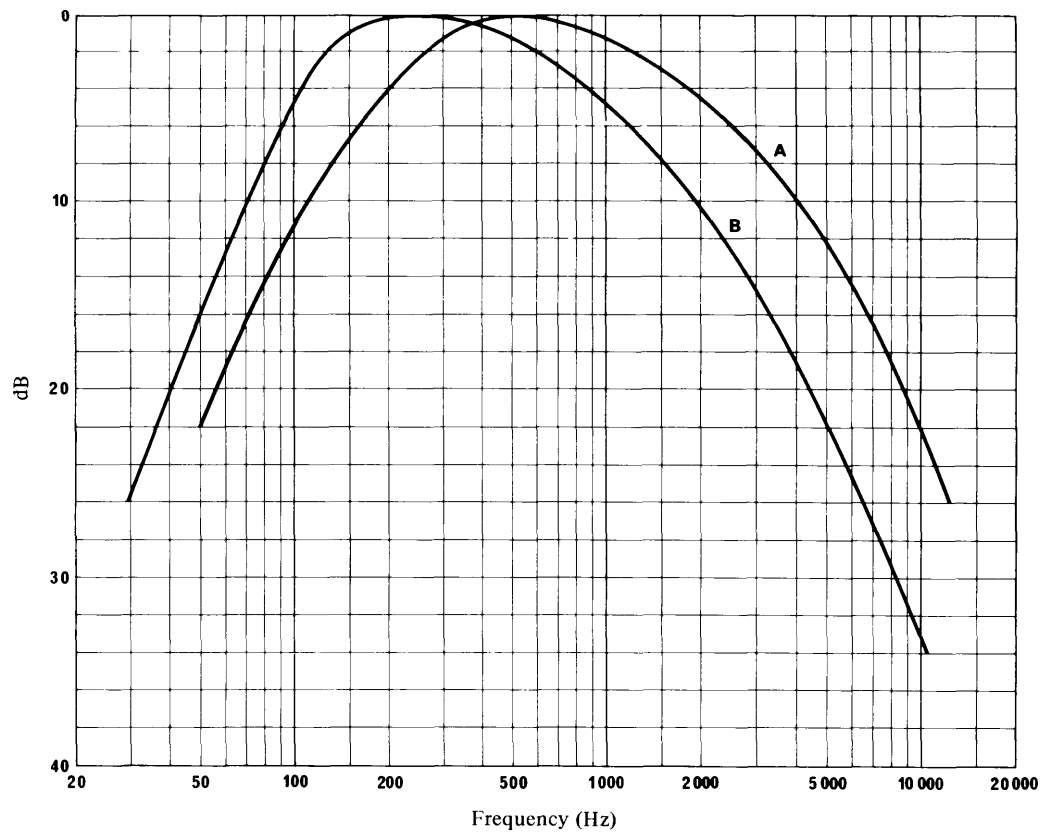


FIGURE 2

Curve A: Frequency spectrum of standardized noise (measured with one-third octave filters)
 Curve B: Frequency response characteristic of filter-circuit

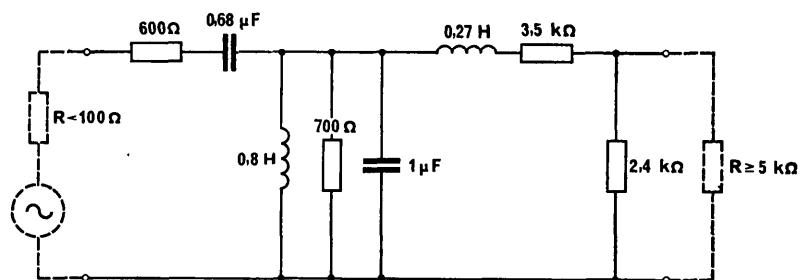


FIGURE 3 – Filter-circuit

1.8 *Influence of non-linear distortion in the signal generators*

The non-linear distortion occurring during the modulation process in the signal generator has components which widen the radio-frequency spectrum and thus give rise to increased radio-frequency wanted-to-interfering signal ratios in the region of the adjacent channel and the adjacent-channel but one.

The non-linear distortion in the signal generators should not, therefore, exceed 1% to 2%.

1.9 *Accuracy*

The results obtained with the objective method have been compared with the results of corresponding subjective tests. From these tests, it has been found that objective measurements give a first approximation to those obtained with the subjective method. In cases where the wanted programme is particularly susceptible to interference (e.g. speech with long pauses) the difference between the objective measurements and the subjective tests may amount to more than 5 dB [CCIR, 1974-78].

2. **Graphical method**

2.1 *Principle*

The graphical method makes use of the principles of the objective two-signal measuring method. It is applicable only if the following assumptions are fulfilled:

- a sinusoidal modulation signal weighted according to curve B of Fig. 2 has the same envelope as the spectrum of a real programme signal;
- the protection ratio against an interfering signal modulated by sinusoids of various frequencies is largely the same as if the interfering signal were modulated only by that one of the audio-frequencies that gives rise to the most severe of the disturbances;
- when reception is interfered with principally by one of the sideband signals of a sinusoidally-modulated carrier on a nearby frequency, the same result is obtained by replacing that sideband signal by an unmodulated radio-frequency signal at the same frequency and with the same amplitude;
- the weighting network of Recommendation 468 represents faithfully the sensitivity of the ear to sinusoidal interference at the different audio-frequencies.

2.2 *Receiver autoprotection curve*

First of all, the curve of the protection ratio against an unmodulated radio-frequency signal is measured, for a given receiver. The curve is determined as follows:

- by means of an r.m.s. instrument (weighting network in accordance with Recommendation 468) connected to the output of the receiver, a *reference level* corresponding to the reception of a wanted transmission, modulated to a depth of 30% by a signal of 1000 Hz is then determined;
- the modulation of the wanted signal is then removed, and the unmodulated interfering radio-frequency signal is introduced and its amplitude is adjusted for each frequency until the instrument indicates N dB less than the reference level.

In this manner, the protection ratio against an unmodulated radio-frequency signal is obtained for an assumed audio-frequency protection ratio of N dB.

The curve of that protection ratio as a function of the frequency spacing is a characteristic of the receiver. It results from the combination of the radio-frequency and intermediate-frequency selectivity characteristics, the audio-frequency response characteristic and the characteristic of the weighting network included in the instrument.

For each value of the protection ratio against an unmodulated radio-frequency signal determined in this manner, that is to say, the wanted signal/interfering signal ratio (WS/IS), there corresponds a reciprocal, IS/WS . This last ratio (interfering signal/wanted signal) defines, for each frequency, a threshold of the interfering signal relative to the wanted signal.

The IS/WS curve can be determined for any particular receiver and is termed the receiver autoprotection curve. For the reception to be free of interference, it is necessary and sufficient that the level of any unwanted signal be below that curve.

2.3 *Transmission diagram*

The transmission diagram is obtained by drawing the envelope of the spectrum of a transmission of known characteristics, using the following scales:

Abcissa: a linear frequency scale, from -15 kHz to zero (zero corresponding to the carrier frequency of the interfering transmission);

Ordinate: levels in decibels, referred to the level of the interfering carrier.

2.4 Utilization of the diagrams

The receiver diagram is obtained by drawing the autoprotection curve of the receiver in question on a transparent sheet. The same scales are to be used as in § 2.3, related however, to the frequency and level of the wanted carrier. The curve need only be drawn for the frequency range from 0 to +15 kHz.

The two diagrams are placed one on top of the other in such a fashion that the axes of their co-ordinates are parallel respectively and the transparent receiver diagram is shifted horizontally and vertically, to bring the two curves into contact. The radio-frequency protection ratio for a given value of the spacing between the carrier frequencies (read off the frequency scale) is the level of the wanted carrier, relative to the level of the interfering carrier (0 dB position of the receiver diagram on the vertical scale of the transmission diagram).

An example of this graphical method is given in Fig. 4. The autoprotection curve of the receiver was determined for an audio-frequency protection ratio of $N = 30$ dB. The method gave a radio-frequency protection ratio of $R = +12$ dB for a spacing of 9 kHz between the carrier frequencies corresponding to the relative radio-frequency protection ratio $A_{rel} = R - N$, resulting in a value of -18 dB.

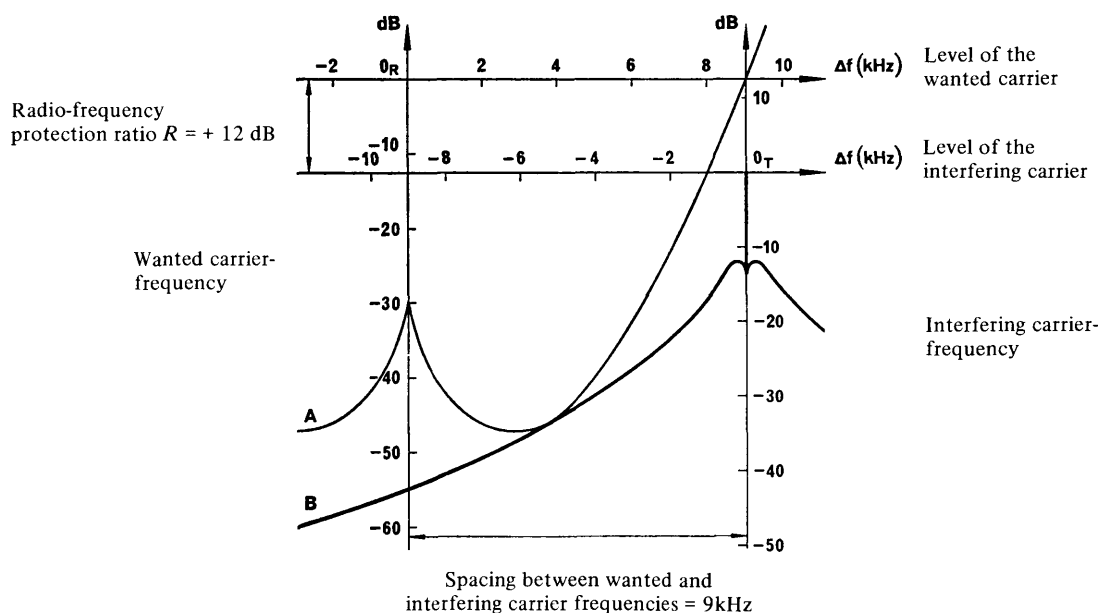


FIGURE 4 – Graphical determination of radio-frequency protection ratios

A: Receiver diagram: origin = 0_R ($0_{reception}$)
 B: Transmission diagram: origin = 0_T ($0_{transmission}$)

— Autoprotection curve
 — Envelope of spectrum

The point of contact between the receiver autoprotection curve and the envelope curve of the transmission spectrum is what finally determines the value of the protection ratio. If, in this particular case, it were required to improve the protection ratio, it would be necessary:

- either to filter the transmission spectrum in such a fashion that the point of contact between the two curves would be lower,
- or to increase the receiver selectivity at that same point.

2.5 Accuracy and limits of the method

This method is, in general, appropriate for estimating protection ratio values, provided there is only one clear point of contact between the two curves. Differences of such values when compared with those derived from objective measurements do not exceed 3 dB.

3. Numerical method

3.1 Principle

To determine the relative radio-frequency protection ratio, the physical process underlying the objective method, viz., the determination of the weighted noise power in the received channel, is simulated by means of a mathematical model.

Two channels with the carrier frequencies f_T and f_R , whose frequency difference is Δf are assumed. The transmitter power density spectrum related to the incremental bandwidth B_{eff} is simulated by the function F_T depending on the relative frequency $|f|$. This function is formed by multiplicative sub-functions (e.g. attenuation, spectral energy distribution, pre-emphasis of the higher audio-frequencies) and additive sub-functions (e.g. out-of-band radiation) or it is built up by polygonal traces. In a similar way, the overall response of the receiver, including weighting of the noise power with the aid of a weighting filter (Recommendation 468) is represented by means of the function F_R depending on the relative frequency $|\Delta f - f|$.

In double-sideband modulation, F_T and F_R are symmetrical with respect to the respective carrier frequencies. Figure 5 shows the fundamental shape of the functions F_T and F_R , the most important sub-functions as well as the meaning of the designations used.

The transmitter power density spectrum with the carrier frequency f_T produces an interference power ΔP_T in the received channel with the carrier frequency f_R , which, at a given frequency difference Δf , can be calculated by integrating the product $F_T \times F_R$. As a result, one obtains:

$$\Delta P_T = \int_{f_1}^{f_2} F_T(|f|) \times F_R(|\Delta f - f|) \times df \quad (1)$$

When performing the integration according to (1), however, for $\Delta f = 0$ (receiver exactly tuned to the transmitter frequency), one obtains the useful receiver power ΔP_N . The relative radio-frequency protection ratio A_{rel} is the ratio of interference power to useful power, in the channel under consideration.

$$A_{rel} = 10 \log (\Delta P_T / \Delta P_N) \quad \text{dB} \quad (2)$$

With the aid of the numerical method it is also possible to determine separately the interference components caused by the carrier beat and by the sidebands. It is expedient to carry out the integration according to (1) with the aid of computers and numerical integration methods. In practice, most problems can satisfactorily be solved with an incremental bandwidth of $B_{eff} = 100$ Hz by numerical integration.

Since the method described is based on the determination of power, it does not provide the additional noise suppression by 3 dB found during measurements of the co-channel interference performed on systems with envelope detection.

The relative radio-frequency protection ratios obtained with the numerical method must therefore be corrected by -3 dB.

3.2 Accuracy and limits of the method

The results obtained for a double-sideband system are shown in Fig. 6 in comparison with measurement results.

As long as the values of the relative radio-frequency protection ratio do not go beyond -40 dB, the deviations between calculation and measurement, amount to about 1 dB. Beyond -40 dB the measurements are increasingly affected by unavoidable noise inherent to the equipment used and by the intermodulation distortion in the receiver, which may no longer be neglected, but these factors are not taken into the calculation.

Note. — The measuring method is more accurate than the graphical or numerical method, since all technical parameters are most exactly taken into account. The graphical and the numerical methods, however, have the essential advantage of permitting the immediate determination of the radio-frequency protection ratio values for any receiver, existing or projected. By means of a single computer programme, the numerical method can be executed in a fraction of the time needed to make objective measurements. The numerical method is, therefore, suitable for the optimization of the technical parameters of any amplitude-modulation transmission system for sound broadcasting in bands 5 (LF) and 6 (MF) and, with only a few minor modifications, for single-sideband systems also.

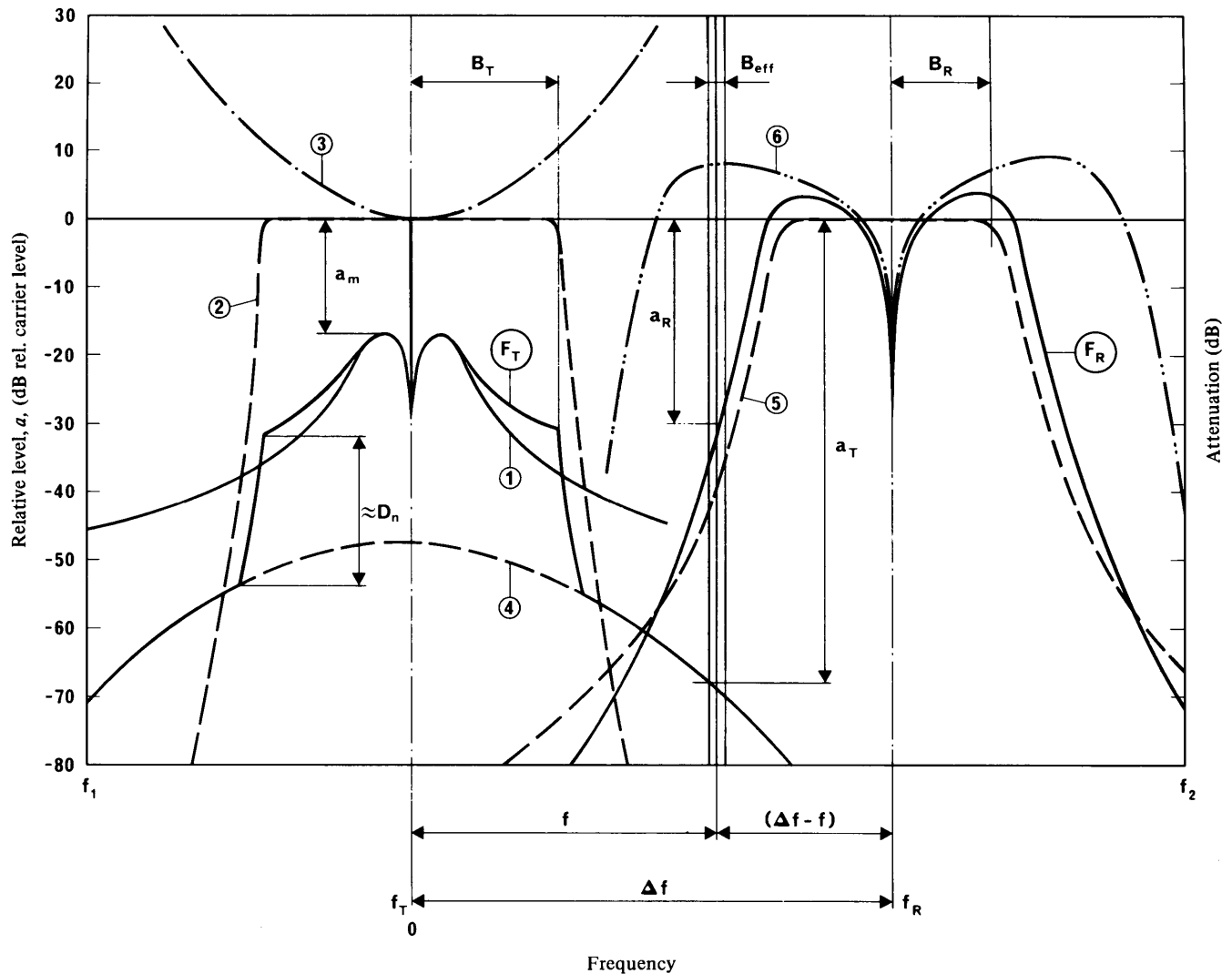


FIGURE 5 – Fundamental relationships

B_T : 3 dB bandwidth of the transmitter (overall)

B_R : 3 dB bandwidth of the receiver (overall)

B_{eff} : incremental bandwidth to which the power spectrum is related and within which the power density and the receiver attenuation response may be assumed to be constant, in each case, for the calculation

f_T : carrier frequency of the transmitter

f_R : carrier frequency in the received channel

Δf : frequency separation $|f_R - f_T|$

f_1, f_2 : lower and upper limits of integration

① : spectral energy distribution in the sideband

② : filter attenuation characteristic for band limitation at the transmitter

③ : pre-emphasis (at high frequencies) at the transmitter

④ : out-of-band radiation of the transmitter

F_T : function representing the transmitter power-density spectrum

D_n : attenuation of the intermodulation products of the transmitter in the case of measurement with two tones

a_m : relative level of maximum power-density in the sideband, related to the carrier level

⑤ : filter attenuation characteristic for band limitation at the receiver

⑥ : weighting curve of the psophometer filter

F_R : function representing the overall attenuation characteristic of the receiver including weighting by means of the psophometer filter (weighted receiver attenuation)

a_T : level of the transmitter power-density spectrum at frequency f

a_R : weighted receiver attenuation at frequency f

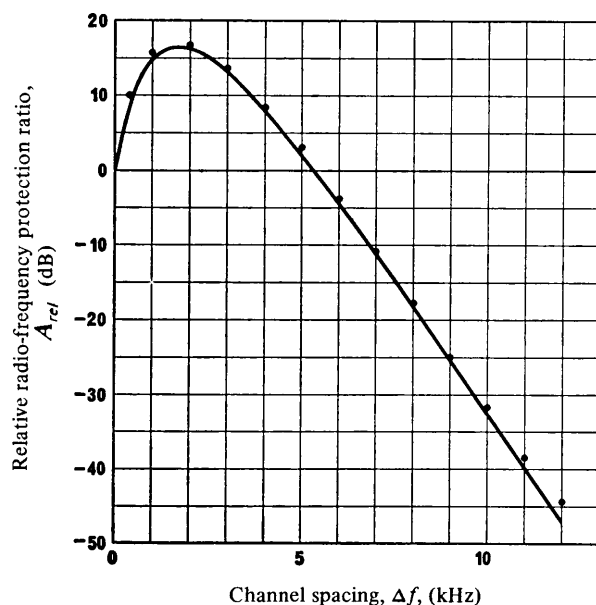


FIGURE 6 – Comparison between the calculated and measured values of the relative radio-frequency protection ratio for a double-sideband system

— : calculated values • : measured values

REFERENCES

CCIR Documents

[1974-78]: 10/324 (U.S.S.R.).

BIBLIOGRAPHY

- BELGER, E. and VON RAUTENFELD, F. [April, 1965] The objective measurement of the RF wanted-to-interfering signal ratio in amplitude-modulation sound broadcasting. *EBU Rev.*, **90-A**, 57-64.
- GRÖSCHEL, G. [1971] Out-of-band radiation and its influence on the adjacent channel with amplitude-modulated sound broadcasting. *Nachrichtentechn. Fachber.*, **41**, 44-49.
- GRÖSCHEL, G. [June, 1978] A mathematical model for the calculation of the adjacent channel interference in single-sideband and double-sideband AM sound broadcasting systems. *EBU Rev. Tech.*, **169**, 122-136.
- PARREAUX, D. [August, 1972] A graphical method of determining protection ratios in the case of LF and MF amplitude-modulated transmission, *EBU Rev. Tech.*, **134**, 163-167.
- PETKE, G. [October, 1973] Determination by calculation of the RF protection ratio for AM transmission systems. *EBU Rev. Tech.*, **141**, 227-234.
- TÜXEN, O. [1941] Die Trennschärfe des Empfangsgeräts (Selectivity of the receiving detector). *Z. für Techn. Physik*, **22**, **1**, 1-9.

REPORT 457-2

**NECESSARY BANDWIDTH OF EMISSION IN
LF, MF, AND HF SOUND BROADCASTING**

(Question 44/10, Study Programme 44A/10)

(1970-1974-1982)

1. Introduction

In an amplitude-modulation double-sideband sound broadcasting system the bandwidth of emission is approximately twice the audio-frequency bandwidth of the programme and, therefore, greatly influences the quality of reception. On the other hand, for a given frequency separation between adjacent channels, a limitation of the bandwidth of emission is desirable to avoid mutual interference.

The difference between the transmitted bandwidth for amplitude-modulation sound broadcasting and the receiver bandwidth has led to research [CCIR, 1966-69a and b; Netzband and Süverkrübbe, 1968; Süverkrübbe, 1969; Petke, 1973] aimed at improving the whole transmission system. It appears that it would be useful to fix values for the audio-frequency bandwidth of the programme to be radiated as well as for the overall response of the receivers and to obtain these values by the use of band-limiting filters. If both these bandwidths are nearly equal and are suitably related to the channel spacing the transmission system provides for the full utilization of the transmitted bandwidth as well as for the most favourable protection against adjacent channel interference [Eden, 1967].

2. Assessment of the necessary bandwidth of emission

Obviously the bandwidth of emission as well as the passband of the receivers should be chosen in such a way that there is no unnecessary impairment of reception quality or any increase in adjacent channel interference [Netzband and Süverkrübbe, 1968]. In this respect a good solution would be to make the channel spacing, the bandwidth of emission and the receiver passband of equal value. Moreover, ideally there should be rectangular limitation of the bandwidth of emission and the received selectivity curve and no non-linear distortion in the transmitter. Under these conditions no adjacent channel interference would occur.

In general, however, these requirements are not met. In many cases the bandwidth of emission exceeds the channel spacing by a considerable amount. It can be seen from Recommendation 560 that excessive adjacent channel interference will result from such operational conditions. Hence, it can be concluded that this type of interference can be reduced if the bandwidth of emission is adapted to the channel spacing.

3. General considerations

3.1 There exists a well-known interrelation between system bandwidth, carrier spacing and adjacent-channel radio-frequency protection ratio [Süverkrübbe, 1969; Petke, 1973].

3.2 The theoretically obtainable optimum value of protection against adjacent channel interference can be assessed by using an ideal receiver with rectangular passband characteristics. In this case the radio-frequency protection ratio is mainly determined by non-linear distortion in the transmitter.

3.3 A theoretical study of the energy spectrum including out-of-band radiation caused by transmitter non-linearities is contained in [Kettel, 1968]. Experimental investigations of the energy spectrum of a high-power transmitter operating in band 6 (MF) [CCIR, 1966-69c] show that the term occupied bandwidth as defined in Article 1, No. 147 of the Radio Regulations does not give an adequate indication of the effects of bandwidth limitation on adjacent channel interference.

4. Relationship between AF bandwidth, RF protection ratio and channel spacing**4.1 Measurement results**

Measurements of the radio-frequency protection ratios for the case of various values of audio-frequency bandwidths, which are equal at both transmitter and receiver, and at different channel spacings have been carried out in the Federal Republic of Germany [Süverkrübbe, 1969] using the objective two-signal measuring method given in Recommendation 559 and Report 794. For the measurements a high quality commercial receiver with an almost ideal passband characteristic was used. The interrelation between the parameters involved is shown in Fig. 1. For a given channel spacing there are many pairs of values of audio-frequency bandwidths and adjacent channel protection ratios. If, however, two of the parameters have been chosen, the third is definitely fixed.

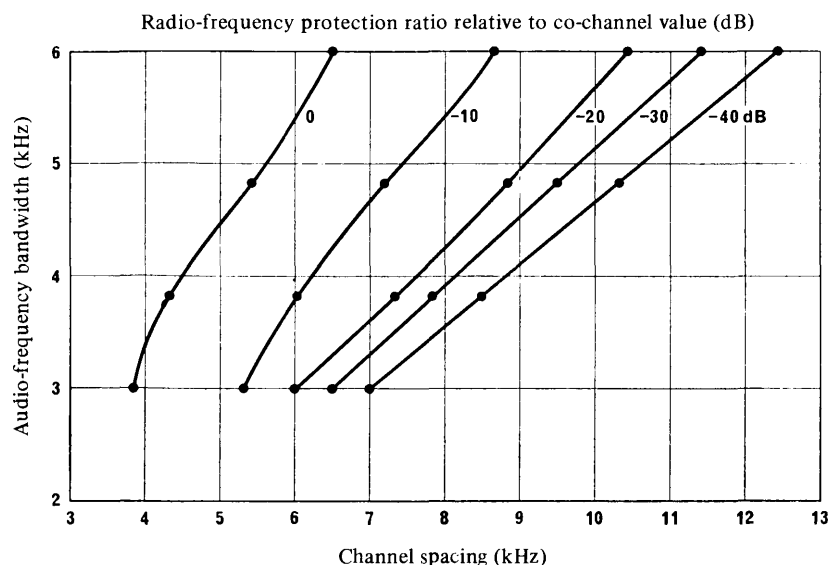


FIGURE 1 – Use of the frequency spectrum

4.2 Computation results

The relationship between system bandwidth, adjacent channel protection ratio and channel spacing can be determined by means of the numerical method (Recommendation 559).

Studies carried out were based on the assumption that both the carrier spacing and the adjacent channel protection ratio are predetermined values. Using Recommendation 560, a relative value of the radio-frequency protection ratio of -26 dB corresponding to a channel spacing of 9 kHz has been assumed. Thereby due account has been taken of the characteristics of current types of receivers.

Any amplitude-modulation sound-broadcasting system has, in principle, the same effect on the reception quality as a low-pass filter. Amplitude-modulation systems designed in conformity with the channel spacing and protection ratio requirements mentioned above may, therefore, differ to some extent in bandwidth and rate of cut-off of the overall amplitude/frequency response. The investigations carried out were, therefore, extended to cover this aspect of the problem of the quality of reception.

It was assumed that the influence on the overall amplitude/frequency response of the entire system was equally distributed between the transmitting and receiving ends. This approach should, however, be considered as a first attempt only and additional studies will have to be carried out for different conditions. As a result of the calculations made it was found that any one of the three overall amplitude/frequency response curves shown in Fig. 3 would provide satisfactory adjacent-channel protection in an 9 kHz channelling system. The curves of Fig. 2 present pairs of values for the bandwidth, b , and rate of cut-off, a_0 , required at either end of the AM sound-broadcasting system. The solid curve is only valid if use is being made of a notch filter in the receiver to eliminate the beat-note between adjacent channel carriers, whereas the broken line applies to the case where there is no notch filter. The particular points in Fig. 2 numbered ①, ② or ③ correspond to terminal equipment characteristics that would provide the overall amplitude/frequency response curves, A, B or C, respectively, in Fig. 3.

The results obtained are in close agreement with Fig. 1 which should be considered to provide limiting values, since it applies to the ideal case of rectangular passband characteristics. The system bandwidth thus decreases rapidly with decreasing rate of cut-off.

4.3 Listening tests

The influence of reproduction quality of an amplitude-modulation sound-broadcasting system with 9 kHz channel spacing and a relative protection-ratio value of -26 dB for adjacent channel interference can be simulated by using three specified low-pass filters. The passband characteristics of these filters are those of curves A, B and C in Fig. 3.

Subjective listening tests then show quite clearly that a better subjective quality impression can be obtained with frequency response curves A and B than with curve C. However, the difference in quality obtained with curves A and B is very small, a fact which may be of considerable economic interest, since the rate of cut-off of the receiver is 20 dB/octave less with curve B than with curve A.

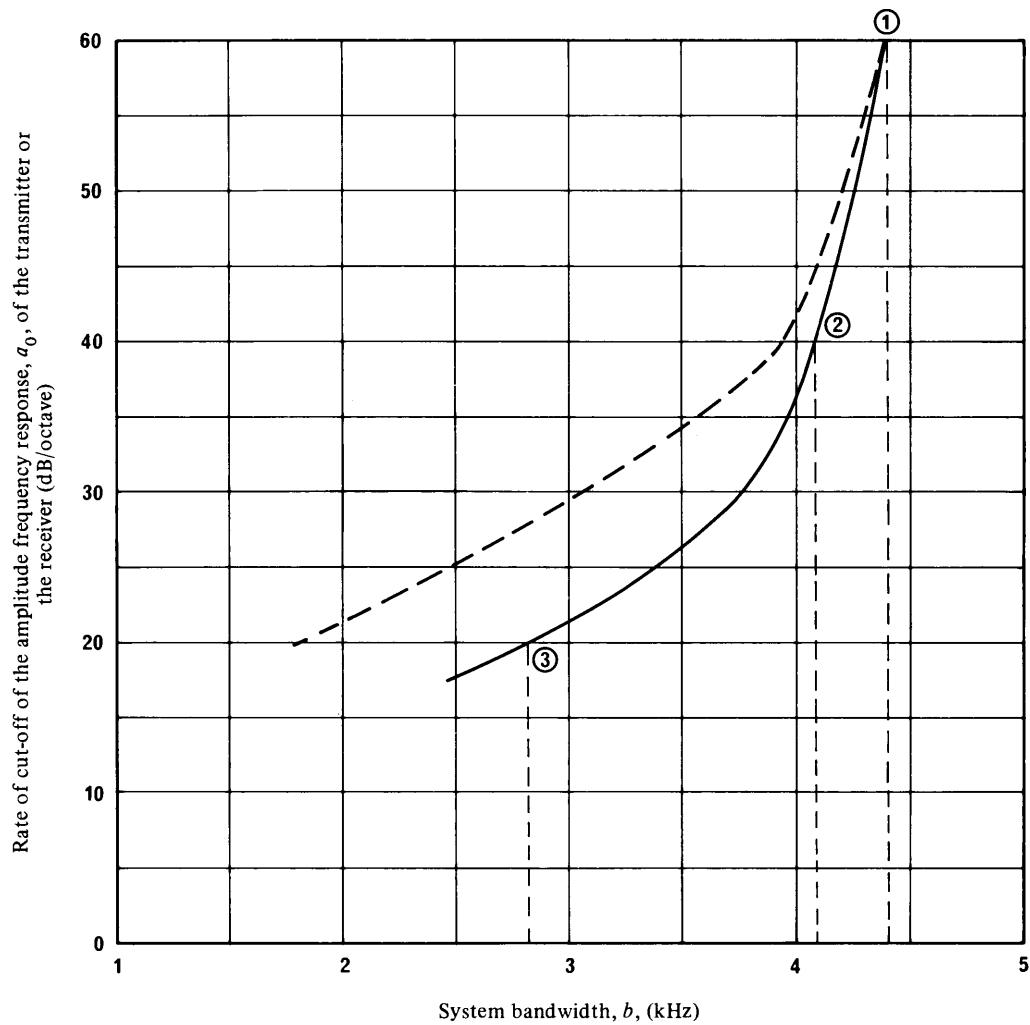


FIGURE 2 – Characteristics of an amplitude-modulation sound-broadcasting system for optimum quality of reproduction

Basic assumptions:

Channel spacing: 9 kHz

Relative adjacent-channel protection ratio: - 26 dB

—: characteristics including the effect of a notch filter for elimination of the carrier beat

- - -: characteristics without notch filter

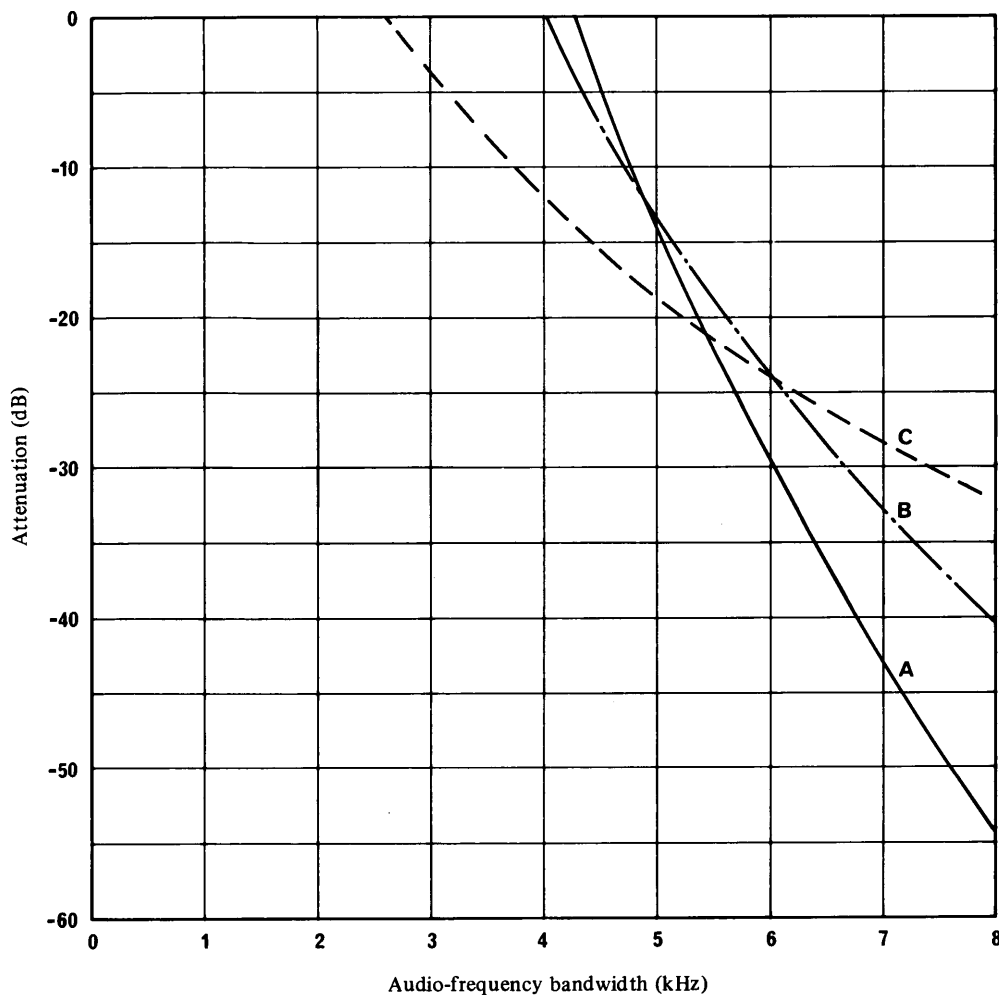


FIGURE 3 – Overall amplitude/frequency response for an amplitude-modulation sound-broadcasting system for optimum quality of reproduction

Curve A : overall rate of cut-off for system – 120 dB per octave
 B : overall rate of cut-off for system – 80 dB per octave
 C : overall rate of cut-off for system – 40 dB per octave

5. Radio-frequency and intermediate-frequency passband characteristics of current types of receiver

Receiver characteristics have been collated in various countries and are partly reproduced in Report 333 (New Delhi, 1970). Radio-frequency and intermediate-frequency passband values between the 6 dB points are quoted ranging between 5 and 10 kHz. It should be noted that the reproduced audio-frequency bands are about half these values. The highest values mentioned are those of “first category” receivers in the U.S.S.R. [CCIR 1966-69d] with variable selectivity.

It is known that there are many receivers with even smaller passbands than those mentioned in the above references. It has, however, been indicated that in some areas there exist receivers with larger passbands.

6. Use of bandwidth limitation in operational practice

Even though the use of bandwidth limitation has been common practice for many years, the public reaction to the effect on programme quality has been negligible. On the other hand, improved reception has been reported in many cases where adjacent channel interference had previously been severe.

According to the Geneva Plan, a large number of transmitters are not operating in bands 5 (LF) and 6 (MF) with a limited bandwidth. In the LF band 50.6% of the total number of transmitters has a bandwidth of emission equal to or less than 10 kHz, whereas in the MF band this value is only 31.3%.

7. A bandwidth-saving overtone transmission and reception system

A new method has been described [Gassman, 1972 and 1973], applicable in bands 5 (LF), 6 (MF) and 7 (HF), which allows improved sound quality at the receiver while the audio-frequency modulating signal is restricted in bandwidth. The system is based on the fact that the human ear is unable to identify overtone frequencies above about 4 kHz in relation to the fundamental tone.

The improvement of the sound quality is effected by the addition of artificial overtones generated in the receiver. The amplitudes of the overtones are controlled by a pilot tone at the upper end of the audio-frequency passband. The pilot tone carries the information on the amplitude of the overtones and the necessary synchronizing signal in the form of a single-sideband modulation.

8. Out-of-band spectrum of double-sideband sound-broadcasting emissions

Recommendation 328, § 3.5.1, gives the limit curves for the level of the out-of-band radiation of amplitude modulated double-sideband broadcast emissions. The curves have no fixed relation to the level of the carrier since this relation depends on:

- the modulation factor of the transmitter (r.m.s. value);
- the necessary bandwidth of the emission;
- the bandwidth of the spectrum analyser.

However, the limit curves have a fixed relationship to the maximum level of the sideband components which depends only on the power distribution within the sidebands.

Detailed information on the corresponding values is contained in Report 325.

9. Necessary bandwidth of emissions in band 7 (HF)

9.1 Listening tests have been made on the quality of reception obtainable on short waves and the effects of a reduction of the necessary bandwidth. From these tests it has been deduced that, although there will be some loss in quality if the audio-frequency band is limited, this loss is not serious. Studies in band 6 (MF) have shown that there is a relationship between system bandwidth, carrier spacing and the adjacent-channel radio-frequency protection ratio. Receivers used for reception in band 7 (HF) will, in general, have the same selectivity characteristics as those used for reception in band 6 (MF).

9.2 In band 7 (HF), 5 kHz channelling is common. Some administrations considered it desirable that the bandwidth of the audio-frequency modulating signal used in band 7 (HF) should be 4.5 kHz and should in no case exceed 5 kHz. This matter requires further study.

10. Conclusions

10.1 Figure 1 shows the relationship between the adjacent-channel radio-frequency protection ratio, the channel spacing and the audio-frequency bandwidth and assumes that the audio-frequency bandwidth of the radiated programme is the same as that reproduced by the receiver. When two of the three parameters are selected, the third is definitely fixed. In general the channel spacing will be given and a particular value of radio-frequency protection ratio will be required. Then the full audio-frequency bandwidth as taken from Fig. 1 can be transmitted but full use of the bandwidth of the radiated signal can only be made if the receivers have selectivity characteristics corresponding to that of the audio-frequency filter at the transmitter.

10.2 The predetermination of values of channel spacing and adjacent-channel protection ratio in an amplitude-modulation sound-broadcasting system is equivalent to a determination of the quality of audio-frequency reproduction. For example, in the case of 9 kHz channel spacing and –26 dB adjacent-channel protection ratio, Fig. 2 shows that, with reasonable values for the rate of cut-off, an audio-frequency bandwidth of 4.4 kHz can hardly be exceeded. Moreover, it is evident from this figure that decreasing rates of cut-off imply decreasing values of audio-frequency bandwidth.

From subjective listening tests it is apparent that, within the predetermined limits shown in Fig. 2, the reception quality mainly depends on the audio-frequency bandwidth. However, when approaching the limits, a slight increase in audio-frequency bandwidth may imply a substantial increase in rate of cut-off, whereas the increase in reception quality may hardly be noticeable.

Similar studies for 8 and 10 kHz channel spacings led to corresponding results showing the same tendencies. The apportionment of the overall amplitude/frequency response equally to the transmitter and receiver does not necessarily correspond to optimum conditions. On the contrary, computations indicate that the adjacent-channel protection ratio is more sensitive to a modification of the amplitude/frequency response at the receiving end than at the transmitting end of the system. From an economic point of view, however, it may be undesirable to improve receiver selectivity. Further studies are necessary before a final decision can therefore be made.

REFERENCES

- EDEN, H. [December, 1967] Perspectives of replanning LF/MF broadcasting. *EBU Rev.*, **106-A**, 242-251.
- GASSMANN, G. G. [October, 1972] Hochwertige Musikübertragung mit nur 7 kHz Bandbreite, Bericht über die 9. Tonmeistertagung, Köln, 26. bis 29. Oktober 1972, herausgegeben vom Verband deutscher Tonmeister. (High quality music transmission at only 7 kHz bandwidth) Report on the 9th meeting of sound engineers, Cologne, 26-29 October 1972, edited by "Verband deutscher Tonmeister" (Association of German sound engineers).
- GASSMAN, G. G. [November, 1973] Verbesserung der AM-Übertragungsqualität bei unveränderter Systembandbreite, Vortrag der NTG-Tagung "Hörrundfunk", Düsseldorf (Improvement of AM transmission quality at unaltered system bandwidth; paper read at the NTG-Conference "Sound broadcasting", Düsseldorf).
- KETTEL, E. [February, 1968] Is the compatible single-sideband principle advantageous for AM broadcasting? *EBU Rev.*, **107-A**, 8-15.
- NETZBAND, R. and SÜVERKRÜBBE, R. [June, 1968] The effects of bandwidth limitation in the transmission and reception of AM sound broadcasting. *EBU Rev.*, **109-A**, 115-124.
- PETKE, G. [October, 1973] Determination by calculation of the RF protection ratio for AM transmission systems. *EBU Rev. Tech.*, **141**, 227-234.
- SÜVERKRÜBBE, R. [August, 1969] System bandwidth and channel spacing in AM sound broadcasting. *EBU Rev.*, **116-A**, 161-164.
- CCIR Documents*
[1966-69]: a. X/16 (USA); b. X/142 (United Kingdom); c. X/212 (Germany (Federal Republic of)); d. X/196 (U.S.S.R.).

RECOMMENDATION 597

CHANNEL SPACING FOR SOUND BROADCASTING IN BAND 7 (HF)

(Question 44/10, Study Programme 44A/10)

(1982)

The CCIR,

CONSIDERING

- (a) that the coverage area achieved in practice depends among other things, upon the channel spacing;
- (b) that there are technical advantages in the adoption of uniform carrier spacing with the nominal carrier frequencies being integral multiples of the channel spacing;
- (c) that the intermediate frequency (or frequencies) of receivers should be chosen so as to be an integral multiple of the channel spacing;
- (d) that the choice of channel spacing should also take into account the possible adoption of SSB (single sideband) in the future;
- (e) that these advantages can only be fully realised if a uniform value for channel spacing is adopted for band 7 (HF),

UNANIMOUSLY RECOMMENDS

1. that for technical reasons a uniform value for channel spacing should be adopted for band 7 (HF) on a world-wide basis;
2. that the choice of a channel spacing should be made so as to maximize coverage to the extent possible;
3. that the nominal carrier frequencies should be an integral multiple of the channel spacing;
4. that, wherever possible, the intermediate frequency (or frequencies) in receivers should be an integral multiple of the channel spacing;
5. that the possible adoption of an SSB system in the future shall be taken into account in the selection of a channel spacing.

REPORT 616-2

PRACTICAL ASPECTS OF MF BROADCASTING COVERAGE

(Question 44/10, Study Programme 44F/10)

(1974-1978-1982)

1. Day-time coverage

The following results are based on the ground-wave propagation curves of Recommendation 368.

Due to the strong absorption of the sky-wave in band 6 during the day-time, only the ground-wave can be used for coverage. The coverage radius (see Annex I) depends upon the frequency and the electrical characteristics of the soil within the coverage area; this radius for higher transmitter powers is about 100 km. A transmitter network optimized for day-time coverage could be based on very low co-channel distances, i.e. on a considerably higher transmitter density than that existing at present. For example, a day-time network based on an average co-channel distance of roughly 500 km would provide at any location, about ten radio programmes with good quality of reception.

Coverage during the day-time therefore does not represent a technical problem.

2. Night-time coverage

With the onset of darkness the absorption of the sky-wave is greatly reduced and high values of field strength may build up during a period of one or two hours at distances of thousands of kilometres. This produces interference and limits the ground-wave coverage range. In general, the sky-wave has been regarded mainly as a source of interference, and the systematic use of the sky-wave for coverage purposes has been envisaged for special cases only.

At night-time, the presence of the sky-wave gives rise to complicated technical problems and necessitates planning methods for very large areas based on internationally agreed rules.

To obtain a clear picture of the possibilities of providing radio programmes in band 6 under various basic assumptions, a great number of frequency-assignment exercises have been carried out within the EBU, and the coverage factors obtained have been calculated. These studies were made for the European and African broadcasting areas.

These exercises were made on the basis of rather evenly distributed transmitters with equal power radiated from omnidirectional antennas, the sites of which, however, coincided with real or planned sites in Europe and Africa. The coverage areas were calculated using a statistical method and taking into account only the interference caused by the other transmitters. This method enables a valid comparison to be made between the results of two different exercises, but the absolute values of the results should not be used without due care.

For the purpose of the calculations, certain values of radio-frequency protection ratio (as defined in Recommendation 447) have been adopted. These different values of radio-frequency protection ratio correspond, of course, to different grades of service. It is evident that the coverage areas so calculated are larger for smaller values of this ratio than for the higher values. The increase in coverage area with decreasing value of protection ratio (i.e. with decreasing grade of service) does not imply that better listening conditions will be obtained; the listening conditions do not depend upon the protection ratio, but only on the power and on the configuration of the interfering transmitters.

It should be noted that, when comparing the results of two different exercises the differences may be more or less pronounced depending upon the radio-frequency protection ratio, i.e. the grade of service adopted. Therefore, the calculation results should not be discussed without making mention of the corresponding grade of service.

Finally it should be recalled that, in the calculations, statistical propagation data have been used. In particular, ionospheric field-strength prediction curves have been taken, which represent median values (i.e., values for 50% of the time) for an average frequency of 1000 kHz.

It can be assumed, therefore, that the results obtained are reasonably suitable for representing the average situation for the whole of the spectrum covered by band 6.

Some of the results are summed up hereafter.

2.1 Ground-wave coverage at night

The total amount of ground-wave coverage depends in the first place on the co-channel distance, i.e. on the transmitter density. For a given transmitter power, the ground-wave coverage increases with increasing co-channel distance (see Rec. 598). Thus, for 300 kW transmitters, and assuming protection ratios of 40 dB, 33 dB and 27 dB, the following percentages of the combined surface areas of Europe and Africa can be covered by the employment of the 121 channels now available in band 6:

TABLE I

Co-channel distance (km)	Ground-wave coverage					
	Radio-frequency protection ratio (dB)					
	40		33		27	
	Number of programmes	Area coverage (%)	Number of programmes	Area coverage (%)	Number of programmes	Area coverage (%)
2700	1	6	1	11	1	21
3500	1	8	1	15	1	25
4100	1	9	1	17	1	28

These coverage factors can possibly be improved by the use of synchronized networks and of directive antennas. Moreover, the population coverage can be made superior to the surface coverage by appropriate transmitter siting. Little numerical information is available on these possible improvements.

The question of the transmitter power which provides the greatest possible ground-wave coverage for a given transmitter density, has been the subject of detailed studies (see Rec. 598), from which a sufficiently accurate answer may be derived. Furthermore, it should be recalled that night-time ground-wave coverage is also limited by interference between the ground-wave and the sky-wave from the same transmitter, but this effect has been ignored in the calculation of the approximate service ranges as given in Annex II.

2.2 Sky-wave coverage

Under the same assumptions as those made in § 2.1 (300 kW transmitters, 40 dB, 33 dB or 27 dB protection ratio) the sky-wave would provide coverage of the combined surface areas of Europe and Africa, using the entire band 6 as follows (see Table II).

It can be seen that at night the sky-wave coverage depends far more than the ground-wave coverage on the transmitter density adopted: for high transmitter densities (i.e. co-channel distances even smaller than 2700 km) nocturnal coverage decreases rapidly, whereas a co-channel distance of 4100 km would permit the reception of several programmes at any location within the area considered. The majority of these programmes would, of course, be originated far from the reception point. Moreover, the fact should not be overlooked that it is impossible, contrarily to the ground-wave, to achieve consistently good quality by means of the sky-wave. Account should also be taken of the fact that, in practice, the area covered at night will not be continuous, for there will be an annulus embracing ranges in the region between 100 km and 200 km in which severe selective fading will be caused by interference between the ground-wave and the sky-wave. This effect has been neglected in the studies made so far. Examples for approximate coverage ranges are given in Annex II. The fact remains that the utilization of the sky-wave would allow better use to be made of the spectrum in respect to area coverage, because the ratio between the coverage area and the area of interference is more favourable. Finally, it should be recalled that, conditions yielding satisfactory night-time ground-wave coverage, will also normally result in a reasonable amount of sky-wave coverage.

TABLE II

Co-channel distance (km)	Sky-wave coverage					
	Radio-frequency protection ratio (dB)					
	40		33		27	
	Number of programmes	Area coverage (%)	Number of programmes	Area coverage (%)	Number of programmes	Area coverage (%)
2700	negligible		1	30	6.1	100
3500	1	15	7.4	100	23.3	100
4100	2.5	100	14.9	100	31.6	100

2.3 *Combination of ground-wave and sky-wave coverage*

It can be concluded from §§ 2.1 and 2.2 that good results for both types of coverage may be obtained if the high-power co-channel transmitters are sufficiently widely spaced.

3. **Combination of day-time and night-time coverage**

As shown in §§ 1 and 2, transmitter networks devised for good coverage during the day-time differ fundamentally from those set up for good coverage at night; the co-channel distances would, for example, be about 500 km for day-time and about 4000 km for night-time. As the corresponding total number of transmitters for these networks would have a ratio equal to the square of the ratio of the co-channel distances, the coexistence of both networks would mean that, in this example, only one out of every 64 transmitters could be operated after sunset. In this example, two extreme cases of optimum coverage conditions are compared, neither of which corresponds to present practice. Any network wherein all transmitters remain in operation day and night will reduce the coverage, either by day or by night, or, in the case of a network based on a compromise between the two types of network, will reduce coverage during day and night.

On the other hand, the transition from efficient day-time operation to efficient night-time operation would lead to some problems of an operational and administrative nature. In fact, as shown, the majority of the day-time transmitters would have to be closed down at sunset, to avoid unacceptable interference during the hours of darkness. The time of close-down itself may then depend on the season and the latitude, especially at high and medium latitudes. Moreover, because of the comparatively slow build-up of the sky-wave after sunset, there will always be a period when either the ground-wave network suffers interference (if all transmitters are still in operation) or the sky-wave signals are still too weak. Although the difficulties mentioned above appear to make the general use of such a mode of operation impracticable, its potential advantages are such that a further study is desirable, particularly in respect to certain special cases.

The engineering assignment standards for sound-broadcasting stations in band 6 in the United States of America * may serve as an example for a combined day-time and night-time coverage. The same standards are generally used throughout Canada, Mexico and some Caribbean countries.

They provide for four classes of MF stations, I, II, III and IV. Class I and II stations are the highest power (50 kW maximum), class I stations being protected at night from interference so as to serve large areas with sky-wave signal. Class II stations receive no night-time sky-wave protection. Class III stations are medium power (5 kW maximum), serving regional areas, but have no night-time sky-wave coverage protected from interference. Class IV stations are low power (1 kW day, 0.25 kW night) and are intended to serve small communities.

4. **Population coverage**

While the area coverage is important, another aspect, namely, of population coverage is also of importance. Studies on the problems of population coverage have been initiated in some countries [Suzuki *et al.*, 1974], but further study is required on this point.

5. **Improvements of coverage**

5.1 *Synchronized networks*

A synchronized network is a group of transmitters intended primarily for a ground-wave coverage radiating the same programme at a common frequency.

In most European countries, the use of synchronized networks to replace single transmitters of equivalent power leads to better adaptation of coverage to population distribution, and thereby increases total population coverage. Annex III shows some examples of the results obtained in various countries. The use of synchronized groups is most effective in those countries where there are widely spread areas of high population density.

It should be emphasized:

- that acceptable reception quality of the sky-wave signal is more likely in those areas where the sky-wave of one transmitter of the synchronized group predominates;
- that the interference from a synchronized group is equivalent to that from a single transmitter sited at the centre of gravity of the group, with a power equivalent to the total power of the group, provided that the average distance between the group of transmitters is not more than about one-tenth of the distance to the nearest co-channel transmitter;

* The Administration of the USA is invited to provide an appropriate reference, in which details of these proposals may be found.

- that synchronized networks are of less value in small countries;
- that the use of directional transmitting antennas improves the coverage from synchronized networks;
- that the use of product demodulators decreases the non-linear distortion due to interference between the transmitters of a synchronized network; this would increase the coverage obtained.

On the other hand, transmitters of a synchronized network may radiate different programmes during daylight hours, if the transmitters are sufficiently widely spaced.

It is obvious that investment and operational costs are higher for a synchronized network than for a single transmitter; nevertheless, the use of synchronized networks should be envisaged in each case where the advantages quoted are to be expected.

5.2 *Antenna directivity*

5.2.1 *Vertical diagram of vertically-polarized transmitting antennas*

An antenna may be designed to have a particular vertical radiation pattern so that the power is concentrated in the particular vertical segment or segments which will achieve the type of coverage required.

By concentrating the power in the *horizontal plane* it is possible to improve the ground-wave day-time coverage or to use a lower transmitter power for the same coverage. Where the onset of fading, and not co-channel interference, is the factor limiting ground-wave coverage, an anti-fade antenna will improve ground-wave coverage. This improvement is only likely to be obtained with frequencies at the lower end of band 6, in situations where ground conductivity is better than average. Finally, although such antennas may lead to a reduction in ionospheric cross-modulation, they provide a poorer sky-wave coverage, for the same interference, at shorter ranges (distances greater than 2000 km).

By concentrating the power away from the horizontal plane, the sky-wave coverage improved, but ground-wave coverage becomes less good and the risk of ionospheric cross-modulation is greater.

5.2.2 *Horizontal diagram of vertically-polarized transmitting antennas*

By concentrating the radiated power in given horizontal directions particular coverage requirements can be met. Although the general use of directional antennas in a frequency plan does not lead to an overall improvement of coverage, the use of directional antennas will be advantageous when considering the coverage within individual countries, mainly because it may lead to a better adaptation to specific wanted coverage areas and also to a reduction of interference in specific cases. In a particular case, the employment of an antenna which is directional in the horizontal plane will allow a frequency channel to be used in a given zone where this frequency could not be used with an omnidirectional antenna. The use of such a directional antenna can reduce the interference in the coverage area of another co-channel transmitter and as a result permit the reduction of the co-channel distance. This is the principal advantage of an antenna with a horizontal directional pattern.

5.2.3 *Economic considerations*

In general any antenna, the vertical or horizontal radiation characteristics of which are designed to fulfil specific requirements, will cost more than non-directional antennas. Special requirements for the vertical radiation pattern normally lead to higher structures, and the cost of a vertical structure increases rapidly with height.

Special requirements for the horizontal radiation pattern lead to multi-element antenna arrangements and therefore to the use of more extensive sites.

The cost of any antenna design will be lower at the higher-frequency end of band 6. Local weather conditions will be an important factor influencing the cost.

5.2.4 *Improving MF coverage by the use of directional antennas*

To minimize interference between MF stations, directional transmitting antennas have been used in the USA since the mid-1930's. At present more than 1500 are in use. Other countries are also using such antennas for similar purposes.

The use of directional antennas for transmitters operating on the same channel within a country, but not in synchronism, can lead to a substantial increase in coverage. Generally speaking, the more directional antenna operations employed, the greater the improvement in coverage efficiency [CCIR, 1974-78].

Directional antennas are particularly effective at night, and are also helpful for day-time operations. Directional antennas are also useful in reducing interference to the transmissions of other countries. Another advantage of operating transmitters with directional antennas in the same channel, but not in synchronism, is that it permits independent local programming.

5.3 *Relative merits of antennas with horizontal and vertical radiating elements*

A conventional vertical transmitting antenna will provide a useful ground-wave coverage for a limited range and a sky-wave coverage at night at greater ranges. At an intermediate range there is a zone where fading is more severe because the ground- and sky-wave field strengths are nearly equal.

The use of a horizontal radiating element or an array of such elements, which is practicable in band 6 (MF), has certain advantages when the main purpose is to provide a night-time, sky-wave coverage, but it is not suitable for providing a day-time coverage by ground-wave.

The main advantage is that it can be designed to provide a nearly constant sky-wave field strength from the transmitter out to the edge of the service area. The design may provide for a coverage range up to the feasible maximum (about 1000 km) or may be designed for a more limited coverage range (e.g., about 500 km). Nevertheless, very close to the transmitter (within a few kilometres) there may be degradation of quality because of interference between the small unavoidable ground-wave and the sky-wave. If this area is required to have a good service, a small "fill-in" transmitter using a different frequency and vertical polarization may be necessary.

Calculations which take account of the differing directivities and polarization-coupling losses for the case of a single horizontal dipole in place of a short vertical antenna, have been presented [Suzuki *et al.*, 1974]. The importance is stressed, of allowing for the effects of imperfect ground conductivity, which not only reduces the low-angle radiation from vertical antennas but also increases the low-angle radiation from horizontal antennas in certain directions. In the latter context, the reduction of co-channel interference from low-angle propagation modes expected from the use of a horizontal transmitting antenna, (if used in place of a vertical antenna), may be over-estimated by as much as 20 dB, particularly if perfectly conducting ground is assumed when in practice the ground conductivity is poor.

The results of the theoretical studies [BBC, 1972] show that, for a given transmitter power, where reflections are confined to the E region, the use of a horizontal dipole in place of a short vertical antenna can reduce the level of co-channel interference by 10 to 15 dB for typical ground characteristics. More recent studies and practical measurements at temperate latitudes have, however, shown that for frequencies and times at which high-angle F-region reflections occur, the advantage is much reduced, because of the strong excitation of multi-hop propagation modes.

A disadvantage of the use of a horizontal antenna is that it is necessary to change over to a vertical antenna for day-time service, but in general, a comparable coverage area may not be obtained without the use of many transmitters. Here also, there is a problem of change-over as discussed already under § 3. Another disadvantage, is that the cost of transmitting antenna may be large, particularly for the lower frequencies in band 6.

In general, it will be necessary to limit the radiated power to suitable values as a function of the angle in the vertical plane, to avoid causing serious ionospheric cross-modulation. (See Annex I to Recommendation 498). This requirement may be more difficult to fulfil with horizontal antenna systems than for a vertical antenna.

It has recently been suggested that a horizontal antenna should consist of one or more pairs of crossed dipoles appropriately fed to transmit elliptically-polarized waves in the wanted directions so as to excite the ordinary wave more strongly than the extraordinary wave. The main advantage over a system radiating linearly-polarized waves is that since ionospheric cross-modulation is caused mainly by the extraordinary wave, less cross-modulation should in theory result for a given transmitter power. A further advantage would be a reduction of polarization coupling loss.

In conclusion, it can be stated that vertical radiation from horizontally-polarized antennas can be valuable in certain special cases. Its general introduction into a frequency-assignment plan, however, cannot be recommended as a means of obtaining a higher density of assignments on the basis of the information available now.

Measurements have been carried out in the People's Republic of Poland to compare the effectiveness of vertical and horizontal polarization for ground-wave coverage using frequencies in the upper part of band 6 (MF). Measurements were made at distances of up to 20 km from the transmitter, the transmission paths being over built-up areas as distinct from open country, and the results indicate that the attenuation of horizontally-polarized waves appears to be considerably less than would be expected from the theory of ground-wave propagation over a smooth earth [Siczek and Stasiński, 1976].

5.4 *Low-power stations*

The purpose of low-power transmitters is to cover limited areas, such as towns, where the field strength of the main transmitters is insufficient, or possibly for the transmission of local programmes.

For an efficient service these stations must be included in the plan. It seems that in practice they can only operate with a usable field strength well above that of other stations (in particular at night).

Apart from low-power transmitters which are part of a synchronized network (see § 5.1), these transmitters may use:

- either channels allocated to transmitters of different powers;
- or one or several special channels (formerly called International Common Frequencies (ICF)).

In the first case, the sites of the stations and their other characteristics must be clearly determined in the plan, and any later addition would be dangerous. In the second case, it would be sufficient to state the geographical areas where these transmitters may be sited (taking into account the adjacent-channel interference) and, in addition, to indicate the number of transmitters per area and the maximum power which may be used.

Studies already made show that the present number of ICFs (two) is quite insufficient, and that a total of five to ten would be preferable.

From a technical point of view, these transmitters would be more efficient if their frequencies were in the lower part of band 6, but in practice some of them would no doubt have to use channels throughout the spectrum. Moreover, the maximum power admissible and the number of low-power transmitters depend on the frequency [Lari and Moro, 1971].

REFERENCES

- BBC [1972] Research Report No. 1972/21: MF propagation: the reduction of interference by the use of horizontal-dipole transmitting aeriels.
- LARI, G. and MORO, G. [October, 1971] Low-power broadcasting transmitters in the European Broadcasting Area. *EBU Rev. Tech.*, **129**, 205-213.
- SICZEK, S. and STASIERSKI, L. [October, 1976] Porównanie skuteczności nadawania z polaryzacją pionową i poziomą (Comparison between effectiveness of vertical and horizontal transmitting antennas). *Prace Instytutu Łączności*.
- SUZUKI, Y., UJIHARA, J., EHARA, S., YAMANOUCHI, S., and TOZUKA, Y. [January, 1974] Influence of propagation curves on the coverage factor. NHK Lab. Note, Serial No. 178.
- CCIR Documents*
[1974-78]: 10/35 (USA).

BIBLIOGRAPHY

- EBU [May, 1974] Technical parameters for LF/MF broadcasting. Doc. Tech. No. 3206.
- LACHARNAY, S., FONTEYNE, J. and MASSUCCI, M. [1978] Radiodiffusion en ondes kilométriques et hectométriques (LF and MF broadcasting). *Radiodif.-Télév.*, **1**.
- CCIR Documents*
[1970-74]: 10/187 (United Kingdom); 10/252 (EBU); 10/271 (People's Republic of Poland).
[1974-78]: 10/34 (USA).

ANNEX I

APPROXIMATE DAY-TIME COVERAGE RANGES

Day-time coverage ranges have been calculated in the absence of interference from unwanted transmitters by using the propagation curves given in Recommendation 368. For the limitation of the coverage ranges tentative values of the minimum field-strength have been assumed:

- 2.2 mV/m (67 dB (μV/m)) for the lower third of band 6 (MF) (525 kHz to 900 kHz approximately);
- 0.8 mV/m (58 dB (μV/m)) for the upper third of band 6 (MF) (1250 kHz, approximately, to 1605 kHz).

Three values of ground conductivity are assumed:

- good conductivity ($\sigma = 10 \times 10^{-3}$ S/m)
- average conductivity ($\sigma = 3 \times 10^{-3}$ S/m)
- poor conductivity ($\sigma = 1 \times 10^{-3}$ S/m)

When considering the figures so obtained, it should be borne in mind that the average situation of transmitting sites in many countries by no means corresponds to a ground conductivity of $\sigma = 3 \times 10^{-3}$ S/m; moreover, the fact that many such sites are situated on hilly or mountainous terrain would normally lead to coverage ranges below the figures quoted in the following sections.

The e.m.r.p. in the horizontal plane is supposed to be 500 kW (c.m.f.: 6700 V).

TABLE III

Frequency (kHz)	Service range (km)		
	$\sigma = 10$ (S/m)	$\sigma = 3 \times 10^{-3}$ (S/m)	$\sigma = 10 \times 10^{-3}$ (S/m)
<i>Lower third of band 6</i> 525 900	80	180 130	310
<i>Upper third of band 6</i> 1 250 1 605		105 90	

ANNEX II

APPROXIMATE NIGHT-TIME COVERAGE RANGES

The following assumptions are made for the calculation of the night-time coverage ranges:

- two transmitters on the same frequency at a distance of 3500 km and radiating the same power, this power being such that mutual interference is the only factor determining the coverage range*; the interference between the ground-wave of the wanted transmitter and its own sky-wave has been ignored;
- ground-wave propagation according to Recommendation 368;
- ground conductivity: $\sigma = 3 \times 10^{-3}$ S/m;
- sky-wave propagation according to Report 575, (Kyoto, 1978);
- protection ratio: 27 dB, 33 dB and 40 dB.

TABLE IV

Protection ratio (dB)	Service range (km)	
	525 kHz	1605 kHz
<i>Ground-wave service</i> 27 33 40	170 135 95	90 70 55
<i>Sky-wave service</i> 27 33 40	635 420 < 300(1)	850 660 450

(1) The curves used in the study are not valid for distances of less than 300 km.

* The trend shown in Table IV also appears for other cases of interference (more than two transmitters, different distances, etc.).

ANNEX III

COVERAGE OBTAINED FROM SYNCHRONIZED TRANSMITTERS

Table V shows the result of studies where the day-time and night-time coverage of existing groups of synchronized transmitters was compared with the coverage that would have been obtained by a hypothetical single transmitter suitably placed and having a total power equivalent to the total power of the synchronized group.

TABLE V – Ratio of the coverage obtained by a synchronized group of transmitters and a single transmitter

Origin	Frequency (kHz)	Number of transmitters	Total power (kW)	Coverage ratio			
				Day		Night	
				Surface	Population	Surface	Population
O.R.F.	1025	4	300	1.45	1.68		1.83
B.B.C.	1214	16	270		1.26		3.2(1) 3.0(2)
RAI	1367	14	85	2.12	3.84	1.39(3) 1.18(4) 0.81(5)	6.24(3) 7.39(4) 17.74(5)

(1) Including interference from transmitters not belonging to the synchronized group.

(2) Interference between the transmitters of the synchronized group only.

(3) Co-channel protection ratio 20 dB against transmitters not belonging to the synchronized group.

(4) Co-channel protection ratio 25 dB against transmitters not belonging to the synchronized group.

(5) Co-channel protection ratio 40 dB against transmitters not belonging to the synchronized group.

RECOMMENDATION 598 *

**FACTORS INFLUENCING THE LIMITS OF AMPLITUDE-MODULATION
SOUND-BROADCASTING COVERAGE IN BAND 6 (MF) ****

(Question 44/10, Study Programme 44F/10)

(1982)

The CCIR,

CONSIDERING

(a) that amplitude-modulation sound-broadcasting coverage within a given frequency band cannot be improved beyond a certain limit imposed by physical and technical factors;

(b) that improved coverage within a given frequency band is directly related to improved spectrum-utilization efficiency;

* This Recommendation replaces Report 400, which is hereby cancelled.

** The operational aspects of broadcasting coverage in band 6 (MF) are discussed in Report 616.

- (c) that improved spectrum-utilization efficiency can only be achieved by:
 - maximizing the useful effects of all transmitters belonging to the network considered;
 - minimizing the interference effects of all transmitters of that network;
 - selecting an appropriate channel width;
 - arranging frequency channels in such a way that interference throughout the network is minimized;
- (d) that a coverage factor can be defined in a way that it is representative of spectrum-utilization efficiency;
- (e) that among the factors influencing the limits of broadcasting coverage in band 6 (MF) there are:
 - the minimum usable field strength;
 - the power level in the network;
 - the radio-frequency protection ratios;
 - the distance between transmitters sharing the same channel;
 - the channel spacing;
 - the bandwidth of emission;
 - wave propagation and the factors by which propagation is influenced;
 - the channel distribution,

UNANIMOUSLY RECOMMENDS

that in frequency planning and for the solution of frequency assignment problems in band 6 (MF) advantage should be taken of existing knowledge of the interrelations between the various factors influencing the limits of broadcasting coverage as they are described in Annex I.

The information contained in Annex I was derived from studies based on regular lattices and linear channel distributions and takes account of omni-directional transmitting antennas only.

ANNEX I

1. Introduction

In the decade preceding the LF/MF Broadcasting Conference for Regions 1 and 3, Geneva, 1974-75, the factors influencing the limits of sound-broadcasting coverage in band 6 (MF) and their interrelations were extensively studied in various countries. The results obtained so far permit a deep insight into the complex problem and may even appear to provide a conclusive answer to it.

For obvious reasons, it was assumed in the studies, that because of the limited MF broadcasting band available, no channel would be assigned exclusively to one transmitter throughout the world. The assignment, however, of the same frequency channel to more than one transmitter supposed to be sufficiently distant from one another inevitably led to co-channel interference problems.

2. Definition of coverage factor

It is first assumed that in an infinitely extended area all transmitters (infinite in number) are operating on the same frequency with an equal power p (kW). The distance between neighbouring transmitters is D (km). The highest density in this co-channel transmitter network can be obtained when three neighbouring transmitters each form an equilateral triangle of the sidelength D (see Fig. 1), and it is supposed that under these conditions spectrum utilization is almost optimal. In the presence of noise and interference from the surrounding co-channel stations the coverage range R (km) of each individual transmitter depends on:

- the frequency;
- the propagation characteristics affecting the field strength of the wanted (E_w) and unwanted (E_i) signals;
- the minimum usable field strength (E_{min});
- the radio-frequency protection ratios a_i .

The coverage range is that distance from the wanted transmitter at which field strength of the wanted transmitter is equal to the usable field strength E_u :

$$E_u = E_w = \sqrt{E_{min}^2 + \sum_{i=1}^n (E_i \times a_i)^2} \quad (\text{see Recommendation 499}).$$

Note. — Where field strengths or protection ratios are expressed in dB($\mu\text{V/m}$) or dB, respectively, the conversion can be made by means of the following formulae:

$$\underline{E} \text{ (}\mu\text{V/m)} = 10^{\frac{E \text{ (dB (}\mu\text{V/m)})}{20}} \quad a = 10^{\frac{A \text{ (dB)}}{20}}$$

In the absence of noise or when interference is by far predominant, the coverage range does not depend on the transmitter power level, whereas in the opposite case it does.

Quite generally, the coverage factor, c , may be defined to be the ratio of the sum of all areas, S_n , covered by the individual transmitters operating on the same frequency in a very extensive area to the total area, S :

$$c = \sum S_n / S$$

For the determination of the coverage factor in the theoretical case of a regular network the infinitely extended area is subdivided into unit areas, each of which consisting of two equilateral co-channel triangles having one side in common. Under these conditions each unit area corresponds to just one of the co-channel transmitters (see Fig. 1). Thus, the coverage factor (per channel) may be defined as:

- either the ratio of the coverage area πR^2 to the unit area $1/2 \sqrt{3} D^2$ (area coverage):

$$c = \frac{2\pi}{\sqrt{3}} \left(\frac{R}{D} \right)^2 \times 100 \quad (\%)$$

- or the ratio of the population in the aforementioned two areas (population coverage).

The concept of area coverage will be retained for the remainder of Annex I because additional information on population distribution would be required if the concept of population coverage were to be used. However, studies of a general nature would be difficult for the latter case.

The influence of the remaining channels as potential sources of interference (e.g. adjacent channels, second channel) should also be considered. In principle, in a unit area, each channel can be assigned to one transmitter only. Depending on whether an even coverage is wanted or not, the channels will either have to be distributed evenly over the unit area in a geometrically regular manner and according to an appropriate (e.g. linear) channel distribution scheme or — in the case of irregular coverage — will have to be arranged differently, maintaining however, sufficiently large distances between transmitters that may cause or suffer interference.

The coverage factor c is normally expressed as a percentage. If the area coverage obtainable by means of all the channels available in band 6 (MF) exceeds unity (100%), this number represents, on the average, the number of programmes that can be received at any location throughout the whole area under consideration.

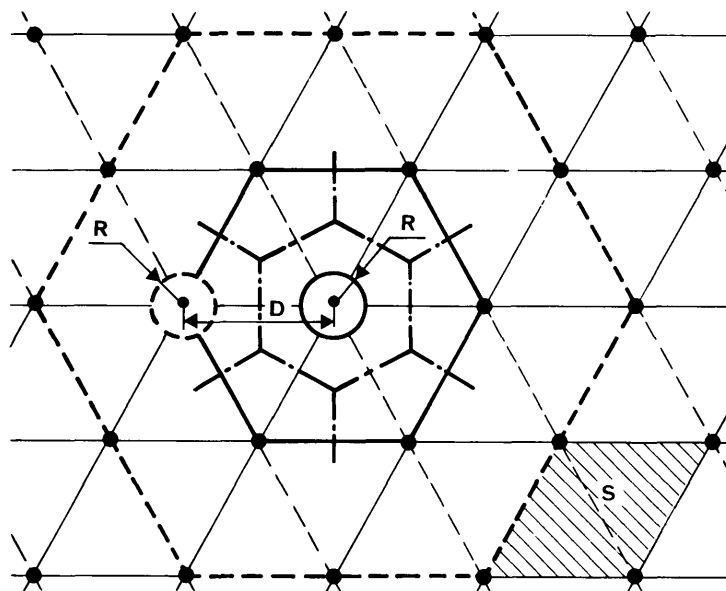


FIGURE 1 — Regular lattice of transmitter sites

D : co-channel distance
 R : coverage radius
 S : unit area

3. Coverage factor c as a function of the distance D between co-channel transmitters

3.1 General

To establish curves showing the dependence of the coverage factor c on the distance D between co-channel transmitters under varying conditions for the remaining parameters two different approaches, A and B, were made, however with the following common bases:

- transmitters of equal power p ;
- ground-wave propagation curves of Recommendation 368;
- sky-wave propagation curves of Recommendation 435 (type 1) or Report 575, (type 2);
- radiation constant in all azimuthal directions and at all angles of elevation.

The two approaches, A and B, differ with respect to the following parameters:

Approach A (results shown in Fig. 2):

- the power level remains unchanged ($p = 1$ kW);
- there is no noise limitation ($E_{min.} = -\infty$ dB);
- the radio-frequency protection ratio varies, in steps of 5 dB, between the limits $A = 20$ dB and $A = 45$ dB;
- the ground conductivity is $\sigma = 3 \times 10^{-3}$ S/m.

Approach B (results shown in Figs. 3 and 4):

- the power level varies, in steps of 5 dB, between the limits $p = 1$ kW and $p = 1000$ kW;
- the minimum usable field strength is $E_{min.} = 60$ dB ($\mu\text{V/m}$);
- the radio-frequency protection ratio values are $A = 40, 30$ or 27 dB;
- the ground conductivity values are $\sigma = 10^{-3}, 3 \times 10^{-3}$ or 10^{-2} S/m.

As a matter of fact, the rigorous and systematic use of directional antennas was also studied for approach B. The results obtained indicated that no substantial improvement in spectrum utilization efficiency can be expected under such conditions. This does not mean, however, that no advantage can be gained when directional antennas having horizontal patterns suitably adapted to the individual interference and coverage problem are used to a large extent (see Report 616).

3.2 Results obtained for a plane Earth model

The curves in Figs. 2, 3 and 4 are given as examples. They show the dependence of the coverage factor c on the co-channel distance D for a frequency of 1 MHz under varying conditions. The figures take account of the interfering co-channel stations on the two nearest hexagons surrounding the wanted transmitter (see Fig. 1). Thus, interference from 18 stations, i.e. 6 stations at the distances D , $D/\sqrt{3}$ or $2D$ was included in the computation. For reasons of symmetry the coverage range was determined as the root mean square of the values obtained for two significant azimuthal directions:

- direction towards interfering stations at the distances D and $2D$,
- direction towards interfering station at the distance $\sqrt{3}D$.

In particular, Fig. 2 shows the results obtained with approach A and is valid when ground-wave coverage is limited by sky-wave interference and when, in the absence of noise, there is no power dependency. The parameter indicated on the curves is the radio-frequency protection ratio A . Also shown in decibels relative to $1 \mu\text{V/m}$ is the field E_1 , of the wanted transmitter at the limit of the coverage area, for a transmission power of 1 kW with a short vertical antenna. For instance, the points of intersection on a curve shown by alternating dots and dashes, for $E_1 = 40$ dB, and the curves $c = f(D)$, for $A = 20$ dB derived for interference by sky waves of type 1 (shown by a full line) or of type 2 (shown by dashes), mean that if the co-channel distance is D (abscissae of the points of intersection, i.e. 2800 km or 4800 km, respectively) and for a protection ratio $A = 20$ dB, the field at the limit of the area, where the radio-frequency protection ratio is ≥ 20 dB, is 0.1 mV/m.

Figure 2 shows that:

- the coverage factor increases with decreasing values of radio-frequency protection ratio, regardless of the type of propagation of the interfering sky-wave signals;
- the general shape of the curves varies considerably with the type of propagation;
- for distances beyond about 1500 km the coverage factor increases when the interfering sky-wave propagation is of type 1;
- the coverage factor is largely independent of the co-channel distance with propagation of type 2;
- there is no pronounced optimum separation between co-channel transmitters as long as there is no limitation by noise.

Moreover, the figures show that at co-channel distances below the optimum distance interference is predominant so that an increase in power is only of limited use and that a power reduction may result in no loss in coverage.

When the sky wave is of type 1 it can, moreover, be seen that:

- the optimum separations between transmitters using the same channel are not very different, under night-time conditions, both for a ground-wave or a sky-wave service;
- at least with high-power transmitters ($p \geq 30$ kW), a sky-wave service would give a coverage similar to that of ground-wave service in the day-time.

The results are remarkably different, however, when the sky-wave propagation is of type 2. In this case:

- the optimum separations, if any, between transmitters using the same channel are noticeably different, under night-time conditions, for a ground-wave and a sky-wave service;
- the coverage of a sky-wave service would be more or less inferior to that of a ground-wave service in the day-time.

Finally, depending on the ground conductivity, the ground-wave coverage during night-time may increase at short distances with decreasing co-channel distance. This effect results in higher coverage at lower co-channel distances whereas the service ranges decrease to a few kilometres only.

The influence on coverage of the radio-frequency protection ratio can be derived from Figs. 3a and 3b, whereas a comparison of Figs. 3b, 4a and 4b permits the influence of the ground conductivity to be ascertained.

As may be expected an increase in the protection ratio leads to reduced coverage which can, at least partly, be compensated for if the co-channel distance is increased. This loss in coverage is particularly pronounced for the night-time sky-wave service obtained with the curves of type 2.

Similarly, decreasing ground conductivity leads to decreasing ground-wave coverage at both the day and the night-time. This can be remedied to some extent by a reduction of the co-channel distance, however, under day-light conditions only. There is, of course, no effect of the ground conductivity on sky-wave coverage.

3.3 *Results obtained for a spherical Earth model*

For interference from sky-wave signals either to a ground-wave or to a sky-wave service, suitable co-channel distances are of the order of the radius of the Earth, so that the spherical nature of the Earth must be taken into account. This has been done in [Eden and Minne, 1969] where only a sky-wave service is considered and where potential interference from the nearest co-channel transmitters, all equally spaced, has been taken into account.

An attempt has been made, therefore, to cover a sphere with a network of equilateral spherical triangles. It can be shown that this can be done by approximating the sphere to a polyhedron. A tetrahedron, octahedron and icosahedron provide surfaces consisting of 4, 8 and 20 equilateral triangles, respectively. These triangles may be developed on to a plane and it is then possible to apply, without difficulty, a linear channel distribution to this development.

However, when reconstituting the polyhedron, some of the triangles will share sides or apices with other triangles, from which they were separated in the plane development. In those groups of triangles the channel distribution will then no longer necessarily be linear, and consequently restrictions on the use of the channels shown on these triangles will occur. The proportion of these (unusable) triangles with respect to the total number will be at most 40% in the case of the icosahedron, 25% in the case of the octahedron and 50% in the case of the tetrahedron. On the other hand, these triangles may be ignored to a large extent by making use of the fact that dry land occupies only one third of the Earth's surface. It is, therefore, still possible to utilise the results that have already been obtained by considering networks on a plane surface.

If it is assumed that for the coverage of the land masses about 50% of the triangular surfaces will in fact be used and if account is taken of the fact that two triangular surfaces each carry the total number of channels available, it is evident that under these circumstances each channel can be used precisely 0.25 times the number of existing triangular planes. It is worth noting that this restriction to the use of any channel is exclusively due to the size and properties of the Earth's surface and that the co-channel distances resulting from the choice of the polyhedron would be about 12 740 km, 10 000 km and 7050 km for a tetrahedron, octahedron and icosahedron, respectively. Smaller co-channel distances and, consequently, a larger number of co-channel transmitters can be obtained by subdivision of the equilateral spherical triangles into smaller triangles which, however, would no longer be equilateral except after development on to a plane.

It is now possible to show as a final result, in one single diagram, the full relationship between:

- the number of transmitters b using one channel;
- the co-channel distance D ;
- the necessary transmitter power P and;
- the coverage factor c that can be obtained.

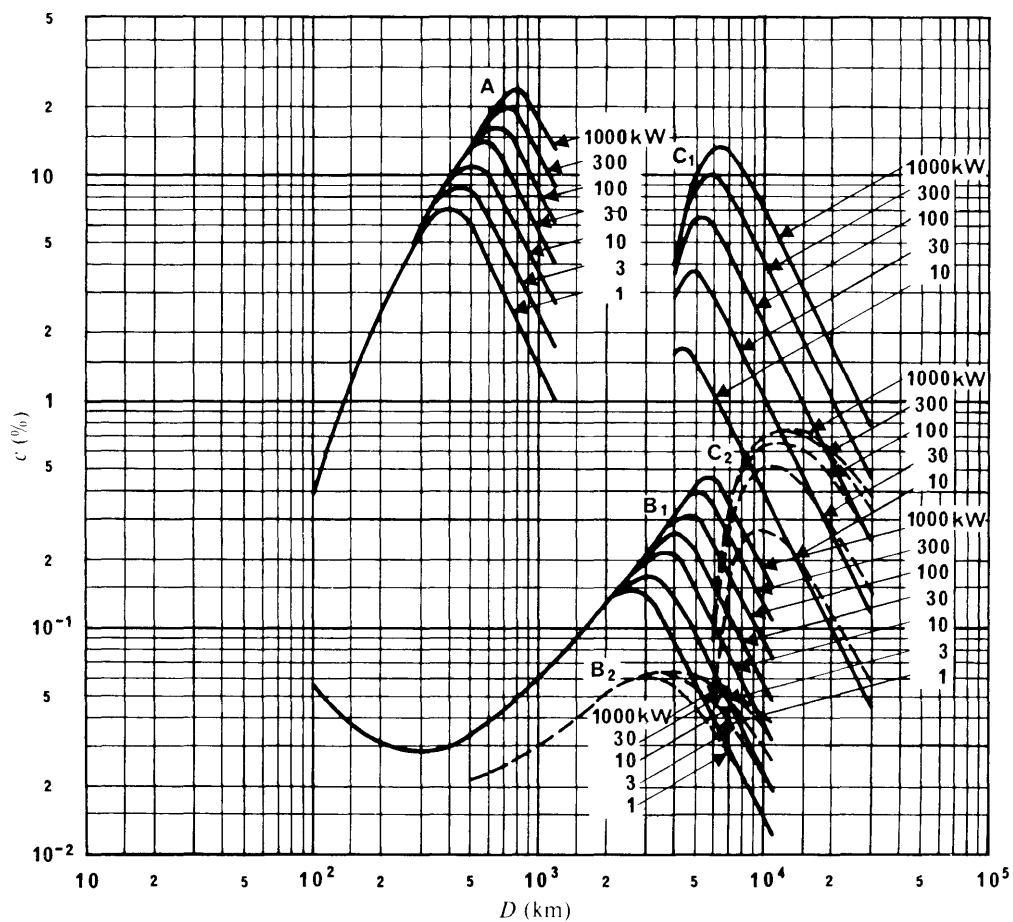


FIGURE 3a – Coverage factor per channel (c) as a function of distance between co-channel transmitters (D) for various propagation conditions

Parameter: transmitter e.m.r.p., p (kW), (p is kept constant at all angles of elevation)

Family of curves ($f = 1$ MHz):

- A: ground-wave service under day-time conditions
- B: ground-wave service under night-time conditions
- C: sky-wave service under night-time conditions

Propagation conditions:

- ground wave: Recommendation 368
- sky-wave: type 1 (index 1): Recommendation 435
- type 2 (index 2): Report 575

Minimum usable field strength: $E_{min} = 60$ dB(μ V/m)

Ground conductivity: $\sigma = 10^{-2}$ S/m

Protection ratio: $A = 40$ dB

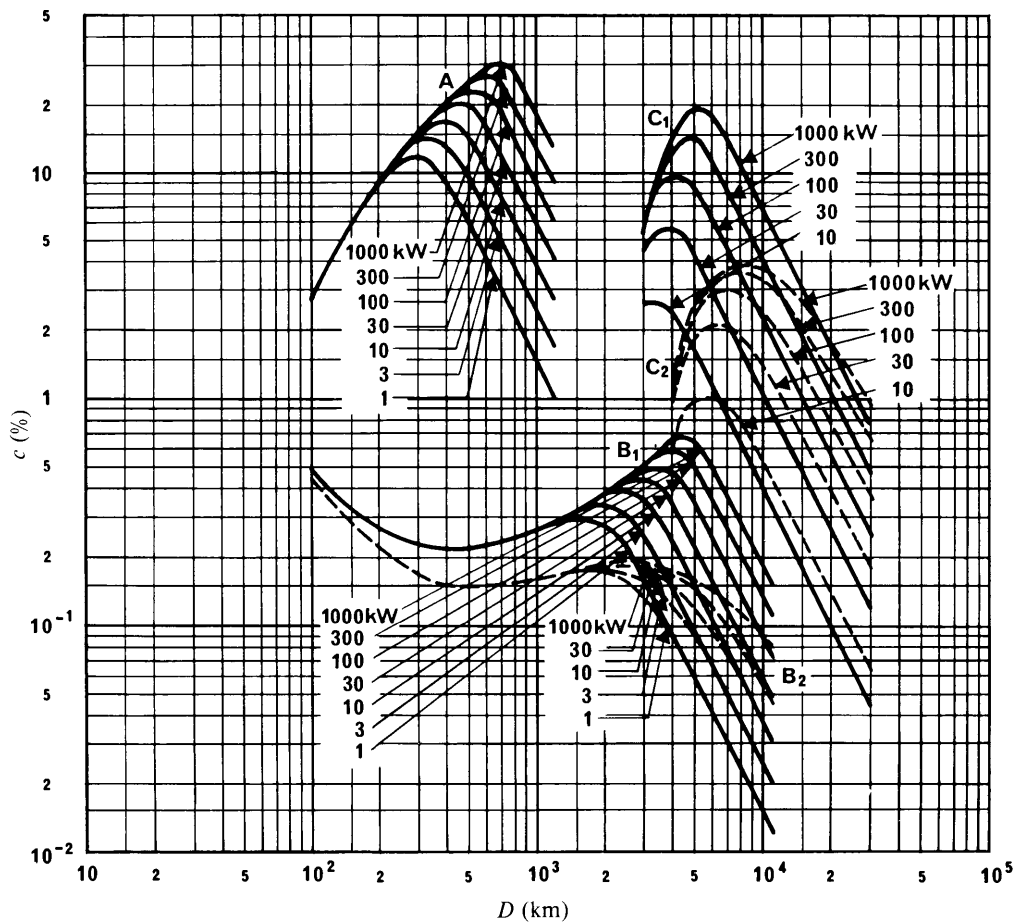


FIGURE 3b – Coverage factor per channel (c) as a function of distance between co-channel transmitters (D) for various propagation conditions

Parameter: transmitter e.m.r.p., p (kW), (p is kept constant at all angles of elevation)

Family of curves ($f = 1$ MHz):

- A: ground-wave service under day-time conditions
- B: ground-wave service under night-time conditions
- C: sky-wave service under night-time conditions

Propagation conditions:

- ground wave: Recommendation 368
- sky-wave: type 1 (index 1): Recommendation 435
- type 2 (index 2): Report 575

Minimum usable field strength: $E_{min} = 60$ dB(μ V/m)

Ground conductivity: $\sigma = 10^{-2}$ S/m

Protection ratio: $A = 30$ dB

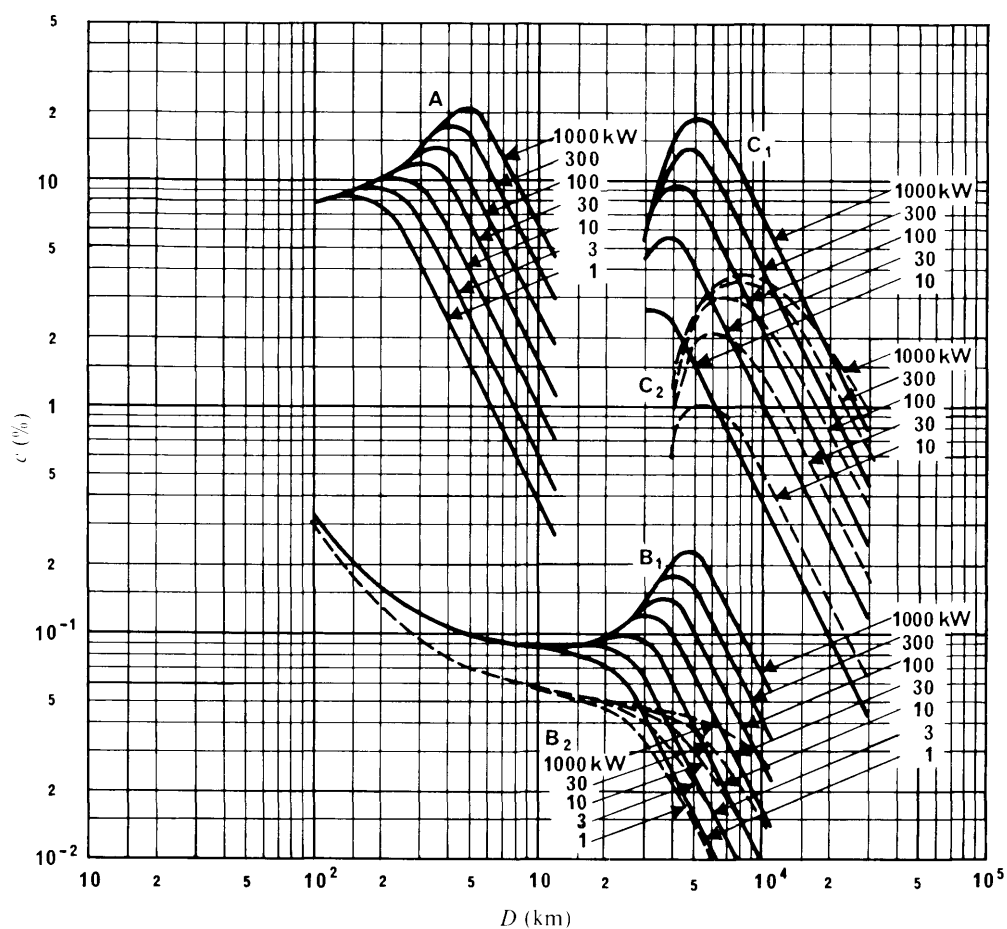


FIGURE 4a – Coverage factor per channel (c) as a function of distance between co-channel transmitters (D) for various propagation conditions

Parameter: transmitter e.m.r.p., p (kW), (p is kept constant at all angles of elevation)

Family of curves ($f = 1$ MHz):

- A: ground-wave service under day-time conditions
- B: ground-wave service under night-time conditions
- C: sky-wave service under night-time conditions

Propagation conditions:

- ground wave: Recommendation 368
- sky-wave: type 1 (index 1): Recommendation 435
- type 2 (index 2): Report 575

Minimum usable field strength: $E_{min} = 60$ dB(μ V/m)

Ground conductivity: $\sigma = 3 \times 10^{-3}$ S/m

Protection ratio: $A = 30$ dB

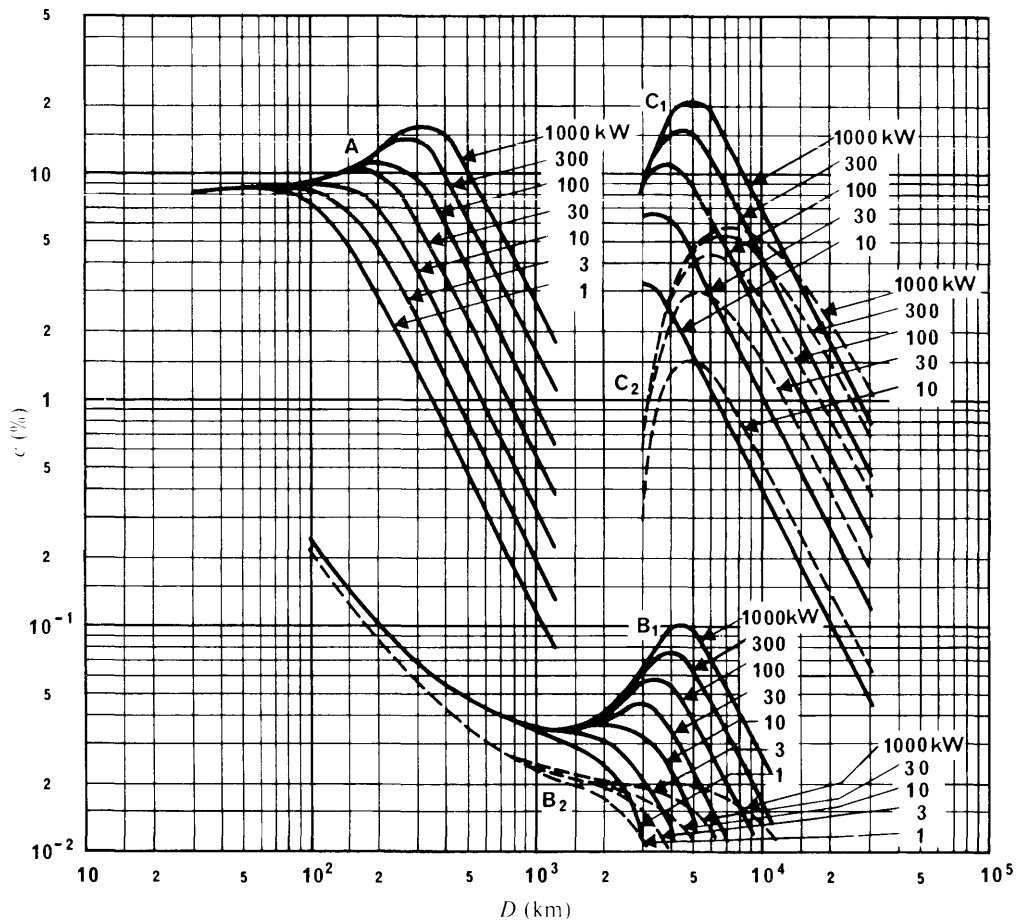


FIGURE 4b – Coverage factor per channel (c) as a function of distance between co-channel transmitters (D) for various propagation conditions

Parameter: transmitter e.m.r.p., p (kW), (p is kept constant at all angles of elevation)

Family of curves ($f = 1$ MHz):

- A: ground-wave service under day-time conditions
- B: ground-wave service under night-time conditions
- C: sky-wave service under night-time conditions

Propagation conditions:

- ground wave: Recommendation 368
- sky-wave: type 1 (index 1): Recommendation 435
- type 2 (index 2): Report 575

Minimum usable field strength: $E_{min} = 60$ dB(μ V/m)

Ground conductivity: $\sigma = 10^{-3}$ S/m

Protection ratio: $A = 27$ dB

Figure 5 shows this result. It should be noted that the absolute value fixed for any one of these parameters determines the values of all the others. When using Fig. 5 it should be borne in mind that it can only give an estimation of these relationships.

In an additional study the influence of the radio-frequency protection ratio on the coverage factor was calculated using the same assumptions as stated previously. The results are shown in Fig. 6 and indicate that the coverage factor increases more rapidly with decreasing values of radio-frequency protection ratio when the distance between co-channel transmitters is relatively small. For a distance of 3000 km, for example, the coverage factor is 100 times higher when the radio-frequency protection ratio is 20 dB instead of 40 dB.

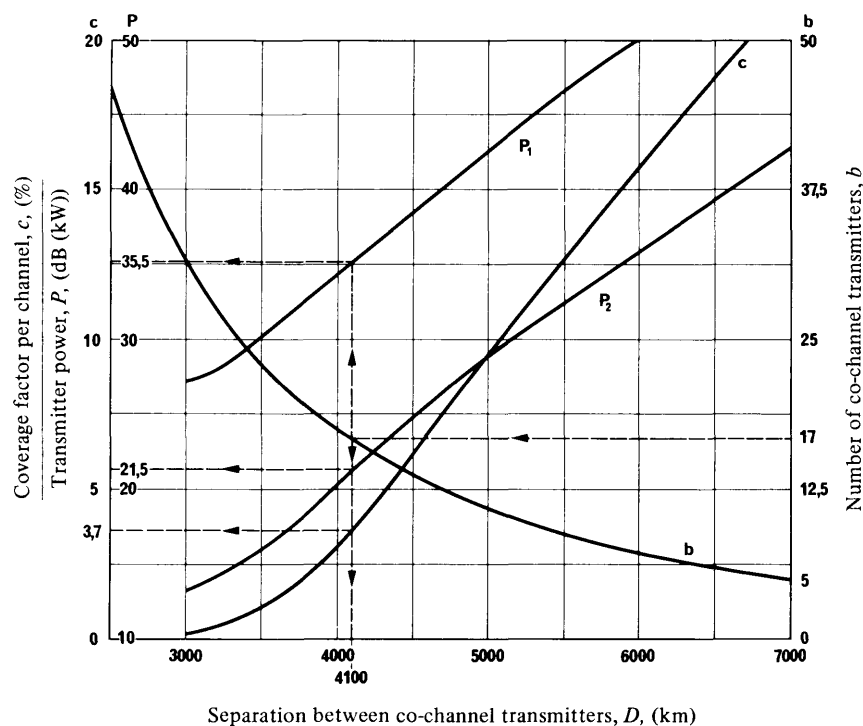


FIGURE 5 – Number of transmitters, b , transmitter power P and coverage factor per transmitter, c , as functions of the separation between co-channel transmitters, D

Curves P_1 : transmitter power (dB (1 kW)) for $E_{min} = 74$ dB(μ V/m)
 P_2 : transmitter power (dB (1 kW)) for $E_{min} = 60$ dB(μ V/m)
 b : number of co-channel transmitters
 c : percentage coverage factor per channel
 Radio-frequency protection ratio: 40 dB
 Frequency f : 1 MHz

Example:

If the number of transmitters sharing the same channel is taken as $b = 17$, then the co-channel transmitter separation is $D = 4100$ km, the coverage factor per channel is $c = 3.7\%$ and the e.m.r.p. necessary for all transmitters to make interference rather than noise the coverage limiting factor is:

$P = 21.5$ (dB (1 kW)) for $E_{min} = 60$ dB(μ V/m)
 or
 $P = 35.5$ (dB (1 kW)) for $E_{min} = 74$ dB(μ V/m)

4. Coverage factor as a function of channel spacing

The influence of the channel spacing on MF area coverage for both ground-wave and sky-wave services at night was investigated by the EBU and in Japan for channel spacings between 5 and 10 kHz. The studies were based on regular channel distributions and on the RF protection-ratio curve of Recommendation 560. Moreover, it was assumed that the number of transmitters N on a given area remains constant when the channel spacing is varied and the area considered was that of the combined European and African Broadcasting Areas (about 42×10^6 km²). Similar studies were carried out in the U.S.S.R. [Schlüger, 1975] based, however, on an RF protection ratio curve obtained from high-quality receivers having adjustable bandwidths which are in wide-spread use in the U.S.S.R. [Kokorev, 1976]. The total area coverage was calculated under various assumptions and some of the results obtained by the EBU and in Japan are presented in Fig. 7 (ground-wave service) and Fig. 8 (sky-wave service) showing the coverage factor as a function of channel spacings between the limits quoted and for various numbers of total frequency assignments as a parameter.

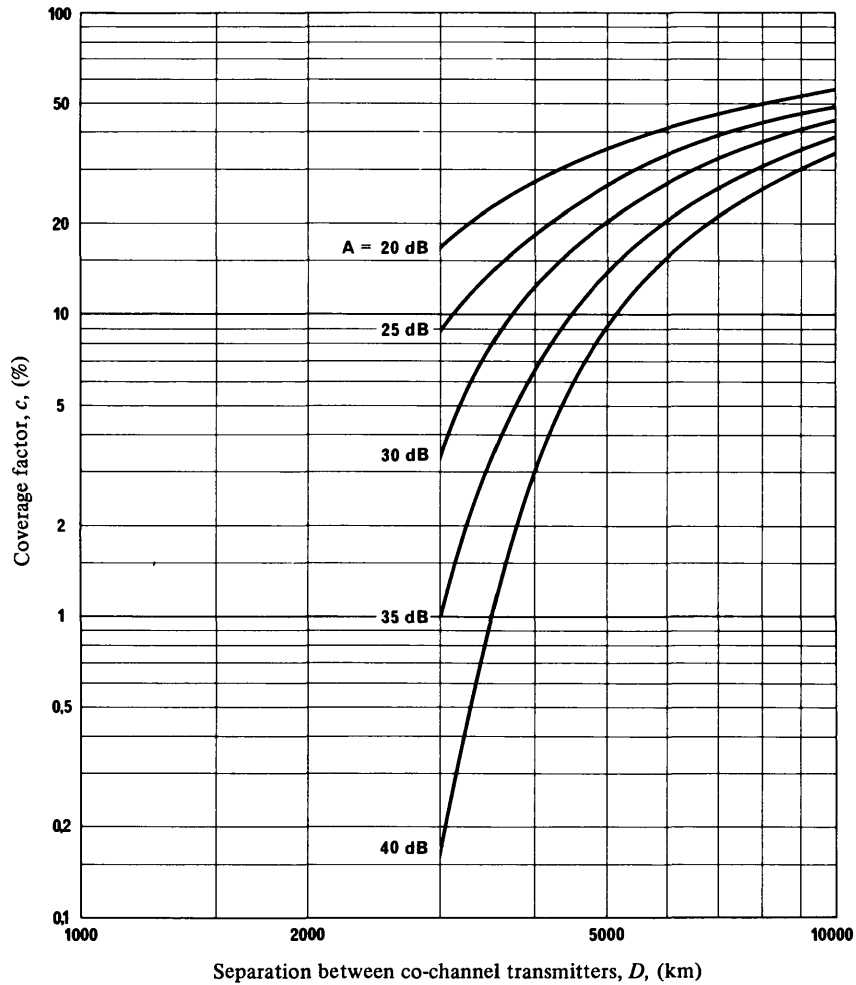


FIGURE 6 – Coverage factor, c , for a spherical Earth, as a function of separation between transmitters, D , with protection ratio, A , as a parameter.

Frequency: 1 MHz

Figures 7 and 8 show that the maximum of coverage is obtained with a channel separation of about 8 kHz, almost independently of the various assumptions made and, in particular, of the number of assignments within the given area. However, the absolute value of coverage does not depend strongly on the number of assignments when the service is provided by the ground-wave (Fig. 7) whereas it depends strongly on this parameter in the case of a sky-wave service (Fig. 8).

The results obtained in the U.S.S.R. indicate that maximum coverage is to be expected with a channel separation of about 9 kHz. As the technical bases of the studies carried out in the various parts of the world were nearly identical except for the RF protection-ratio curve it is obvious that the difference in the results is solely a consequence of the different shapes of the RF protection ratio curves used.

The fact that there is only one specific optimum value for either set of basic conditions, i.e. 8 kHz or 9 kHz respectively, can best be explained with the help of Fig. 9.

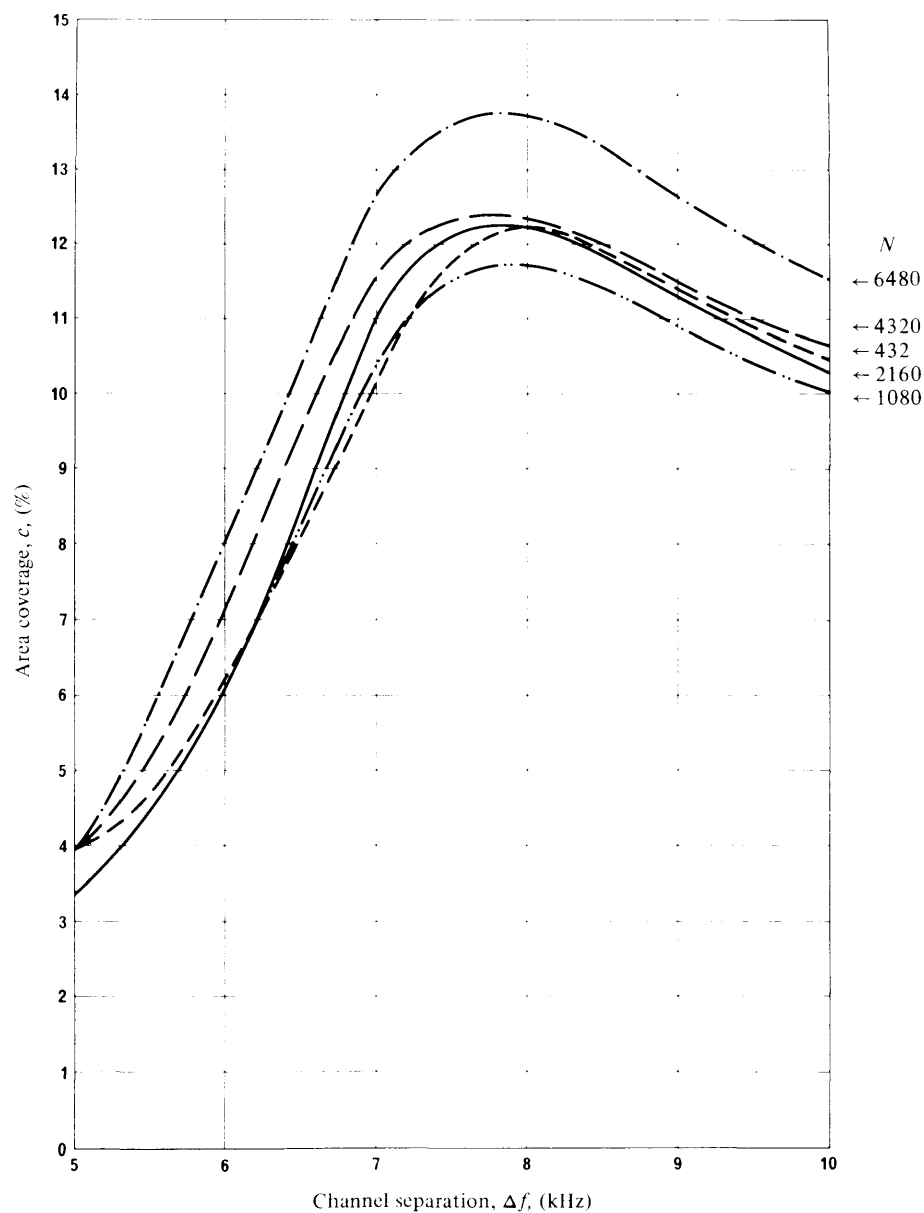


FIGURE 7 — Coverage, c , obtainable using a 1080 kHz band with N stations in an area of $42 \times 10^6 \text{ km}^2$ by a ground-wave service under night-time conditions

Propagation curve used:

Ground-wave:	Recommendation 368
Sky-wave:	($\sigma = 3 \times 10^{-5} \text{ S/m}$) at 1 MHz
Protection ratio, A :	Report 575 (Kyoto, 1978)
Adjacent channel protection ratio curve:	26 dB
	Recommendation 560, curve A

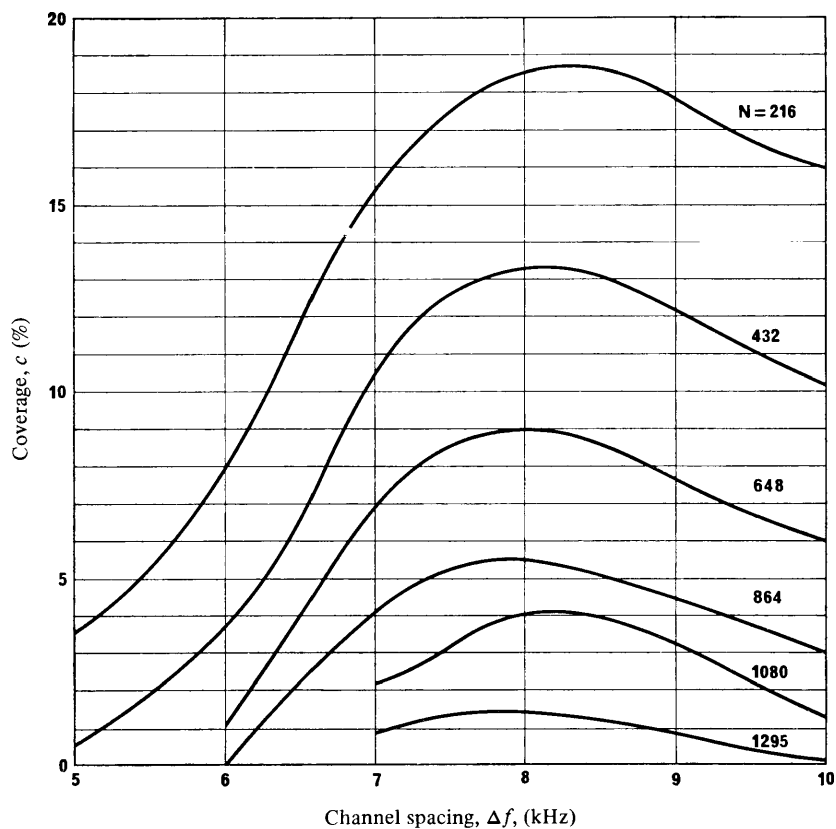


FIGURE 8 – Coverage, c , obtainable by the sky-wave with all channels in band 6 (MF)

Parameter: number of frequency assignments, N

- Basic assumptions: – total area: $42 \times 10^6 \text{ km}^2$
 – co-channel protection ratio for the median field: 27 dB
 – relative protection ratios: curve of Recommendation 560
 – each wanted transmitter interfered with by three co-channel and three adjacent-channel transmitters
 – sky-wave propagation curves:
 wanted signal: Report 575 (Kyoto, 1978)
 unwanted signal: Report 575, footnote to equation (4)
 [Eden and Minne, 1973]

If N frequency assignments in band 6 (MF) to transmitters (or synchronised groups) are required in a given area S and if co-channel interference only has to be taken into account, the coverage improves with decreasing channel spacing, thus increasing the number of channels available. It is obvious that, in such a case, the average co-channel distance will also increase (curve A of Fig. 9) and that interference will be reduced by this measure. Low values of channel spacing would, in this case, be preferable.

If, however, adjacent-channel instead of co-channel interference had to be taken into account, the rest of the parameters remaining unchanged, interference would increase and, hence coverage would decrease with decreasing channel spacing (curve B of Fig. 9). High values of channel spacing would, therefore, be desirable in this case.

In practice, however, both types of interference have to be considered and it is obvious that the resulting coverage curve, as a function of frequency spacing, will be situated below the two curves discussed above.

Furthermore, from the shape of the two limiting curves, it is very probable that the resulting curve will have a maximum and, in fact, there is a maximum (curve C of Fig. 9) which is, however, relatively flat.

It has been shown in a further study that the optimum channel spacing corresponding to maximum coverage depends mainly on the relative RF protection-ratio curve and, more precisely, corresponds roughly to a value of about $A_{rel} = -20$ dB. Hence, the differing results obtained in the various parts of the world are by no means inconsistent and rather confirm, to some extent, the usefulness of this additional study.

The family of curves in Fig. 10 provides a simple but efficient means for the determination of the optimum channel spacing for a given RF protection-ratio curve. Figure 10 shows the coverage factor as a function of the channel spacing, where both co-channel and adjacent channel interference are taken into account. However, for the particular purpose the adjacent-channel protection-ratio values are used as a parameter which is independent of the channel separation. Thus, the curves of Fig. 10 can be used in conjunction with either Fig. 1 of Recommendation 560 or any other pertinent relative RF protection-ratio curve for the purpose envisaged. If in Fig. 10, at each channel spacing, the pertinent curve representing the actual relative RF protection ratio is marked, e.g. by a little circle (in Fig. 10 this has been done for the relative RF protection-ratio curve C of Recommendation 560) or a little square (representing relative RF protection-ratio values obtained from U.S.S.R. high-quality receivers having a wide pass band) the sequence of these little circles or squares shows the real dependence of the coverage factor on the channel spacing and in fact indicates, as can be seen from the figure, a maximum at a spacing of about 8 kHz or 9 kHz, respectively.

It should not be overlooked, however, that the results showing the superiority of a specific value of channel spacing were obtained in studies based on regular transmitter lattices and linear channel distributions. If in particular, the distance between adjacent-channel transmitters varies over a wide range throughout the planning area including in many cases, relatively short distances, the effect of adjacent-channel interference will become more severe than in the theoretical case. In such conditions it may be necessary to select channel spacings in excess of the theoretical optimum.

5. Conclusions

The coverage that can be obtained in band 6 (MF) is mainly determined by the distance between any two transmitters sharing the same channel, i.e. the co-channel distance, and by the frequency spacing between adjacent channels.

The optimum co-channel distance depends on many parameters, namely the frequency, the power level of the transmitter network, the radio-frequency protection ratio, the minimum usable field strength, and the propagation properties of the ground wave and the sky wave, as the case may be. The choice of an adequate co-channel distance immediately and irrevocably determines the number of transmitters that may operate in the same channel and vice-versa. This relationship is shown, among others, in Fig. 5.

The optimum channel separation depends on the relative radio-frequency protection-ratio curve taken to be representative of receivers in the area to be planned.

It should be noted, however, that coverage can be considerably improved beyond the limits derived in this Annex by (see Report 616):

- use of directional transmitting antennas suitably adapted to the particular situation;
- the use of synchronized transmitter networks;
- transmitter powers carefully adapted to the individual coverage problem.

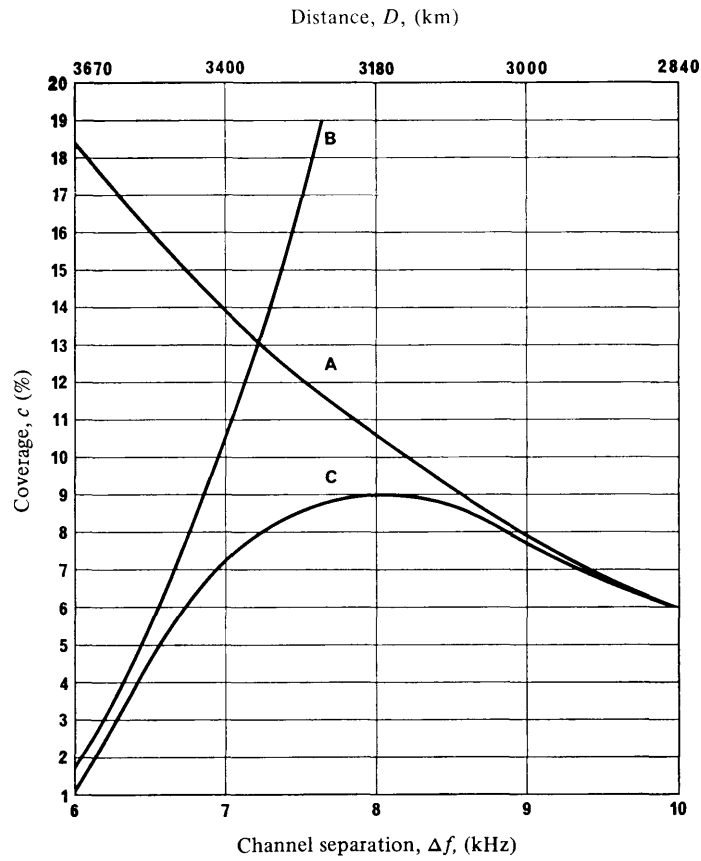


FIGURE 9 – Limits for area coverage (radio-frequency protection ratio: 27 dB)

Curve A: area coverage in the presence of co-channel interference (three transmitters)

Curve B: area coverage in the presence of adjacent-channel interference (three transmitters)

Curve C: area coverage obtainable in the presence of co-channel and adjacent-channel interference

Protection ratio A : 27 dB

Number of frequency assignments N : 648

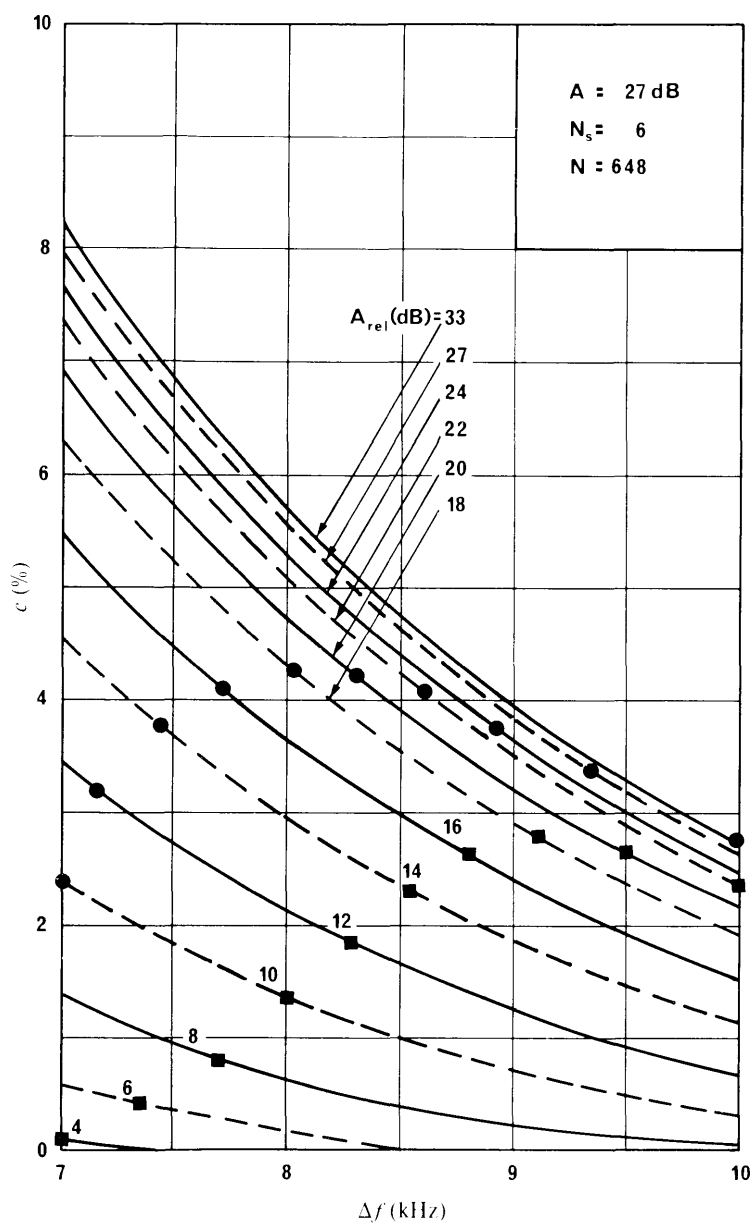


FIGURE 10 – Coverage factor (c) as a function of channel spacing

Parameter: relative radio-frequency protection ratio (A_{rel})

● : specific value of A_{rel} , see Recommendation 560, Fig. 1, curve C

■ : specific value of A_{rel} , see [Kokorev, 1976], Fig. 2

N : total number of frequency assignments

N_s : number of groups of interfering transmitters each consisting of one co-channel and one adjacent-channel transmitter

REFERENCES

- EDEN, H. and MINNE, D. [June, 1969] The determination of the limits of coverage in the MF broadcasting band, using regular, plane and spherical transmitter networks. *EBU Rev.*, **115-A**, 109-120.
- EDEN, H. and MINNE, D. [December, 1973] Broadcasting coverage in the LF/MF bands. *EBU Rev. Tech.*, **142**, 262-272.
- KOKOREV, A. W. [1976] Choice of adjacent-channel protection ratios in LF/MF broadcasting networks. *NIIR Proc.*, **4**.
- SHLÜGER, I. S. [1975] Choice of the separation between carrier frequencies in the LF/MF bands. *Elektrosviaz*, **3**, 15-17.

BIBLIOGRAPHY

- EBU [May, 1974] Technical parameters for LF/MF broadcasting. *Tech. Doc. 3206*.
- SHAMSHIN, V. A. and SHLÜGER, I. S. [October, 1975] Adjacent channel protection ratios for LF/MF sound broadcasting (150-1605 kHz). *Telecomm. J.*, Vol. 42, X, 606-607.

RECOMMENDATION 561-1 *

DEFINITIONS OF RADIATION IN LF AND MF BROADCASTING BANDS

(1978-1982)

The CCIR

UNANIMOUSLY RECOMMENDS

that the following terminology should be used to define and determine the radiation from sound-broadcasting transmitters:

1. Cymomotive force (c.m.f.) (in a given direction)

The product formed by multiplying the electric field strength at a given point in space, due to a transmitting station, by the distance of the point from the antenna. This distance must be sufficient for the reactive components of the field to be negligible; moreover, the finite conductivity of the ground is supposed to have no effect on propagation.

The cymomotive force (c.m.f.) is a vector; when necessary it may be expressed in terms of components along axes perpendicular to the direction of propagation.

The c.m.f. is expressed in volts; it corresponds numerically to the field strength in mV/m at a distance of 1 km. (The determination of c.m.f. is given in Annex I, § 1.)

2. Effective monopole-radiated power (e.m.r.p.) (in a given direction)

The product of the power supplied to the antenna and its gain relative to a short vertical antenna in the given direction. (Radio Regulations, No. 157.)

Radio Regulations No. 154 (c) defines the gain of an antenna in a given direction relative to a short vertical antenna as the gain relative to a loss-free reference antenna consisting of a linear conductor, much shorter than one quarter of a wavelength, normal to the surface of a perfectly conducting plane which contains the given direction.

The reference antenna, when fed with a power of 1 kW, is considered to radiate an e.m.r.p. of 1 kW in any direction in the perfectly conducting plane and produces a field strength of 300 mV/m at 1 km distance (equivalent to a c.m.f. of 300 V).

An e.m.r.p. of 1 kW is assumed in the derivation of the ground-wave propagation curves of Recommendation 368. An e.m.r.p. of 1 kW at all angles of elevation is assumed in the presentation of the sky-wave curves of Recommendation 435.

(The determination of e.m.r.p. is given in Annex I, § 2.)

* This Recommendation should be brought to the attention of the CMV.

ANNEX I

1. Determination of the cymomotive force

1.1 *Vertical antennas:* For vertical antenna systems which are actually in operation, the c.m.f. in a horizontal direction is obtainable by measurements of field strength on a radial line over the range, 2λ to 15λ , from the antenna system. Here, λ , is taken to be either the wavelength or the maximum dimensions of the antenna, whichever is the greater, in order to avoid the effect of reactive fields. If E is the field strength at distance, d , the product, Ed , is plotted graphically against d . The line is extrapolated to $d = 0$, and the product (E_0d_0) gives the c.m.f.

For a single mast, it is desirable to take the average of values for a few radials. For a multiple mast system, separate measurements are required on a number of radials to establish the c.m.f. as a function of bearing.

For directions above the horizontal, a correction should be derived theoretically from the behaviour over a perfectly conducting plane. Alternatively, field-strength measurements may be made from a helicopter.

For antenna systems which have not yet been constructed, or whenever for some other reason measurements cannot be made reliably, the c.m.f. may be estimated from a calculation of the system performance over a perfectly conducting surface, and from the estimated efficiency of the antenna system.

1.2 *Horizontal dipole array:* In this case, the most practical method is a computation for the array over a perfectly conducting ground, assuming the total transmitter power (less the feeder loss) represents the radiated power. In this case the c.m.f. should be the combination of two orthogonal components, perpendicular to the direction of propagation, made on a root mean square basis.

1.3 *Transmitter carrier power as a function of c.m.f.*

For a single vertical mast radiator, neglecting losses:

$$p = (F_c/300)^2 \cdot (1/G_v) \quad (1)$$

where,

p : transmitter carrier power (kW);

F_c : c.m.f. in the horizontal direction (V);

G_v : gain of antenna relative to a short vertical antenna.

More generally, the *total power radiated* into space (in other words, the power to be supplied to the antenna if losses are neglected) is related to the c.m.f. by:

$$W = \frac{1}{120\pi} \int \int_{\text{sphere}} F_c^2(\varphi, \theta) \cos \theta \cdot d\theta d\varphi \quad (2)$$

where $F_c(\varphi, \theta)$ is the c.m.f. as a function of the azimuth φ and the angle of elevation θ , (W is in watts and F_c is in volts).

2. Determination of the effective monopole radiated power

For vertical antennas only, the e.m.r.p. may be measured or estimated in the manner described in § 1 of Annex I for the determination of the c.m.f.

3. Relationship between e.m.r.p. and c.m.f.

The value of the e.m.r.p. is related to the c.m.f. (V) by the expression:

$$\text{e.m.r.p.} = (\text{c.m.f.}/300)^2 \text{ kW}$$

Table I gives some practical examples of c.m.f. and e.m.r.p. in the absence of losses.

TABLE I

Transmitter power (kW)	Antenna	Gain relative to a short vertical antenna (dB)	c.m.f. (V)	c.m.f. (dB (300 V))	e.m.r.p. (kW)
0.01	} short vertical	0	30	- 20	0.01
0.1		0	95	- 10	0.1
1		0	300	0	1
10		0	950	+ 10	10
100	} $\lambda/2$ vertical	2	3 800	+ 22	160
300		2	6 600	+ 27	475
1000		2	12 000	+ 32	1600

4. Use of propagation curves

The ground-wave propagation curves of Recommendation 368 and the sky-wave propagation curves given in Recommendation 435 are drawn nominally for a field strength of 300 mV/m at 1 km and thus apply to a c.m.f. of 300 V. However, the sky-wave curves were established from measurements to which a correction was applied in each case for the vertical radiation pattern (over good ground) of the transmitting antenna; but no correction was applied for the effect of finite ground conductivity on the sky-wave field strength. These curves therefore, include the effect of average ground conductivity, which (as compared with a perfectly conducting ground) can cause significant reduction of sky-wave at low angles. This effect is discussed in Report 401. It can be shown that for all types of vertical antenna systems of interest for applications in bands 5 (LF) and 6 (MF), the ground effect is substantially independent of the type of antenna, and correction for the antenna gain and vertical radiation pattern may be made with good accuracy by correcting the calculated pattern for a perfectly conducting flat earth.

The practice is already established for propagation curves to apply to a radiated power of 1 kW from a short vertical antenna and this corresponds to a c.m.f. in the horizontal direction of 0 dB relative to 300 V.

RECOMMENDATION 499-2 *

DEFINITIONS OF SPECIFIC FIELD STRENGTHS AND COVERAGE AREA IN LF, MF, HF AND VHF SOUND BROADCASTING

(Question 44/10, Study Programme 44B/10)

(1974-1978-1982)

The CCIR

UNANIMOUSLY RECOMMENDS

that the following definitions should be used for sound broadcasting in bands 5 (LF), 6 (MF), 7 (HF) and 8 (VHF).

1. Minimum usable field strength (E_{min})

Minimum value of the field strength necessary to permit a desired reception quality, under specified receiving conditions, in the presence of natural and man-made noise (see Report 322), but in the absence of interference from other transmitters.

Note 1. — The desired quality is determined in particular by the protection ratio against noise, and for fluctuating noise, by the percentage of time during which this protection ratio must be ensured.

Note 2. — The receiving conditions include, amongst others:

- the type of transmission, and frequency band used;
- the receiving equipment characteristics (antenna gain, receiver characteristics, siting);
- receiver operating conditions, particularly the geographical zone, the time and the season.

Note 3. — Where there is no ambiguity, the term “minimum field strength” may be used.

Note 4. — The term “minimum usable field strength” corresponds to the term “minimum field strength to be protected” which appears in many ITU texts.

2. Usable field strength (E_u)

Minimum value of the field strength necessary to permit a desired reception quality, under specified receiving conditions, in the presence of natural and man-made noise and interference, either in an existing situation or as determined by agreements or frequency plans.

Note 1. — The desired quality is determined in particular by the protection ratios against noise and interference and, in the case of fluctuating noise or interference, by the percentage of time during which the required quality must be ensured.

* This Recommendation should be brought to the attention of Study Groups 1, 8, 11 and the CMV.

Note 2. — The receiving conditions include, amongst others:

- the type of transmission and frequency band used;
- the receiving equipment characteristics (antenna gain, receiver characteristics, siting);
- receiver operating conditions, particularly the geographical zone, the time and the season, or if the receiver is mobile, the local variations of the field strength due to propagation effects.

Note 3. — The term “usable field strength” corresponds to the term “necessary field strength” which appears in many ITU texts. Use of the latter term is not desirable.

Note 4. — For the determination of the usable field strength see Annex I for information.

3. Reference usable field strength (E_{ref})

The agreed value of the usable field strength that can serve as a reference or basis for frequency planning.

Note 1. — Depending on the receiving conditions and the quality required, there may be several reference usable field-strength values for the same service.

Note 2. — Where there is no ambiguity, the term “reference field strength” may be used.

Note 3. — The term “reference usable field strength” corresponds to the term “nominal usable field strength” which appears in some ITU texts.

4. Coverage area (of a broadcasting transmitter in a given broadcasting band)

The area within which the field strength of a transmitter is equal to or greater than the usable field strength.

In the case of fluctuating interference or noise, the percentage of time during which this condition is satisfied should be stated.

The coverage area may be different under day-time and night-time conditions or vary with other factors.

Note 1. — The coverage area is determined solely by the technical conditions specified, irrespective of administrative or regulatory considerations.

Note 2. — See also Recommendation 573, Vol. XIII.

ANNEX I *

For the determination of the usable field strength E_u (dB(V/m)) = $20 \log E_u$ (V/m) one of the following two methods can be used; in the formulas presented below, no account is taken of receiving antenna directivity.

1. Power sum method

$$E_u = \sqrt{\sum_i (a_i b_i E_{ni})^2 + E_{min}^2}$$

where:

E_u : the usable field strength;

E_{ni} : the field strength of the i -th unwanted transmitter;

E_{min} : the minimum usable field strength;

a_i : the radio-frequency protection ratio associated with the i -th unwanted transmitter, expressed as numerical ratio of field strengths;

and where the various field strengths at the point of reception are expressed in the same units, e.g. in mV/m.

This method is normally used for frequencies below 30 MHz. It may also be used for higher frequencies but does not take account of the statistical variations of the field strength with location and its use leads to results which tend to be more optimistic than those obtained with the simplified multiplication method.

* This Annex is given for information only.

2. Simplified multiplication method

The usable field strength E_u , in dB ($\mu\text{V}/\text{m}$), is determined for a specific coverage probability (with respect to time and location) and depends on the values of the nuisance fields:

$$E_{si} = P_i + E_{ni}(50, T) + A_i$$

where:

- P_i : the e.r.p., in dB(kW), of the i -th unwanted transmitter;
- $E_{ni}(50, T)$: the field strength, in dB($\mu\text{V}/\text{m}$), normalized to an e.r.p. of 1 kW, of the i -th unwanted transmitter. This field strength is exceeded at 50% of the locations during at least $T\%$ (e.g. 1%) of the time;
- A_i : the radio-frequency protection ratio associated with the i -th unwanted transmitter, expressed in dB.

Appropriate account of the effect of multiple interference can be taken by the use of statistical computation methods among which the simplified multiplication method is the least complex (see Report 945). However, it is rather more complicated to use than the power sum method.

The essence of the simplified multiplication method is to calculate the usable field strength, E_u , by way of iteration from:

$$p_c = \prod_{i=1}^n L(E_u - E_{si})$$

where:

- p_c : the probability to provide coverage to $p\%$ of locations during at least $(100 - T)\%$ of the time (e.g. $p = 50\%$);
- $L(z)$: the probability integral for a normal distribution (see Report 945).

REPORT 619

SKY-WAVE RECEPTION IN LF, MF AND HF BROADCASTING

(Question 44/10, Study Programme 44C/10)

(1974)

Studies carried out in Australia have shown that the effects of fading in the night-time interference zone in band 6 (MF) and band 7 (HF), can be substantially reduced by the use of a simple diversity receiving antenna system.

The method utilizes two ferrite rod antennas mounted orthogonally in the horizontal plane with their outputs separately received and processed up to the stage of detection. The audio outputs are combined.

Tests have shown that there is negligible correlation between the two components of the field and that the diversity effectiveness is not substantially affected by the orientation of the antenna system.

BIBLIOGRAPHY

CCIR Documents

[1970-1974]: Doc. 10/199, Australia.

RECOMMENDATION 410

MULTIPLE FREQUENCY USE PER PROGRAMME IN HF BROADCASTING

(Question 44/10)

(1963)

The CCIR,

CONSIDERING

that Article 17, No. 1751, of the Radio Regulations, states: "... their number (of frequencies) should be the minimum necessary to provide satisfactory reception of the particular programme in each of the areas for which it is intended ...",

UNANIMOUSLY RECOMMENDS

1. that, wherever possible, only one frequency should be used to radiate a particular programme to a given reception area;
2. that in certain special circumstances, namely:
 - over certain paths, e.g. very long paths, those passing through the auroral zone, or paths over which the FOT is changing rapidly;
 - areas where the depth of the area extending outwards from the transmitter is too great to be served by a single frequency;
 - when highly directional antennas are used to maintain satisfactory signal-to-noise ratios, thereby limiting the geographical area covered by such antennas;
 it may be found necessary to use more than one frequency per programme;
3. that the decision to use more than one frequency per programme should be made on the merits of the particular case concerned.

RECOMMENDATION 411-2

FADING ALLOWANCES IN HF BROADCASTING

(Question 44/10, Study Programme 44C/10)

(1963–1966–1978)

The CCIR

UNANIMOUSLY RECOMMENDS

that the values given in Table I below should be used for the fading factors necessary to ensure a satisfactory signal-to-interference ratio for given percentages of the time.

TABLE I

Ratio (dB)	(1)	(2)	(3)	(4)
Radio-frequency signal-to-interference	10	13	23	16
Wanted signal-to-atmospheric noise	6	16	22	17
Wanted signal-to-industrial noise	6	10	16	12

Column 1: the short-term fading allowance which must be made to ensure that the steady-state ratio is attained for 90% of any given hour.

Column 2: the long-term fading allowance which must be made to ensure that the steady-state ratio is achieved for 90% of the hours in any one month at a particular time of day in 90% of the cases.

Column 3: the sum of the values in columns 1 and 2, and is the overall variability allowance which must be made to ensure that the steady-state ratio is attained for 90% of any one hour in 90% of the hours in any month at a particular time of day and in 90% of the cases. This represents an assured steady-state ratio for 96% of the overall time.

Column 4: the square root of the sum of the squares of the values (in dB) given in columns 1 and 2, and is the overall variability allowance which must be made to ensure that the steady-state ratio is attained for 90% of the time.

Note. — The figures in the above Table, relating to the time availability of service, were selected on a theoretical basis and on experience derived principally from broadcasting in band 6 (MF).

RECOMMENDATION 498-1

IONOSPHERIC CROSS-MODULATION IN THE LF AND MF BROADCASTING BANDS

(Question 44/10, Study Programme 44E/10)

(1974–1978)

The CCIR,

CONSIDERING

that excessive radiation towards the ionosphere may result in ionospheric cross-modulation and hence harmful interference,

UNANIMOUSLY RECOMMENDS

that the maximum permissible radiation at any angle of elevation should be such that annoyance due to ionospheric cross-modulation does not exceed that agreed for co-channel interference (see Recommendation 560).

ANNEX I *

The effects of ionospheric cross-modulation in bands 5 (LF) and 6 (MF) may become a problem of increasing severity as the power of transmitters continues to increase.

1. Detailed experiments on this subject have been carried out within the framework of the EBU in several countries, notably in the United Kingdom and in the Federal Republic of Germany [Haberkant and Vogt, 1966; Haberkant *et al.*, 1971]. From these experiments which were carried out with conventional amplitude-modulation double-sideband transmissions, the following results may be deduced:

1.1 The percentage of cross-modulation increases practically linearly with the power of the interfering transmitter and also increases with the depth of modulation.

Note. — The percentage of cross-modulation is the percentage by which the carrier of the wanted transmitter is modulated by the modulating frequencies of the interfering transmitter.

1.2 Cross-modulation depends primarily on the power radiated by the interfering transmitter in the direction of the reflection point of the wanted signal in the ionosphere.

Cross-modulation of percentages less than 10% are directly proportional to the power [Knight, 1973]; an increase of 3 dB in the interfering transmitter power therefore, increases the cross-modulation levels by 6 dB. The percentage of cross-modulation is also directly proportional to the depth of modulation of the interfering transmitter [Knight, 1973].

* This Annex is given for information.

1.3 The percentage of cross-modulation decreases as the modulating frequency of the interfering transmitter increases. Laboratory experiments [Whyte and Reed, 1973] have shown that the subjective effect of cross-modulation can be related to co-channel interference. To produce a given subjective grade of impairment, interference resulting from ionospheric cross-modulation requires 6 dB less input signal-to-interference ratio than does co-channel interference, providing that the cross-modulation is referred to a modulation frequency of 300 Hz.

1.4 It should be noted that the studies on the problem of ionospheric cross-modulation carried out by Study Group 6 are summarized in Report 574.

2. Figure 1 shows the percentages of cross-modulation measured in many experiments [Knight, 1973]. Each measurement has been standardized to the value which would have been observed if the interfering transmission had been radiated from a short vertical antenna with a carrier power of 100 kW and amplitude modulated at 300 Hz to a depth of 80%.

Figure 1 includes a semi-empirical curve which shows the greatest percentage of cross-modulation, averaged over a short period, likely to be observed; the condition for this is that the wanted signal should traverse the region of the ionosphere most strongly illuminated by the interfering transmitter. Figure 1 shows that cross-modulation rises to a second maximum when the frequency of the interfering transmitter is close to the gyro-magnetic frequency. Figure 5 shows a map giving the value of the gyro-magnetic frequency for different parts of the world [Laitinen and Haydon, 1950].

3. The effects of cross-modulation should be taken into account not only for sky-wave reception, but also for ground-wave reception at the edge of the service area when at night the sky-wave is no longer negligible. However, the effect of cross-modulation is reduced approximately in the ratio of the wanted signal levels, ground-wave to sky-wave, at the receiving point.

4. The percentages of ionospheric cross-modulation have been calculated for LF and MF and their dependence on the powers of the wanted and unwanted transmitter has been determined. Results of theoretical studies and practical experiments have been compared. [Shluyger *et al.*, 1976].

5. Preliminary conclusions

On the basis of measurements [Haberkant and Vogt, 1966; Haberkant *et al.*, 1971] examples may be given of the power-flux levels, or the transmitter power as a function of the angle of elevation, which can cause disturbance to wanted transmissions.

For this purpose, an assumption is first made regarding the tolerable level of the percentage of cross-modulation. According to Recommendation 560, Report 575 and Report 794 (Short-term fadings), a radio-frequency protection ratio of approximately 30 dB is agreed for 10% of the time in the case of a fluctuating unwanted signal. Ignoring the effect mentioned in § 1.3, the same disturbing effect is produced by 3% cross-modulation for 10% of the time. It has been shown [Haberkant *et al.*, 1971] that for frequencies at the upper end of the MF broadcasting band 6 (MF) this level of cross-modulation may be produced by a power flux within the E region of the ionosphere of about $2 \mu\text{W}/\text{m}^2$ ($-57 \text{ dB}(\text{W}/\text{m}^2)$), which corresponds to a maximum field strength of 27 mV/m ($89 \text{ dB}(\mu\text{V}/\text{m})$).

Assuming a height of 100 km of the reflecting layer (E region), it is possible to calculate the power radiated from various types of antenna which would produce this power flux within the E region. The vertical transmitting antennas that are commonly used show a vertical radiation pattern which depends in a well-defined fashion on the height (expressed in fractions of the wavelength, λ). In particular, such vertical antennas do not radiate at an angle of elevation of 90° . Table I [Haberkant *et al.*, 1971] indicates, for a number of vertical transmitting antennas at different heights the transmitter powers to be fed into these antennas to meet the above-mentioned requirements.

TABLE I

Length of vertical antenna	$< 0.25 \lambda$	0.25λ	0.5λ	0.55λ	0.64λ	$0.64 \lambda(1)$
Transmitter carrier power (kW)	320	340	560	670	370	840

(1) First side lobe compensated.

It is possible to calculate the dependence of the radiated power on the angle of elevation required to produce the same power flux, covering the whole range from 0° (horizontal radiation) to 90° (vertical radiation). The results are given in Table II.

TABLE II

Angle of elevation	0°	10°	20°	30°	40°	45°	50°	60°	70°	80°	90°
e.m.r.p. (dB (1 kW)) or c.m.f. ⁽¹⁾ (dB (300 V))	39.5	32	27.5	24.3	22.5	22	21.5	20.2	19.3	18.7	18.5
e.m.r.p. (kW)	9000	1600	570	230	190	160	140	105	85	75	70

(1) e.m.r.p.: effective monopole radiated power; } See also Recommendation 561
 c.m.f. : cymomotive force.

The above Tables give only approximate values because it is known, from theory, that ionospheric cross-modulation may be influenced by several parameters, such as the frequencies of the wanted and of the interfering transmitter (in particular seen in their relationship to the gyro-frequency) and the polarization of emission.

The powers given in Tables I and II are examples based on a small number of measurements at a frequency near the top end of band 6 (MF); they make no allowance for the change of cross modulation with carrier frequency of the disturbing signal, nor do they include the effect of reduced cross-modulation at the higher audio frequencies which permits interfering-transmitter powers to be increased by 3 dB.

It may be noted that services other than broadcasting have also suffered degradations due to ionospheric cross-modulation.

The results of many other measurements of ionospheric cross-modulation have been compared [Knight, 1973] and Fig. 1 shows that 100 kW radiated from a short vertical antenna at frequencies in the lower part of the broadcast band 6 (MF) produces cross-modulation which may exceed 2% for 50% of the time. It may be shown [Haberkant *et al.*, 1971] that this corresponds to a cross-modulation level of 3% exceeded for 10% of the time. The power of 100 kW may therefore be directly compared with the power of 320 kW given in Table I. The greater power in Table I arises because the series of measurements on which it was based appear to give lower cross-modulation than the estimated worst case values shown by the curve in Fig. 1.

Figure 1 also shows that cross-modulation levels caused by disturbing transmitters, operating either at frequencies in band 5 (LF) or at frequencies close to the gyromagnetic frequency, may be 10 dB greater than levels arising at frequencies in the lower part of band 6. A 5 dB reduction of disturbing-transmitter power reduces the cross-modulation level by 10 dB. Allowing for the modulation-frequency effect we conclude that, depending on the disturbing frequency in bands 5 (LF) and 6 (MF), transmitter powers in a range varying from the values in Tables I and II down to 7 dB lower may, at worst, give interference to a sky-wave service comparable with co-channel interference for 30 dB protection ratio.

Somewhat greater disturbing-transmitter powers may be radiated if ground-wave services, rather than sky-wave services, are to be protected from the effects of ionospheric cross-modulation, because the disturbing transmitter influences only the sky-wave component of the received signal. If the limit of the ground-wave service area is defined as the line where the ground-wave field strength exceeds the median sky-wave field strength by 10 dB; the median cross-modulation of the resultant signal will be 14 dB less than the median cross-modulation of the sky-wave. Disturbing-transmitter powers may therefore be greater than the equivalent powers when the sky-wave is being protected.

6. Practical application of the conclusions

The EBU has investigated the consequences on the planning of broadcasting networks in bands 5 (LF) and 6 (MF) to be drawn from the preliminary conclusions summarized in § 5 of this Annex. The most urgent problem is that of maximum effective monopole-radiated power as a function of the angle of elevation and type of antenna when a certain amount of interference by ionospheric cross-modulation is not to be exceeded. The conclusions drawn so far from these studies are set out hereafter.

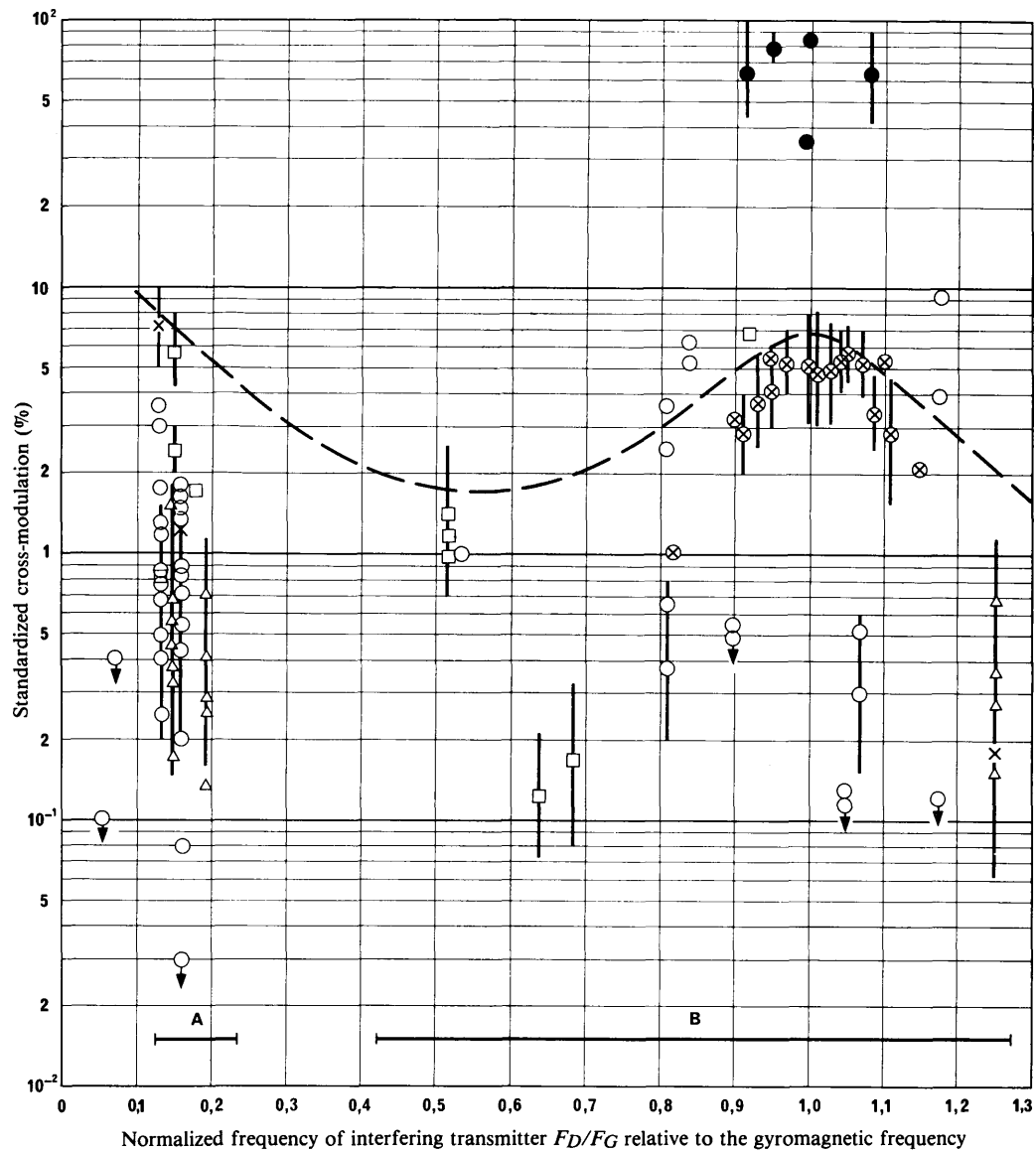


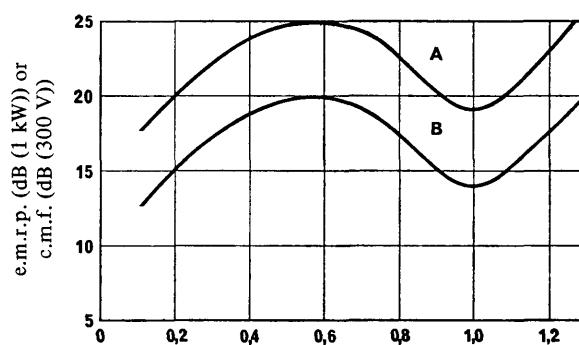
FIGURE 1 – *Measurements of ionospheric cross-modulation at medium latitudes*

□ : measurements before 1945	[van der Pol and van der Mark, 1935; Bäumler and Pfitzer, 1935; Bailey, 1937; Grosskopf, 1938]
○ : measurements at Cambridge and Birmingham	[Huxley <i>et al.</i> , 1947; Ratcliffe and Shaw, 1948; Huxley <i>et al.</i> , 1948; Huxley, 1950; Shaw, 1951; Bell, 1951]
● : measurements in Italy	[Cutolo and Ferrero, 1948 and 1949; Cutolo <i>et al.</i> , 1950; Cutolo, 1952]
⊗ : measurements in Australia	[Bailey <i>et al.</i> , 1952; Hibberd, 1964]
△ : measurements in Western Europe after 1945	[Haberkant and Vogt, 1966; Haberkant <i>et al.</i> , 1971]
× : other measurements	
— — — : semi-empirical upper limit	
A : band 5 (LF)	
B : band 6 (MF)	

Note – The vertical lines represent a range of median values measured during the course of a night, or on different nights.
The arrows pointing downwards indicate measured values which are less than the value indicated.

It is recommended that the annoyance due to cross-modulation should not exceed that resulting from co-channel interference with a protection ratio of 30 dB. However, cross-modulation, unlike co-channel interference, decreases with increasing modulation frequency, so that subjective experiments are necessary to relate the two effects. Such experiments have been carried out, and have shown that the maximum percentage of cross-modulation could be 6.3% when the interfering transmitter is 80% modulated by 300 Hz tone. It is recommended that this should be regarded as the maximum acceptable limit of cross-modulation.

Taking into account the dependance of cross-modulation on the carrier frequency of the unwanted emission and the height of the reflecting layer, Fig. 2 (curve A) shows the maximum effective monopole-radiated power (dB (1 kW)) or cymomotive force (dB (300 V)) directed vertically upwards which would produce, for 50% of the time, the percentage of cross-modulation specified above. The abscissa is the ratio of the unwanted carrier frequency F_D to the gyro-frequency F_G (about 1.25 MHz in Europe). This curve is based on a large number of measurements in Europe and Australia as described in § 5 and Fig. 1, taking the observed values of cross-modulation as representing the worst values likely to occur over the most unfavourable geographical path.



Frequency of interfering emission relative to the gyromagnetic frequency F_D/F_G

FIGURE 2 – Vertically-incident radiation giving a quasi-maximum of 6.3% cross-modulation at 300 Hz

Curve A: for protection of ground-wave services
Curve B: for protection of sky-wave services

In practical cases, account must be taken of the vertical radiation pattern of the antenna and of the increasing distance between the antenna and the reflecting point in directions other than vertical. Fig. 3 shows the permissible increase in e.m.r.p. in directions other than vertical, allowed by the increasing distance only. An additional increase or decrease in power resulting from the vertical diagram of the antenna has to be taken into account. For practical application, the influences of increasing distance to the reflecting point and of the vertical radiation pattern of the antenna have been combined into one single correction factor ΔP which has to be added to that read from Fig. 2. This correction factor has been calculated for vertical antennas of different electrical length $\chi \approx 1/\lambda$ and horizontal dipoles 0.5λ long, at different heights $\chi \approx h/\lambda$ above ground, assuming a height of 85 km for the region of the ionosphere in which cross-modulation should occur. The result of this calculation is given in Fig. 4.

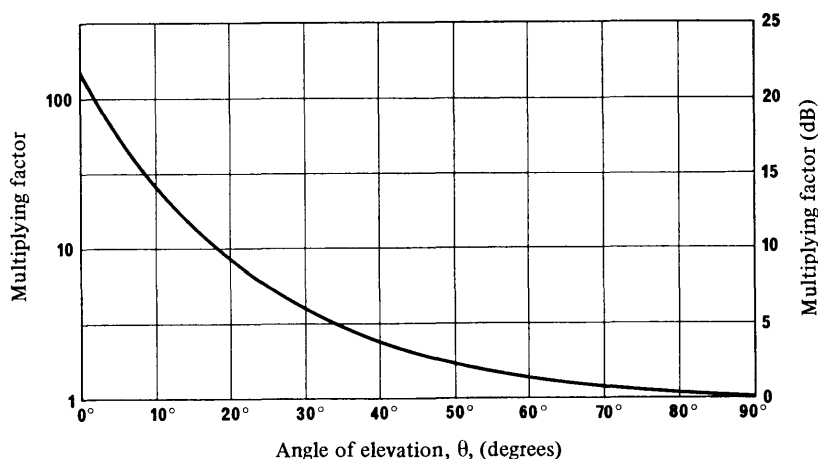


FIGURE 3 – Variation of permissible radiation with angle of elevation

(Curvature of the Earth taken into account, assuming that cross-modulation takes place at a height of 85 km)

In a ground-wave service which is to be protected against cross-modulation at night, it may be assumed that the sky-wave field strength of the wanted transmitter is 10 dB below the ground-wave field strength at the service limit. Since only the sky-wave component is subject to cross-modulation, an increase of 5 dB in radiation is permissible if only ground-wave services need be considered. This leads to curve B of Fig. 2.

As a practical example, consider a short vertical antenna in band 5 (LF) ($F_D/F_H = 0.2$). Figure 2 shows that to protect a ground-wave service, the maximum e.m.r.p. in a vertical direction would be 20 (dB (1 kW)) i.e. 100 kW. However, a short antenna produces a maximum value of field strength in the ionosphere at an angle elevation of 45° ; Fig. 3 shows that an increase of 3 dB is permitted at that angle, giving an e.m.r.p. of 200 kW. However, it is more convenient to specify the e.m.r.p. in the horizontal direction; for a short antenna this is 3 dB greater than at 45° , i.e. 400 kW.

Accordingly, in this case, for a short vertical antenna ($l/\lambda \ll 0.1$), the value of $\Delta P = +6$ dB can be read from curve A in Fig. 4, which results in a total power fed to the antenna of $P = +26$ dB (1 kW) i.e. ≈ 400 kW.

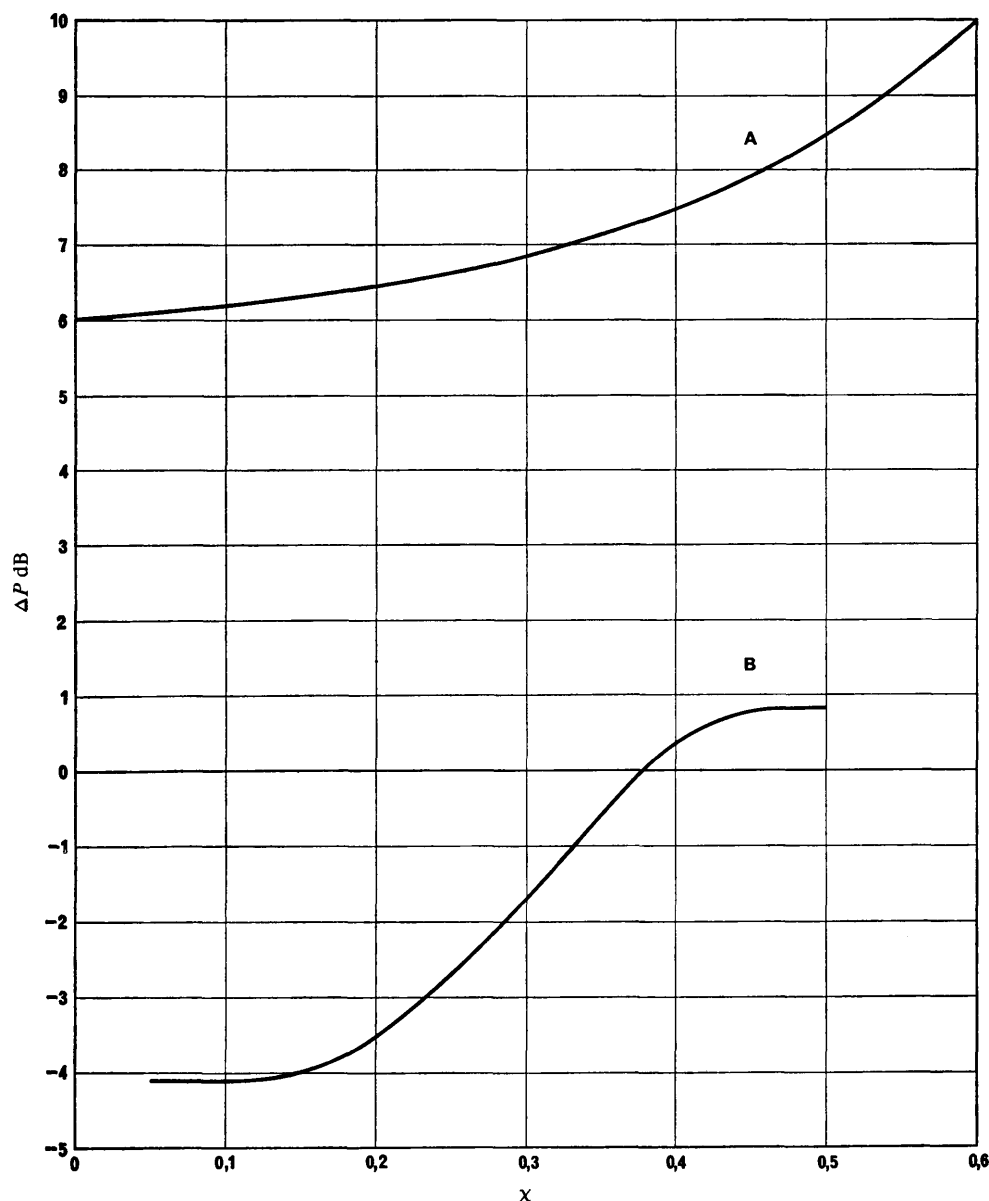


FIGURE 4 – Correction factor, ΔP , for different types of antenna

- Curve A: vertical antenna
 χ : relative length of antenna, l/λ
- Curve B: horizontal dipole ($l = 0.5\lambda$)
 χ : relative height above ground, h/λ

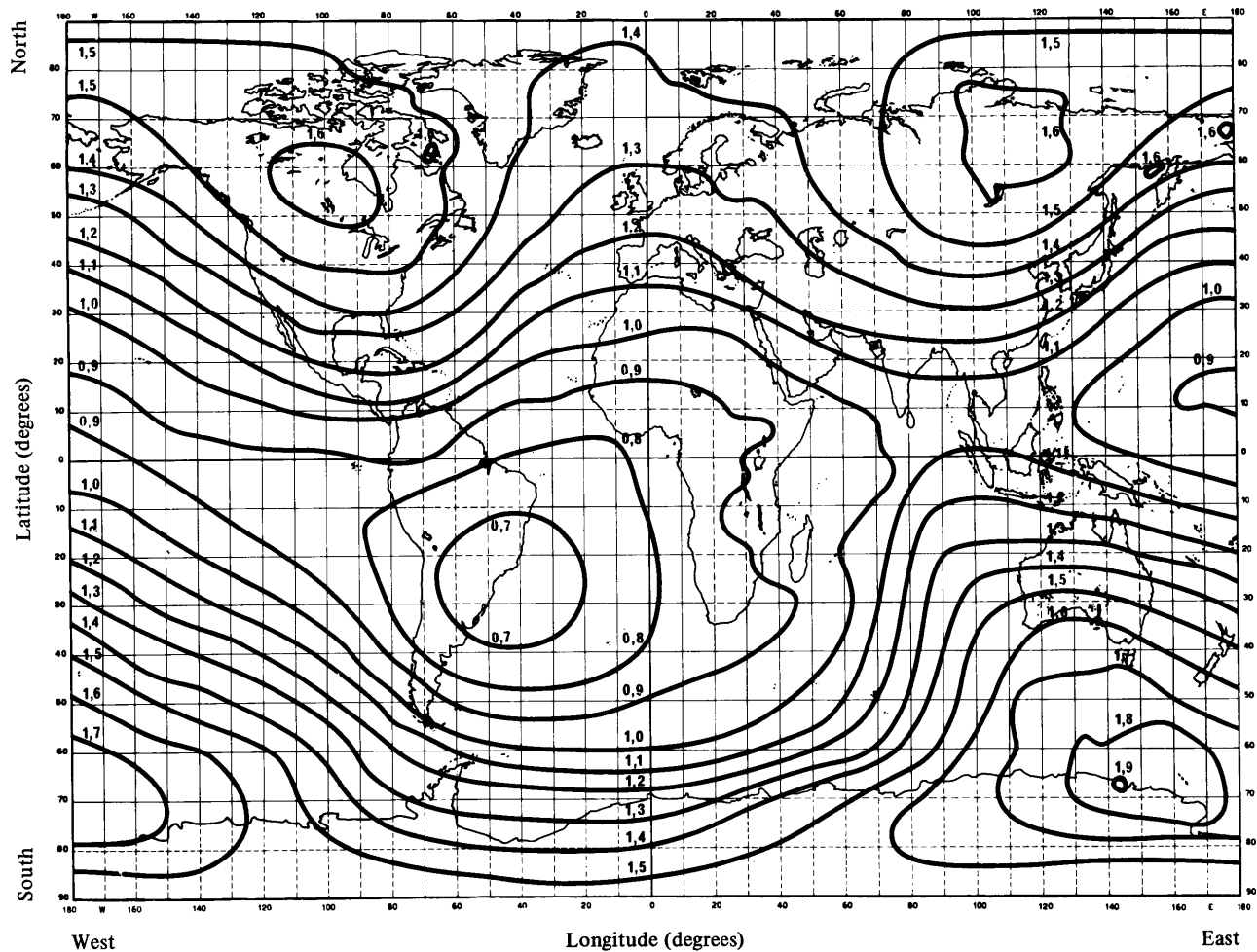


FIGURE 5 – World-wide distribution of gyro-frequency (MHz)

REFERENCES

- BAILEY, V. A. [15 May, 1937] Resonance in the interaction of radio waves. *Nature*, 838-839.
- BAILEY, V. A., SMITH, R. A., LANDECKER, K., HIGGS, A. J. and HIBBERD, F. H. [May, 1952] Resonance in gyro-interaction of radio waves. *Nature*, Vol. 169, 4309, 911-913.
- BÄUMLER, M. and PFITZER, W. [December, 1935] Untersuchung der gegenseitigen Modulationsbeeinflussung elektrischer Wellen mit deutschen Rundfunksendern (Investigation of the influence of cross modulation of electric waves with the German broadcasting transmitters). *Hochfrequenztechnik und Electroakustik*, Vol. 46, 181-186.
- BELL, D. A. [1951] Ionospheric interaction in disturbed conditions. *Proc. Phys. Soc. (Section B)*, Vol. 64, 1053-1062.
- CUTOLO, M. [May, 1952] Determinazione sperimentale delle curve di risonanza nel moto degli elettroni lenti dell'alta atmosfera (Experimental determination of the resonance curves for the motion of slow electrons in the upper atmosphere). *Nuovo Cimento*, Vol. IX, 391-406.
- CUTOLO, M. and FERRERO, R. [October, 1948] Misura del grado di modulazione parassita nel fenomeno di girointerazione (Measurement of the degree of parasitic modulation on the phenomenon of gyro-interaction). *Alta Frequenza*, Vol. XVII, 212-216.
- CUTOLO, M. and FERRERO, R. [January, 1949] Photographic record and diagrams of Luxembourg effect with resonance (gyro-interaction). *Nature*, Vol. 163, 58-59.
- CUTOLO, M., FERRERO, R. and MOTOZO, M. [1950] Determinazione sperimentale della curva di risonanza nel fenomeno di giro-interazione (Experimental determination of the resonance curve in phenomenon of gyro-interaction). *Alta Frequenza*, Vol. XIX, 3-8.
- GROSSKOPF, J. [January, 1938] Die gegenseitige Modulationsbeeinflussung elektromagnetischer Wellen in der Ionosphäre (The influence of cross modulation of electric waves in the ionosphere). *Hochfrequenztechnik und Elektroakustik*, Vol. 51, 18-30.

- HABERKANT, E. and VOGT, K. [August, 1966] Measurement of ionospheric cross-modulation affecting two high-power LF broadcast transmitters. *EBU Rev.*, **98-A**, 154-161.
- and
- [1966] Messung der ionosphärischen Kreuzmodulation bei den Langwellen-Rundfunksendern Europa I und Luxemburg (Measurement of ionospheric cross modulation on the long-wave broadcasting emissions Europe I and Luxembourg). *Rundfunktechn. Mitt.*, **4**, 206-212.
- HABERKANT, E., HEINZELMANN, G. and VOGT, K. [April, 1971] The measurement of ionospheric cross-modulation. *EBU Rev.* **126-A**, 50-55.
- and
- [1971] Die Messung der ionosphärischen Kreuzmodulation (The measurement of ionospheric cross-modulation). *Rundfunktechn. Mitt.*, **2**, 49-55.
- HIBBERD, F. H. [1964] An experimental study of gyro-interaction in the ionosphere, at oblique incidence. National Bureau of Standards Technical Note 211, Vol. 4, 45-64.
- HUXLEY, L. G. H. [February, 1950] Ionospheric cross-modulation at oblique incidence. *Proc. Roy. Soc.*, Vol. 200, Series A, 486-511.
- HUXLEY, L. G. H. [1952] A synopsis of ionospheric cross-modulation. *Nuovo Cimento*, Supplement to Vol. IX, Series IX, 59-89.
- HUXLEY, L. G. H., FOSTER, H. G. and NEWTON, C. C. [1 March, 1947] Gyro interaction of radio waves. *Nature*, 300-301.
- HUXLEY, L. G. H., FOSTER, H. G. and NEWTON, C. C. [August, 1948] Measurements of the interaction of radio waves in the ionosphere. *Proc. Phys. Soc.*, Vol. 61, 134-146.
- KNIGHT, P. [May, 1973] LF and MF propagation: a study of ionospheric cross-modulation measurements. BBC Engineering, **94**, 12-21.
- LAITINEN, O. P., HAYDON, G. W. [1950] Analysis and prediction of sky-wave field intensities in the HF-band, RPU 203, Technical Report No. 9, Signal Corps Radio Propagation Agency, Fort Monmouth, New Jersey, USA.
- RATCLIFFE, J. A. and SHAW, I. J. [July, 1948] A study of the interaction of radio waves. *Proc. Roy. Soc.*, Vol. 193, Series A, 311-343.
- SHAW, I. J. [January, 1951] Some further investigations of ionospheric cross-modulation. *Proc. Phys. Soc. (Section B)*, Vol. 64, 1-20.
- SHAW, I. J. [November, 1951] Ionospheric cross-modulation. *Wireless Eng.*, Vol. 28, 335-342.
- SHLUYGER, I. S., WASKOW, W. V. and MILICH, G. M. [1976] Cross-modulation by high-power radio waves in the LF and MF broadcasting band. *Geomag. i Aeronom.* **1**, 110.
- VAN DER POL, B. and VAN DER MARK, J. [1935] Interaction of radio waves. *Tijdsch. Nederl. Radio Gschp.*, Vol. 7, Part I, 12-17, Part II, 93-97.
- WHYTHE, D. J. and REED, C. R. G. [1973-75] Ionospheric non-linearity: protection ratios required against cross-modulation interference (Luxembourg Effect). BBC Research Department Report 1973/5.

BIBLIOGRAPHY

- BAILEY, V. A. [1956] On the interaction of radio waves. *Nuovo Cimento*, Supplement to Vol. IV, Series X, 1430-1449.
- BBC [6 November, 1968] Research Department. Report RA-17. Ionospheric non-linearity. Doc. COM. T (A) 73/COM. T. (B) 97.

REPORT 461

REDUCTION OF SKY-WAVE IN MF BROADCASTING

(Question 44/10, Study Programme 44D/10)

(1970)

1. Introduction

Studies have been carried out in Australia to investigate a method of sky-wave field strength reduction which exploits the high absorption of extraordinary waves for transmission frequencies near the gyro-frequency. The transmitting antenna for this system is required to radiate a signal polarized in such a manner that waves entering the ionosphere do so exclusively through extraordinary modes. The system is termed orthogonal transmission.

2. Experimental tests

[CCIR, 1966-69], describes propagation tests conducted in 1965 and 1967 which indicate that the median value of the sky-wave field strength from a broadcasting transmitter operating in band 6 (MF) may be reduced by 16 dB on paths to the north in the southern hemisphere, when conventional vertically-polarized transmission is replaced by orthogonal transmission. No significant change in this reduction was evident on south-north paths extending from 243 km to 695 km. The reduction decreased on paths with eastward or westward components due to features in the design of the transmitting antenna, which did not provide the polarization ellipse tilt required on such paths. A field-strength reduction of 13 dB was measured on paths which were 19° to the east or west of the bearing of the target area (magnetic North).

REFERENCES

CCIR Documents

[1966-69]: X/133 (Australia).

BIBLIOGRAPHY

DIXON, J. M. [December, 1965] The absorption of medium frequency sky-waves by close coupling to the extraordinary mode. *Proc. IREE*, **26**, 369-380.

DIXON, J. M. [December, 1968] Experimental tests with orthogonal transmission. *Proc. IEE*, Vol. 115, **12**, 1755-1761.

REPORT 516-2

FIELD STRENGTH RESULTING FROM SEVERAL ELECTROMAGNETIC FIELDS

(Question 44/10, Study Programme 44A/10)

(1970-1978-1982)

Studies have been carried out in Italy [CCIR, 1966-69] and in Hungary [CCIR, 1978-82] on the composition of several stable electromagnetic fields at the same point. Studies in Italy for fields affected by fading are now reaching their conclusion.

1. Field strength resulting from two stable electromagnetic fields

If two fields of different frequencies are considered at a point in space:

$$E_1 = A \cos \omega t \quad (1)$$

$$E_2 = B \cos [(\omega + \Delta\omega)t + \varphi] \quad (2)$$

where A , B , ω , $\Delta\omega$ and φ are constant in time, and if it is assumed that both fields are polarized in the same direction, the instantaneous amplitude of the vector representing the resultant field is:

$$E = \sqrt{A^2 + B^2 + 2AB \cos(\Delta\omega t + \varphi)} \quad (3)$$

The mean value of E in the period $T = 2\pi/\Delta\omega$ is:

$$E_R = \frac{1}{T} \int_{t_0}^{t_0 + T} E(t) dt = Af(A/B) \quad (4)$$

The $\Delta\omega$ frequency component of E for the same period is:

$$E_{\Delta\omega} = \left(\frac{2}{T}\right) \int_{t_0}^{t_0 + T} E(t) \cos(\Delta\omega t + \varphi) dt \quad (5)$$

If the values A , B , E_R and $E_{\Delta\omega}$ (dB(μ V/m)) are designated by E_1 , E_2 , $(E_1 + \Delta R)$ and $(E_2 + \Delta E)$ respectively and assuming that $E_1 \geq E_2$, a graph can be drawn of the values of ΔR , as indicated by a field measuring device, and of ΔE as a function of $(E_1 - E_2)$, and the curves shown in Fig. 1 (continuous line) and Fig. 2 are obtained.

The dotted line shown in Fig. 1 is obtained by calculating the r.m.s. of the amplitudes of the two fields:

$$E_R = \sqrt{A^2 + B^2} \quad (6)$$

The values of the first curve (continuous line) in Fig. 1 are always lower than those of the second curve, for each value of $(E_1 - E_2)$. The maximum difference is 0.9 dB for $E_1 = E_2$.

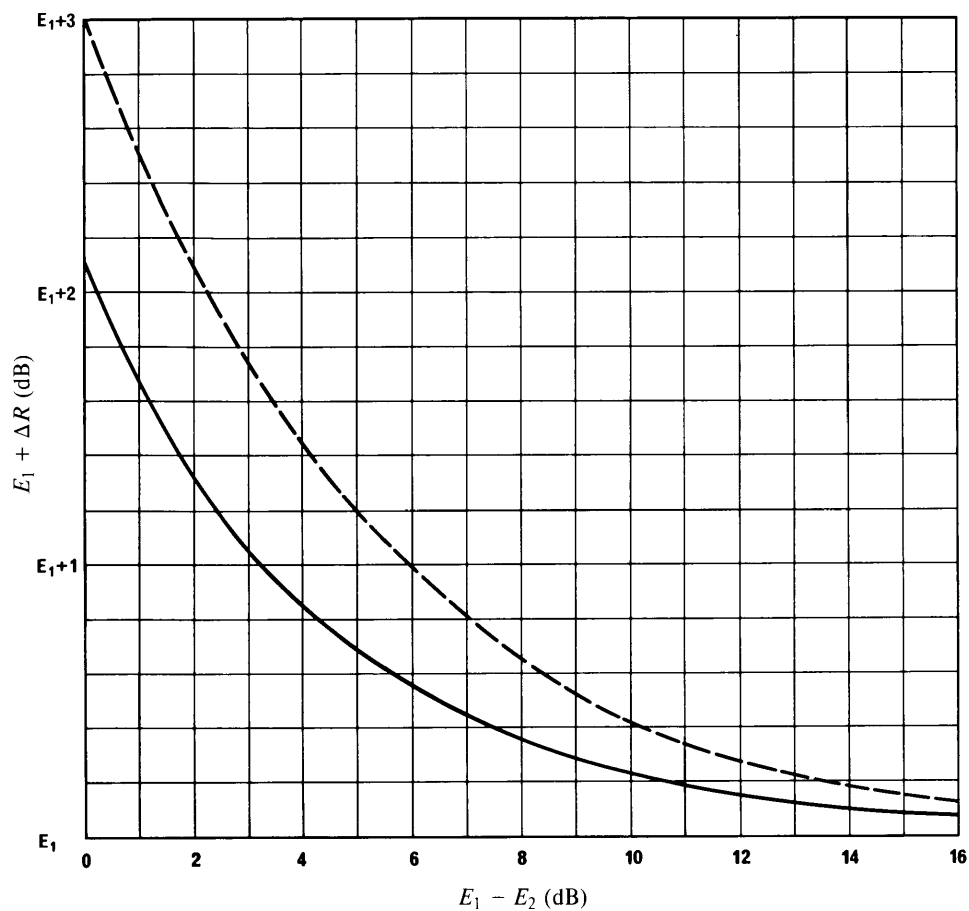


FIGURE 1 – Resultant ($E_1 + \Delta R$) of two stable electromagnetic fields ($E_1 > E_2$)

— : value indicated by a field measuring device
 - - : value calculated by adding the powers of the two signals

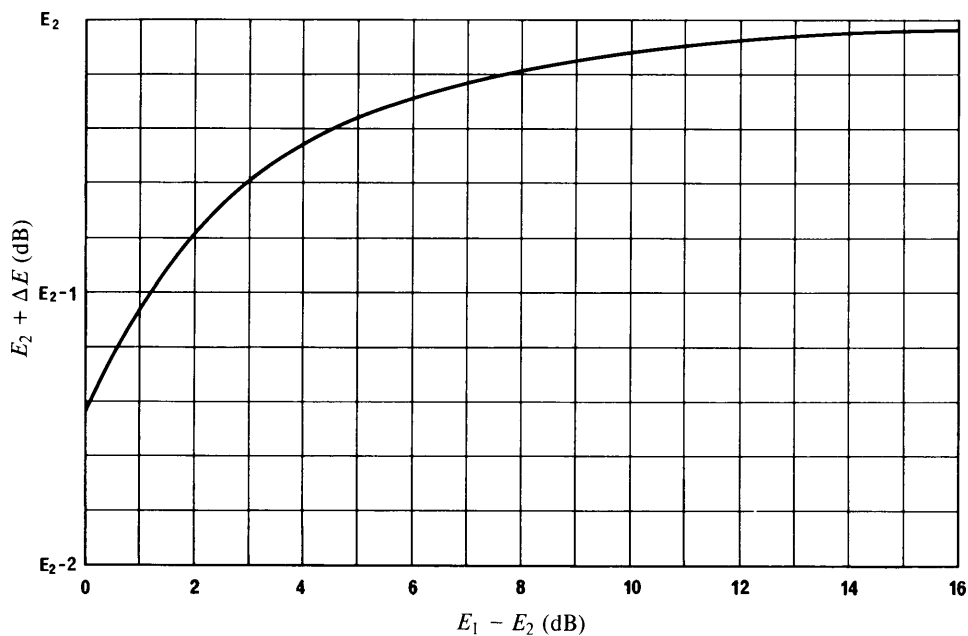


FIGURE 2 – ($E_2 + \Delta E$) component in the resultant of two stable electromagnetic fields ($E_1 > E_2$)

2. Field resulting from three stable fields

Let:

$$E_1 = A \cos \omega t$$

$$E_2 = B \cos [(\omega + \Delta\omega_1)t + \phi_1]$$

$$E_3 = C \cos [(\omega + \Delta\omega_2)t + \phi_2]$$

be three fields (with the same assumptions as before).

If the values A , B , C , the mean value and amplitude of the components of the vector representing the resultant (dB($\mu\text{V}/\text{m}$)) are designated by E_1 , E_2 , E_3 , $(E_1 + \Delta R)$, $(E_2 + \Delta E_1)$ and $(E_3 + \Delta E_2)$ respectively and assuming that $E_1 \geq E_2$ and $E_1 \geq E_3$, graphs can be drawn in which the curves give the values of ΔR and ΔE_1 , ΔE_2 as a function of $(E_1 - E_2)$ and $(E_1 - E_3)$.

The results are shown in Figs. 3 and 4.

It can be seen, for example, that when $E_1 = 63$ dB, $E_2 = 62$ dB and $E_3 = 60$ dB, then $\Delta R = 2.8$ dB, $\Delta E_1 = 3.7$ dB and $\Delta E_2 = 3$ dB.

For information concerning the measurement of ΔE , ΔE_1 and ΔE_2 , refer to Report 273.

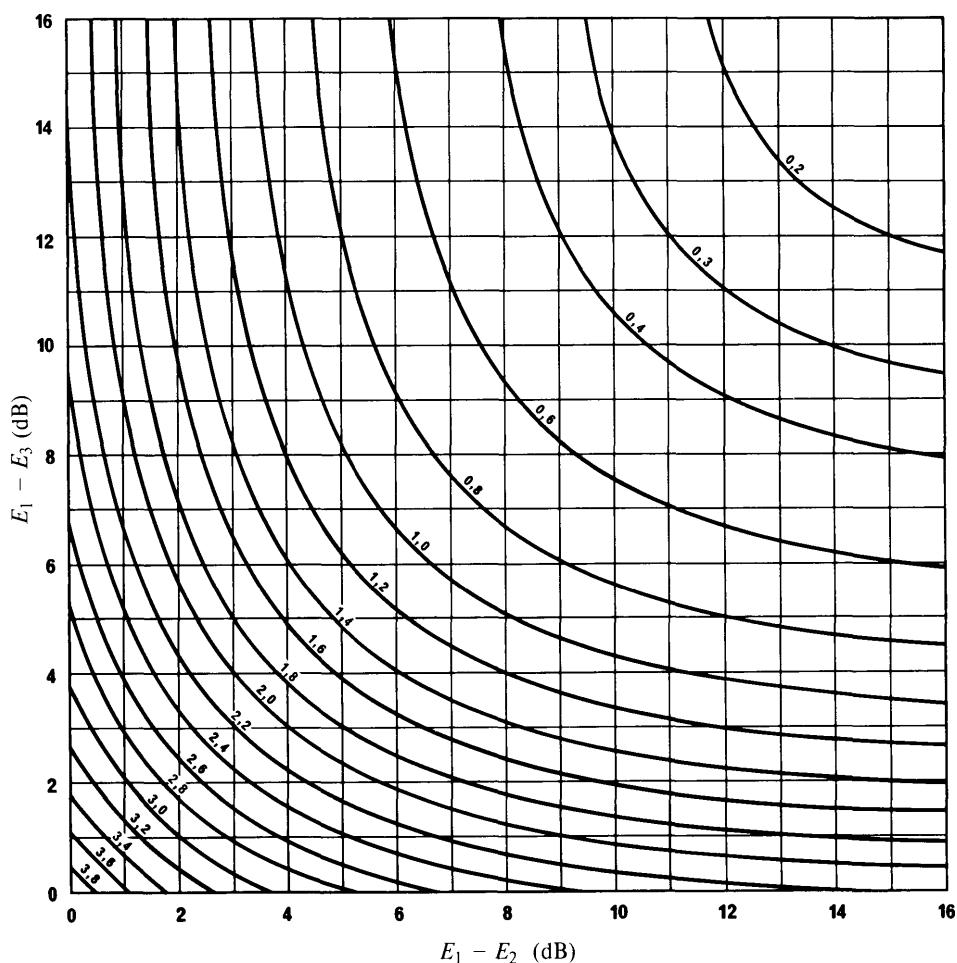


FIGURE 3 – Family of curves $(E_1 + \Delta R)$ resulting from three stable electromagnetic fields ($E_1 > E_2$, $E_1 > E_3$)

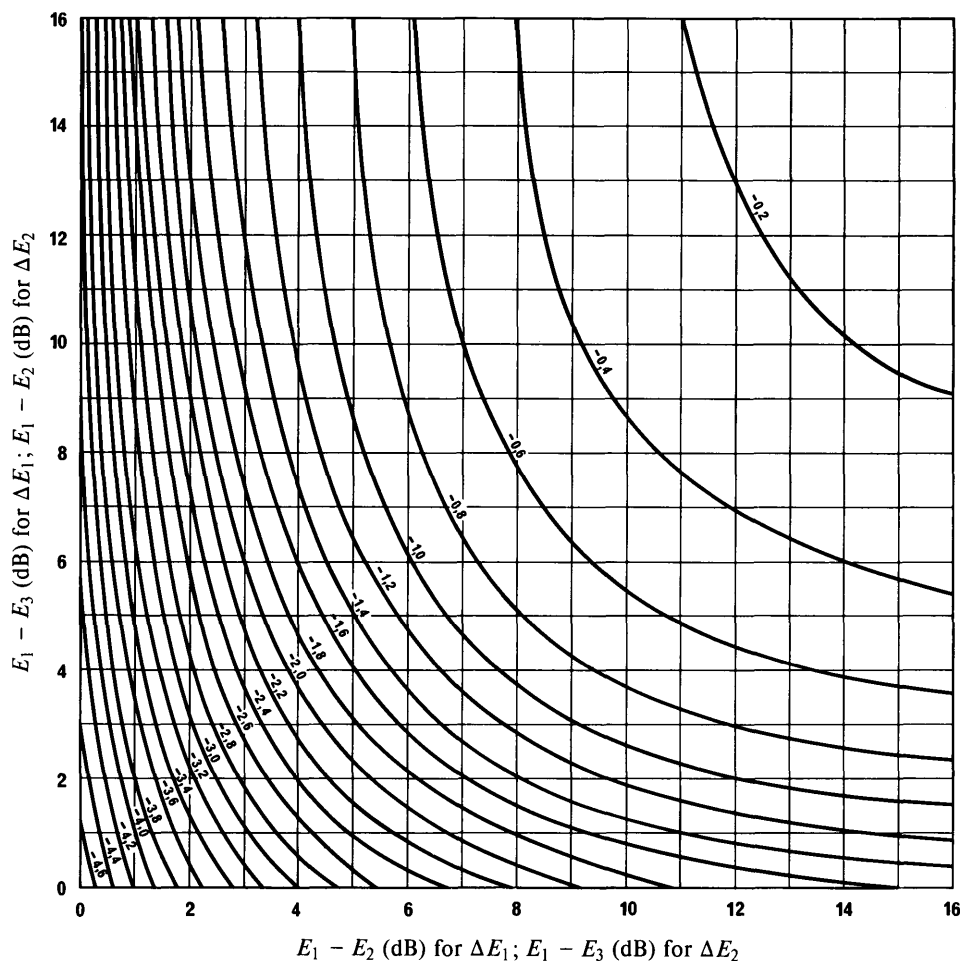


FIGURE 4 – Family of curves $(E_2 + \Delta E_1)$ and $(E_3 + \Delta E_2)$ in the resultant of three stable electromagnetic fields

3. Experimental results

Measurements of field strength carried out at the RAI monitoring centre at Monza and at the Hungarian monitoring station at Tárnok have led to the following deductions:

- considering two or three amplitude-modulation emissions in band 6 (MF) on the same channel;
- assuming a difference of at least a few hertz between the carrier frequencies, and
- assuming that the signals at the reception point are stable,

it may be assumed that the measured value of the resultant field is, with an approximation of 0.2 dB, that which is deduced from the continuous lines in Figs. 1 to 4 respectively.

REFERENCES

CCIR Documents

[1966-69]: X/56 (Italy).

[1978-82]: 1/143, 10/198 (Hungary (People's Republic of)).

REPORT 945

METHODS FOR THE ASSESSMENT OF MULTIPLE INTERFERENCE

(Question 46/10, Study Programme 46L/10)

(1982)

1. Introduction

The usable field strength depends among other factors on the interfering field strength caused by the unwanted transmitters.

For the calculation of these interferences basically two categories of methods are in use:

- statistical methods;
- non-statistical methods.

Normally use is made either of the “simplified multiplication method” as an example for a statistical method or of the non-statistical “power sum method”.

Both methods are described and indications are given for the efficient use of a particular method.

Details for the use of the simplified multiplication method and its physical bases are to be found in Annex I and in [O’Leary and Rutkowski, 1982].

2. Power sum method

Use has been made of the power sum method for the assessment of multiple interference at the LF/MF Broadcasting Conference for Regions 1 and 3, Geneva, 1975, and at the WARC for the broadcasting-satellite service, Geneva, 1977, where the propagation curves used showed no variation with locations. The method is based upon the following assumptions:

- random phase relationship for interfering signals at the point of reception;
- full correlation with location and time between the wanted and unwanted field strength;
- no account is to be taken of the statistical variations of both the wanted and unwanted field strength with location;
- the effect of man-made and other noise is accounted for by including the minimum usable field strength as an interfering source.

The following simple expression can be used as a means of collectively accounting for such interference:

$$E_u = \sqrt{\sum_i (a_i b_i E_{ni})^2 + E_{min}^2} \quad (1)$$

where:

- E_u : the usable field strength,
- E_{ni} : the field strength of the i -th unwanted transmitter,
- E_{min} : the minimum usable field strength,
- a_i : the radio-frequency protection ratio associated with the i -th unwanted transmitter, expressed as a numerical ratio of field strengths,
- b_i : the receiving antenna discrimination expressed as numerical ratio

and where the various field strengths at the point of reception are expressed in $\mu\text{V/m}$.

3. The simplified multiplication method

Four statistical computation procedures which can be used to calculate the effects of multiple interference have been developed to date [*Ad hoc* Committee 1949, 1950]. These are:

- the integration method,
- the log-normal method,
- the multiplication method,
- the simplified multiplication method.

These procedures attempt to make use of the statistical (in locations) nature of propagation curves such as those given in Recommendation 370. Although, essentially based on a single theoretical approach, these procedures differ from one another as a result of different physical assumptions. These are made in each procedure in order to simplify the mathematical calculations. The use of any of these procedures results in distribution functions which describe the location probability of reception used in conjunction with Reports 228 and 485 to calculate coverage.

The simplified multiplication method is the least complex of the four procedures and has been used for the assessment of multiple interference at the VHF/UHF European and African Broadcasting Conferences in 1961 and 1963, respectively.

This method is based on the following assumptions:

- no correlation exists between the fields of interest;
- the time dispersion of the field strength of the desired transmitter can be neglected, compared to that of the unwanted transmitter;
- one interfering field dominates at the reception location;
- the influence of noise can be neglected, to compensate the errors introduced by the other approximations.

The usable field strength is determined for a specified coverage probability (with respect to time and location) and depends on the values of the nuisance fields.

$$E_{si} = P_i + E_{ni}(50, T) + A_i + B_i \quad (2)$$

where:

P_i : the e.r.p., in dB(kW), of the i -th unwanted transmitter.

$E_{ni}(50, T)$: the field strength, in dB(μ V/m), normalized to an e.r.p. of 1 kW, of the i -th unwanted transmitter. This field strength is exceeded at 50% of the locations during at least $T\%$ (e.g. 1%) of the time.

A_i : the radio-frequency protection ratio associated with the i -th unwanted transmitter, expressed in dB.

B_i : the receiving antenna discrimination, expressed in dB.

Appropriate account of the effect of multiple interference can be taken by the use of statistical computation methods among which the simplified multiplication method is the least complex. With this method the usable field strength E_u can be calculated by way of iteration from:

$$p_c = \prod_{i=1}^n L(E_u - E_{si}) \quad (3)$$

where:

p_c : the coverage probability (e.g. 50% of locations, $(100 - T)\%$ of time).

L : the probability integral for a normal distribution.

For further details see Annex I and [O'Leary and Rutkowski, 1982].

4. Comparison of the results obtained by the simplified multiplication method and the power sum method

4.1 General considerations

The comparison of calculations, using the two methods under equal conditions (no receiving antenna discrimination) is given below. This comparison is intended to enable the reader to estimate the difference to be expected, when applying one method or the other, rather than to advocate a specific method. It should be noted in this respect that either method can be expected to yield only approximate values of the usable field strength.

Differences between the results of both methods may be considerable, and the utmost care should be exercised when deriving further conclusions from these results, e.g. with respect to the number of channels required for satisfactory coverage by one programme.

It should, however, also be recognized that it would be possible to use, with comparable degree of precision, either method as a basis for comparison of different variants of a plan.

4.2 Results

Figures 1 and 2 exhibit the differences ΔE in usable field strengths when computed according to the simplified multiplication method (E_M) for a percentage of receiving locations of 45% and 50% respectively, or to the power sum method (E_P) for an undefined percentage of receiving locations. The differences ΔE depend on the relationship between the interference potentials of the various individual transmitters, i.e. their technical characteristics, their distance from the wanted transmitter and the frequency spacing. Normally there is one predominant source of interference producing nuisance field E_1 , following by a second and less harmful source of interference creating nuisance field E_2 and the remaining interfering transmitters causing gradually decreasing nuisance fields $E_3 \dots E_n$.

In Figs. 1 and 2 values of

$$\Delta E = E_M - E_P = f(E_1 - E_2)$$

are plotted for 50 ΔE values obtained for the first (in alphabetical order) 50 out of 345 transmitters operating at present in the Federal Republic of Germany. These 50 values are thought to be representative of these

345 VHF/FM transmitters. Moreover, two limiting curves, A and B, have been included between which all the 50 values obtained are situated. These limiting curves take account of the n interfering sources $E_1 \dots E_n$ in different ways: for the lower limiting curve (A) only nuisance fields E_1 and E_2 are taken into account, whereas for the upper limiting curve (B) there are $(n - 2) = 8$ additional sources of interference equal in severity with E_2 :

$$E_2 = E_3 = E_4 = \dots = E_{10}$$

It can be seen from Figs. 1 and 2 that in the majority of cases the simplified multiplication method yields values which are up to about 7 dB higher than those obtained with the power sum method, depending on the network configuration.

5. Conclusions

The simplified multiplication method is statistical in nature and can be used for interference assessments for any desired percentage of locations. On the other hand the power sum method is less complicated to use but its use leads to results which tend to be more optimistic than those obtained with the simplified multiplication method.

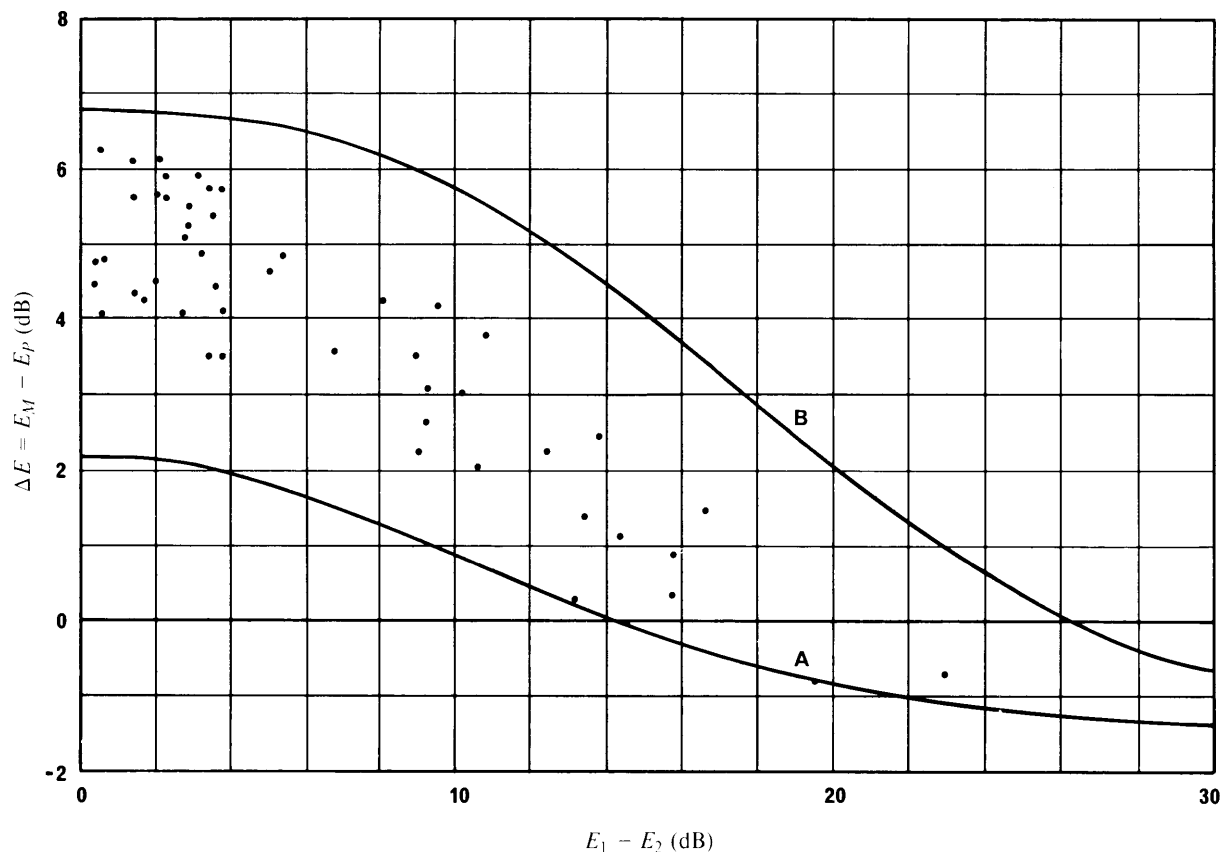


FIGURE 1 - Difference in usable field strength, ΔE , as a function of the difference between nuisance fields, E_1 and E_2 . Percentage of locations for the simplified multiplication method: 45%.

- : 50 transmitters
- $E_1 - E_2$: difference between nuisance fields of the two strongest interfering transmitters
- $\Delta E = E_M - E_P$: difference between the values of usable field strength obtained with either the simplified multiplications method (E_M), or the power sum method (E_P).
- Curves A : limiting curve obtained for the case of 2 nuisance fields, E_1 and E_2
- B : limiting curve obtained for the case of 10 nuisance fields, E_1 and 9 times the value of E_2

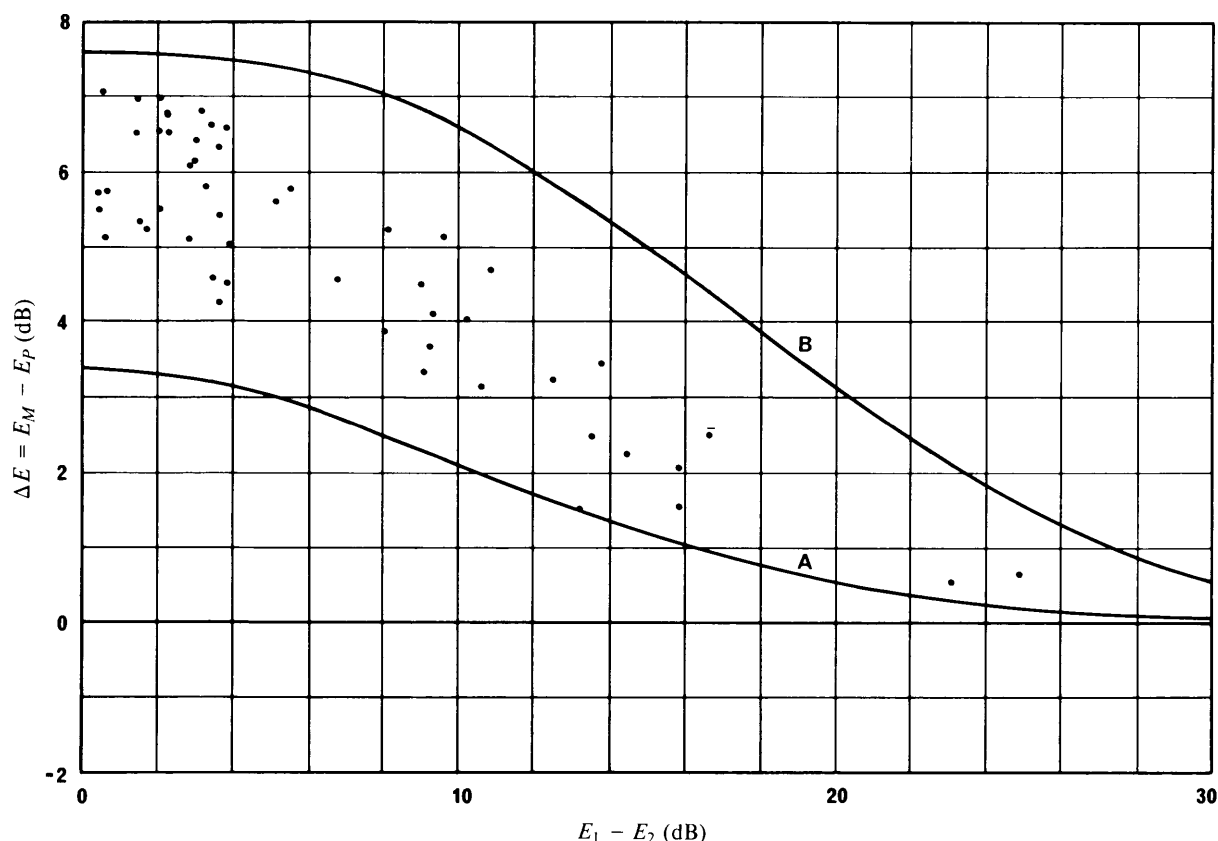


FIGURE 2 – Difference in usable field strength, ΔE , as a function of the difference between nuisance fields, E_1 and E_2 . Percentage of locations for the simplified multiplication method: 50%.

- : 50 transmitters
- $E_1 - E_2$: difference between nuisance fields of the two strongest interfering transmitters
- $\Delta E = E_M - E_P$: difference between the values of usable field strength obtained with either the simplified multiplication method (E_M), or the power sum method (E_P)
- Curves A : limiting curve obtained for the case of 2 nuisance fields, E_1 and E_2
- B : limiting curve obtained for the case of 10 nuisance fields, E_1 and 9 times the value of E_2

ANNEX I

HOW TO USE THE SIMPLIFIED MULTIPLICATION METHOD FOR CALCULATING USABLE FIELD STRENGTHS (IN FM SOUND BROADCASTING)

1. Introduction

It has been proposed, on an international level [CCIR, 1961], to determine the influence of interfering transmitters (co-channel, adjacent channel and second channel) by means of the simplified multiplication method, which was developed by the [Ad hoc Committee 1949, 1950] and is described in detail in [Grosskopf, 1952]. In the following, a step-by-step explanation of the method is given for the practical user without deeper theoretical justification.

2. The concept of the usable field strength

The usable field strength E_u is a quantity which designates the deterioration caused by the interfering transmitters. As such, the usable field strength at the (wanted) transmitter site is a value characterizing the coverage situation. If the usable field strength is large, the influence of the interfering transmitters is also large, whereas the influence of these transmitters is small if the usable field strength is small.

In order to calculate the usable field strength it is necessary to determine all those transmitters:

- whose frequencies lie within the band which can lead to interference ($-400 \text{ kHz} \leq \Delta f \leq +400 \text{ kHz}$);
- which lie within a definite range of the wanted transmitter (about 800 km according to experience).

For these interfering transmitters the following values are determined from field strength and protection ratio curves, using the effective radiated power P_i (if necessary taking account of the antenna diagram of the interfering transmitter):

- field strength value E_{ni} (50, 1), at the site of the wanted transmitter, according to Recommendation 370;
- protection ratio A_i , according to Recommendation 412.

The results for the i -th interfering transmitter, the so-called nuisance field

$$E_{si} = P_i + E_{ni}(50,1) + A_i.$$

The usable field strength E_u is a function of n nuisance fields E_{si} and is calculated according to the formula:

$$p_c = 0.5 = \prod_{i=1}^n L(E_u - E_{si}) \quad (4)$$

in which $p_c = 0.5$ represents the coverage probability for 50% of locations. * The function L is the probability integral for a normal distribution:

$$L(z) = \frac{1}{\sigma \sqrt{2\pi}} \int_{-\infty}^z [\exp(-\xi^2/2\sigma^2)] d\xi \quad (5)$$

In this function z is the difference between the usable field strength E_u and the interference factor E_{si} , σ is the standard deviation (location) of the resulting field.

Identical values are assumed for the location standard deviations of the wanted and interfering transmitters: $\sigma_n = \sigma_s$. For the standard deviation of the resulting field we have:

$$\sigma = \sqrt{\sigma_n^2 + \sigma_s^2} = \sigma_n \sqrt{2}$$

The value $\sigma_n = 8.3$ dB is assumed for the frequency bands I to III. For band IV/V this value is dependent on the terrain attenuation g . σ is then calculated according to the formula $\sigma_n = 9.5 + 0.405 g$. The terrain attenuation factor g can be derived from Δh .

3. Calculation of the usable field strength

The probability integral in the form:

$$\varphi(x) = \frac{2}{\sqrt{2\pi}} \int_0^x [\exp(-t^2/2)] dt \quad (6)$$

can be found evaluated in Table I.

$L(z)$ can be brought into this form in two steps:

First step: substitute:

$$t = \frac{\xi}{\sigma}$$

The function L is then transformed into:

$$L\left(\frac{z}{\sigma}\right) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z/\sigma} [\exp(-t^2/2)] dt \quad (7)$$

* p_c can be set to any other value of coverage probability (e.g. 45% $\rightarrow p_c = 0.45$).

Second step: modify the limits of integration:

since
$$\int_{-\infty}^{\infty} [\exp (-t^2/2)] dt = 1$$

and
$$\int_{-\infty}^0 [\exp (-t^2/2)] dt = 1/2$$

it follows that:
$$L\left(\frac{z}{\sigma}\right) = \frac{1}{\sqrt{2\pi}} \int_0^{z/\sigma} [\exp (-t^2/2)] dt + 1/2$$

thus, using
$$\frac{z}{\sigma} = x,$$

$$L(x) = \frac{\varphi(x)}{2} + 1/2$$

Since equation (4) cannot be solved explicitly for E_u , it must be solved iteratively. We begin with an initial value for E_u , determine the corresponding value for $\varphi(x)$ from Table I, evaluate $L(x)$, and calculate a correction to the initial value E_u from the difference between the right side of equation (4) and the value 0.5, and then start the whole process once again, etc.

Experience has shown that it is expedient to begin with a value for E_u , which is 6 dB larger than the largest of the E_{s_i} . If the difference between the result of equation (4) and 0.5 equals Δ , it is appropriate to modify the value of E_u by $\frac{\Delta}{0.05}$ to obtain a better approximation.

For the calculation of the usable field strength in an example with 5 interfering transmitters, see Table II. The values of $\varphi(x_i)$ can be taken from Table I.

TABLE I - Probability integral

$$\varphi(x) = \frac{2}{\sqrt{2\pi}} \int_0^x [\exp(-t^2/2)] dt$$

x	$\varphi(x)$	x	$\varphi(x)$	x	$\varphi(x)$	x	$\varphi(x)$
0.00	0.0000	0.60	0.4515	1.20	0.7699	1.80	0.9281
01	0.0080	61	0.4581	21	0.7737	81	0.9297
02	0.0160	62	0.4647	22	0.7775	82	0.9312
03	0.0239	63	0.4713	23	0.7813	83	0.9328
04	0.0319	64	0.4778	24	0.7850	84	0.9342
0.05	0.0399	0.65	0.4843	1.25	0.7887	1.85	0.9357
06	0.0478	66	0.4907	26	0.7923	86	0.9371
07	0.0558	67	0.4971	27	0.7959	87	0.9385
08	0.0638	68	0.5035	28	0.7995	88	0.9399
09	0.0717	69	0.5098	29	0.8029	89	0.9412
0.10	0.0797	0.70	0.5161	1.30	0.8064	1.90	0.9426
11	0.0876	71	0.5223	31	0.8098	91	0.9439
12	0.0955	72	0.5285	32	0.8132	92	0.9451
13	0.1034	73	0.5346	33	0.8165	93	0.9464
14	0.1113	74	0.5407	34	0.8198	94	0.9476
0.15	0.1192	0.75	0.5467	1.35	0.8230	1.95	0.9488
16	0.1271	76	0.5527	36	0.8262	96	0.9500
17	0.1350	77	0.5587	37	0.8293	97	0.9512
18	0.1428	78	0.5646	38	0.8324	98	0.9523
19	0.1507	79	0.5705	39	0.8355	99	0.9534
0.20	0.1585	0.80	0.5763	1.40	0.8385	2.00	0.9545
21	0.1663	81	0.5821	41	0.8415	05	0.9596
22	0.1741	82	0.5878	42	0.8444	10	0.9643
23	0.1819	83	0.5935	43	0.8473	15	0.9684
24	0.1897	84	0.5991	44	0.8501	20	0.9722
0.25	0.1974	0.85	0.6047	1.45	0.8529	2.25	0.9756
26	0.2041	86	0.6102	46	0.8557	30	0.9786
27	0.2128	87	0.6157	47	0.8584	35	0.9812
28	0.2205	88	0.6211	48	0.8611	40	0.9836
29	0.2282	89	0.6265	49	0.8638	45	0.9857
0.30	0.2358	0.90	0.6319	1.50	0.8664	2.50	0.9876
31	0.2434	91	0.6372	51	0.8690	55	0.9892
32	0.2510	92	0.6424	52	0.8715	60	0.9907
33	0.2586	93	0.6476	53	0.8740	65	0.9920
34	0.2661	94	0.6528	54	0.8764	70	0.9931
0.35	0.2737	0.95	0.6579	1.55	0.8789	2.75	0.9940
36	0.2812	96	0.6629	56	0.8812	80	0.9949
37	0.2886	97	0.6680	57	0.8836	85	0.9956
38	0.2961	98	0.6729	58	0.8859	90	0.9963
39	0.3035	99	0.6778	59	0.8882	95	0.9968
0.40	0.3108	1.00	0.6827	1.60	0.8904	3.00	0.99730
41	0.3182	01	0.6875	61	0.8926	10	0.99806
42	0.3255	02	0.6923	62	0.8948	20	0.99863
43	0.3328	03	0.6970	63	0.8969	30	0.99903
44	0.3401	04	0.7017	64	0.8990	40	0.99933
0.45	0.3473	1.05	0.7063	1.65	0.9011	3.50	0.99953
46	0.3545	06	0.7109	66	0.9031	60	0.99968
47	0.3616	07	0.7154	67	0.9051	70	0.99978
48	0.3688	08	0.7199	68	0.9070	80	0.99986
49	0.3759	09	0.7243	69	0.9090	90	0.99990
0.50	0.3829	1.10	0.7287	1.70	0.9109	4.00	0.99994
51	0.3899	11	0.7330	71	0.9127	4.417	$1 - 10^{-5}$
52	0.3969	12	0.7373	72	0.9146		
53	0.4039	13	0.7415	73	0.9164		
54	0.4108	14	0.7457	74	0.9181	4.892	$1 - 10^{-6}$
0.55	0.4177	1.15	0.7499	1.75	0.9199	5.327	$1 - 10^{-7}$
56	0.4245	16	0.7540	76	0.9216		
57	0.4313	17	0.7580	77	0.9233		
58	0.4381	18	0.7620	78	0.9249		
59	0.4448	19	0.7660	79	0.9265		
0.60	0.4515	1.20	0.7699	1.80	0.9281		

TABLE II

1. Approximation $E_u = 78$ dB					$\sigma_n = 8.3$ dB
i	E_{Si} (dB)	$z_i = E_u - E_{Si}$ (dB)	$x_i = \frac{z_i}{\sigma_n \sqrt{2}}$	$\phi(x_i)$ (from Table 1)	$L(x_i) = \frac{\phi(x_i)}{2} + \frac{1}{2}$
1	64	14	1.19	0.7660	0.8830
2	72	6	0.51	0.3899	0.6950
3	60	18	1.53	0.8740	0.9370
4	50	28	2.39	0.9831	0.9916
5	45	33	2.81	0.9950	0.9975
$\prod_{i=1}^{\sigma} L(x_i) = 0.5688$ $\frac{\Delta}{0.05} = \frac{0.5 - 0.5688}{0.05} = -1.38 \text{ dB}$					
2. Approximation $E_u = 76.62$ dB					
1	64	12.62	1.08	0.7199	0.8600
2	72	4.62	0.39	0.3035	0.6518
3	60	16.62	1.42	0.8444	0.9222
4	50	26.62	2.26	0.9762	0.9881
5	45	31.62	2.69	0.9929	0.9965
$\prod_{i=1}^{\sigma} L(x_i) = 0.5090$ $\frac{\Delta}{0.05} = \frac{0.5 - 0.5090}{0.05} = -0.18 \text{ dB}$					
3. Approximation $E_u = 76.44$ dB					
1	64	12.44	1.06	0.7109	0.8555
2	72	4.44	0.38	0.2961	0.6481
3	60	16.44	1.40	0.8385	0.9193
4	50	26.44	2.25	0.9756	0.9878
5	45	31.44	2.68	0.9927	0.9964
$\prod_{i=1}^{\sigma} L(x_i) = 0.5016$ $\frac{\Delta}{0.05} = \frac{0.5 - 0.5016}{0.05} = -0.03 \text{ dB}$					

The 4th approximation yields $E_u = 76.44 - 0.03 = 76.41$ dB.
This value can be considered as sufficiently exact.

REFERENCES

- AD HOC COMMITTEE [1949, 1950] Report of the ad hoc Committee for the evaluation of the radio propagation factors concerning the television and frequency modulation broadcasting service in the frequency range between 50 and 250 Mc. Volume I, 31 May 1949, Volume II, 7 July 1950. Appendix B, C, D, E, references E and L.
- CCIR [23 March, 1961] Report of the CCIR Meeting of experts to prepare for the European VHF/UHF broadcasting conference. CCIR Meeting of experts, Cannes, 1961; Doc. 64.
- GROSSKOPF, J. [1952] Die Verfahren zur Ermittlung der Versorgungswahrscheinlichkeit im Feld eines von beliebig vielen Störsendern beeinflussten Nutzsenders (Methods of determining the probability of coverage in the field of a desired transmitter with interference from any number of interfering transmitters). *Techn. Hausmitteilungen des NWDR*, Sonderheft, 18-34.
- O'LEARY, T. and RUTKOWSKI, J. [1982] Combining multiple interfering field strengths, the simplified multiplication method and its physical and mathematical basis (to be published in Telecommunication Journal).

BIBLIOGRAPHY

CCIR Documents

[1978-82]: **a.** 10/237 (Germany (Federal Republic of)); **b.** 10/240 (EBU).

REPORT 458-3

CHARACTERISTICS OF SYSTEMS IN LF, MF AND HF BROADCASTING

(Question 44/10)

(1970-1974-1978-1982)

1. Introduction

Question 44/10 relates to the possibility of standardizing one or more sound broadcasting systems on a world-wide basis. It is clear that the study of this complex question is not sufficiently advanced to achieve this aim. The present Report, therefore, is only a summary of the information available, intended to encourage administrations, broadcasting organizations and industry, to take an interest in these questions and to undertake the studies necessary to solve them.

At present, broadcasts in bands 5, 6 and 7, unlike sound and television broadcasting in band 8 (VHF), are operated throughout the world with an almost complete absence of internationally standardized transmission characteristics; with the exception of channel spacings and carrier frequencies for bands 5 and 6, but even these differ from Region to Region. The other transmission characteristics vary from country to country and in many cases even from transmitter to transmitter [EBU, 1971].

2. Systems available for standardization

The following list of possible systems cannot, at the present time, be considered complete. Several of these systems are compared in [Haviland, 1969]. This study also shows that interference between transmitters must be considered when defining a system and the importance of well defined channel spacings becomes apparent.

Each of the above systems may incorporate modulation processing devices (see Note). If such a device is necessary in the receiver to obtain full advantage of a similar device in the transmitter, the code should be completed by a suitable abbreviation. Thus, an amplitude-modulation double-sideband (DSB) system with envelope demodulation comprising a compressor in the transmitter and an expander in the receiver, is coded AM-DSB-ENV-COMPANDOR. An example is given in Annex I.

Note. — By "modulation processing" is understood any process consisting of altering certain characteristics of the modulation, such as the dynamic range, audio-frequency bandwidth, etc.

Descriptions of amplitude-modulation double-sideband systems with synchronous detection appear in [Netzbund, 1969] and [CCIR, 1966-69] and it should be noted that only these systems can serve as transition systems from amplitude-modulation double-sideband systems with envelope detection to single-sideband (SSB) systems with synchronous detection. Receivers based on synchronous detection would produce undistorted audio-frequency signals for both the above systems ("receiver compatibility").

TABLE I

Modulation	Detection	Code
Amplitude-modulation, double sideband	Envelope detection	AM-DSB-ENV
Amplitude-modulation, double sideband	Synchronous detection	AM-DSB-SYNC
Compatible single-sideband, amplitude-modulation	Envelope detection	CSSB
Single-sideband, amplitude-modulation	Synchronous detection	SSB-SYNC
Frequency modulation (narrow band)		FM

3. Characteristics to be specified

For the systems mentioned in § 2, the characteristics whose standardization will be required are given below. This list is not necessarily complete.

3.1 All systems

- channel spacing,
- carrier frequencies,
- intermediate frequency or frequencies,
- receiver oscillator frequency stability.

Note 1. – The relationship between these characteristics is shown in Annex II.

- audio-frequency bandwidth of the programme,
- necessary bandwidth of emission,
- overall bandwidth of the receiver.

Note 2. – For the relationship between these characteristics and the channel spacing, see Report 457. Deviations from standardized values may be tolerated, if they do not result in unacceptable interference.

- characteristics of modulation processing devices.

In addition, the following characteristics should be standardized:

3.2 Amplitude-modulation double-sideband systems

- maximum depth of modulation.

When laying down the characteristics of the transmission system and the reference receiver, in order to obtain the best adaptation of a frequency-assignment plan to receivers of reasonable performance, the following rules should be taken into account:

3.2.1 The transmission system and receiver characteristic should be suitably related, particularly in the amplitude/frequency response. Harmonic distortion should be reduced to acceptable values. In this respect, criteria for the determination of tolerances for the overall amplitude and phase characteristics and ways for the assessment of practical values are set out and discussed in [Makiedonski, 1974].

3.2.2 The audio-frequency bandwidth transmitted should be related to the carrier spacing (see Report 457). (The precise bandwidth cannot be given; some administrations are of the opinion that it should be one half of the spacing between carriers, and some of them believe that this value may even achieve the value of unity; but this depends on the absolute channel spacing.)

3.2.3 Uniform carrier spacings, with nominal carrier frequencies being an integral multiple of the carrier spacing, should be adopted, at least within the broadcasting bands 5 and 6. (There are technical advantages also in the adoption of uniform carrier spacing on a world-wide basis, including band 7.)

3.2.4 The intermediate frequency (or frequencies) of the receiver should be chosen so that interference created internally within the receiver is at a minimum. With stable local oscillators (see Annex II) this condition is best met when the intermediate frequency (or frequencies) of the receiver is an integral multiple of the carrier spacing.

3.3 *Single-sideband systems with synchronous detection*

- degree of reduction of the carrier wave (see Recommendation 326, § 1.5),
- degree of suppression of the unwanted sideband,
- maximum permissible values of intermodulation products,
- auxiliary signals to obtain receiver synchronization.

The considerations under § 3.2 would apply, and where possible the same characteristics should be adopted.

Note 3. — Some information on a range of suitable values for the degree of carrier reduction, an acceptable level of intermodulation products, the advantages obtained by the application of synchronous detection and some further factors which need to be taken into account, is contained in Annex III (see also [CCIR, 1970-74]).

Note 4. — The EBU has a preference for the adoption of an SSB system for HF broadcasting having the following characteristics:

- the upper sideband should be transmitted,
- degree of reduction of the carrier wave, relative to peak envelope power: 12 dB (to facilitate the introduction of SSB transmissions, a value of 6 dB may be used initially),
- necessary bandwidth of emission: 4.5 kHz.

3.4 *Frequency modulation*

- modulation index,
- maximum modulation frequency.

3.5 *Compatible single-sideband systems* (see Report 299)

- maximum depth of modulation;
- degree of suppression of the unwanted sideband;
- maximum permissible values of intermodulation products.

Note 5. — It is the opinion of the EBU that compatible single-sideband systems are unsuitable for general use in amplitude-modulation sound broadcasting.

4. **Transition period**

At the outset of the transition period there will be a gradual transition from DSB to SSB transmissions and it will be necessary to replace or modify existing conventional transmitters, a disadvantage which, depending on the case, may be offset by the economic advantages due to energy savings. Additionally it will be necessary to replace DSB receivers, e.g. at the end of their normal lives, and listeners who continue to use DSB receivers will have to tolerate a poorer reception quality (harmonic distortion) with SSB transmissions. In order to minimize this deterioration in reception quality, it is proposed to operate SSB transmitters with less carrier reduction than indicated above. A value of 6 dB is deemed suitable. This, on the other hand, will have a bearing on the necessary output power of SSB transmitters if the same coverage is required.

The advantages to be obtained with SSB transmissions will become apparent *from the beginning of the transition period*, and are as follows:

- a more efficient utilization of the frequency spectrum by a reduction of interference;
- the capability of improving the required protection ratio between adjacent channels in the case of a sufficient carrier reduction;
- the capability of considerably reducing the transmission power without changing the service range;
- the capability of improving the quality of reception, in particular under poor propagation conditions (selective fading), with SSB receivers.

REFERENCES

- EBU [August, 1971] Modulation processing techniques in AM sound broadcasting. Doc. Tech. No. 3088.
- HAVILAND, R. P. [June, 1969] A comparative study of communications systems using different modulation-demodulation techniques. *EBU Rev. Tech.*, **115-A**, 102-108.
- MAKIEDONSKI, A. [1974] Analiza zniekształcen obwiedni sygnału zmodulowanego przy jednoczesnym występowaniu zniekształcen tłumieniowych i fazowych jego grupy falowej (Analysis of the envelope distortions of a signal modulated in the simultaneous presence of attenuation and phase distortion of its spectrum). *Prace Instytutu Łączności*, Vol. XXI, **375**.
- NETZBAND, R. [April, 1969] A novel arrangement for the reception of single-sideband transmissions as a result of frequency error and harmonic distortion. *EBU Rev. Tech.*, **114-A**, 60-63.

CCIR Documents

[1966-69]: X/135 (USA).

[1970-74]: 10/14 (Germany (Federal Republic of)).

BIBLIOGRAPHY

LACHARNAY, S., FONTEYNE, J. and MASSUCCI, M. [1978] Radiodiffusion en ondes kilométriques et hectométriques (LF and MF broadcasting). *Radiodif.-Télév.*, **1**.

CCIR Documents

[1978-82]: 10/15 (EBU).

ANNEX I

THE USE OF VARIOUS MODULATION PROCESSING DEVICES

In the OIRT, studies have been made of the possibilities of increasing the modulation factor, i.e., the sideband power, by either trapezoidal modulation or dynamic-compression operation, with transmitters operating in bands 6 (MF) and 7 (HF) [CCIR, 1970-74a]. The results were that dynamic compression without clipping should be preferred, if the objective is to increase the sideband power with a minimum loss of quality (e.g. for music programmes). On the other hand, if a loss of quality is deemed unimportant (e.g. for speech programmes), trapezoidal modulation leads to a higher degree of sideband power.

Experiments carried out in the RFZ, Berlin, have confirmed the assumed increase of the sideband power as follows:

- *Compression of the dynamic range by 12 dB:*
average gain with a rise-time of 0.5 ms and a decay-time of 35 ms: ≈ 6 dB.
- *Compression of the dynamic range by 6 dB:*
average gain with a long decline period (1.5 s) for programmes with a wide dynamic range: ≈ 3 dB.
- *Trapezoidal modulation*
average gain with 5 dB increase in the level of the audio-frequency signal and clipping: ≈ 3 dB.

Studies have been carried out in Sweden concerning the improvement in radio-frequency wanted-to-interfering signal ratio obtained by using audio-frequency compression and expansion in connection with a double-sideband amplitude-modulation system and a frequency-modulation system with a maximum deviation of ± 5 kHz [CCIR, 1966-69].

The audio-frequency range was from 40 to 5000 Hz.

The compressor reduced the dynamic range of the audio-frequency signal, expressed in decibels, to half its value, the time-constants were 2 ms for the rise-time and 20 ms for the decay-time. The expander had characteristics reciprocal to those of the compressor.

The test results can be summarized as follows:

In the absence of interference, no change in quality was observed when using both compressor and expander in the system. The quality was also judged to be satisfactory by listening when only the compressor was used.

In the presence of co-channel interference, the radio-frequency protection ratios (dB) were found to be as follows:

	Type of modulation	
	Amplitude	Frequency
– without compressor and expander	40 to 50	40 to 45
– with compressor only	30 to 40	30 to 40
– with compressor and expander	20 to 25	25 to 30

It should be noted that these values were obtained when the unwanted transmitter was not equipped with a compressor.

In a more extensive study covering double-sideband amplitude-modulation only, the effect of compression and expansion on the radio-frequency protection ratio was investigated when the unwanted transmitter was also equipped with a compressor [CCIR, 1970-74b]. The study was made with different types of programmes transmitted by both the wanted and the unwanted transmitters.

When a speech programme was interfered with by another speech programme, the reduction of the radio-frequency protection ratio was about 15 dB when using compression and expansion. No deterioration in reproduction quality has been reported. When only compression was applied there was a smaller reduction in protection ratio of about 10 dB; in this case, the quality of the reproduced sound was considered lower than acceptable and significantly worse than when no compression was applied.

When a music programme was disturbed by either music or speech, the result depended to a great extent on the character of the wanted programme. The advantage obtained with compression plus expansion or with compression only, was always smaller than when the wanted programme was speech, and sometimes even negligible.

REFERENCES

CCIR Documents

[1966-69]: X/153 (Sweden).

[1970-74]: a. 10/66 (OIRT); b. 10/43 (Sweden).

ANNEX II

CHANNEL SPACING, PROTECTION RATIO AND INTERMEDIATE FREQUENCY

When choosing the carrier frequencies, channel spacing and also the intermediate frequencies to be used in receivers, it is important that they should be chosen so as to minimize interference from:

- the local oscillators of the receivers in use, or of nearby receivers, either by a fundamental or a harmonic frequency;
- harmonics of a transmitted frequency, or other possible intermodulation products [CCIR, 1963-66; SCART, 1966; CCIR, 1970-74].

If both the carrier frequencies and the intermediate frequency are an integral multiple of the carrier spacing, then all interfering products will also be integral multiples of the carrier spacing. Theoretically, therefore, maximum protection could then be obtained because the frequency difference between any interfering signal of this kind and the wanted carrier frequency, would be zero or a multiple of the channel spacing.

If these requirements are to be met with in a particular broadcasting band, it would be essential for the channel spacing to be uniform throughout the band. It would be more advantageous, moreover, if this condition could be met with in both bands 5 and 6, or better still, throughout bands 5, 6 and 7. On the other hand, this condition should be satisfied on a world-wide scale or at least in those areas, where a single frequency assignment plan exists or will be established [Eden, 1967].

However, it must be noted that the disturbance caused by an interfering signal increases rapidly as its frequency difference from the wanted signal increases from zero.

Under present-day conditions in band 7 the frequency differences might have any possible value and this may require an additional protection ratio of up to 17.5 dB. With the adoption of the proposed arrangement, the maximum frequency difference would depend on the accuracy with which the local oscillator frequency and the centre frequency of the intermediate-frequency passband can be controlled. To achieve an improvement close to the maximum possible it would be necessary to achieve stabilities of the order of 100 Hz. As far as the intermediate-frequency stability is concerned this could be achieved by using ceramic or mechanical filters rather than using conventional intermediate-frequency coils. The control of the initial tuning operation and the frequency drift of the local oscillator may require special techniques in which automatic frequency control may be required. The adoption of the proposal would, therefore, give little improvement in the short term, with existing receivers, but would offer the chance of substantial improvement in the future, without any disadvantages under present-day conditions.

REFERENCES

EDEN, H. [December, 1967] Perspectives of replanning LF/MF broadcasting, *EBU Rev.*, **106-A**, 242-251.

SCART [May, 1966] Contribution à l'étude de la fréquence intermédiaire pour les récepteurs de radiodiffusion destiné à recevoir les émissions en ondes kilométriques et hectométriques. (Contribution to the study of the intermediate frequency for broadcasting receivers for LF and MF emissions). Fascicule de documentation SCART, VII, ed. SDSA, 16, rue de Presles, Paris, France.

CCIR Documents

[1963-66]: X/161 (France).

[1970-74]: 10/273 (France).

ANNEX III

SINGLE-SIDEBAND SYSTEMS *

1. Introduction

In the event of the introduction of the single-sideband technique-modulation broadcasting, it would seem desirable to use the definitions existing in Recommendation 326.

According to this Recommendation, the carrier component is defined in relation to the peak envelope power P_p of a radio transmitter, by the acceptable intermodulation level D_n .

For single-sideband broadcasting transmitters, the acceptable intermodulation level D_n determines the non-linear distortion (quality), and the out-of-band radiation (adjacent channel interference).

In single-sideband reduced carrier systems, the precision of the locally re-inserted carrier is important for the reception quality.

The system parameters for a future SSB-system for sound broadcasting in band 7 (HF) must be chosen in such a way that the different requirements of the transition period (reception of SSB-signals with receivers using envelope detection) as well as those of the period thereafter, when only receivers with synchronous (or product) demodulation will be used, are taken into account [CCIR, 1978-82a].

2. Carrier and sideband power relationships in DSB and SSB systems

The sideband power P_s of a transmitter, depends on the peak envelope power P_p and the chosen carrier reduction, a .

The peak-envelope power should be regarded as nominal power of an SSB-transmitter for planning purposes.

For a single-sideband broadcasting transmitter, the most appropriate value of a will depend mainly on the carrier recovery requirements in the cheap single-sideband receiver. To be able to produce the reference carrier for the product demodulator at an acceptable cost, carrier reduction must be restricted to between about 6 and 12 dB, at the transmitter.

Figure 1 shows the relation between the sideband power P_s and the carrier reduction, a , for a given peak envelope power of the transmitter. The indication (1) denotes the values for modulation by a sinusoidal signal and (2) denotes the values for noise or programme modulation. The values of the voltages U and the powers P are given as percentages related to their peak envelope values. With programme modulation and a carrier suppression of more than 30 dB, the sideband power P_s (2) will be about 10% of P_p . A transmitter operating with a carrier reduction of 6 dB can, when modulated with a programme signal, only radiate a sideband power P_s (2) of about 2.5% of its nominal peak envelope power.

For the calculation of P_s (2) it has been assumed that the ratio of the mean power to the peak envelope power is 0.1 (see Recommendation 326, Table I).

3. Equivalent sideband power

If a DSB transmitter (carrier power P_c) for sound broadcasting in band 7 (HF) had to be replaced by an equivalent SSB transmitter, the sideband powers of both transmitters would have to be the same. This is justified at least during the transition period, when SSB emissions will also have to be received by DSB receivers having a bandwidth equal to $2 B_N$, twice as large as necessary for reception of the SSB emission, and also because the coverage of the target area must be the same.

* According to the Radio Regulations (see also Recommendation 326) the following power terms should be used:

- peak envelope power (PX);
- means power (PY)
- carrier power (PZ)

To enable uniform presentation in this Report, which includes a large number of other power and voltage terms following designations differing from those recommended by R.R. and Rec. 326 are used:

$$\begin{aligned} PX &= P_p \\ PY &= P_m \\ PZ &= P_c \end{aligned}$$

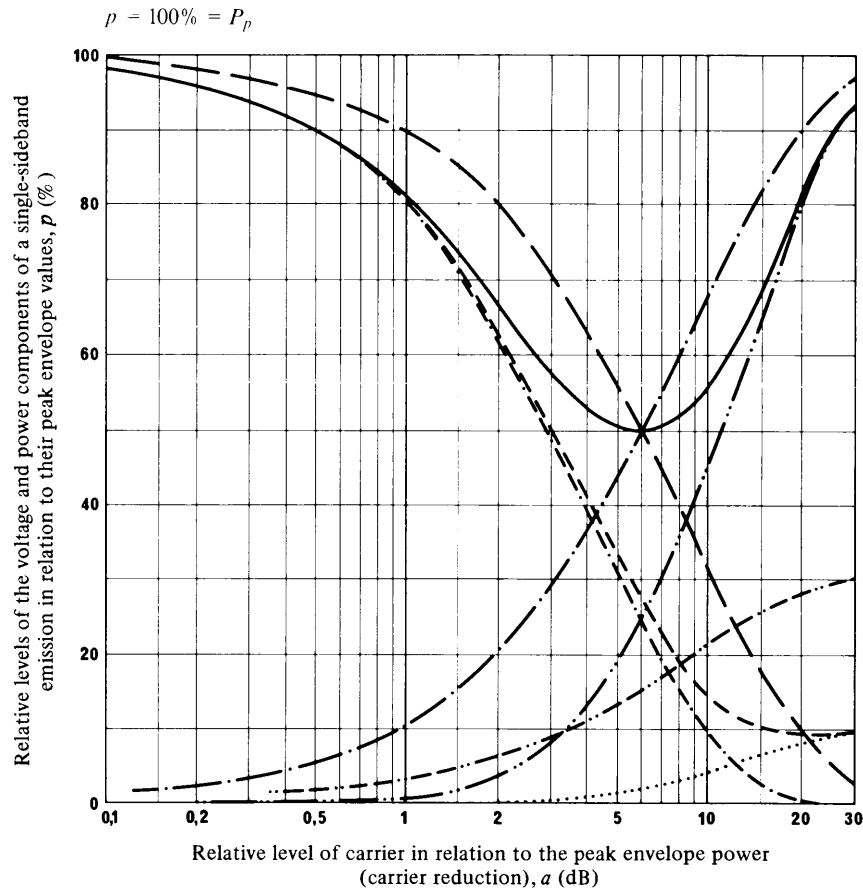


FIGURE 1

- P_p : peak envelope power of the transmitter (defined by means of the acceptable intermodulation level D_n)
- — — — — U_c : carrier voltage (r.m.s. value)
- - - - - $U_s(1)$: sideband signal voltage for modulation with a sinusoidal signal (r.m.s. value)
- · · · · $U_s(2)$: sideband signal voltage for programme or noise modulation (r.m.s. value)
- · - · - P_c : carrier power
- · · · · $P_s(1)$: sideband power for modulation by a sinusoidal signal
- · · · · $P_s(2)$: sideband power for programme or noise modulation
- — — — — $P_m(1)$: transmitter mean power for modulation by a sinusoidal signal
- - - - - $P_m(2)$: transmitter mean power for programme or noise modulation

After the transition period, when only receivers with product demodulation and half the bandwidth of a DSB receiver will be used, theoretically the sideband-power of all SSB transmitters could be reduced to one half of the original value. The signal-to-noise ratio at the output of the receiver, however, would be unchanged only if the spectrum causing the co-channel and adjacent-channel interference within the receiver passband had a uniform power density. Because of the presence of a carrier and the unequal distribution of power in the spectrum of sound-broadcasting emissions, this condition is not met in practice [Gröschel, 1978].

Thus, for the equivalent sideband power P_s of the future SSB transmitters in HF sound broadcasting the following expression might be more suitable:

$$P_s(\text{SSB}) \approx (0.5 \text{ to } 1) \times P_s(\text{DSB})$$

A factor nearer to 1 might be realistic.

Some more details on the necessary peak-envelope power of future SSB transmitters replacing present DSB transmitters in HF sound broadcasting are given in Fig. 2. During the transition period the special receiving conditions will necessitate a peak-envelope power of the transmitter about 2 to 3 times higher than will be needed later on after the transition period [CCIR, 1978-82a].

A1	DSB	A2	SSB: $a = -4.5$ dB	A3	SSB: $a = -6$ dB	A4	SSB: $a = -12$ dB
$\Sigma = 2 \cdot U$		$\Sigma = 1.74 \cdot U$		$\Sigma = 1.414 \cdot U$		$\Sigma = 0.944 \cdot U$	
B1		B2		B3		B4	
$P_m = 1.5 \cdot P$		$P_m = 1.56 \cdot P$		$P_m = 1 \cdot P$		$P_m = 0.556 \cdot P$	
C1		C2		C3		C4	
$\Sigma = 2$ $(\Sigma)^2 = 4$		$\Sigma = 1.74$ $(\Sigma)^2 = 3.03$		$\Sigma = 1.414$ $(\Sigma)^2 = 2$		$\Sigma = 0.944$ $(\Sigma)^2 = 0.891$	
$P_p = 4 \cdot P$		$P_p = 3 \cdot P$		$P_p = 2 \cdot P$		$P_p = 0.891 \cdot P$	

FIGURE 2 – Relation between carrier- and sideband-levels and powers with DSB and SSB transmission depending on carrier reduction

(For comparison carrier power and level of the DSB transmitter were assumed to be equal to 1. Full modulation with a single sinusoidal tone; sideband level constant)

A1...A4: level of spectral-components (at the output of the transmitter)

B1...B4: average output power of the transmitter

C1...C4: peak-envelope power at the output of the transmitter

Index 1: DSB signal

Index 2: SSB signal, carrier reduction: -4.5 dB

Index 3: SSB signal, carrier reduction: -6 dB (class of emission H3E)

Index 4: SSB signal, carrier reduction: -12 dB (class of emission R3E)

U : carrier level of the DSB transmitter

U_s : level of sidebands

U_c : carrier level of the SSB transmitter

P : carrier power of the DSB transmitter

P_c : carrier power of the SSB transmitter

P_m : average power

P_p : peak envelope power

4. Acceptable intermodulation level in SSB transmitters

The value for the acceptable intermodulation attenuation of D_N will largely depend on the required quality of the transmission with respect to non-linear distortion. Theoretical considerations based on a mathematical model for the calculation of adjacent-channel interference in SSB systems [Gröschel, 1978] show that with respect to adjacent-channel interference the intermodulation attenuation D_N of SSB broadcasting transmitters need not be

better than 20 to 25 dB. In the future SSB system the acceptable intermodulation level therefore must be determined according to the wanted quality of the received signal. A range of $D_N = 26$ dB ($\approx 6.5\%$ harmonic distortion) to $D_N = 35$ dB ($\approx 2.3\%$ harmonic distortion) seems to be suitable for future SSB sound-broadcasting transmitters depending on the type of the prevailing programme (speech, music).

5. The precision of the locally re-inserted carrier in SSB receiver

In single-sideband reduced carrier systems, the precision of the locally re-inserted carrier is important for the reception quality. Comprehensive subjective listening tests have shown [Thiessen, 1973] that the effects of non-linear distortion and inaccuracy of the re-inserted carrier superimpose and can be described by:

$$\Delta Q = (k_2/10\%)^2 + (k_3/6\%)^2 + (\Delta f/12 \text{ Hz})^2 \quad (1)$$

where

ΔQ : impairment of quality on the basis of a 6-grade scale,

k_2, k_3 : distortion factors of the 2nd and 3rd harmonics,

Δf : frequency error, (Hz), of the re-inserted carrier.

A maximum value $\Delta Q_{max} = 0.25$ appeared to be just tolerable. Values of $k_2 = 2.9\%$, $k_3 = 1.7\%$ and $\Delta f = 3.5$ Hz would be jointly admissible if the disturbing effects are assumed to be evenly distributed.

6. Carrier reduction

The amount of carrier reduction of an SSB signal determines the additional non-linear distortion that occurs when this signal is demodulated by envelope detection in a conventional DSB receiver. This additional distortion depends both on the carrier reduction a , and on the modulation depth. Because of this additional distortion to be expected during the transition period, the carrier reduction should then not be more than -6 dB rel. to peak envelope power (class of emission H3E) or even less (e.g. $a = -4.5$ dB).

Intermodulation distortion is prevailing. The amount of distortion reached with full modulation is quite large. In practice (average modulation factors ≈ 35 to 45%), this distortion will be smaller.

7. Product demodulation

Broadcasting in the HF bands is based almost exclusively on sky-wave coverage. Because of selective fading the reception of sky-wave signals with double sideband (DSB) modulation and envelope (linear) detection at the receiver suffers severely by non-linear distortion. This degradation may be largely avoided when synchronous demodulation is used.

Test transmissions in band 6 (MF) using sinusoidal modulation (800 Hz) have been analyzed to determine the non-linear distortion occurring with envelope detection (A3E) and with synchronous detection (R3E).

The results are shown in Fig. 3. They show clearly that the non-linear distortion caused by effects of ionospheric propagation, such as selective fading, will be largely diminished by the application of product demodulation in the receiver. The same improvement would be possible, even with class A3E emissions, if product demodulation were applied. No improvement will be achieved in compatible single-sideband (CSSB) emissions [CCIR, 1978-82b].

8. Further factors to be taken into account

8.1 The suppression of the same sideband (upper or lower) would have to be adopted within each broadcasting band. The present state of research indicates that, in the technology of intermediate-frequency and audio-frequency filters, suppression of the lower sideband is preferable. It is therefore suggested that for broadcasting in bands 5 and 6 the upper sideband should contain the full audio-frequency modulation.

8.2 The degree of carrier reduction should not exceed 12 dB.

8.3 Agreement would be required as to whether one sideband should be totally suppressed or whether there should be a form of vestigial-sideband transmission according to a fixed amplitude/frequency response.

8.4 The audio-bandwidth transmitted should be related to the carrier spacing. (The precise bandwidth cannot be given, the fraction of the channel spacing might well approach unity.)

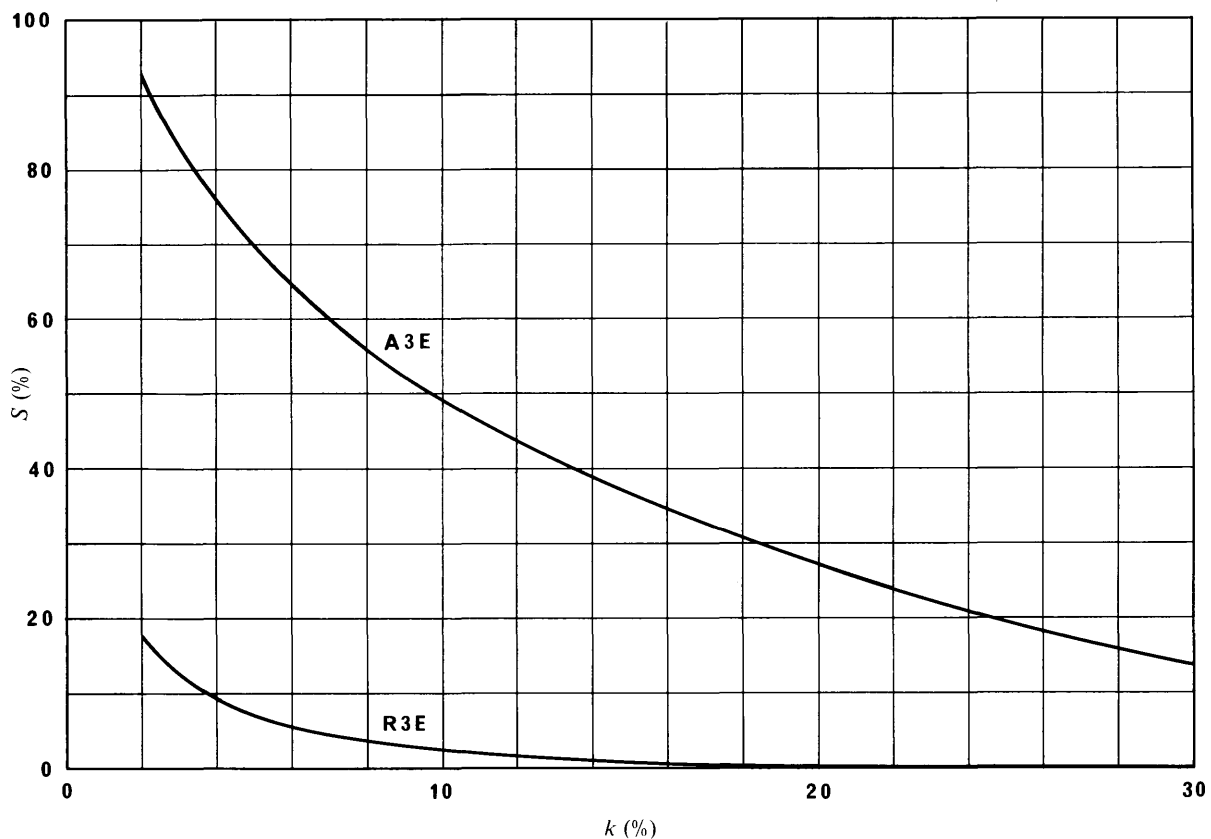


FIGURE 3 – Cumulative frequency (S) of the non-linear distortion (k) averaged over the whole measuring period – Comparison between A3E (envelope) and R3E (synchronous) detection

9. Experience with J3E emissions (fully-suppressed carrier)

The Swedish Administration has reported on test transmissions initially using a peak envelope power of 30 kW (from 1976) then increased to 100 kW (1977) since which time the broadcasts have been confined to a national programme, broadcast more than 5000 hours yearly [CCIR, 1978-82c].

The test transmissions comprising mainly speech programmes have shown that it is possible to establish a regular single-sideband broadcast service with fully suppressed carrier to certain categories of listeners, mainly ships' radio officers, embassy staff and the country's nationals employed abroad. Satisfactory reception of the test transmissions was reported by users of professional receivers, as well as by users of some types of domestic receivers, using beat frequency oscillator techniques, which, however, needed very careful and precise tuning.

10. Conversion of double-sideband transmitters to the single-sideband mode

The majority of existing double-sideband transmitters use anode modulation in the final RF stage, with class C operation and a high anode efficiency. In order to convert such a transmitter into a single-sideband transmitter (reduced carrier) a number of changes are generally necessary. The single-sideband modulation is achieved in a low power level stage and the subsequent stages must function as linear amplifiers. The final stage must be operated in a class AB or B mode.

This involves significant changes in the anode voltage, the grid bias voltages and the matching of the antenna. It may also involve changes to the rectification and smoothing of the power supply.

The peak envelope power which can be delivered by the final RF stage depends on:

- its anode dissipation;
- the acceptable non-linear distortion;

thus, in general, the possible peak envelope power will not exceed the carrier power of the original DSB transmitter.

The feasibility of converting an existing DSB transmitter to the SSB mode will depend on the age of the transmitter, the willingness of its manufacturer, etc. Furthermore, it must be borne in mind that, after the additional cost for the conversion has been invested, the transmitter itself has not been renewed.

Manufacturers have expressed the view that, generally, it is not economically attractive to convert existing DSB transmitters for operation in the SSB mode.

When new transmitters are designed, the possibility of economical conversion from DSB to SSB at a later date should be considered in the design.

11. Comparison of power consumption of equivalent DSB and SSB transmitters

One of the aims of the introduction of SSB modulation in sound broadcasting in the HF bands, apart from a better utilization of the spectrum, is a considerable reduction of transmitter power consumption. Optimum saving of power can eventually be achieved when SSB receivers (having only half the bandwidth of DSB receivers) are in common use, thus permitting a change in carrier level from -6 dB to -12 dB.

On the assumption of programme modulation with 40% effective modulation factor, a value which is reached if the modulation signal is substantially compressed, representative values for the power consumption of transmitters for DSB and SSB modulation with equivalent sideband power have been calculated and are summarised in Tables II and III. They are valid for transmitters which are either converted from the DSB to the SSB mode, or designed as SSB transmitters.

This comparison is based on an overall efficiency factor of 55% for DSB transmitters and 26% for SSB transmitters. These values have been derived from existing medium-wave SSB transmitters. Despite the smaller efficiency factor of an SSB transmitter which results from the necessary linear operation of its final stage, a considerable saving in power consumption will be possible after the introduction of SSB receivers.

In this case an SSB transmitter with e.g. 12 dB carrier reduction and with an equivalent sideband power (equal to half the DSB sideband power) will have about 19% of the total power consumption of an equivalent DSB transmitter.

During the transition period when reception with DSB receivers must be assumed, a carrier reduction of 6 dB might be a suitable value. In this case an SSB transmitter with equivalent sideband power (equal to the DSB sideband power) will have about 14% more power consumption than an equivalent DSB transmitter.

Smaller degrees of carrier reduction than 6 dB will increase the power consumption of the SSB transmitter.

TABLE II – Output power ratios

Carrier reduction (dB)	Main output power of an SSB transmitter relative to DSB carrier power	
	Sinusoidal modulation $m_{eff} = 100\%$	Programme modulation $m_{eff} = 40\%$
4.5	1.56	1.14
6	1.00	0.58
12	0.56	0.136
12 (1)	0.28	0.096

(1) Carrier reduction referred to peak envelope power with half the sideband power of DSB mode.

TABLE III – *Power consumption ratio*

Carrier reduction (dB)	Power consumption of an SSB transmitter relative to that of a DSB transmitter	
	Sinusoidal modulation $m_{eff} = 100\%$	Programme modulation $m_{eff} = 40\%$
4.5	2.20	2.24
6	1.41	1.14
12	0.79	0.27
12 (1)	0.39	0.19

(1) Carrier reduction referred to peak envelope power with half the sideband power of DSB mode.

REFERENCES

- GRÖSCHEL, G. [June, 1978] A mathematical model for the calculation of the adjacent channel interference in single-sideband and double-sideband AM sound-broadcasting systems. *EBU Rev. Tech.*, **169**, 122-136.
- THIESSEN, P. [August, 1973] Assessment of the deterioration in quality of single-sideband transmissions as a result of frequency error and harmonic distortion. *EBU Rev. Tech.*, **140**, 179-187.

CCIR Documents

[1978-82]: a. 10/41 (Germany (Federal Republic of)); b. 10/11 (Germany (Federal Republic of)); c. 10/22 (Sweden).

RECOMMENDATION 205-2

SYNCHRONIZED TRANSMITTERS IN HF BROADCASTING

(Question 44/10, Study Programme 44L/10)

(1953-1956-1966-1982)

The CCIR,

CONSIDERING

- (a) that the overloading of the HF bands is well known and that the use of synchronized transmitters is an accepted technique for improving the efficient use of the spectrum;
- (b) that Recommendation No. 503 of the WARC-79, referring specifically to HF broadcasting, invites “administrations to take advantage to the maximum extent practicable, of synchronized frequency transmitter operation”,

UNANIMOUSLY RECOMMENDS

that synchronized transmitters:

- at the same site, driven by a common oscillator and modulated by the same programme in the correct phase;
 - at separate sites, driven by separate oscillators, the frequencies of which are precisely controlled (a carrier frequency difference of 0.1 Hz or less) and modulated by the same programme;
- should be considered as not introducing any appreciable deterioration in reception.

This conclusion is valid:

- for non-overlapping coverage areas;
- for overlapping coverage areas, provided that due consideration is given to:
 - the shape and size of the reception area;
 - the availability of suitable transmitting antennas;
 - the propagation conditions over the respective transmission paths.

Synchronized transmitters should also be considered to offer advantages in respect of the more efficient use of the spectrum through the utilization of the same frequency for broadcasting the same programme to different areas resulting in improved protection ratios and increased coverage (see Report 794).

ANNEX I

Subjective listening tests carried out in India indicated that a large majority of listeners did not observe any degradation in quality of programme even in a zone where the field strength of the two synchronized HF transmitters differed by only 2 or 3 dB at a distance of about 2000 km from the transmitters.

Note. – This Annex is given for information only.

REPORT 299-3

COMPATIBLE SINGLE-SIDEBAND TRANSMISSION IN SOUND BROADCASTING *

(Question 44/10, Study Programme 44K/10)

(1963–1966–1970–1974)

1. Proposed methods of generating compatible single-sideband signals

Compatible single-sideband transmission has been the subject of study in several countries, namely, Australia [Dixon, 1961], Czechoslovak Socialist Republic, Federal Republic of Germany, Netherlands, People's Republic of Poland, United States of America and the U.S.S.R., as well as in the European Broadcasting Union.

For modulation of a radio-frequency f , by a sinusoidal signal at a frequency F , it can be shown that the required single-sideband signal, with an undistorted envelope, can be formed from a signal with three components f , $(f + F)$ and $(f + 2F)$, as shown in (1):

$$E = \zeta \sin 2\pi ft + a \sin 2\pi(f + F)t + (a^2/4\zeta) \sin 2\pi(f + 2F)t \quad (1)$$

of which the envelope amplitude is given by:

$$A = \zeta + (a^2/4\zeta) + a \cos 2\pi Ft \quad (2)$$

At low indices of modulation only two components are required. It is possible also to calculate the degree of phase- (or frequency-) modulation necessary to produce, together with the required amplitude-modulation, the required compatible single-sideband signal. The required phase-modulation is given by:

$$\phi = \arcsin \{ [a \sin 2\pi Ft + (a^2/4\zeta) \sin 4\pi Ft] / [\zeta + (a^2/4\zeta) + a \cos 2\pi Ft] \} \quad (3)$$

In spite of a similar theoretical background, workers in the various countries have worked along different lines to bring about results which are very close to the theory.

1.1 In the *United States of America* [Kahn, 1961], a signal is generated by passage of a single-sideband signal through two different non-linear circuits. By a suitable combination of addition and mixing procedures, a phase-modulation is achieved which is appropriate for eliminating the unwanted sideband, and which gives a close approximation to the waveforms of the three-component signals.

* A transmission is said to be "compatible" if it can be received on an existing conventional receiver, without any modification whatsoever to the receiver, and then gives a quality of reception at least as satisfactory as that obtained at present in a double-sideband system.

1.2 In the *Netherlands* [van Kessel *et al.*, 1962], it was observed that it would be possible to achieve the necessary three-component signal by squaring a full-carrier single-sideband signal. However, a correction must be applied to neutralize intermodulation distortion.

1.3 In the *Czechoslovak Socialist Republic* [Vackar], a signal is obtained which is very nearly a single-sideband signal, from the original audio-frequency input by a combination of a non-linear network and a phase-shift network. Suppression of the unwanted sideband is then improved by the use of negative feedback.

1.4 In the *U.S.S.R.* [Tetel'baum, 1939; Korenblyum *et al.*, 1951; Tetel'baum and Grinevich, 1957], a compatible single-sideband signal is generated by dividing the audio-frequency input signal along two paths: the first path, through a delay-line and an amplitude-modulator; the second, through a special integrating network and a phase-modulator.

2. Standardization aspects

The standardization of a compatible single-sideband system should take account of the following factors:

2.1 It must satisfy the provisions of Recommendations 328 (out-of-band radiation for amplitude-modulation emissions) and 329 (spurious emissions).

Moreover, it is essential that out-of-band radiation should not exceed that specified for existing double-sideband systems, and that this condition be maintained, in practice, under normal conditions of operation. In particular, no system should be standardized which requires constant supervision of the working transmitter to satisfy this stipulation.

2.2 It is necessary to define the audio-frequency response. It is likely that different definitions will be needed for:

- broadcasting in band 5 (LF) and band 6 (MF),
- broadcasting in band 7 (HF).

2.3 The extent (in decibels) to which the unwanted sideband should be reduced.

2.4 To avoid the need for highly selective filters, suppression of the unwanted sideband below 300 Hz should not be required.

2.5 In connection with § 2.4, there is a possible advantage in permitting double-sideband or reduced sideband transmission up to 750 Hz. However, this transmission may lead to increased co-channel interference on account of fixed beat-frequencies.

2.6 Distortion and interference in normal types of receiver should be of the same order as those acceptable in normal double-sideband broadcasting.

2.7 It is not necessary to use always the same sideband (upper or lower). [CCIR, 1962], gives a channel arrangement ("tête-bêche" channels), which would permit either an increase in the number of channels or an improvement in the quality of services, depending upon the interpretation given to the various technical data relating to the problem.

3. Harmonic distortion of the envelope of the modulated radio-frequency signal

3.1 In the People's Republic of Poland theoretical and experimental investigations have been carried out on the sensitivity of some compatible single-sideband systems [Kahn, 1961; van Kessel, Stumpers and Uyen, 1962] to harmonic distortion of the envelope of the modulated radio-frequency signal, caused by transmission of the signal over lines, the amplitude-frequency and phase-frequency transfer characteristics of which are imperfect.

The results of these investigations [CCIR, 1966-69a] suggest that both the systems considered are more sensitive to harmonic distortion than double-sideband systems.

3.2 In the People's Republic of Poland, investigations were carried out of the harmonic distortion produced in the envelope of the compatible single-sideband and double-sideband emissions when they pass in the receiver through a piezo-ceramic, intermediate-frequency bandpass filter [CCIR, 1966-69b].

The results of a comparative analysis show, that the values of harmonic distortion in the envelope of the compatible single-sideband signal are similar to those for the double-sideband signal. For this reason, broadcast receivers equipped with properly designed piezo-ceramic intermediate-frequency bandpass filters are more suitable for reception of compatible single-sideband emission, than existing receivers with conventional types of intermediate-frequency filter.

3.3 [CCIR, 1966-69c] gives information concerning the preliminary investigations carried out in the People's Republic of Poland, into the harmonic distortion of the modulated signal envelope. This distortion originated in electro-mechanical filters (designed for conventional single-sideband receivers), when the compatible single-sideband or double-sideband signal passed through the filter.

The results of these investigations show that the harmonic distortion in the compatible single-sideband signal at the output of this filter is greater than in a double-sideband signal.

3.4 Similar theoretical studies [Kettel, 1964; Besslich and Burkhardtsmaier, 1964; Kettel, 1968] and experimental investigations [Netzband and Süverkrübbe, 1965] on a compatible single-sideband system [Kahn, 1961] have been carried out in the Federal Republic of Germany. The results show that in current type receivers the amplitude and phase responses of the passband filters cause higher harmonic distortion to a compatible single-sideband signal than to a double-sideband signal.

3.5 Theoretical studies in the analysis of envelope distortion covering the case when the modulated signal consists of three spectral components, for example, a carrier modulated by a sinusoidal tone, have been carried out in the People's Republic of Poland [CCIR, 1970-74a]. In these studies, it has been assumed that the modulated signal is affected by both amplitude and phase distortion [Makiedonski, 1974].

As a result of this analysis, which applies for both double-sideband and compatible single-sideband modulation, formulae are given and graphs are produced which show the dependency of envelope distortion on the amplitude and phase characteristics in the case of this three-component signal.

3.6 On this basis, a further contribution of the People's Republic of Poland [CCIR, 1970-74b] describes ways for the determination of tolerances for the overall amplitude and phase characteristics of a double-sideband or a compatible single-sideband transmission system with respect to harmonic distortion.

3.7 Harmonic distortion when receiving sky-wave transmissions over path lengths of up to 600 km has been studied by the European Broadcasting Union [CCIR, 1966-69d]; [Eden and von Rautenfeld, 1969].

Once again the distortion factor due to receiver passband filter effects was 2.5 to 4 times higher for compatible single-sideband transmissions [Kahn, 1961] than for double-sideband transmissions as was the case with ground-wave reception. In the sky-wave service area the distortions were still higher, but the ratio of the distortion factors of the received compatible single-sideband and double-sideband signals remained virtually unchanged.

3.8 With current types of receivers the compatible single-sideband systems described do not appear to have any important advantages over the double-sideband system. In particular, the quality of the received compatible single-sideband signal is often inferior to that of a double-sideband signal for both ground-wave and sky-wave reception. It is, therefore, not appropriate to use these systems unless reception quality is not an essential factor.

4. Other points of general interest

4.1 Measurement results obtained in the Federal Republic of Germany [CCIR, 1963-66; Netzband and Süverkrübbe, 1965] with the system described in [Kahn, 1961] indicate that correct operation of the automatic gain control in current types of double-sideband receiver depends on the modulation depth and in practice this leads to dynamic distortion.

4.2 In present types of receivers, where the intermediate-frequency bandwidth limits the audio-reproduction that can be achieved, the use of compatible single-sideband may permit an increase of up to 1.5 to 2 kHz in the audio-frequency bandwidth, as long as no change in channel allocation is made.

The extended audio-frequency bandwidth can only be obtained when the receiver is detuned by an amount equal to the extension. This measure, however, gives rise to additional non-linear and dynamic distortion [Besslich and Burkhardtsmaier, 1964; Netzband and Süverkrübbe, 1965].

4.3 The effect of the introduction of compatible single-sideband operation on the service area of a transmitter depends on the factors which limit this area. If the area is limited by interference from other transmitters, measurements of radio-frequency wanted-to-interfering signal ratio would clarify the problem. If the area is limited only by noise, the additional energy in the wanted sideband may assist in increasing the service area.

4.4 In a compatible single-sideband system, it is important that correct tuning of the receiver shall not be made appreciably more difficult than that of a current double-sideband receiver.

4.5 From theory it is clear that demodulation techniques using a reinserted carrier cannot be used for the demodulation of compatible single-sideband signals.

4.6 In [CCIR, 1970-74c] the EBU has expressed the following view:

4.6.1 It is possible, in theory, and there exist several practical methods, to produce compatible single-sideband signals adequate for transmission. The shape of the radio-frequency envelope of these compatible single-sideband signals is sufficiently close to that of the modulating signal, but it is more difficult to reduce out-of-band radiation in the suppressed sideband with a compatible single-sideband system. Furthermore, transmitters are required to be tuned and maintained far more carefully than conventional double-sideband transmitters as out-of-band radiations of high magnitude will occur for maladjustments.

4.6.2 Due to imperfections of current type receivers, which have no bearing on the reproduction quality when receiving double-sideband transmissions, it can be expected that:

4.6.2.1 dynamic distortion may occur when the automatic gain control follows a portion of the spectrum with high energy density rather than the carrier;

4.6.2.2 non-linear distortion may occur due to the amplitude and phase response within the radio-frequency and intermediate-frequency stages.

4.6.3 Additional distortions, similar to those which affect double-sideband signals, are to be expected when receiving sky-wave signals. These non-linear distortions cannot be reduced by using a different demodulation technique instead of envelope detection. For example, product demodulation would greatly reduce non-linear distortion in the reception of double-sideband emissions, whereas serious distortion under all conditions of reception rather than a reduction of distortion would occur with compatible single-sideband emissions.

4.6.4 It is, therefore, the opinion of the EBU that compatible single-sideband systems are unsuitable for general use in amplitude-modulation sound broadcasting.

REFERENCES

- BESSLICH, P. and BURKHARDSMAIER, W. [1964] Eigenschaften, Aufbereitungsverfahren und Demodulationsverzerrungen des kompatiblen Einseitenbandsignals (Characteristics, methods of preparation and demodulation distortion of the compatible single-sideband signal). *Telef., Ztng.*, **37**, 260-275.
- DIXON, J. M. [August, 1961] Envelope modulation. *Proc. IREE*, 401-406.
- EDEN, H. and VON RAUTENFELD, F. [December, 1969] A comparison of the sky-wave reception quality of a conventional double-sideband AM transmission and of a compatible single-sideband transmission. *EBU Rev.*, **118-A**, 258-262.
- KAHN, L. R. [1961] Compatible single-sideband. *Proc. IRE*, **49**, 1503-1527.
- KETTEL, E. [1964] Einseitenbandsignale und das Problem einer Einseitenbandmodulation, bei der die Nachricht in der Envelope liegt (Signals and problems of compatible single-sideband modulation, when the audio-frequency is contained in the envelope). *Telef. Ztng.*, **37**, 247-259.
- KETTEL, E. [February, 1968] Is the compatible single-sideband principle advantageous for AM broadcasting? *EBU Rev.*, **107-A**, 8-15.
- KORENBLYUM, B. I., KREYN, M. G. and TETEL'BAUM, S. I. [1951] K matematicheskoy teorii metoda OAF modulyatsii (On the mathematical theory of a method of optimum amplitude-phase modulation). *Sb. trudov Instituta Elektrotekhniki an Ukrain SSR*, Vyp. 7, Kiev.
- MAKIEDONSKI, A. [1974] Analiza zniekształceń obwiedni sygnału zmodulowanego prozy jednoczesnym występowaniu zniekształceń tłumieniowych i fazowych jego grupy falowej (Analysis of the envelope distortions of a signal modulated in the simultaneous presence of attenuation and phase distortion of its spectrum). *Prace Instytutu Łączności*, **XXI**, 3(75).
- NETZBAND, R. and SÜVERKRÜBBE, R. [1965] Untersuchungen einer kompatiblen Einseitenband – Übertragungskette (Investigations carried out by means of a compatible single-sideband transmission chain). *Rundfunktechn. Mitt.*, **9**, 75-90.
- TETEL'BAUM, S. I. [1939] Od odnom metode povychenia effektivnosti radiosvazi (On a method of increasing the efficiency of radio communications). *Zhurn. Techn. Fiziki IX*, Vyp. 17.
- TETEL'BAUM, S. I. and GRINEVICH, J. G. [1957] Eksperimentalnoye issledovaniye metoda optimalnoy amplitudnofazovoy modulyatsii (Experimental investigation of the method of optimum amplitude-phase modulation). *Radiotekhnika*, **5**.
- VACKAR, J. Czechoslovak Patent No. 91.295.
- VAN KESSEL, Th. J., STUMPERS, F. L. H. M. and UYEN, J. M. A. [1962] A method for obtaining compatible single-sideband modulation. *EBU Rev.*, **71-A**, 12-19.

CCIR Documents

- [1962] Bad Kreuznach: X/33 (France).
- [1963-66]: X/32 (Germany (Federal Republic of)).
- [1966-69]: a. X/47 (P. R. of Poland); b. X/49 (P. R. of Poland); c. X/48 (P. R. of Poland); d. X/204 (EBU).
- [1970-74]: a. 10/79 (P. R. of Poland); b. 10/78 (P. R. of Poland); c. 10/48 (EBU).

BIBLIOGRAPHY

- EDEN, H. [December, 1967] Perspectives of replanning LF/MF broadcasting. *EBU Rev.*, **106-A**.
- KACHEL, A. [1967] Compatible single-sideband transmission for amplitude-modulation sound-broadcasting services. *Telecomm. J.*, **5**, 166-173.
- MAKIEDONSKI, A. [1965] Analiza zniekształceń harmoniczných w systemach modulacyjnych wykorzystajacych modulację amplitudy fali nosnej (Analysis of harmonic distortion in modulation systems utilizing carrier amplitude modulation). *Prace Instytutu Łączności*, **XII**, 2/38, 51-90.
- VAN KESSEL, J. and UYEN, J. M. A. [1963-1964] Compatible single-sideband modulation. *Philips Tech. Rev.*, **25**, 11/12.

REPORT 401-4

TRANSMITTING ANTENNAS IN LF AND MF BROADCASTING

(Question 44/10, Study Programme 44G/10)

(1966-1970-1974-1978-1982)

1. Antenna with reduced vertical radiation

[CCIR, 1963-66] describes a high-efficiency anti-fading antenna consisting of a sectionalized tower of two 120° sections (used at the WOAI station at San Antonio, Texas). The fading zone area relative to the ground-wave service area is reduced from approximately 50% (for a 0.311λ antenna) to about 30% for a ground conductivity of 10×10^{-3} S/m. The Document emphasizes that with this type of antenna the current distribution must be kept as sinusoidal as possible by using a thin structure of uniform cross-section.

Observations. — From experience in other countries it is evident that a high-efficiency anti-fading antenna should be of sectionalized construction and have a total electrical height of $2 \lambda/3$ to λ , to produce the necessary rapid rise of sky-wave field-strength near the point where it equals that of the ground-wave. The effect of the resistive component of the antenna current on the vertical radiation pattern of a sectionalized tower can be reduced or compensated by multiple feeding. It should be noted that the location and extent of the fading zone varies due to changes in the properties of the reflecting ionospheric layers.

In practice, the fading zone is somewhat larger than that calculated. This might be due, on the one hand, to variations of the E-layer reflection, and on the other hand, to F-layer reflections. The design of antennas should take care of these effects.

2. Influence of ground conductivity on the vertical radiation pattern

[CCIR, 1970-74a] gives the results of a theoretical study into the influence of ground conductivity on the vertical radiation patterns of typical vertical antennas. The study takes account of the diffraction of waves around the curvature of the Earth.

Figure 1 shows the field-strength reduction which would occur if flat perfectly conducting ground were replaced by an imperfectly conducting curved Earth. Figure 1 applies to vertical transmitting antennas up to 0.6λ high. The curves of Fig. 1 extend to negative angles of radiation, which apply when waves diffract around the curvature of the Earth and which are defined as the angular distance between the antenna and the tangent point for the wave.

Ground loss may be defined as the reduction in field strength which occurs above a curved Earth when land replaces sea water. Ground loss may therefore be derived from Fig. 1 by subtracting field-strength reductions for sea water from those for ground of the appropriate conductivity. The corresponding increase which occurs when land is replaced by sea water is known as "sea gain".

[CCIR, 1966-69a] gives the results of field-strength measurements carried out to determine the effects of ground conductivity on low angle radiation over a relatively long transmission path of 1400 km. Transmissions from Rome at 845 kHz were measured simultaneously at coastal and inland sites along a radial extending 100 km inland from a coastal site in Southern England. Because of the principle of reciprocity it is immaterial whether the antenna transmits or receives.

Figure 2 shows the results of measurements in terms of field strength at the inland sites, *B* to *K*, relative to the coastal site, *A*. This figure, therefore, shows how ground loss varies with distance from the sea at the frequency 845 kHz for an angle of arrival of about 4° . Also shown in Fig. 2 are theoretical curves for ground conductivities of 5×10^{-3} S/m and 10^{-2} S/m which are believed to be the limits for most of the area. Part of the theoretical curve for 2×10^{-2} S/m is also included since the first 10 km inland was known to be of about this value. Figure 2 clearly demonstrates the large ground loss at sites well inland from the coast.

The effective ground loss as a function of the propagation path for single and multi-hop propagation has been calculated and is shown in Fig. 3. E-layer propagation has been assumed.

It is concluded that a transmitter operating in the MF band (band 6) will radiate sky-waves more efficiently at low angles of radiation if it is situated on a coastline facing the area to be served and that the ground loss does not reach its limiting value until the antenna is at least 50 km inland. To obtain maximum advantage open sea must extend from the coastline for a distance of at least 100 wavelengths in the direction of propagation.

Ground loss applies equally to transmitting and receiving antennas.

[CCIR, 1966-69b] shows the influence of ground conductivity on sky-wave reception.

Field-strength measurements were made over a 450 km transmission path (corresponding to the angle of elevation of about 24°) simultaneously at two points, one on the coast and the other situated inland about 2 km away in the same direction. In the first case, the wave was reflected by the sea and in the second, by the ground. Two transmitters in Rome, one operating at 845 kHz and the other at 1331 kHz, were used.

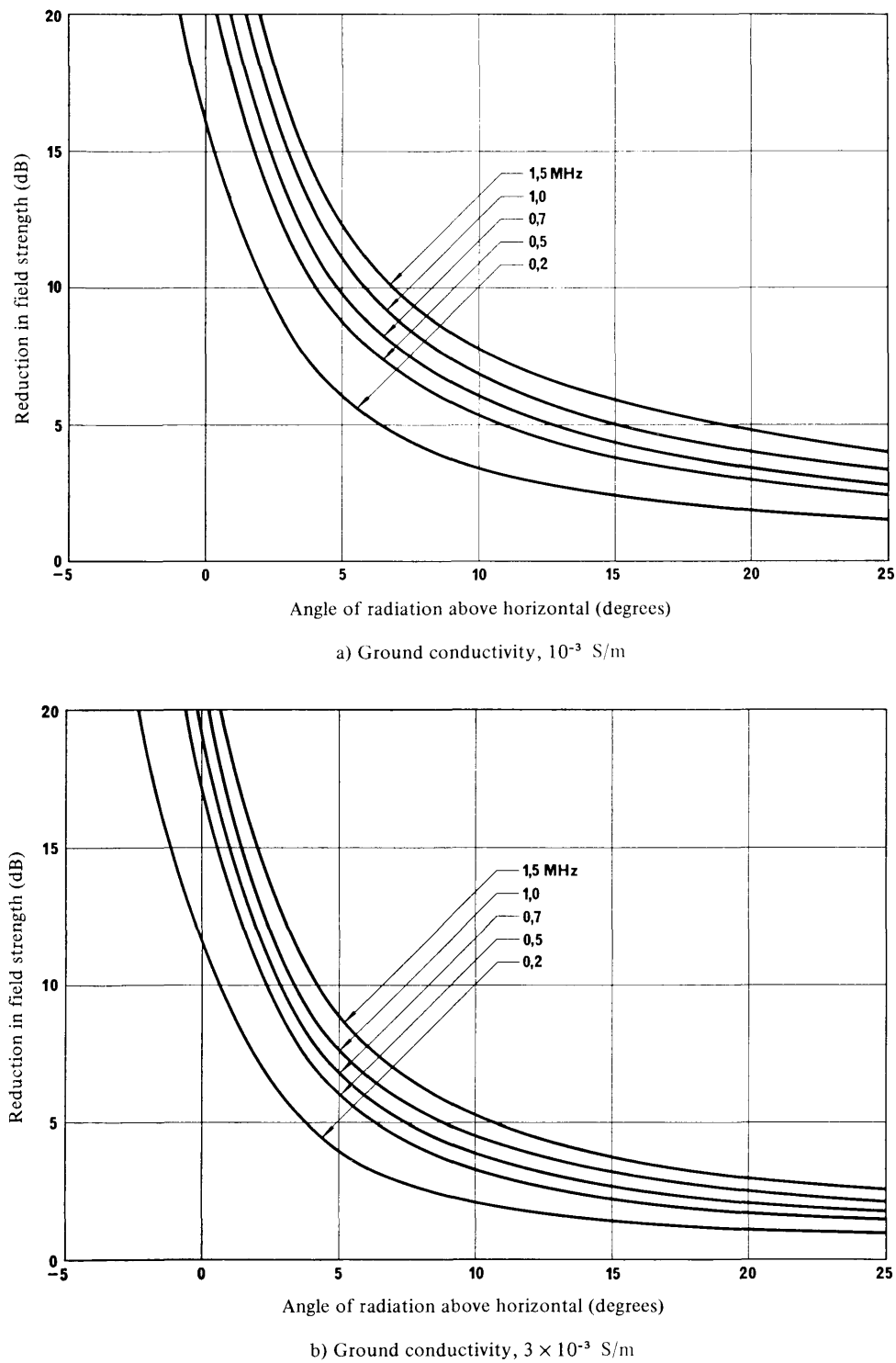
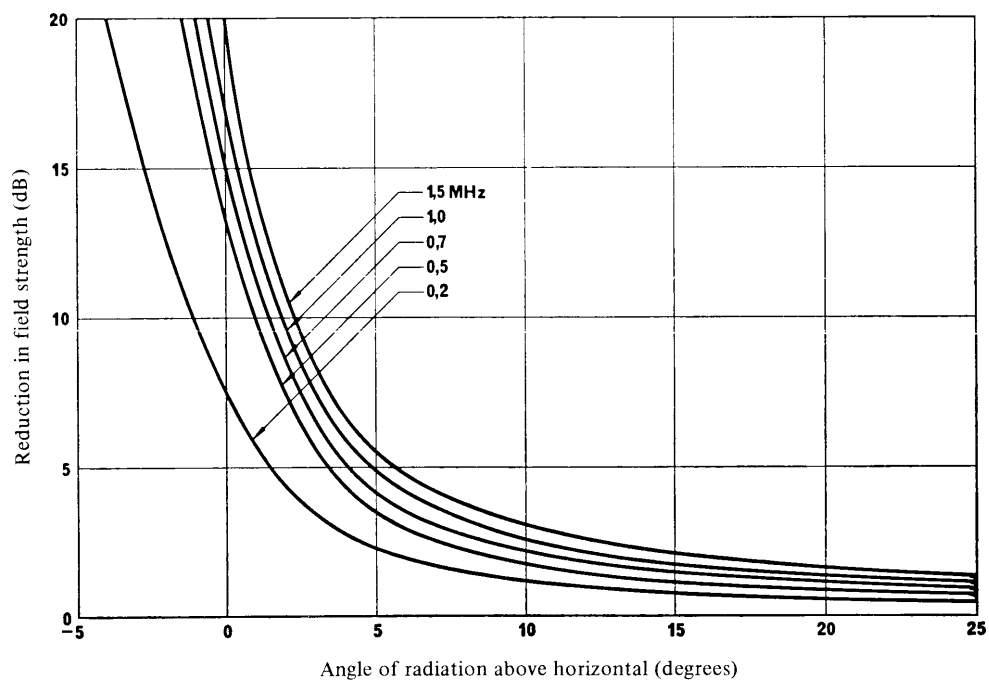
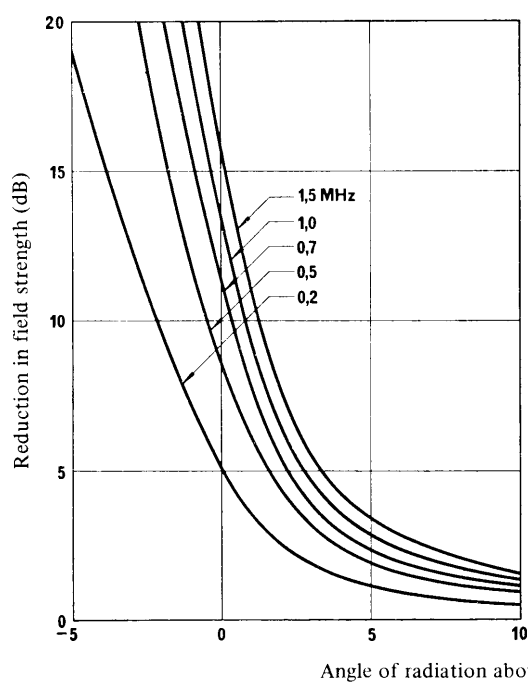
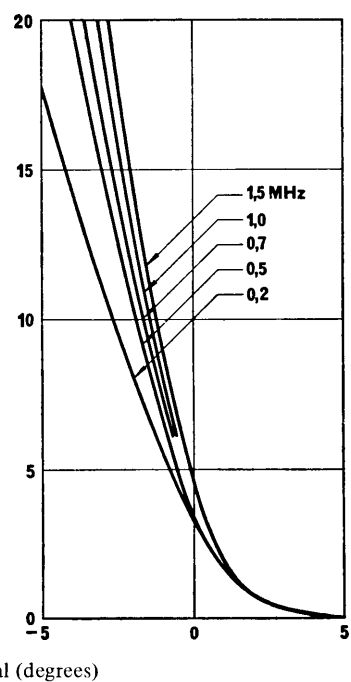


FIGURE 1 – Reduction in field strength for vertical antennae up to 0.6λ high, including the effect of the curvature of the Earth

c) Ground conductivity, 10^{-2} S/md) Ground conductivity, 3×10^{-2} S/m

e) Ground conductivity, 4 S/m (sea water)

FIGURE 1 – Reduction in field strength for vertical antennas up to 0.6λ high, including the effect of the curvature of the Earth

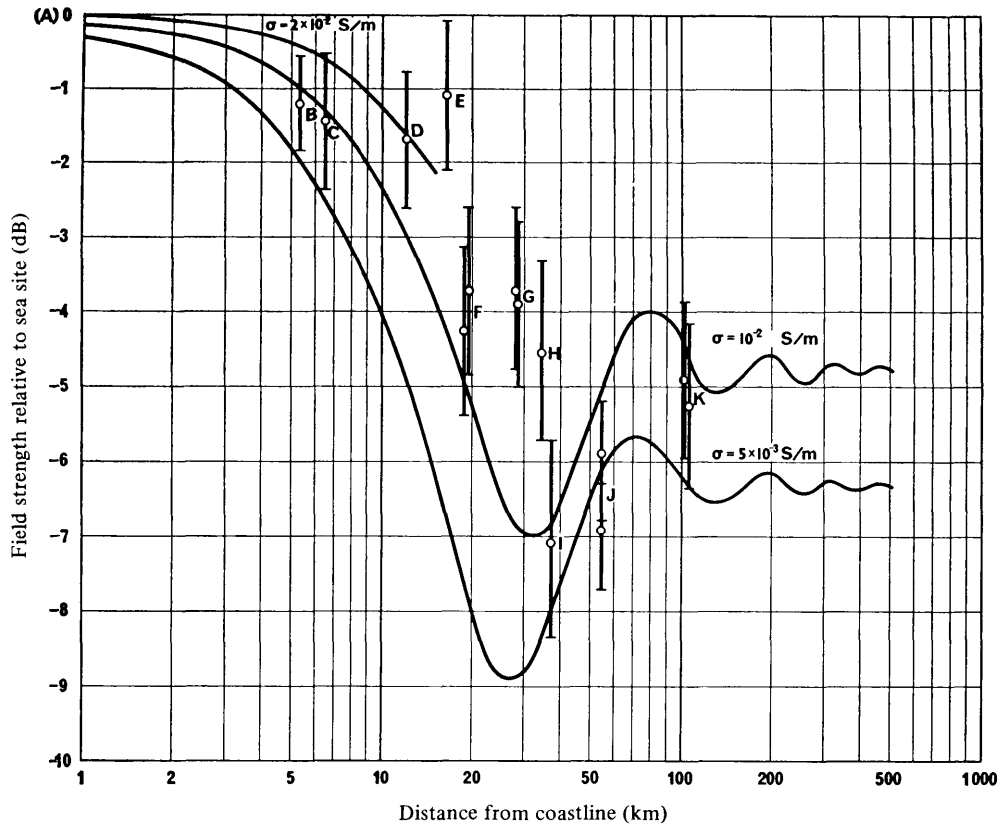


FIGURE 2 – Theoretical and measured ground loss

— : theoretical ground loss

○ : measured ground loss

(Vertical lines indicate confidence limits)

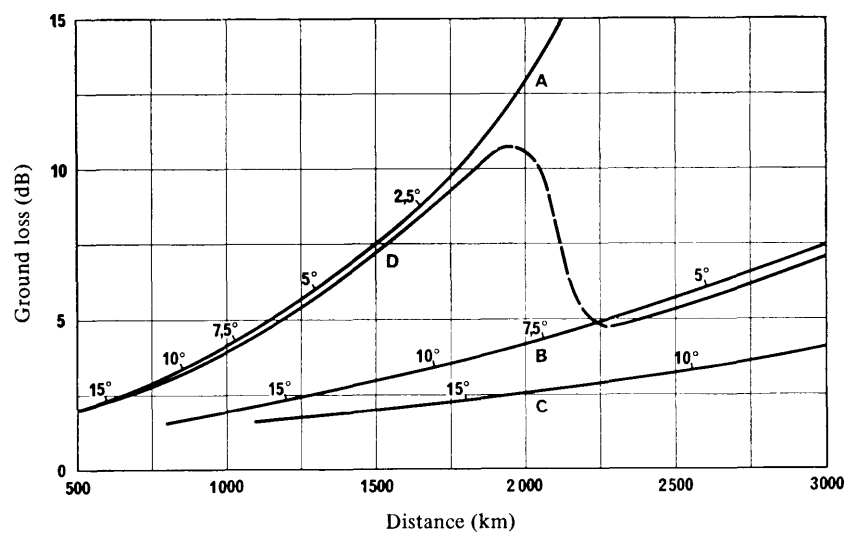


FIGURE 3 – Ground loss for multi-hop propagation

The curves show the ground loss which occurs when sea water is replaced by ground of conductivity 5×10^{-3} S/m at one end of the path. E-layer reflection (layer height 90 km) is assumed and the numbers against the curves denote angles of radiation.

Curve A: single-hop mode

B : two-hop mode

C : three-hop mode

D : effective ground loss for all modes

All the data recorded at both receiving points indicate that the median field strength at the coastal site on both frequencies, is 0.5 dB higher than the value measured inland. This result is in agreement with the calculated theoretical value.

[CCIR, 1970-74b] gives comparative field-strength measurement data in the frequency band 150-1500 kHz. The data were obtained at two receiving points of different ground conductivity, one of which was located near the sea and the other inland at a distance of 60 km from the coast in the direction of the transmitter. Measurements were made on different frequencies over transmission paths of 1200 to 1500 km.

Median field strengths were measured at the two receiving points and compared with calculated values for a parallel polarized wave and for the corresponding ground surface by means of the modulus and phase of the Fresnel reflection coefficients.

The measured results indicate that the increase in field strength from a transmitter sited near to the sea when compared with an inland sited transmitter, depends to a large extent, upon the length of the transmission path and that, on long paths, it may exceed 6 dB.

3. High-efficiency transmitting antennas

It should be emphasized that the capital and maintenance costs of a high-efficiency transmitting antenna should not be considered in isolation, but rather with regard to the cost and effectiveness of the broadcasting station as a whole. For example, for a broadcasting station with a transmitter output power of 100 kW or more, the cost of the antenna is often a relatively small part of the total expenditure.

3.1 [CCIR, 1966-69c] describes a transmitting antenna for use in band 5 (LF), which improves the coverage area by virtue of its high radiation efficiency. This antenna operates in the band 150 to 160 kHz, has a height of about $\lambda/10$ and a flat frequency response up to at least ± 6 kHz of the carrier frequency. Its radiation pattern is that of a vertical unipole antenna of the same physical height.

3.2 [CCIR, 1966-69d] gives information on experience gained with the broadcasting ring antenna for use in band 5 at Motala (191 kHz). The antenna is a stationary field ring antenna consisting of one central element (a vertical radiator of height 250 m) and five vertical radiators with a height of 200 m, equally spaced on a radius of 630 m (0.4λ). The total field strengths at distances of up to 300 km from the antenna were recorded at night over a period of several years at several locations, both before, and after, the change was made from a short vertical radiator to the ring antenna. The measurements show a substantial extension of the fading-free zone after the change of antenna. The theoretical vertical radiation diagram shows suppression of radiation at angles of 40° to 45° ; and this has been roughly confirmed by measurements from aircraft.

3.3 [CCIR, 1970-74c] describes a switchable transmitting antenna for optimized day and night service in band 6 (MF). Two antennas of this type are in use at two broadcasting stations (Ismaning, 1602 kHz and Langenberg, 1586 kHz). The antenna consists of three insulated sections and this permits very flexible adjustment of the current distribution and allows changes in the vertical radiation pattern over a wide range. For example, it is possible to effect a reduction of the low angle radiation by up to 3.5 dB, a side-lobe attenuation up to a maximum of 38 dB, and a gain in the horizontal plane of up to 6 dB. A suitable combination of these parameters results in an improvement in the co-channel radio-frequency wanted-to-interfering signal ratio of between 3 dB and 10 dB.

3.4 [CCIR, 1970-74d] describes a double half-wave cage-type antenna for use in band 6 (MF). This antenna consists of four cages of copper or aluminium wires. The cages are suspended on an earthed, non-divided mast, each cage ($\lambda/4$) being galvanically connected with the mast at its upper end and insulated from the mast at its lower end (see Fig. 4). In the document are given the results of a theoretical analysis of the antenna and the results of measurements on a metre-wave model.

By appropriate selection of the ratio and phase of the currents in the two dipoles, the vertical radiation pattern can be shaped within a wide range. This enables selection of the optimum operating conditions for both day-time and night-time conditions.

3.5 [CCIR, 1970-74e] reports on the existence of a high-gain band-6 (MF) broadcasting antenna at Lille-Camphin on a frequency of 1376 kHz. This antenna is of the full-wave type and is designed to increase the horizontal gain by reducing radiation in directions other than that of the horizon. It is centre-fed, but its quarter-wave skirt structure avoids cutting the tower with insulators. There is also no insulator at the base of the tower. Feeder matching is effected without the classical antenna unit, inductance or capacitance. The radiation diagram was regulated with the help of measurements made using a helicopter. A detailed description of the antenna is available [Lacharnay, 1969].

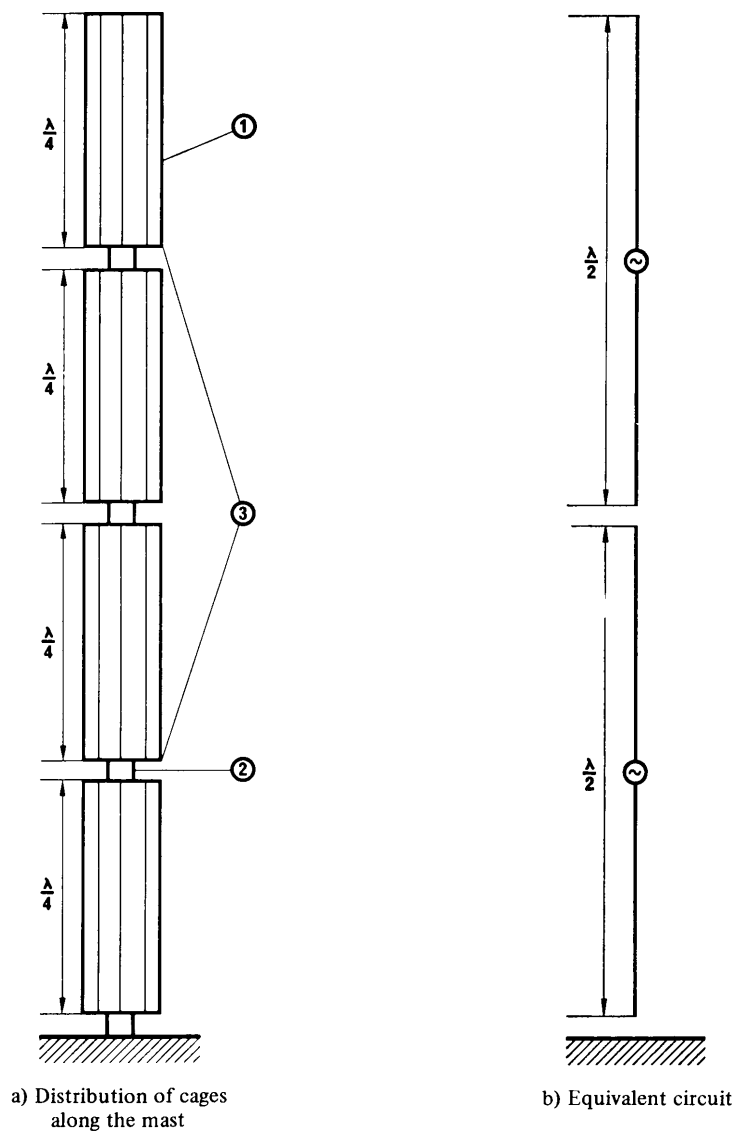


FIGURE 4 – Double half-wave cage-type antenna

3.6 [CCIR, 1970-74f] describes the design of an antenna, the radiation pattern of which can be regulated in the vertical plane. The upper part of the antenna is a normal vertical radiator whilst the lower part is a vertical radiator with a reactance in the form of a short circuit loop connected to the base. To reduce its characteristic impedance, inclined wires are suspended from the upper part of the antenna. A vertical wire screen is fixed to the lower part of the antenna, reaching from the ground to a height of $H_1 = 0.4 H$.

Regulation of the radiation pattern in the vertical plane is provided by adjusting the current distribution by means of distributed constant lines. The antenna possess anti-fading properties in a wide frequency band and has a gain of up to twice that of a base driven half-wave antenna.

The antenna can be used in band 6 (MF) with regulation of the current distribution and in band 5 (LF) under conditions corresponding to current antinode at the lower end of the screen.

[CCIR, 1974-78a] describes a band 6 (MF) directional antenna with a controlled horizontal radiation pattern. [Timonina, 1971].

The antenna consists of four radiators located at the corners of a square of side D . Two of the radiators are active whilst the other two act as passive reflectors tuned by means of a short-circuited stub. The radiation pattern in the horizontal plane is controlled over the sector 0° to 360° . The direction of maximum radiation may be changed in steps of 90° . Assuming $D = 0.25\lambda$ to 0.28λ then the back radiation level is -18 dB to -20 dB relative to the main beam, whilst over an angular sector of 100° this level averages about -14 dB.

A four-mast antenna with an adjustable current distribution [Bielousov, 1974; Bielousov *et al.*, 1976] and height $H = \lambda$ with $D = 0.28\lambda$ has a gain of 10 dB when tuned for maximum radiation in the forward direction.

3.7 [CCIR, 1974-78b] refers to a published article [Lacharnay, 1976] which describes various directional transmitting antennas employing vertical mast-radiators for LF and MF broadcasting, characterized by very low radiation over wide sectors, both in elevation and azimuth. Such antennas render it possible to reduce the interference in overcrowded frequency bands. Some practical installations are described and details are given of the attenuation that can be obtained (30 dB at present) as well as the stability of the antenna adjustments, verified over several years.

REFERENCES

- BIELOUSOV, S. P. [1974] Srednevolnovyie anteny s regulirujemym raspredelenijem toka (MF antenna with regulated current distribution), *Sviazizdat*.
- BIELOUSOV, S. P., KUZNETSOV, V. D. and TIMONINA, V. I. [1976] Srednevolnovyie antifedingovaya antenna s zazemlennym osnovaniem ARRTZ-2 (MF anti-fading antenna with earthed base), *Elektrosviaz*, **2**, 40-46.
- LACHARNAY, S. [1969] Nouvelle antenne hectométrique à grand gain à l'émetteur de radiodiffusion de Lille-Camphin (antenne à jupe). *Rev. Française de Radiodif. et de Télév.*, **11**.
- LACHARNAY, S. [September-October, 1976] Directional transmitting aerials for LF/MF broadcasting. *Radiodif.-Télév.* **44-4/5**, 1-11.
- TIMONINA, V. I. [1971] Srednevolnovaya napravlennaya antennaya sistema soupravlyaemoi diagrammoi napravlennosti v gorizontanoi plosnosti (MF directional antenna system with radiation pattern rotatable in the horizontal plane). *Radiotekhnika*, Vol. 26, **1**, 17-25.

CCIR Documents

- [1963-66]: X/21 (USA).
- [1966-69]: a. X/143 (United Kingdom); b. X/31 (Italy); c. X/57 (Federal Republic of Germany); d. X/190 (Sweden).
- [1970-74]: a. 10/188 (United Kingdom); b. 10/294 (U.S.S.R.); c. 10/28 (Germany (Federal Republic of)); d. 10/62 (Poland (People's Republic of)); e. 10/73 (France); f. 10/292 (U.S.S.R.).
- [1974-78]: a. 10/108 (U.S.S.R.); b. 10/272 (France).

BIBLIOGRAPHY

- AIZENBERG, G. Z., BIELOUSOV, S. P., LINDBERG, A. H. and JAMPOLSKIJ, W. S. [1961] Antifedingovaya antienna dlja radiowieszczanija (An anti-fading antenna for radio broadcasting). *Radiotekhnika*, **16**, **12**, 21-30.
- ANDERSEN, J. B. [1963] Reception of sky-wave signals near a coastline. *NBS J. Res.*, **67D**, **3**, 325-330.
- ANDERSEN, J. B. [1963] The radiation field from a vertical dipole on an inhomogeneous ground. *Electromagnetic Theory and Antennae* (ed. by E. C. Jordan), 1099-1112, Pergamon Press, Oxford, UK.
- BEM, D. J. [1973] Antena klatkowa z ksztaltowana charakterystyka promieniowania w plaszczyznie pionowej (A cage antenna with controlled radiation pattern in the vertical plane). *Prace Instytutu Łączności*, **XX**, 1(69).
- BIELOUSOV, S. P. [1967] Sredniewolnowyje antienny s regulirujemym raspredielenjem toka (Antenna for band 6 (MF) with adjustable current distribution). *Vestnik Svazi*, **8**.
- CCIR [1978] Antenna diagrams.
- CLEMMOV, P. C. [1953] Radio propagation over a flat earth across a boundary separating two different media. *Phil. Trans. Roy. Soc.*, Series A, **246**, 905, 1-55.
- COLLARD, M. [October, 1973] The reduction of the results of field-strength measurements to standardized conditions, for the purpose of studying LF and MF ionospheric propagation, *EBU Rev. Tech.*, **141**.
- JEFFERS, C. L. and KERSHNER, S. W. [March, 1960] Design and performance measurements on a new antifade antenna for radio station WOAI. *IRE Trans. Broadcasting*, Vol. B.C.6, **1**, 34-43.
- KNIGHT, P. and THODAY, R. D. C. [1969] Influence of the ground near transmitting and receiving aerials on the strength of medium-frequency sky-waves. *Proc. IEE*, **116**, **6**, 911-919.
- LACHARNAY, S., FONTEYNE, J. and MASSUCCI, M. [1978] Radiodiffusion en ondes kilométriques et hectométriques (LF and MF broadcasting). *Radiodif.-Télév.*, **1**.
- MAGNUSSON, E. and STRANDEN, F. [June, 1960] Planning the new Motala long-wave broadcasting station, *EBU Rev. A*, 107-113.
- MALLACH, P. [1971] Gestaltung des Vertikaldiagramms von Mittelwellen-Antennen (Design of vertical pattern of MF antennae). *Nachrichtentechn. Fachber.*, **41**, Hörrundfunk 2 – VDE – Verlag, Berlin.

- MILLAR, R. F. [1967] Propagation of electromagnetic waves near a coastline on a flat earth. *Radio Sci.*, 2, 261-286.
- MONTEATH, G. D. [1951] Application of the compensation theorem to certain radiation and propagation problems. *Proc. IEE*, 98, IV, 1, 23-30.
- MONTEATH, G. D. [March, 1958] The effect of the ground constants, and of an earth system, on the performance of a vertical medium-wave aerial. *Proc. IEE*, Vol. 105, Part C, 7, 292.
- PAGE, H. and MONTEATH, G. D. [May, 1955] The vertical radiation patterns of medium-wave broadcasting aerials. *Proc. IEE*, Vol. 102, Part B, 3, 279.
- SPONZILLI, L. [1968] Confronto tra ricezioni notturne indirette di onde medie su terra e su mare (Comparison between night reception on land and at sea, of medium waves arriving via the ionosphere). *Elettronica*, 3, III trim.
- WILLIAMS, H. P. [May, 1947] The broadcast antenna: presented in the 1947 Radio Convention of the British Institute of Radio Engineers.

REPORT 32-4

TRANSMITTING ANTENNAS IN HF BROADCASTING

(Question 44/10, Study Programme 44H/10)

(1953-1966-1974-1978-1982)

1. The use of directional and non-directional antennas

Non-directional antennas should only be used if the transmitter location is in the centre of the listening area. Typical non-directional antennas are quadrant antennas, vertical monopoles or other suitable combinations of horizontal dipoles. Gains are approximately 4 to 6 dB relative to a half-wave dipole. Distances to be served are relatively short. Frequencies used are at the lower end of the HF band.

Directional antennas serve a double purpose. The first is to prevent interference to other users of the spectrum by means of their directivity. The second is to provide sufficient field strength for the listener's satisfaction by means of their gain.

For intermediate distances of up to 5000 or 6000 km, directional curtain antennas of the type HR* 2/2... or logarithmic-periodic antennas serve the purpose; typical antenna gains are between 10 and 15 dB. Their use is justified if the listening area is in conformity with the horizontal beamwidth (between 6 dB points) of these antennas, which is between 45° and 70°. If the azimuthal width of the listening area is narrower, HR 4/.../... antennas, which have a beamwidth of the order of 30°, should be used.

At greater distances, HR 4/4... are recommended for use. Their increased gains of between 16 and 21 dB are needed to provide sufficient field strengths. The typical horizontal beamwidth of these antennas is also 30°. Antennas of extremely narrow horizontal and vertical beamwidth should not be used because variations of the ionosphere could change the location of the coverage area.

Although rhombic antennas are used for broadcasting, their use should be discouraged because of the size and number of their sidelobes, which could create unnecessary interference.

2. Reduction of subsidiary lobes

Study Programme 44H/10 is also concerned with the reduction of subsidiary lobes in high-frequency broadcasting directional antenna systems, for the purpose of avoiding interference in frequency sharing. This interference is generally caused by the radiation pattern of the transmitting antenna having subsidiary lobes in unwanted directions, or by scatter of the energy of the main lobe, due to propagation anomalies. Reduction in intensity of the subsidiary lobes is possible by correct antenna design, while the propagation scatter in unwanted directions presents a complex problem, and its effect should be treated statistically.

A large amount of work has been done on the properties of directional antennas and on the elimination of subsidiary lobes. Foster [Foster, 1937] has shown that, by proper choice of rhombic antenna parameters, optimum subsidiary-lobe reduction can be obtained, within a limited frequency range, without significant impairment of the main lobe. A convenient method of design of such an antenna is presented by Laport [Laport, 1952]. Further improvements in subsidiary-lobe reduction can be achieved by stacked or coplanar arrays, as shown by Christiansen [Christiansen, 1946; Christiansen *et al.*, 1946; Christiansen, 1947]. Such arrays, although more complex, will provide a more satisfactory pattern than a single antenna.

* Nomenclature explained in Appendix 2 (III) of the Radio Regulations.

In broadside arrays, reduction of subsidiary lobes is, in general, accomplished to a higher degree than in the rhombic arrays; using the binomial distribution [Kraus, 1950], the subsidiary lobes can be eliminated to a large extent although the main beam is slightly broadened. A narrower beam with small subsidiary lobes is possible by applying the Dolph-Tchebyscheff distribution [Kraus, 1950; Dolph, 1946]. Thus, for a maximum subsidiary lobe intensity 20 dB below that of the main lobe, it is possible to get a beamwidth of 27° . It should be noted that Christiansen [Christiansen, 1947] attains results from a four-unit array of rhombics which are equivalent to large arrays of tuned elements. He confirmed this on radiotelegraph circuits over a period of some years.

Reduction of subsidiary lobes when the main beam is slewed is a difficult problem, as the angle of slew, type of antenna, and distortion of its radiation pattern must be considered. This makes it more difficult to give general rules for subsidiary-lobe reduction.

A type of array commonly used [Hayes and MacLarty, 1939] consists of four rows of radiating elements, each containing four elements with the lowest row one wavelength above ground. The array is normally provided with a reflector, and the feeder arrangements usually allow for reversing or slewing. The slewing in azimuth of the direction of maximum radiation of this type of array is achieved by the adjustment of the relative phase of the current distribution between the left and right halves of the array. The limit of effective slewing by this means can be taken as 17° on either side of the normal direction, but the amount of slew commonly used does not as a rule exceed 15° .

While this method of slewing does not appreciably affect the horizontal width of the main lobe of radiation, it does increase its asymmetry and at the same time produces a principal subsidiary lobe of considerable intensity. The ratio of the field strength of the main lobe in a slewed array, compared with that in the unslewed condition, has been determined theoretically; for the type of antenna under discussion the ratios for 0° , 5° , 10° and 15° slew would be 1.0, 0.98, 0.94 and 0.84. Similarly, the ratio of the field strength of the principal subsidiary lobe to that of the main lobe can also be determined and for the same angles of slew would be 0.18, 0.27, 0.45 and 0.7 respectively. These theoretical figures are in close agreement with measured values [Page, 1945].

Although it is possible, as described in the publications mentioned above, to achieve a substantial degree of suppression of side lobes with either rhombic or curtain arrays, the methods so far employed introduce mechanical difficulties and increase the cost. It is therefore proposed that further consideration be given to the best method of specifying a degree of suppression, for example:

- by limiting radiation in a specified direction, so as to avoid interference in the reception area of another transmission, to a certain proportion of that given by an omnidirectional antenna;
- by limiting the radiation over a wide angle, which excludes the main lobe and any neighbouring strong subsidiary lobes, to a certain proportion of that given by an omnidirectional antenna;
- by limiting radiation in all directions, other than those comprised in the main lobe, to a certain proportion of that given by an omnidirectional antenna.

Tests have been carried out in Italy [CCIR, 1963-66a] with an array of HR5/4/1.5 dipoles with reflectors in which each stack of dipoles is fed separately. The five feeders are so adjusted as to reduce the amplitude of the subsidiary lobes. Measurements showed that the reduction was substantial (about 8 dB). This property is maintained when the main lobe is slewed; the largest subsidiary lobe is then very greatly reduced (15 dB for an 18° slew of the main lobe). The whole array remains simple and the increase in the cost price is slight.

Type HR4/4 antennas have recently been manufactured in France. Their special feature is that the reflector is fed, an arrangement which makes it possible to adjust accurately the voltage amplitudes and phases in the arrays, back and front. Measurements of the pattern from a helicopter showed that it resembled the theoretical patterns very closely (nulls about 40 dB). Compared with systems with passive reflectors, the new arrays have a larger bandwidth and are more easily adjusted.

3. Actual protection obtained with directional antennas

The United Kingdom and the Republic of South Africa have carried out an experimental study of the real protection at a great distance by the use of directional antennas in band 7 (HF) [CCIR, 1962; 1963]. This was done by comparing, in South Africa, the field strength produced by two transmitting antennas located at the same and at different sites in the United Kingdom, directed towards South Africa and South Asia respectively. Frequencies in the 21 MHz broadcasting band were used. A system of simultaneous reception with signal strength recordings enabled the effects of short-term propagation variations to be reduced to a minimum and a large number of measurements were made to take account of longer-term variations.

It was observed that the real protection provided by the transmitting antennas at the same site was, under these conditions, about 22.5 dB (average value), as compared with a protection of 19 dB calculated on the basis of Recommendation 80. The protection deduced from the theoretical antenna characteristics was about 38 dB.

Using transmitting antennas at different sites, which were separated by 250 km, the real protection as measured was 21.3 dB (average value), as compared with a protection of 16 dB calculated on the basis of Recommendation 80. The protection deduced from theoretical antenna considerations was in this case about 35 dB.

The difference between the measured value and that calculated on the basis of Recommendation 80 is considered to be sufficiently small to establish the validity of the Recommendation in these particular cases.

[CCIR, 1963-66b] describes a further experiment carried out between the United Kingdom and the Federal Republic of Germany over medium distances of about 1000 km.

The field strength measured at the receiving station indicated that in only one of five cases was the real protection greater than the theoretical protection. In all other cases the real protection was 1 to 7 dB less than the theoretical value.

On the other hand, the real protection was greater than that determined on the basis of Recommendation 80 by 3 dB, 6 dB and 9 dB in three cases, whilst it was 2 dB and 3 dB less in the remaining two cases.

The protection measured in these particular tests was considered sufficiently close to that obtained by the application of Recommendation 80 to confirm the validity of the Recommendation for medium distances.

[CCIR, 1970-74] describes a further series of tests carried out over the transmission path Ascension Island to the United Kingdom, a distance of 6800 km. Field strength measurements of the Ascension transmissions, which utilized directional antennas of the stacked horizontal dipole type, gave an indication of the real protection obtained with this type of array. The transmission frequencies were in the 6 MHz and 9 MHz HF broadcasting bands and the measurements indicated a real protection of some 30 dB less than would be expected from an examination of the transmitting antenna theoretical radiation patterns. Moreover, the real protection was about 5 dB less than that calculated on the basis of Recommendation 80.

These results were disappointing and it is not known whether the wide discrepancies between the measured protection and the theoretical protection were due to propagation effects or the transmitting site characteristics, or a combination of both. Further investigations appear to be necessary.

[CCIR, 1974-78] describes a study carried out by All India Radio into the protection afforded by directional antennas in band 7 (HF). In New Delhi extensive field strength measurements of BBC transmissions radiating in different directions were made. Using published data regarding the transmission characteristics, protection ratios were evaluated. It has been found that, based on theoretical considerations, such directional antennas do not, in practice, afford the protection expected in different unwanted directions and the observed values of protection are comparable with those obtained from Recommendation 80. Off-beam radiation can, therefore, cause harmful interference in directions other than those of the main beam and needs to be considered when evaluating interference under practical conditions.

REFERENCES

- CHRISTIANSEN, W. N. [September, 1946] Directional patterns for rhombic antennae. *AWA Tech. Rev.*, 7, 33.
- CHRISTIANSEN, W. N. [October, 1947] Rhombic antenna arrays. *AWA Tech. Rev.*, 7, 361.
- CHRISTIANSEN, W. N., JENVEY, W. W. and CARMEN, R. D. [December, 1946] Radio-frequency measurements on rhombic antennae. *AWA Tech. Rev.*, 7, 131.
- DOLPH, C. L. [June, 1946] A current distribution for broadside arrays which optimizes the relationship between beamwidth and side lobe level. *Proc. IRE*, 24, 335.
- FOSTER, D. [October, 1937] Radiation from rhombic antennae. *Proc. IRE*, 25, 1327.
- HAYES, L. W. and MacLARTY, B. N. [September, 1939] The Empire Service broadcasting station at Daventry. *JIEE*, 85, 573.
- KRAUS, J. D. [1950] *Antennae*. First Ed., 93, McGraw-Hill, New York, USA.
- LAPORT, E. A. [March, 1952] Design data for horizontal rhombic antennae. *RCA Rev.*, Vol. 13, 1, 71 (see especially Fig. 4 of this Report).
- PAGE, H. [June, 1945] The measured performance of horizontal dipole transmitting arrays. *JIEE*, 92, 18.

CCIR Documents

- [1962] (Bad Kreuznach): X/15 (United Kingdom)
- [1963] (Geneva): X/221 (United Kingdom)
- [1963-66]: a. X/49 (Italy); b. X/124 (United Kingdom)
- [1970-74]: 10/180 (United Kingdom)
- [1974-78]: 10/57 (India).

BIBLIOGRAPHY

- LACHARNAY, S. [August, 1966] Nouvelles antennes rideaux en ondes décamétriques au centre d'Issoudun (France) (New HF curtain antennae at Issoudun (France)). *EBU Rev.*, **98-A**.
- PARMEGGIANI, C. [1963] Progetto e realizzazione delle nuove cortine a larga banda del Centro onde corte di Prato Smeraldo (Plan and implementation of new wide-band arrays at the Prato Smeraldo short-wave centre). *Elettronica*, **3**.
- PARMEGGIANI, C. [1964] Antenne a più dipoli con particolari leggi di distribuzione delle correnti di alimentazione (Multi-dipole antennae with feeder currents following different distribution laws). *Elettronica*, **1** and **2**.

RECOMMENDATION 80-1

DIRECTIONAL ANTENNAS IN HF BROADCASTING

(Question 44/10, Study Programme 44H/10)

(1951-1978)

The CCIR,

CONSIDERING

- (a) that the formation of strong subsidiary lobes of radiation can be avoided by the multiple feeding of, and appropriate current distribution in, appropriately spaced radiation elements;
- (b) that, by this means, it is theoretically possible to reduce the subsidiary lobes to a small value for a limited angle of slew of the main beam, provided the working frequency does not differ materially from the frequency for which an array is designed;
- (c) that the realization of these conditions is, however, not considered to be practicable on grounds of complexity of installation, difficulty of operation and maintenance of design performance,

UNANIMOUSLY RECOMMENDS

that in practical operating conditions, for purposes of calculating interference, the field strength in directions other than that of the main lobe cannot be assumed to be less than 222 mV/m at a distance of one kilometre for 1 kW of power supplied to the antenna.

RECOMMENDATION 414

PRESENTATION OF ANTENNA DIAGRAM

(Question 44/10, Study Programme 44G/10 and 44H/10)

(1963)

The CCIR

UNANIMOUSLY RECOMMENDS

1. that the new diagrams to be published in the CCIR Book of Antenna Diagrams be presented in the same form as at present, but that the curves of equal field strength be expressed in dB referred to the maximum, instead of in percentages of power;

2. that the curves of equal field strength be determined by the following values (in dB below the maximum):

0, 1, 2, 3, 4, 6, 8, 10, 13, 16, 20, 25, 30, 40 and ∞

or at least for some of these values, preferably:

0, 3, 6, 10, 20, 40 and ∞ .

REPORT 943 *

PROTECTION OF LF-MF SOUND-BROADCASTING STATIONS AGAINST LIGHTNING

(Question 48/10)

(1982)

Two documents have been submitted on this subject [CCIR, 1978-82a and b]. The information therein is summarized below:

1. Incidents occur not only at power inputs but also in transmitting antennas. Lightning strikes can cause flash-overs between the mast and the ground or on the guy insulators. At high powers (100 kW carrier), the arc is sustained by the transmitter power and may lead to the destruction of insulators.

Moreover, the surges thus created may result in equipment being damaged (matching unit capacitor of the antenna or transmitter in particularly with solid state circuitry, antenna feed line etc.). The capacitors are particularly vulnerable.

2. The frequency of incidents varies considerably from one geographical point to another. In France, they are appreciably more frequent in the southern part of the country and in high mountainous areas, and in Japan, in the northern part with heavy snowfalls.

3. The main methods of protection against these incidents are as follows:

- Use of traditional protection measures against overloads, such as spark-gaps of various kinds. In Japan, special circuits with judiciously placed spark-gaps are used for 1 kW solid-state transmitters.
- Use of non-linear resistance of about one megohm (for low voltages) at the guy-insulator terminals. These resistances release the static charges on the insulated parts of the guys; the static charges, which occur in stormy weather even without lightning, facilitate flash-overs, but the resistances are often destroyed if lightning strikes the mast directly.
- Shutting off the transmitter, by a very rapid device, in the event of an appreciable increase of the standing-wave ratio (SWR) at the antenna terminals (mismatching generally due to an arc).
- Substantial reduction of transmission power during storms (for very high powers, e.g., above 100 kW carrier).

4. It is important that the maximum magnitude of lightning strikes be determined, in order that devices to provide countermeasures such as:

- discharge capacity of the ball spark-gaps;
- current-carrying capacity of the conductors used in the matching circuits;

may be designed quantitatively.

A method for this estimation has been developed in Japan.

5. *The Allouis LF antenna (164 kHz)*: an LF antenna specially designed for protection against lightning has been developed in France. It consists of masts less than $\lambda/4$ high and the ring of guys at the top of each mast has no insulators; this means that lightning strikes are released directly into the ground and the guys form a protective cage for the other parts of the antenna. The radiation pattern is the same as for a conventional mast. The efficiency of this type of antenna has been proved during 7 years' operation.

For antennas higher than $\lambda/4$, or when it is necessary to radiate several frequencies from the same antenna, this type of design does not seem to be practicable at present.

REFERENCES

CCIR Documents

[1978-82]: a. 10/179 (France); b. 10/187 (Japan).

BIBLIOGRAPHY

LACHARNAY, S. [1975] Antenne de radiodiffusion à B. km protégée contre la foudre (LF broadcasting antenna protected against lightning). *Radiodif. Télév.* 36.

* This Report should be brought to the attention of Study Group 1 and Study Group VIII of CCITT.

REPORT 617-2

SOUND-BROADCASTING RECEIVERS AND RECEIVING ANTENNAS

Principal characteristics for frequency planning purposes

(Question 49/10)

(1974-1978-1982)

1. Introduction

Many characteristics of sound-broadcasting receivers and antennas may be defined together with methods of measurements and limiting values but only those concerned with frequency planning are of interest to the CCIR. Certain aspects of these characteristics are treated in numerous Recommendations and Reports (see Recommendations 237 (Kyoto, 1978), 239, 331, 332, 333 (Kyoto, 1978), 334, 412, 415, 416, 447, 559, 560; Reports 184, 185 (Kyoto, 1978), 186 (Kyoto, 1978), 193 (Kyoto, 1978), 300, 302, 458, 464, 794).

Many of the contents of these Recommendations and Reports have been rendered obsolete by changes in receiver design techniques. Furthermore, the data on some receiver characteristics is presented in the form of maximum, mean and minimum values for a wide range of designs.

This Report lists the characteristics of sound-broadcasting receivers and antennas necessary for frequency planning work with appropriate references where definitions, methods of measurement and limits come within the scope of other international organizations such as the IEC and CISPR.

2. Categories of receivers

A planning conference should take into consideration the category of receiver which will be used for the system of broadcasting service envisaged.

Data collected in accordance with this Report should relate only to the mean values of the characteristics for receivers that are typical of good, current engineering practice in the country concerned. This is to avoid undue influence being exerted on future planning standards by receiver designs at the extreme upper and lower ends of the performance range.

A reference receiver for planning purposes may be assumed to be a hypothetical receiver of approximately average performance with respect to currently available domestic receivers.

3. Technical characteristics**3.1 Antennas***Frequency-modulation reception*

The values of antenna characteristics contained in Recommendation 599 and Report 122 relate to antennas *in situ*. Only data relating to directivity, forward gain and cross polarization protection of antennas tested under idealized conditions need be recorded.

Definitions and methods of measurement are contained in IEC Publication 138.

Amplitude-modulation reception

No characteristics are suggested for antenna systems.

Note. — IEC Publication 315-1A describes methods of coupling signals into magnetic antennas for measurements.

3.2 Selectivity**3.2.1 Pass-band and attenuation slope***Amplitude-modulation receivers*

These forms are defined in IEC Publication 315-3, clause 17:

“17. Definitions

The *pass-band* B_a , is the band of radio-frequencies or intermediate frequencies limited by the two frequencies for which the attenuation exceeds that at the most favoured frequency by some agreed value (a) dB (see clause 19).

Note. — The CCIR suggests that this value in general be 6 dB, except for high-quality radio telephony receivers, where this value is 2 dB (Recommendation 332).

The *attenuation slope* on each side of the pass-band is the ratio of the difference between the attenuations corresponding to two different frequencies beyond the pass-band, and the difference between these frequencies. It is expressed in dB/Hz or dB/kHz (see clause 19).

Note 1. — This property is important in those cases where an excessively large attenuation slope may lead to serious distortion of the phase/frequency characteristics in the pass-band.

Note 2. — The CCIR suggests that sufficient indication of single-signal selectivity is obtained by considering the frequency differences corresponding to attenuations of 20 dB, 40 dB, 60 dB and, if possible, 80 dB, reckoned from the limit frequencies of the pass-band. These differences are indicated as B_{a+20} , B_{a+40} , B_{a+60} and B_{a+80} , respectively. If the values thus obtained are essentially equal for the two sides of the pass-band, it is sufficient to give mean values.

Note 3. — An alternative method of obtaining sufficient indication of single-signal selectivity is to consider the frequency difference corresponding to attenuations of 20 dB, 40 dB, 60 dB and if possible, 80 dB, higher than that at the actual operating frequency. These differences are indicated as B_{20} , B_{40} , B_{60} and B_{80} respectively.”

Method of measurement

The adjacent channel selectivity of the receiver is measured according to clause 30 of IEC Publication 315-3, and the results expressed as stated in clause 31 (*ibid.*). From these results the pass-band and attenuation slope may be measured.

FM receivers

For FM receivers the terms are defined similarly but are difficult to measure due to limiting effects.

The adjacent channel rejection curve may be measured directly by the method of IEC Publication 315-4 *, and compared with the RF protection ratio curves given in Recommendation 412.

3.2.2 Overall radio frequency and audio frequency response (including loudspeaker)

Definition and method of measurement

The definition corresponds to that in IEC Publication 315-2, § 50, on the understanding that the option of using a modulated radio frequency input signal is adopted in the method of measurement (*ibid.* clause 51). If it is not practical to make acoustic response measurements, an alternative is to make the corresponding electrical response measurement (*ibid.* clause 57) and to correct this measurement from the best information available on the loudspeaker response.

Presentation of results

The unweighted response is normally recorded as a smoothed curve for frequencies up to 12 kHz. For planning purposes a tabulation at the following frequencies is adequate:

Frequency (kHz): 0.4; 1.0; 2.0; 3.15; 4.0; 5.0; 6.3; 7.1; 8.0; 9.0; 10.0; and 12.5.

3.2.3 Intermediate-frequency rejection ratio

This characteristic is of interest for both amplitude- and frequency-modulation receivers.

Definition: for AM receivers see IEC Publication 315-3, clause 24;

for FM receivers see IEC Publication 315-4 *.

Note. — An interfering signal at the intermediate frequency of an FM receiver may be either amplitude or frequency modulated, and, if the receiver has a balanced antenna input circuit, can be applied in either a balanced or an unbalanced mode. Different values of rejection will in general, be obtained in each of these four conditions. This subject is under consideration in IEC Sub-Committee 12A.

Method of measurement

The single-signal method described in IEC publications 315-3 and 315-4 *.

Presentation of results

From the graphs obtained according to clause 27 of Publication 315-3 only the worst figure in each broadcasting band is recorded.

3.2.4 Image rejection ratio

Definition: IEC publications 315-3, clause 24 for amplitude-modulation and 315-4 * for frequency-modulation.

Method of measurement

For the amplitude-modulation bands the single-signal method described in IEC Publication 315-3 clause 25 is used.

* In preparation.

For frequency-modulation broadcasting in band 8 (VHF) it is necessary to use a two-signal method as described in IEC Publication 315-4 *.

Presentation of results

From the graphs obtained according to IEC Publications 315-3, clause 27 and 315-4 *, only the worst figure in each broadcasting band is retained.

3.2.5 Intermediate-frequency values

The main factors determining the interference in receivers are: the value of image and intermediate-frequency rejection ratio and the production of harmonics of the intermediate frequency and/or the oscillator frequency.

It is necessary to choose the value of the intermediate frequency carefully to minimize the risk of interference without unduly increasing the cost of the receiver.

Amplitude-modulation receiver

Numerous intermediate frequencies are, at present, in use; some of these are given in Table I:

TABLE I

Country	Oscillator position	Intermediate frequency (kHz)			Observation
		(1)	(2)	(3)	
France	High	455	480		
United Kingdom	High	460	470		
German Democratic Republic	High	455	468		
Japan	High	455			

For the future, attention is drawn to Report 458, § 3.2.4 which states the conditions for an appropriate choice. Annex II to Report 458 should also be taken into account.

After the establishment of a frequency plan for Regions 1 and 3 with a 9 kHz carrier-frequency separation in both band 5 (LF) and band 6 (MF), two intermediate frequencies, integral multiples of 9 kHz should be standardized to minimize interference and to permit all available channels to be used.

The reference [CCIR, 1970-74a] gives in its Annex II additional information on the determination of intermediate frequency (see also [CCIR, 1970-74b, c, d, e, f and g].

3.3 Sensitivity

3.3.1 Definition

For planning purposes, "sensitivity" is understood to mean "noise-limited sensitivity" defined for amplitude modulation receivers in IEC Publication 315-3, and for frequency modulation receivers in IEC Publication 315-4 *. This refers to a chosen value of audio-frequency signal-to-noise ratio which is defined in IEC Publication 315-3, clause 72.

Sensitivity should be presented as a single mean figure for each broadcasting band, from which the minimum usable field-strength may be calculated.

Other limitations may be significant, for example, impulsive noise, galactic noise, atmospheric noise, man-made noise, etc., depending on the location and on the receiving antenna used.

3.3.2 Conditions of measurement

According to IEC Publications 315-3, clauses 76 and 77, for amplitude modulation and 315-4 * for frequency modulation.

* In preparation.

No specific signal-to-noise ratio is standardized at this moment, but a choice may be made for the type of receiver being considered.

The following parameters are suggested:

- audio-frequency signal-to-noise ratio: 26 dB for amplitude modulation
30 dB for frequency modulation
- output power: 50 mW.

Note. — For receivers of high audio-frequency output power, a reference output power greater than 50 mW may be convenient.

3.4 *Radio-frequency protection ratios*

General

The radio-frequency protection ratio *, for planning purposes, is defined as the radio-frequency wanted-to-interfering signal ratio at the receiver input, producing a specified grade of sound impairment. It will depend, among other things, on the nature of the wanted signal (modulation characteristics, frequency deviation, etc.), on the type of interfering signal (AM, FM, CW, etc.) and their frequency separation. The information should be presented in the form of graphs showing the protection ratio, for interference assessed as Grade 4 impairment **, i.e. perceptible, but not annoying, as a function of frequency separation between the wanted and unwanted signals for each type of unwanted signal. If the protection ratio varies with the wanted signal level (due to non-linearity in the input stages of the receiver), this should be indicated. For frequency planning purposes the protection ratio figures obtained, for Grade 4 impairment, would need to be modified to take into account the grade of impairment that can be tolerated, bearing in mind the percentage of the time the impairment can be suffered. For this purpose, additional observations for more than one grade of impairment would be valuable.

“Usable field strength” and “coverage area” are defined in Recommendation 499.

Frequency-modulation receivers

The radio-frequency protection ratio graphs should cover frequency separations from zero to approximately 1 MHz above and below the wanted signal frequency.

It should be noted that protection ratio is only directly related to impairment grade under linear conditions. For example, whereas a 6 dB increase in the level of an unwanted co-channel signal may result in an impairment assessment that is numerically one grade smaller, a similar increase in the level of an adjacent channel interfering signal may lower the impairment grading by more than one grade. To convert a protection ratio based on Grade 4 impairment to that for a lower grade, it is necessary to define this relationship. This can be done by making observations at levels of impairment other than that of Grade 4.

Amplitude-modulation receivers

Radio-frequency protection ratio for amplitude-modulation receivers employing an external antenna is defined in terms of the wanted-to-interfering signal ratio at the receiver input terminals. However, for receivers employing built-in magnetic antennas, the protection ratio is more conveniently expressed in terms of the ratio of wanted-to-interfering field-strength required to produce a specified grade of sound impairment. The protection ratio will depend, amongst other things, on the depth of modulation, the programme material of both signals, the extent of any audio-frequency bandwidth restriction, the degree of compression applied at the transmitter and the frequency spacing between wanted and unwanted signals. The protection ratio figures for Grade 4 impairment should be presented in graphical form, relating them to frequency spacing from zero up to 3 or 4 channel widths.

In some instances objective methods are available which provide good correlation with subjective observations.

3.5 *Oscillator frequency*

The position of the oscillator frequency relative to that of the wanted signal should be indicated as follows: “low” or “high”.

3.6 *Interference generated by the receiver*

The radiation of the oscillator at its fundamental frequency and its harmonics on the one hand and of the intermediate-frequency and its harmonics on the other hand should comply with CISPR Recommendation No. 24 (see IEC/CISPR Publication No. 7, Geneva).

* The basic definition of RF protection ratio is given in Recommendation 447. Recommendation 412 gives information on the protection ratios for FM receivers.

** See Recommendation 562.

4. Results (receivers)

§	Characteristics	Band (R.R., art. 2)	Country			
			UK(1)	Japan(3)	Japan(3) (4)	India(5) (6)
3.2.1	Passband at 6 dB (kHz)	LF	5,9	6,5		5,90
		MF	6,4			
		HF	—			
		VHF	—			
	Attenuation slope at 26 dB (dB/kHz)	LF	3,3	4,0		2,90
		MF	2,95			
		HF	—			
		VHF	—			
	Attenuation slope at 46 dB (dB/kHz)	LF	2,35	3,3		2,30
		MF	2,25			
		HF	—			
		VHF	—			
	Attenuation slope at 66 dB (dB/kHz)	LF	—			2,0
		MF	—			
		HF	—			
		VHF	—			
3.2.2	Overall (RF + AF) frequency response (dB)	at				
		0,4 kHz				0
		1,0 kHz				0
		2,0 kHz				— 1,5
		3,15 kHz				— 3,0
		4,0 kHz				— 5,0
		5,0 kHz				— 8,0
		6,3 kHz				— 14,0
		7,1 kHz				—
		8,0 kHz				— 20,6
		9,0 kHz				— 22,5
		10,0 kHz				— 24,9
		12,5 kHz				—
3.2.3	Intermediate-frequency rejection ratio (dB)	LF	— 27			
		MF	— 27			
		HF	—			
3.2.4	Image rejection ratio (dB)	LF	— 38	—	—	—
		MF	— 36	39	—	—
		HF	—	9	75	20
		VHF	—	—	—	—
3.2.5	Intermediate-frequency value	MF-LF (kHz)	460 or	455	2,0 MHz	450 to
		HF (kHz)	470		or 10,7 MHz	460 kHz
		VHF (MHz)	—	10,7	or 66,4 MHz	
3.3.2	Sensitivity (noise limited) audio-frequency signal-to-noise ratio 26 dB Input (mV/m)	LF	1,2			0,15
		MF	0,5			
		HF	—			
	Audio-frequency signal-to-noise ratio 30 dB Input (mV/m)	VHF	—			
3.5	Oscillator frequency	LF-MF-HF (kHz) VHF (MHz)	High —	High —		High —
3.6	Interference generated by receiver		(2)			

(1) See [CCIR, 1974 – 78].

(2) Receivers comply with CISPR Recommendation No. 24.

(3) See [CCIR, 1978 – 82a].

(4) Double superheterodyne.

(5) See [CCIR, 1978 – 82b].

(6) Measurements made at 6 MHz.

REFERENCES

CCIR Documents

[1970-74]: **a.** 10/273 (France); **b.** 10/186 (United Kingdom); **c.** 10/272 (France); **d.** 10/274 (France); **e.** 10/275 (France);
f. 10/276 (France); **g.** 10/277 (France).

[1974-78]: 10/130 (United Kingdom).

[1978-82]: **a.** 10/184 (Japan); **b.** 10/204 (India).

SECTION 10A-2: SOUND BROADCASTING IN THE TROPICAL ZONE

Recommendations and Reports

RECOMMENDATION 48-1

**CHOICE OF FREQUENCY FOR SOUND BROADCASTING
IN THE TROPICAL ZONE**

(Question 45/10, Study Programme 45E/10)

(1951-1978)

The CCIR,

CONSIDERING

- (a) that an audible interfering beat note may occur between two adjacent broadcasting carriers in the shared bands, irrespective of the position of the frequencies used by other services;
- (b) that mobile stations, due to their lower frequency stability and variable location, are likely to cause more interference to sound broadcasting in the Tropical Zone, than fixed stations, particularly when operated within the shared bands, when using class of emission A3E,

UNANIMOUSLY RECOMMENDS

1. that it is not necessary for frequencies of other services sharing frequency bands with sound broadcasting in the Tropical Zone to be assigned only midway between the broadcasting frequencies. When, however, mid-spaced frequencies are not assigned, it is desirable that the same frequencies should be assigned for other services, than broadcasting;
2. that, wherever possible, administrations should avoid the operation of mobile stations in the Tropical Zone within the bands shared with broadcasting, particularly as regards the use of class of emission A3E by such mobile stations.

RECOMMENDATION 49

**CHOICE OF TRANSMITTER SITE AND
TYPE OF ANTENNA FOR SOUND BROADCASTING
IN THE TROPICAL ZONE**

(Question 45/10, Study Programme 45E/10)

(1951)

The CCIR,

CONSIDERING

- (a) the provisions of Art. 18, Nos. 1805 to 1809, of the Radio Regulations;
- (b) that all possible sources of interference to broadcasting should be minimized,

UNANIMOUSLY RECOMMENDS

1. that administrations should make every effort to comply, as soon as possible, with the Regulations with regard to the siting of stations and the use of directional antennas when the nature of the service permits;
2. that administrations should take steps to ensure that all interference to broadcasting and other radio services in the Tropical Zone produced by radiation, such as key-clicks, sideband spread, etc., be kept to a minimum;
3. that the broadcasting services in the Tropical Zone should, for their part, reciprocally take similar precautions to facilitate the operation of other services working in other zones in the shared bands.

RECOMMENDATION 216-2

PROTECTION RATIO FOR SOUND BROADCASTING IN THE TROPICAL ZONE

(Report 302, Question 45/10, Study Programme 45E/10)

(1951-1953-1956-1978-1982)

The CCIR,

CONSIDERING

- (a) that it is necessary to establish a value for the protection ratio for sound broadcasting within the shared bands in the Tropical Zone;
- (b) that the operation of sound broadcasting transmitters with 10 kHz separation makes it difficult to measure the protection ratio with a receiver having an audio-frequency cut-off in excess of 5 kHz;
- (c) that more information concerning noise values in various parts of the Tropical Zone is necessary to arrive at a more accurate value of minimum field strength to which the protection ratio should be maintained; however, this minimum field strength should provide satisfactory reception at the limit of the broadcast station coverage area, as provided by No. 2666 of the Radio Regulations,

UNANIMOUSLY RECOMMENDS

1. that, for the present, and wherever practicable, in the Tropical Zone, the ratio of median-wanted sound broadcasting carrier to median-unwanted carrier shall be 40 dB, to provide a signal-to-interference ratio of not less than 23 dB for at least 90% of the hours and 90% of the days (taking into consideration the effect of short- and long-term fading — see Recommendation 411);
2. that the protection ratio thus defined should be measured at the output of a receiver provided with a filter having an audio-frequency cut-off of 5.0 kHz;
3. that, for the present, the protection ratio, as defined in § 1, should be maintained throughout the broadcast coverage area in the Tropical Zone to a minimum field strength of 200 $\mu\text{V/m}$ or any lower value consistent with satisfactory reception;
4. that the conditions of operation required for sound broadcasting in the Tropical Zone should be compatible with the protection ratio required for other services outside the Tropical Zone, in accordance with Number 346 of the Radio Regulations.

REPORT 303-2 *

DETERMINATION OF THE EFFECTS OF ATMOSPHERIC NOISE
ON THE GRADE OF RECEPTION IN THE TROPICAL ZONE

(Question 45/10, Study Programme 45D/10)

(1978)

1. Introduction

One of the primary requisites for establishing the limits of power for sound broadcasting is the determination of the value of the signal-to-noise ratio required for satisfactory listening in the absence of any other interference. Availability of reliable noise data is, therefore, necessary. In most of the countries in the Tropical Zone, which are either underdeveloped or developing and where man-made noise is comparatively low, atmospheric radio-noise is the principal source of interference in band 7 (HF).

* In view of the opinion expressed by Study Group 6, Study Group 10 will consider the possibility of transferring this text to Study Group 6 at the appropriate time.

2. Results of studies

2.1 The characteristics of atmospheric radio noise such as amplitude, duration and repetition rate of individual impulses are important in determining the noise response of the receiver. Atmospheric radio noise can be classified as either "fluctuation noise" or "impulsive noise". A theoretical analysis of the problem, i.e. dependence of the response of the receiver on fluctuation and impulsive noise has been made by [Thomas and Burgess, 1947]. It has been concluded there that:

2.1.1 the r.m.s. and peak values of the output response produced in a receiver by fluctuation noise are both proportional to the square root of the receiver bandwidth;

2.1.2 the peak and r.m.s. values of the output response produced in a receiver by a unit impulse are respectively proportional to the bandwidth and the square root of the bandwidth;

2.1.3 the output waveform is independent of the waveshape of the impulse if its duration is less than the order of the reciprocal of the receiver bandwidth, but is dependent only on its time integral;

2.1.4 the minimum value of tolerable signal-to-noise ratio for a high quality sound-broadcasting service is 40 dB.

[Landon, 1936; Jansky, 1939] have also found, on the basis of some experiments, the same bandwidth relationship.

2.2 [CCIR, 1956a] gives the results of an experimental study based on both objective and subjective methods of determining the signal-to-atmospheric noise ratios. A series of experiments were carried out at Nagpur (India) during the years 1953 and 1955 to determine the signal-to-noise ratio required for satisfactory listening. More than 6000 opinions were collected. It was concluded that a signal-to-noise ratio of 40 dB was required for satisfactory listening under steady signal conditions.

2.3 [CCIR, 1956b] gives the results of studies carried out to determine the signal-to-noise ratio. During March/April 1951, more than 3000 readings were taken and the corresponding noise values determined. The average values of signal-to-noise ratio of 41, 42 and 41 dB were observed at 2.5, 5 and 10 MHz respectively. The conclusion of these studies was that an average of 41 to 42 dB signal was necessary to establish a relatively good short-wave broadcasting service. However, South African Broadcasting Corporation uses signal-to-noise ratio of 40 dB.

2.4 [CCIR, 1959], entitled "Determination of noise level for tropical broadcasting", reports measurements of atmospheric noise made in Delhi, using an experimental arrangement, similar to the well-known Thomas method and the determination of minimum signal required for satisfactory listening. It was concluded on the basis of analysis of these measurements that 40 dB protection over the prevailing noise was required for satisfactory listening for 50% listener satisfaction for 90% of the time irrespective of the frequency of operation and the time of the day.

3. Conclusion

Results of the studies, relating bandwidth and noise response, are mainly based on theoretical considerations and laboratory experimentation. It is, therefore, necessary that a detailed study under actual conditions, correlating the receiver response and noise encountered in the Tropical Zone, be made to find an answer to § 1 of Question 45/10.

On the basis of the studies described in this Report, it is also reasonable to recommend provisionally a signal-to-noise ratio of 40 dB to ensure a satisfactory reception for at least 90% of the time. Further investigation by different administrations in the Tropical Zone is required to confirm this.

REFERENCES

- JANSKY, K. G. [1939] An experimental investigation of the characteristics of certain types of noise. *Proc. IRE*, Vol. 27, 763-768.
 LANDON V. D. [1936] A study of the characteristics of noise. *Proc. IRE*, Vol. 24, 1514-1521.
 THOMAS H. A. and BURGESS R. E. [1947] Survey of existing information and data on radio noise over the frequency range 1-30 MHz. DSIR Radio Research Report No. 15.

CCIR Documents

- [1956] (Warsaw): a. 358 (India); b. 423 (Republic of South Africa).
 [1959] (Los Angeles): 92 (India).

REPORT 302-1

INTERFERENCE TO SOUND BROADCASTING IN THE SHARED BANDS IN THE TROPICAL ZONE

(Question 45/10 and Study Programme 45E/10)

(1956-1959-1963-1978)

1. Introduction

This Report is a summary of the information available on the question of interference in the bands shared with sound broadcasting in the Tropical Zone for the determination of the radio-frequency protection required for a broadcast signal in the presence of interference. The radio-frequency (RF) protection ratio is the value of the radio-frequency wanted-to-interfering signal ratio that enables, under specified conditions, the necessary audio-frequency protection ratio to be obtained at the output of a receiver (Recommendation 447). These specified conditions include such diverse parameters as spacing Δf of the wanted and interfering carrier, emission characteristics (type of modulation, modulation depth, frequency deviation, etc.), receiver input and output levels as well as the receiver characteristics (selectivity and susceptibility to cross-modulation, etc.). The audio-frequency (AF) protection ratio is the agreed minimum value of the audio-frequency signal-to-interference ratio considered necessary to achieve a subjectively defined reception quality. This ratio may have different values according to the type of service desired (Recommendation 447). The wanted signal is from a broadcasting station operating in the shared bands in the Tropical Zone and the interfering signal may be either:

- from A1A/A1B and A2A/A2B telegraphy,
- A3E telephony and broadcasting or combinations of more than one type of emission.

Agreed values of protection ratios are necessary for the solution of frequency assignment problems in amplitude modulation sound-broadcasting systems and may also serve as basic reference data for the evaluation of the relative effectiveness to be expected of various amplitude modulation transmission systems.

The minimum wanted field to which this protection ratio is to be maintained is also to be determined taking into account the noise levels prevalent in different parts of the Tropical Zone.

In this Report, Part I deals with the considerations for the determination of protection ratios and Part II is concerned with the determination of the minimum value of the wanted field to which the recommended protection ratio is to be maintained.

PART I (PROTECTION RATIO)

2. Studies and measurements

Various administrations have carried out studies to determine, by subjective tests, the protection ratios for different percentages of listener satisfaction. In general, the measurements have been carried out at the output of the receiver, fitted with simple filters having an audio-frequency cut-off of 5 kHz. Some measurements have been made for cut-off frequencies of 6, 7, 8 and 9 kHz also. These measurements have been carried out for various carrier frequency separations up to 10 kHz. The permissible frequency tolerances of both wanted and unwanted signals, as specified in Appendix 7 of the Radio Regulations, have been taken into account while determining the protection ratios.

3. Results

3.1 [CCIR, 1956a], gives the results of an extensive series of subjective tests carried out by generally simulating domestic broadcast listening conditions in the absence of fading. A broadcast receiver, with a substantially flat response up to about 4 kHz, but with a filter giving an attenuation of about 8 dB at 5 kHz and a sharp cut-off above this frequency, was used.

For unwanted signals of classes of emission A2A/A2B and A3E and for various frequency separations between the carriers of the wanted and unwanted signals, listeners were presented with various ratios of wanted-to-unwanted signal in random order and asked to state whether they considered the reception satisfactory or unsatisfactory. Table I gives information for the wanted-to-unwanted signal ratios required to provide 90%, 70% and 50% listener satisfaction for unwanted signals of classes of emission A2A/A2B telegraphy, A3E telephony and broadcasting and for:

- frequency separation of 0 kHz and 5 kHz exactly; and
- nominal frequency separations of 0 kHz and 5 kHz under the most unfavourable conditions that could arise within the maximum permissible frequency tolerances of both wanted and unwanted signals, as were specified in the Radio Regulations, Atlantic City, 1947.

Utilizing the information given in the above document, curves giving relative protection ratios for frequency separation between 0 and 5 kHz have been derived and are shown in Fig. 1. The actual values for any frequency separation up to 5 kHz can, however, be obtained from these curves and from the value of co-channel protection ratio given in Table I for different percentages of listener satisfaction.

3.2 [CCIR, 1956b], gives details of the results of subjective tests made to determine the ratio of wanted-to-unwanted signal as a function of the frequency separation of the carriers of the two signals. Two typical broadcast receivers were used, having a fairly uniform response up to about 4 kHz falling to about -8 dB to -10 dB at 5 kHz. The unwanted signal was modulated by speech with a frequency range limited to 3 kHz. The ratio necessary to satisfy nearly all listeners varied from about 54 dB at 1 kHz separation, to a maximum of 56 dB between 2 and 3 kHz separation, falling to 52 dB at 5 kHz separation. The corresponding ratios when nearly all the listeners found the conditions unsatisfactory, were about 15 dB lower. Subsequent tests to determine the ratio at which interference was "perceptible" gave intermediate values.

TABLE I

Interfering emission	Maximum frequency tolerance (App. 7 to Radio Regulations) (Hz)	Frequency separation (kHz)	Signal-to-interference ratios for 90%, 70% and 50% listener satisfaction (dB)					
			Ignoring frequency tolerances			Allowing for maximum frequency tolerances		
			90%	70%	50%	90%	70%	50%
A2B – fixed (525 Hz tone)	150	0	35	31	28	42	38	34
A2B – mobile (525 Hz tone)	1000	0	35	31	28	49	45	42
A3E – fixed (3 kHz maximum modulation)	150	0	33	30	28	40	36	33
A3E – mobile (3 kHz maximum modulation)	1000	0	33	30	28	50	47	44
A3E – broadcasting	150	0	33	30	28	44	40	36
A2B – fixed (525 Hz tone)	150	5	39	37	36	43	40	38
A2B – mobile (525 Hz tone)	1000	5	39	37	36	49	46	43
A3E – fixed (3 kHz maximum modulation)	150	5	48	44	40	50	46	42
A3E – mobile (3 kHz maximum modulation)	1000	5	48	44	40	52	48	45
A3E – broadcasting	150	5	48	46	44	49	46	44

3.3 [CCIR, 1956c], gives the results of similar tests made with two types of receiver, one a narrow-band receiver with considerable attenuation above 3 kHz, and the other a wider-band receiver with an attenuation of about 8 dB at 5 kHz. For the wide-band receiver, as commonly used for broadcast listening, the wanted-to-unwanted signal ratio for various frequency separations follows the same general curve as before and, at a frequency separation of 5 kHz, is 43 dB for 90% listener satisfaction.

3.4 Comparison of the results arrived at in the three documents shows that there is a considerable degree of agreement. The values are within ± 5 dB and those in the United Kingdom and Federal German Republic documents are almost of the same order as those given by India. There is, therefore, sufficient justification to assume that the values of the wanted-to-unwanted signal ratio which provide the various degrees of listener satisfaction given in Table I are reliable.

From an examination of Table I, it will be seen that, when the unwanted signal is a mobile A3E emission, there is a considerable increase in the required wanted-to-unwanted signal ratio when allowance is made for maximum frequency tolerances. The possibility of interference to broadcasting services from mobile services would be appreciably reduced, particularly where the two services have the same nominal frequency, if the mobile services operated within closer frequency tolerances, if possible with the same tolerance as the fixed and broadcasting services.

Although the sidebands of the unwanted signal contributed to some extent to the interference, the heterodyne beat note between the carriers of the wanted and unwanted signals was always predominant. This was the case for a frequency separation of 5 kHz between the two signals and, although the receivers used provided an attenuation of some 8 to 10 dB to the beat note, the use of a filter to provide further attenuation would have reduced the required wanted-to-unwanted signal ratio. Further studies are needed to ascertain what additional attenuation at 5 kHz could usefully be provided and what would then be the required wanted-to-unwanted signal ratio. For this purpose, consideration should also be given to the possibility of providing suitable filters in new and existing receivers.

It is agreed that since the figures shown in Table I are derived from measurements made under steady-state conditions, appropriate allowance should be made for fading, when using these figures to derive the protection ratios to be used in practice. The value of fading allowance to be used for broadcasting in the Tropical Zone requires further study.

India has given the opinion that protection ratios should be based on those figures in Table I that provide 90% listener satisfaction and that the figures for 70% and 50% are for information only and should not be regarded as the lower limit of acceptability. Australia, the Republic of South Africa and France are of the opinion that a listener satisfaction higher than 50% should be provided. The Republic of South Africa and Australia consider that it would be impracticable to achieve 90% listener satisfaction from the point-of-view of signal-to-noise ratio, particularly under heavy static conditions, and therefore, to aim at achieving about 80% listener satisfaction for signal-to-interference would be more realistic. The United Kingdom is of the opinion that the wanted-to-unwanted signal ratios given in Table I are based on too critical an assessment and that lower figures would be generally acceptable. The United Kingdom is also of the opinion that, because of practical considerations, protection ratios will have to be based on figures providing about 50 to 70% listener satisfaction.

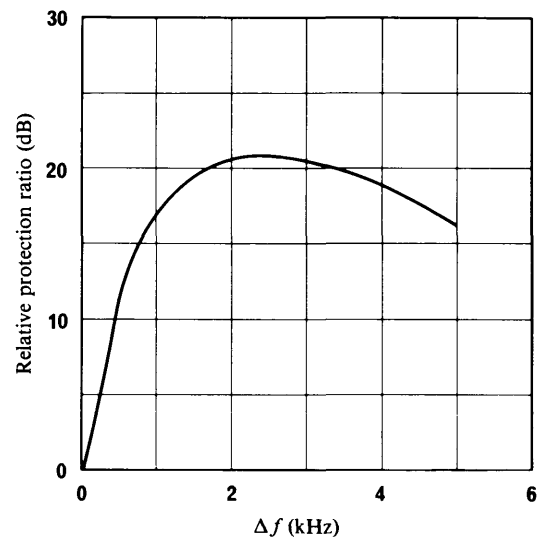
3.5 [CCIR, 1959a], summarizes the data presented at various times regarding the protection ratio of the wanted-to-unwanted signal that is required for just tolerable interference at various values of separation of carrier frequencies. The curves obtained in the document are given in Fig. 2. A summary of the conditions of the Post Office tests is also given in the document and is reproduced in § 3 of Annex I.

3.6 [CCIR, 1959b], describes work carried out in connection with Question 1/XII. Protection ratios required against A1A and A1B emissions, both for speech and music programmes, A2A/A2B and A3E emissions for music programmes have been assessed. The results are in § 4 of Annex I.

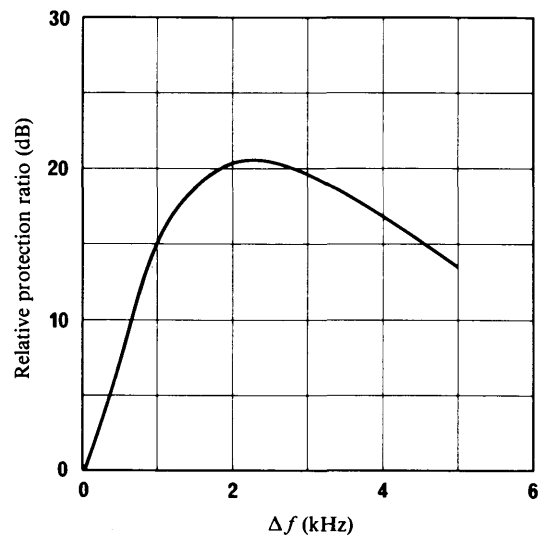
[CCIR, 1959b] takes into consideration the standards for frequency tolerances laid down in the Radio Regulations, Atlantic City, 1947. The summary is confined to two limiting cases, namely frequency separations of 0 and 5 kHz respectively and indicates the protection ratios required for various types of emission. The document also states that the results refer to steady-state conditions and that an appropriate allowance should be made for fading.

An analysis of selectivity characteristics of receivers in use in India is also given in the document. Extensive tests were carried out to investigate, from the point of view of listener satisfaction, the effect of reducing the bandwidth of broadcast transmissions on overall quality.

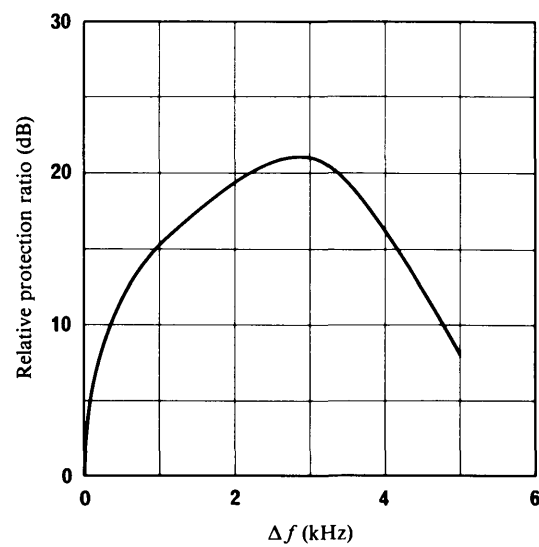
The conclusions in the Indian document is that it is necessary to maintain the normal bandwidth of modulating frequencies to well beyond 5 kHz. Any modifications to the design of broadcast receivers tending to attenuate frequencies at 5 kHz and lower will, therefore, result in serious deterioration in the quality of reception.



a) Wanted: broadcasting
Unwanted: broadcasting



b) Wanted: broadcasting
Unwanted: telephony (A3E)



c) Wanted: broadcasting
Unwanted: telegraphy
(A3B with 525 Hz tone modulation)

FIGURE 1 – Relative protection ratio as a function of frequency separation, Δf

3.7 [CCIR, 1962 and 1963a], give results of further listening tests for frequency separation of 5 to 10 kHz. The experimental set-up was the same as before, except that, as recommended in Study Programme 1C/XII (1966), filters with cut-off frequencies at 5, 6, 7, 8 and 9 kHz were incorporated at the output of the receiver (ordinary domestic type with average selectivity and fidelity characteristics). The attenuation at 1 kHz below the nominal cut-off frequency of the filter is 6 dB; it is more than 30 dB at the cut-off frequency and very steep thereafter. The wanted signal was modulated with a speech programme, the interfering signals were modulated with music, speech, A1A/A1B and A2A/A2B telegraphy (Morse — 525 Hz tone modulation). The documents show that, on the basis of these experiments, which relate to values required for 90% listener satisfaction, the protection ratio required in each case gradually decreases as the carrier separation increases beyond 5 kHz and also as the cut-off frequency of the filter decreases. Table II gives the values of the protection ratios required for various types of interference when no filter is used in the output circuit of the receiver.

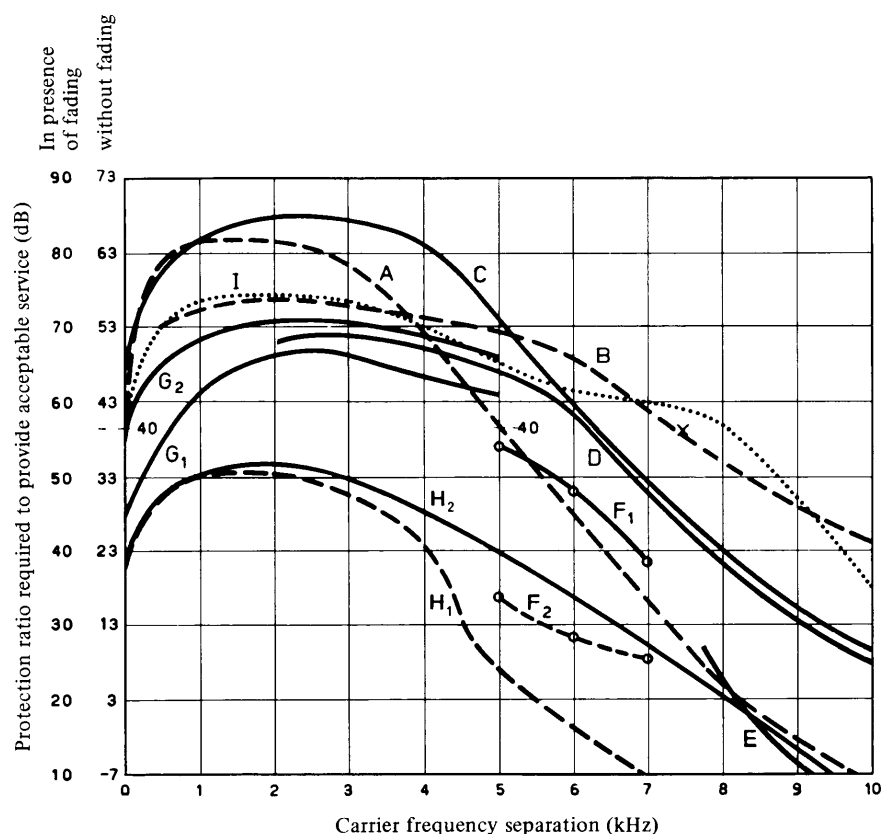


FIGURE 2 — Protection ratios required to provide acceptable service

DESIGNATION OF CURVES

A*	VAN DER POL (1933)	G ₁ **	Indian tests (50% satisfaction)
B*	BRAILLARD (CCIR, Bucharest, 1937)	G ₂ **	Indian tests (90% satisfaction)
C*	B.P.Q tests, 1948	H ₁ **	Curve used by the IFRB, 1956, for HF broadcast plans
D**	B.P.O. tests, 1950	I***	French tests, 1962
E**	B.P.O. tests, 1951	H ₂ **	Curve drawn from values of "Receiver Discrimination" given in IFRB Technical Standards Series "A" 1968.
F ₁ **	B.P.O. tests, 1956 (no filter)		
F ₂ **	B.P.O. tests, 1956 (whistle filter)		

* Criterion of test : Just perceptible interference

** Criterion of test : Just tolerable interference

*** Corresponding to a "tolerable" interference for five different types of receivers.

TABLE II

Wanted signal	Interfering signal	Frequency separation (kHz)	Desired protection ratio (dB)
Speech	Music	5	46
Speech	Music	10	22
Speech	Speech	5	44
Speech	Speech	10	16
Speech	A3B telegraphy	5	38
Speech	A3B telegraphy	10	8
Speech	A1B emission	5	38
Speech	A1B emission	10	8
Music	Music	5	38
Music	Music	10	12
Music	Speech	5	38
Music	Speech	10	6

Note. — The protection ratios quoted refer in all cases to the ratios at the input to the receiver, no account having been taken of the effect of using directional receiving antenna or of the advantage that can be obtained by using different polarization for transmission of the wanted and unwanted signals.

With the incorporation of filters at the output of the receiver, the required protection ratios become less; the degree of reduction depends upon the frequency separation, the cut-off frequency of the filter and to some extent on the nature of the interference. The details are shown in [CCIR, 1962], (Table II and Figs. 1 to 5) and [CCIR, 1963a] (Table III and Figs. 1 to 3).

The documents conclude that, in assessing the required protection, the allowable frequency tolerance limits of various emissions must be taken into account. Considering the frequency tolerance standards, as laid down in the Radio Regulations, the increase in the required protection has been estimated. For a frequency of operation of 5 MHz, in the limiting case of interference from a broadcast station, the increase in required protection would be of the order of 2 dB for 5 kHz frequency separation and 1 dB for 10 kHz frequency separation. For frequencies of operation higher than 5 MHz, such protection ratios would be still higher. In the other limiting cases of interference from mobile stations, the increase in protection ratio at 5 MHz would be of the order of 4 dB for 5 kHz frequency separation and 3 dB for 10 kHz frequency separation. The incorporation of filters with lower cut-off frequencies would result in the reduction of the required protection ratios, only at the cost of the quality of received music programmes.

Since the results presented have been derived under steady-state conditions, appropriate allowance should be made for fading under actual operating conditions.

3.8 [CCIR, 1963b], describes the results of measurements of protection ratio made in the medium-frequency band under steady-state conditions on various types of receivers of recent manufacture.

The measurements were made by the usual method with a wanted signal and an unwanted signal, the level of the latter being set to give a level of interference considered tolerable by the listeners. Various types of programme were used for the tests but programme material particularly susceptible to interference (e.g. music of high quality with a wide dynamic range) and programmes only slightly susceptible to interference (e.g. modern dance music with a restricted dynamic range) were excluded.

The results of the measurements are shown by curve I of Fig. 2.

There are two main conclusions to be drawn from [CCIR, 1963b], namely that, for medium frequency reception at least, and with the great majority of receivers in use, the protection ratio necessary with no frequency separation (± 20 Hz) is 40 dB, and with 5 kHz spacing, 46 to 50 dB.

The incorporation of special cut-off filters would reduce the required protection ratios, but only at the expense of the quality of received music programmes.

4. PART II (MINIMUM FIELD TO BE PROTECTED)

4.1 [CCIR, 1956d] indicates that listening tests have shown that for most of the time a satisfactory signal-to-noise ratio (estimated at 40 dB) can be obtained with a broadcasting system using arrays having vertical incidence radiation and a transmitter power of 5 kW, within a local service area.

For a given power and frequency the day-time field within a given service area is less than the night-time value. On the other hand the day-time noise levels are considerably less than the night-time values.

With the limited amount of information available on atmospheric noise levels in the tropical areas, the day-time and night-time median signal strengths of 100 $\mu\text{V/m}$ and 1000 $\mu\text{V/m}$ respectively would be necessary. These would provide a satisfactory broadcasting service in the Tropical Zone using bands shared with broadcasting having a median signal to upper decile noise ratio of 30 dB (median signal to median noise ratio of 36 dB).

In the light of the above and the fact that the fixed and mobile services must set up a satisfactory signal-to-noise ratio in their own service areas besides giving the necessary protection to the broadcast services, it has been suggested by the United Kingdom that the minimum value of the field intensity of a broadcast signal to be protected in the bands 2300 kHz to 5060 kHz within the local service area, should be 150 $\mu\text{V/m}$ by day and 250 $\mu\text{V/m}$ by night.

4.2 [CCIR, 1959c], gives the results of studies carried out for determination of noise level in tropical regions and the minimum signal required for satisfactory listening. Based on these studies, the minimum signal required for various frequency bands for different times of the day and seasons are given in Fig. 3. These figures indicate that for satisfactory reception higher values of signal are required during night-time as compared with day-time.

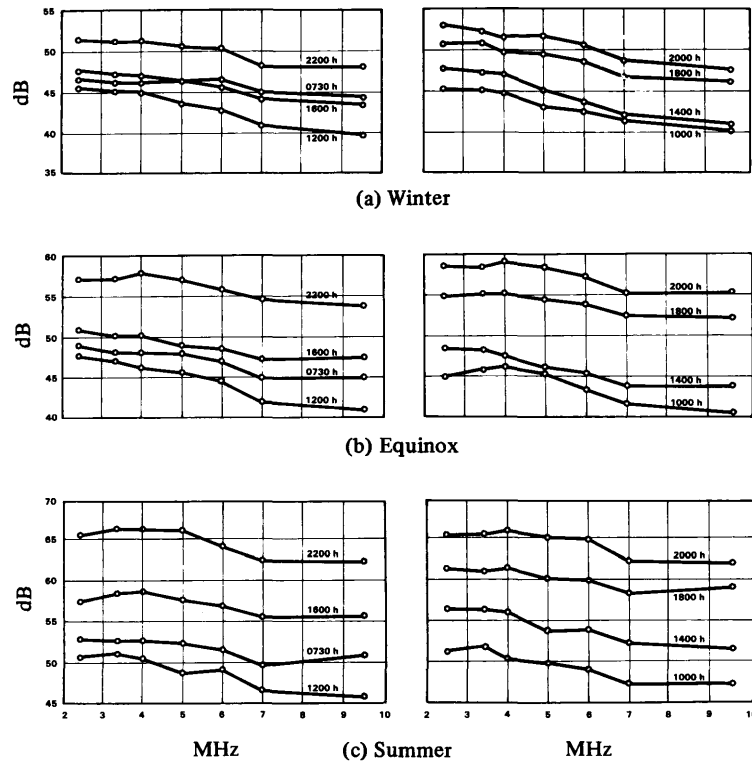
4.3 The conclusions of the two documents referred to in §§ 4.1 and 4.2, that noise level is considerably higher at night-time as compared with day-time, are also indicated in Report 322.

5. Conclusions

The protection ratio values given in Tables I, II and IV and those in Fig. 2 indicate that there is some divergence in the results that have been obtained. This may be due to the variety of experimental set-ups, types of receiver and different percentage of listener satisfaction employed by various administrations for the determination of protection ratios. Nevertheless, the values given in Tables I, II and IV and those in Fig. 2 for different frequency spacings and percentages of listener satisfaction give a consistent trend and the results could be applied to the solution of frequency assignment problems. However, the curves 'H1' and 'H2' give protection ratios much lower than any of the measured data (Fig. 2).

With the present state of unsatisfactory interference position in high frequency bands, it would be difficult to realise in practice the values of protection ratios given by the curves A to G and I of Fig. 2. Comprehensive data on radio-frequency protection ratios may perhaps be collected now by other than the subjective methods hitherto used, employing objective methods as described in CCIR Recommendation 559. Based on the data so collected, further studies may be necessary to determine the lower limit of protection ratios which would be acceptable in practical considerations.

Regarding the minimum field to be protected, it may be mentioned that due to the prevalence of much higher noise levels during night-time as compared with day-time in the Tropical Zone the night-time field should be higher than the day-time field. This aspect has to be taken into consideration while stipulating the minimum signal to be protected for satisfactory listening.

FIGURE 3 – Minimum signal required for satisfactory listening (dB ($\mu V/m$))

ANNEX I

1. Conditions of test for curve A

The tolerable signal-to-interference ratio (with the receiver tuned to the wanted signal), was chosen as the criterion of receiver sensitivity.

The receiver sensitivity was adjusted to apply 150 mW low-frequency power to the loudspeaker, the wanted signal being modulated by a 400 Hz tone to a depth of 30%. The quasi-maximum of the modulation of the interfering signal corresponded to a modulation index of 90%.

The amplitude of the interfering signal was then increased, up to the point when its interfering effect on an unmodulated wanted signal was just perceptible to the ear at a distance of about 50 cm from the loudspeaker.

Furthermore, if the wanted signal was also modulated, the above ratio may be multiplied by a factor of between 3 and 5. * (Documents of the European Radiocommunication Conference, Lucerne, 1933, 280-282, and Documents of the Fourth Reunion of the CCIR, Bucharest, 1937, Vol. I, 109-112.)

2. Conditions of test for curve B

Similar conditions to those of curve A, but relating to very high-quality reception (Documents of the CCIR, Bucharest, 1937, Vol. I, 241).

3. Conditions of tests for curves C, D, E and F (British Post Office tests)

The conditions under which tests F were conducted require some detailed comment.

A "standard" condition of co-channel interference was set up, this in the first place providing an interfering broadcast signal 23 dB below the wanted carrier level. As finally set up, however, short-term Rayleigh-type fading was introduced and, on the basis of some practical evidence, this was taken to require the

* Note by the Director, CCIR. — The original van der Pol curve was plotted as the ratio of the "tolerable interfering signal to the wanted signal". Accordingly, with the curve A of Fig. 2, which is plotted as the ratio of the wanted signal to the interfering signal, this factor should be 1/3 to 1/5 (–9.5 to –14 dB).

co-channel protection ratio to be increased to 33 dB. An allowance of 7 dB for long-term fading would thus give the figure of 40 dB for planning purposes, as used at the Mexico City Broadcasting Conference, 1948. The tests F, however, were carried out only with artificially produced short-term fading and all adjacent channel figures, therefore, relate to a co-channel protection ratio of 33 dB. In the final presentation, these figures have therefore been reduced by 10 dB to equate the results to the non-fading conditions used for all other tests. The ordinate has been so labelled that protection ratios can be read off either for non-fading conditions, or for full fading conditions incorporating a total allowance of $10 + 7 = 17$ dB for short-term and long-term fading. For some of these measurements under test F, a simple whistle filter was placed in the loudspeaker input leads, so that the improvement in protection ratio, that might readily be gained by reducing the audible heterodyne whistle at 5, 6 and 7 kHz, could be assessed.

TABLE III

Test	Date of test	Wanted signal		Unwanted signal	
		Type	Modulation index	Type	Modulation index
C	1948	Music (0–8 kHz)	30% average, peaking to 100% occasionally	Speech (0–8 kHz)	30% average, peaking to 100% occasionally
D	1950	Broadcast speech	idem	Telephony (0–3 kHz)	70%
E	1951	Broadcast speech	idem	Speech (0–6 kHz)	30% average, peaking to 100% occasionally
F	1956	Broadcast speech	idem	Music (6 dB down at 4.6 kHz)	idem

4. Conditions of test for curves G1 and G2 (Indian tests with 50% and 90% listener satisfaction respectively for broadcasting)

See Tables I and IV.

5. Conditions of test curves H1 and H2

5.1 Curve H1 was the protection ratio used by the IFRB in the preparation of the tentative 1956 HF broadcasting plans only.

5.2 Curve H2 is the modified H1 curve based on the data of receiver discrimination given in IFRB Technical Standards, Series A, 1968 (Ref. CCIR Recommendation 449-2 (Geneva, 1974)), where both wanted and the interfering emissions are broadcasting emissions.

6. Conditions of test for curve I

See § 3.8 of the Report.

TABLE IV

Wanted singal	Interfering emission	Frequency separation (kHz)	Protection ignoring frequency tolerance (dB)	Maximum frequency tolerance in the shared bands (Atlantic City) (Hz)	Protection taking into account the tolerance in column 5 (dB)
Speech	A1B-fixed (40 w.p.m.)	0	26.5	150	33.5
	A1B-mobile (40 w.p.m.)	0	26.5	1000	44.5
	A3B-fixed (mod. at 525 Hz)	0	35	150	42
	A3B-mobile (mod. at 525 Hz)	0	35	1000	49
	A3E-fixed (mod. at 3 kHz max.)	0	33	150	40
	A3E-mobile (mod. at 3 kHz max.)	0	33	1000	50
	A3E-broadcasting	0	33	150	44
	A1B-fixed (40 w.p.m.)	5	41.5	150	43
	A1B-mobile (40 w.p.m.)	5	41.5	1000	47
	A3B-fixed (mod. at 525 Hz)	5	39	150	43
	A3B-mobile (mod. at 525 Hz)	5	39	1000	49
	A3E-fixed (mod. at 3 kHz max.)	5	48	150	50
	A3E-mobile (mod. at 3 kHz max.)	5	48	1000	52
	A3E-broadcasting	5	48	150	49
	A3E-broadcasting	0	33	645	51.5
	A3E-broadcasting	5	48	645	50.5
Music (vocal)	A1B-fixed (40 w.p.m.)	0	27.5	150	36
	A1B-mobile (40 w.p.m.)	0	27.5	1000	42.5
Music (instrumental)	A3B-fixed (mod. at 525 Hz)	0	24	150	28.5
	A3B-mobile (mod. at 525 Hz)	0	24	1000	36
Music (vocal)	A3E-fixed (mod. at 3 kHz max.)	0	26	150	34
	A3E-mobile (mod. at 3 kHz max.)	0	26	1000	41.5
	A1B-fixed (40 w.p.m.)	5	37	150	39
	A1B-mobile (40 w.p.m.)	5	37	1000	43
Music (instrumental)	A3B-fixed (mod. at 525 Hz)	5	39	150	40
	A3B-mobile (mod. at 525 Hz)	5	39	1000	43
Music (vocal)	A3E-fixed (mod. at 3 kHz max.)	5	42.5	150	44
	A3E-mobile (mod. at 3 kHz max.)	5	42.5	1000	46.5

REFERENCES

CCIR Documents

- [1956] (Warsaw): **a.** 356 (India); **b.** 231 (United Kingdom); **c.** 553 (Federal Republic of Germany); **d.** 428 (United Kingdom).
 [1959] (Los Angeles): **a.** XII/1 (United Kingdom); **b.** XII/6 (India); **c.** 92 (India).
 [1962] (Bad Kreuznach): XII/7 (India).
 [1963] (Geneva): **a.** 94 (India); **b.** 218 (France).

REPORT 304-1 *

FADING CHARACTERISTICS FOR SOUND BROADCASTING IN THE TROPICAL ZONE

(Question 45/10, Study Programme 45B/10)

(1956–1959–1963–1978)

1. Introduction

The fluctuations of the received signal in time, space and frequency which occur as random short-period variations, irregular long-period variations and more or less regular variations, are collectively described as “fading”. To plan sound-broadcasting services, it is necessary to have precise information on the types and characteristics of fading that may be expected to be encountered in the received signal.

2. Types of fading

Fading may be caused by various effects of ionospheric phenomena. Depending on the cause, the different types of fading, in general, may fall into the following principal classes.

2.1 Interference fading

Interference fading results from interference between two or more waves which travel by different paths to arrive at the receiving point. This type of fading may be caused by:

- interference between sky wave and ground wave;
- interference between multiple reflected sky waves;
- interference between the two oppositely polarized magneto-ionic components – the ordinary and the extraordinary waves;
- interference between various wavelets diffractively scattered from different scattering centres, caused by the steady horizontal drift of the irregularities present in the ionosphere or by their random movement or both.

Interference fading may last for a period of a fraction of a second to a few seconds, during which time the resultant field intensity may vary over wide limits.

2.2 Polarization fading

Polarization fading occurs as a result of changes in the direction of polarization of the downcoming wave, relative to the orientation of the receiving antenna, due to random fluctuations in the electron density along the path of propagation.

Like interference fading, polarization fading also lasts for a period of a fraction of a second to a few seconds.

2.3 Absorption fading

Absorption fading is caused by variation in the absorption of radiowave propagated through the ionosphere due to changes in the densities of ionization and it usually lasts longer – maybe sometimes last even more than one hour.

2.4 Skip fading

Skip fading may be observed at receiving locations near the skip distance at about sunrise and sunset, when, because of the instability of ionization density of ionosphere, MUF for a transmission path may oscillate around the actual frequency. The amplitude of the received signal may fall abruptly when the skip distance crosses over the receiving point and may suddenly increase with the decrease in the skip distance, thus causing fading.

2.5 Selective fading

In general, fading is faster at high frequencies than at low frequencies, because for given movement in the ionosphere, there is a greater phase-shift on the shorter wavelengths either on reflection or on scattering from irregularities. Sometimes on a modulated carrier, the frequency components in the sidebands fade differently and independently, giving rise to distortion of the modulation envelope. This is called “selective fading”.

* The attention of Study Group 6 is drawn to this Report.

In general, all the above types of fading are encountered in the Tropical Zone. However, some special types of fading observed only in the Tropical Zone and at low magnetic latitudes are discussed in § 4.

3. Character of fading

The terms “severity” and “rapidity” of fading refer to the characteristics of the variation of the amplitude of the received signal.

3.1 Severity of fading

Severity or depth of fading is measured by the amplitude distribution or probability distribution function.

3.1.1 Analysis of severity of fading

In a fading curve i.e. the time variation of the received signal, if R is the amplitude of the downcoming wave at any instant t and dR represents a small change in R in the time interval $(t + dt)$, then $P(R) dR$ denotes the probability of finding the amplitude between the limits R and $(R + dR)$. The probability density function is usually given by:

$$\int_0^{\infty} P(R) dR.$$

Probability density functions, computed analytically to describe the envelope of a fading signal, differ in form and depend upon the mechanism of fading of the received signal. Depending upon the amplitude and phase of the signals which form the resultant descending wave, the amplitude distributions normally observed conform in general to the following three standard statistical curves:

- Rayleigh distribution,
- normal or Gaussian distribution,
- log-normal distribution.

3.1.1.1 Rayleigh distribution

If the downcoming wave consists of a large number of waves scattered from the irregularities and moving in a random manner, the resultant amplitude of the signal at any instant will be the vector sum of the scattered waves each having a random phase. The probability distribution of the resultant amplitude R of the envelope will then be represented by a Rayleigh distribution.

$$P(R) = (R/\psi) \exp(-R^2/2\psi) \quad (1)$$

where,

R : amplitude at any instant,

ψ : density in the power spectrum and a parameter related to the average value $\bar{R}$, the r.m.s. value R_0 and the most probable value R_m as follows:

$$\bar{R} = \sqrt{\pi\psi/2}, R_0 = \sqrt{2\psi}, R_m = \sqrt{\psi}$$

It is sometimes convenient to evaluate ψ from the plot of $\log P(R)/R$ as a function of R^2 . The corresponding log plot is a straight line, the slope of which is $\psi/2$ and the intercept $\log(1/\psi)$.

Fig. 1(a) shows the Rayleigh type of probability distribution of amplitude R , and Fig. 1(b), shows the corresponding plot of $\log [P(R)/R]$ against R^2 .

3.1.1.2 Normal or Gaussian distribution

The normal distribution is represented by:

$$P(R) = \left(1/\sigma \sqrt{2\pi}\right) \exp \left[-\frac{1}{2} \left(\frac{R - R_M}{\sigma} \right)^2 \right] \quad (2)$$

where σ is the standard deviation in Gaussian distribution and R_M is the median value of R .

The normal distribution is usually observed when the downcoming wave consists of a random component and a steady component because of specular reflection in the ionosphere. The contribution due to the specular component is of a considerable amount in comparison with the random one.

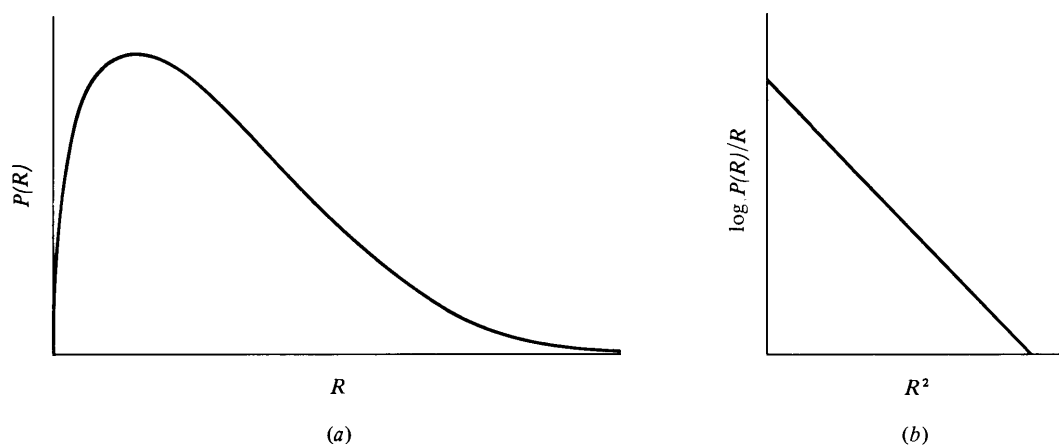


FIGURE 1

Fig. 2 shows the probability distribution curve following a normal or Gaussian distribution:

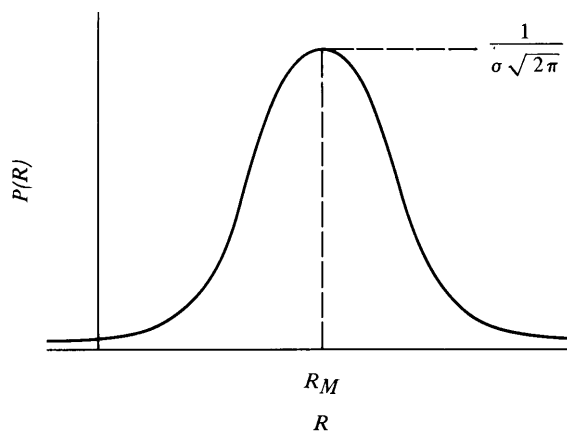


FIGURE 2

3.1.1.3 Log-normal distribution

The amplitude analysis of fading records representing a log-normal distribution is given by:

$$P(x) = (1/\sigma_x \sqrt{2\pi}) \exp(-x^2/2\sigma_x^2) \quad (3)$$

where,

$$x = 20 \log(R/R_M)$$

R_M is the median value of the amplitude R . In this case the field strength measured logarithmically is distributed normally. Fig. 3 gives a typical log-normal distribution curve.

3.1.1.4 A general formula for intensity distribution

For a general form of fading, the signal at the receiving point may be assumed to be composed of a steady sinusoidal component and a random fluctuating component. This leads to a probability density function described by several workers [Nakagami, 1943; McNicol, 1949; Nakagami, 1960].

In this case, following work of Rice [1944-1945], the probability distribution of the resultant amplitude Q of the envelope may be expressed as:

$$P(Q) = (Q/\psi) \exp [(-Q^2 + B^2)/2\psi] I_0 (QB/\psi) \quad (4)$$

where,

I_0 : is the Bessel function of zero order and imaginary argument;

B : is the amplitude of the steady signal;

ψ : is related to the amplitude of the random fluctuating component in the following manner:

$$\psi = R_0^2/2 \text{ or } R_m^2$$

where,

R_0 : is the r.m.s. value;

R_m : is the most probable value of the random component.

$$\text{In general } \overline{Q^2} = B^2 + 2\psi.$$

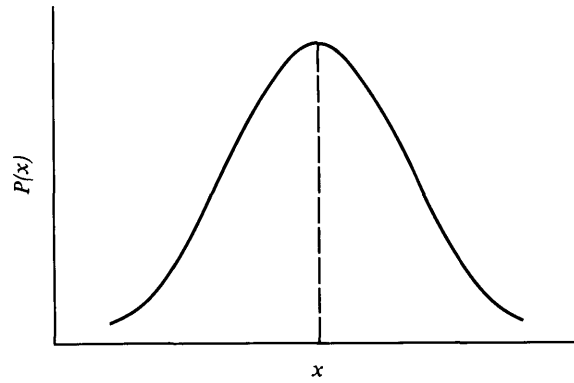


FIGURE 3

Fig. 4 describes the general behaviour of $P(Q)$ in terms of b , where $b = B/\sqrt{\psi}$ a ratio of the amplitude of the steady signal and the most probable value of the random signal.

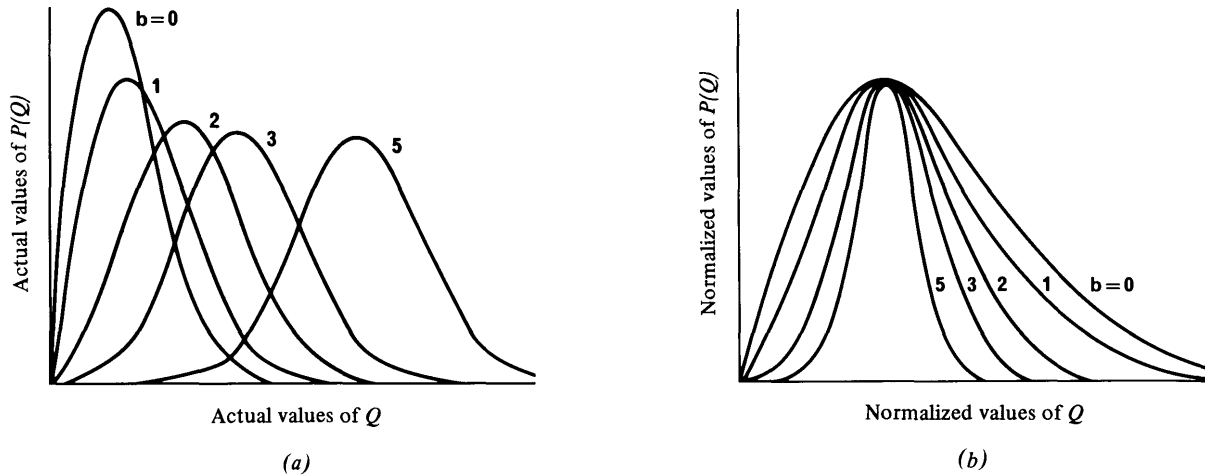


FIGURE 4 – Probability distributions of the amplitude Q of a steady signal plus a random signal

(a) Actual curves

(b) Normalized curves

If $b < 1$, then equation (4) reduces to:

$$P(Q) \approx (2Q/R_0^2) \exp (-Q^2/R_0^2) \quad (5)$$

which approximates to a Rayleigh distribution.

If $b > 3$,

$$P(Q) \approx (1/\sqrt{2\pi\psi}) \times \sqrt{Q/B} \times \exp [-(Q-B)^2/2\psi] \quad (6)$$

The distribution is Gaussian, with a standard deviation of $\sqrt{\psi}$.

McNicol [1949] has shown that (6) can be rewritten in the form:

$$P(Q) = (1/\sqrt{2\pi\psi}) \times \exp [-(Q - Q_m)^2/2\psi] \quad (7)$$

within an accuracy of 1%;

where,

$$Q_m = \sqrt{\psi(b^2 + 1)}.$$

A plot of $\log P(Q)$ as a function of $(Q - Q_m)^2$ gives a straight line, the slope of which is $1/2\psi$. Knowing ψ and Q_m (from the distribution curve) one can evaluate b , which represents the relative proportion between the steady and the random signals in the received wave.

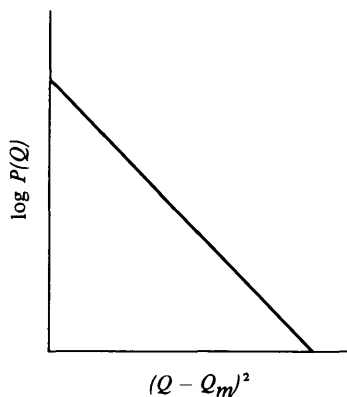


FIGURE 5

In addition to the above probability density functions, another distribution, “ m -type” may also occasionally be encountered.

The functional form of the m -distribution by Nagakami [1960] as:

$$P(R) = \frac{2m^m R^{2m-1}}{\Gamma(m) \Omega^m} \exp -(m/\Omega) R^2 \quad (8)$$

where, $\Omega = \overline{R^2}$ (time average of R^2)

and

$$m = (\overline{R^2})^2 / (\overline{R^4} - \overline{R^2}^2) \geq 0.5$$

always, that is the inverse of the normalized variance of R^2 .

Fig. 6 shows an m -type amplitude distribution.

Quantitative estimates of the severity of fading which can be obtained from the statistical distributions of the received signal are dealt with in § 5.

3.1.2 Experimentally observed amplitude distribution

Measurements on fading on transmissions in several areas in the Tropical Zone at different times of the day and at various distances from the transmitters have been reported through CCIR documents.

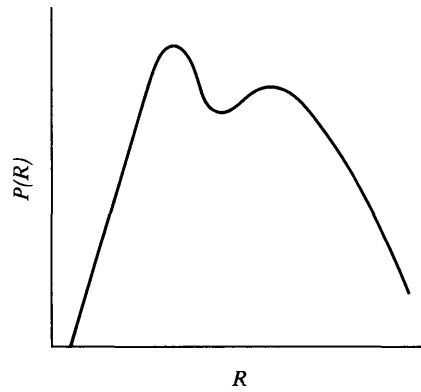


FIGURE 6

The fading records obtained at Barbados, Trinidad, Ghana, Singapore and Johannesburg by the Administration of the United Kingdom [CCIR 1959b; 1962b] agree fairly closely with the Rayleigh type of distribution for ranges between 0 and 350 km. However, for ranges exceeding 350 km, considerable departure from a Rayleigh type of distribution has been observed.

Measurements on the fading of CW transmissions at oblique incidence on 4.7, 9 and 15 MHz bands and on pulsed transmissions on the equivalent vertical incidence frequency were carried out by All India Radio. The distributions observed from the analysis of the fading curves were found to be Rayleigh, normal or log-normal [CCIR, 1959a].

Apart from the usually observed distribution of fading signal i.e. Rayleigh, normal or log-normal, *m*-type probability distribution was also reported in India [Das Gupta and Vij, 1960; Khastagir *et al.*, 1968; Srivastava *et al.*, 1972].

3.2 Rapidity of fading

The rapidity or speed of fading can be characterized in different ways [Fürth and MacDonald, 1947; McNicol, 1949; Booker *et al.*, 1950; Rice, 1958]. The various forms, characterizing the rapidity of fading, are discussed below:

3.2.1 Analysis of rapidity of fading

An important statistical property of the instant-to-instant variation of amplitude is given by the autocorrelation function. The rapidity or the speed of fading can be described in terms of the time auto-correlation function of the amplitude or in terms of the power spectrum of fading, which is the Fourier transform of the auto-correlation function.

If $A(t)$ represents the amplitude as a function of time, such that the average value is constant over the interval t to $t + \tau$, then the auto-correlation function $\rho(\tau)$ is defined by:

$$\rho(\tau) = \frac{1}{\tau} \int_t^{t+\tau} A(t) \cdot A(t + \tau) \cdot dt \quad (9)$$

If f represents the fading frequency and $F(f)$ is the Fourier transform of $A(t)$, i.e.

$$F(f) = \frac{1}{2\pi} \int_{-\infty}^{\infty} A(t) \cdot \exp(-i\omega t) dt$$

then the power spectrum $W(f)$ of the fading signal is given by $W(f) = |F(f)|^2$ which is proportional to $\int \rho(\tau) \exp(-i\omega\tau) d\tau$, the Fourier transform of $\rho(\tau)$.

Hence the frequency spectrum of the fading signal may be obtained with the aid of auto-correlation function. The width of the fading power spectrum is related to the speed of fading.

Assuming that fading is produced by diffractive scattering from a large number of ionospheric irregularities and the scattered wavelets, having random amplitudes and phases, combined at the ground to give a resultant signal at any instant; [Booker *et al.*, 1950] have shown that the auto-correlation function $\rho R(\tau)$ of the amplitude R of the received fluctuating signal is proportional to:

$$\exp [(-16\pi^2 v_0^2 \tau^2)/\lambda^2] \quad (10)$$

where v_0 is the r.m.s. velocity of the irregularities in the line of sight.

The auto-correlation function falls to e^{-1} after a time $\tau = \lambda/4\pi v_0$ which can conveniently be called "fading time", since it will, on the average, represent the time which must elapse before the received signal has altered appreciably.

For oblique incidence,

$$\rho R(\tau) = \text{const.} \exp [(-16\pi^2 v_0^2 \tau^2 \cos^2 \varphi)/\lambda^2] \quad (11)$$

where φ is the angle of incidence of the radiowave to the ionosphere.

Whenever fading is random, the amplitude distribution is Rayleigh type and auto-correlogram is a smooth curve having exponential decrease. If however, the fading is not absolutely random, but has a tendency towards periodicity, the auto-correlogram will show a number of maxima and minima. The corresponding amplitude distribution is often a Gaussian curve [CCIR, 1959a].

Figs. 7(a) and 7(b) show the auto-correlograms for two types of fading curves:

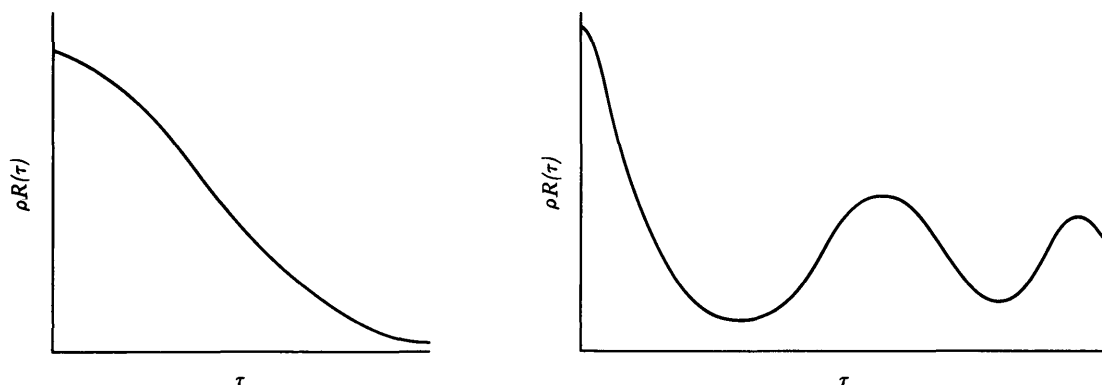


FIGURE 7

(a) Auto-correlogram for a Rayleigh type of fading

(b) Auto-correlogram for Gaussian type of fading

Other forms used for characterizing the rapidity of fading do not represent as complete a description of fading as auto-correlation functions, but nevertheless they also provide useful information concerning fading rates, as discussed below.

Following the work of [Fürth and MacDonald, 1947] on noise, speed of fading may be obtained by analyzing successive differences of amplitudes of signals in the fading curve. They have shown from an extension of Rice's theory on random noise that, in the case of Rayleigh amplitude distribution, the probability distribution of v_τ , the successive difference between two amplitudes ($R_2 - R_1$) within a small interval of time τ , is given by:

$$\rho v_\tau dv_\tau = (1/\pi) \exp (-x^2) dx \quad (12)$$

where,

$$x = v_\tau / (2\pi\sigma\tau\sqrt{2\psi})$$

and the power spectrum is Gaussian with standard deviation σ .

The power spectrum $W(f)$ is given by:

$$W(f) = (\psi/\sigma\sqrt{2\pi}) \exp [-(f - f_0)^2/2\sigma^2] \quad (13)$$

where $\psi = \int_0^\infty W(f) df$ is the total energy in the power spectrum.

A similar expression may be derived in the case of a randomly fading signal. In that case, f_0 is the incident wave frequency and f is the Doppler shifted frequency of the reflected wave from the moving irregularities.

The average value of $|\nu_\tau|$ is defined by:

$$|\bar{\nu}_\tau| = 2 \int_{-\infty}^{\infty} \nu_\tau \cdot \rho_{\nu_\tau} \cdot d\nu_\tau$$

From (12) and (13) above, we get:

$$|\bar{\nu}_\tau| = 2 \sqrt{2\pi\psi} \cdot \sigma\tau$$

$$|\bar{\nu}_\tau/\tau| = \sqrt{2\pi\psi} \cdot 2\sigma$$

$|\bar{\nu}_\tau/\tau|$ is called the “speed of fading”.

A simple form of defining fading rate is the number of positive crossings per unit time through any specified level. The number of maxima, N , of the amplitude of the received signal envelope per unit time may be used as a measure of the rapidity of fading. Rice has shown that if σ is the standard deviation of the power spectrum of the received signal, then $N = 2.52 \sigma$.

The rapidity of fading may also be calculated from the derivative of the amplitude of the received signal and is given by $|dR/dt|/\bar{R}$, where R is the instantaneous amplitude of the received signal.

3.2.2 Some measured values of fading rates

A few typical values of the fading rate measured in the Tropical Zone are given below:

In [CCIR, 1959a], India reported a fading rate of 11.9 fades per minute on an average, while the fading rate in general is observed to vary between 4 and 16 per minute.

Average fading frequency taken on 2.3 MHz in the E-region during daytime and night-time was found to be 10.96 cycles/min (0.183 Hz) and 14.002 cycles/min (0.233 Hz). In the case of F2 region, average fading frequency taken on 5.6 MHz during daytime and night-time is observed to be 11.22 cycles/min (0.187 Hz) and 8.37 cycles/min (0.14 Hz) respectively [Rao and Rao, 1967].

Increased rate of fading is observed almost throughout the Tropical Zone after sunset. The Administration of the United Kingdom reported this phenomenon through [CCIR, 1959b]. Typical value of the rapidity of fading is 10 Hz at 15 MHz [Davies and Barghausen, 1967]. Rapid fading rates up to 15 Hz were noticed by [McNamara, 1971].

The fading rate of signals reflected from Es layer is found to be more than normal E or F region. Rates of 0.2 to 5 Hz are typical [Rastogi *et al.*, 1966; Skinner and Wright, 1962].

[Skinner and Wright, 1962] found that, for the equatorial q-type Es, the fading rates are of the order of 4 Hz and the fading rate increases almost linearly with increasing wave frequency. For the blanketing type of Es, fading rates are much smaller than those of the q-type Es and are of the order of 0.8 Hz.

Observations in India at Thumba on the magnetic equator have shown that the speed of fading of the radiowaves reflected from the Es layer, has a strong diurnal variation, being very rapid in the early morning and evening hours and very slow at midday [Rastogi *et al.*, 1966].

4. Features of fading specially encountered in the Tropical Zone

Fading of signals in the tropical regions at low geomagnetic latitudes has some special characteristics due to:

- a particular type of sporadic E layer associated with the equatorial electrojet, which is a regular daytime occurrence;
- irregularities present in the night-time F layer, often mentioned as spread F.

4.1 *Fading due to sporadic-E*

Fading observed during daytime in the equatorial zone is very often attributed to sporadic E. An analysis carried out by All India Radio [CCIR, 1962a] shows that sporadic E is one of the causes of the day-to-day fluctuations of signals.

4.1.1 *The characteristics of sporadic E in the Tropical Zone*

In the Tropical Zone, depending on the latitude, two types of sporadic E are usually prevalent:

- temperate zone sporadic E;
- equatorial zone sporadic E.

Temperate zone sporadic E observed at middle latitudes is predominantly a summer-time phenomenon occurring both by day and night and more intensely by day. In a narrow zone near the magnetic equator ($\pm 6^\circ$ magnetic dip), a special type of highly transparent sporadic E called equatorial sporadic E or Es-q appears regularly during daytime [Matsushita, 1962; Knecht and McDuffie, 1962]. It is observed that there is a narrower zone right at the dip equator, where the blanketing type of sporadic E is usually absent [Knecht and McDuffie, 1962; Bowles and Cohen, 1962].

But [Oyinloye, 1971] suggests that blanketing Es would sometimes occur over the dip and geomagnetic equator.

4.1.2 *Observed effects on fading due to sporadic E*

The fading characteristics of radiowaves reflected from Es layers studied by different workers indicate different results.

Some of the characteristics of echoes from the two principal daytime types of Es at Ibadan (Geomag. Lat. 10.6° N), Nigeria, have been investigated by means of vertical incidence pulsed transmissions in the frequency range 4 to 8 MHz. It has been observed that for the higher frequencies in the frequency range 4.3 to 8.5 MHz, the signal reflected from q-type Es is almost randomly phased with Rayleigh amplitude distribution, whereas at the lower frequencies near 4.5 MHz, amplitude distribution follows Rice function. Rayleigh type amplitude distribution is observed from the fading records at 5.7 and 7.5 MHz from the blanketing type of Es observed at midday at Ibadan [Skinner and Wright, 1962].

It is observed at Tirupati (Geomag. Lat. $3^\circ 45'$ N) in India, that at times well before ground sunrise, the amplitude distribution of the echoes from sporadic E fitted most closely with the Rayleigh function, whereas just before ground sunrise and during the day, the amplitude distribution followed Gaussian or Rice functions [Venkateswarlu and Ramu, 1964]. However, observation at Thumba, situated at the magnetic equator, has shown that the probability distribution of the amplitude of signal strength does not fit with the theoretical Rayleigh or Gaussian distribution [Rastogi *et al.*, 1966]. Analysis of fading records at Calcutta (Geomag. Lat. 12.3° N) shows that the statistical distributions of amplitude are both Rayleigh and Rice types at noon, whereas during morning, evening and early night, other types of amplitude distribution — very often double-peaked or m-type have been observed [Ganguly and Samanta, 1967].

§ 3.2.2 may be referred to for the fading rates on high frequency signals reflected from the Es region.

4.2 *Fading due to F-region irregularities (flutter fading)*

A peculiar type of very rapid fading has been observed in the equatorial region after sunset. This is termed as flutter fading, the cause of which is attributed to F-region irregularities commonly known as spread F.

4.2.1 *Characteristics of F-region irregularities of spread F in the Tropical Zone*

In the equatorial zone after sunset, irregularities develop in the F-region ionization inside a belt extending approximately between geomagnetic latitudes of 30° N and 30° S. Its occurrence is high within $\pm 20^\circ$ geomagnetic latitude. It is seen that just after local sunset F-region over the equatorial belt exhibits a marked increase in height and seems to break up progressively into patchy regions or irregularities in patches, generally known as spread F [Lyon *et al.*, 1961]. The characteristics of equatorial spread F have been studied by many workers in the past few years [Osborne, 1952; Bhargava, 1958; Shimazaki, 1959; Lyon *et al.*, 1960; Rangaswamy and Kapasi, 1963; Krishnamurthy, 1966; Rao, B.C.N., 1966; King, 1970; Davies, 1972; Bowman, 1975; Röttger, 1976]. The main features are as follows:

The presence of the irregularities in F region is manifested as echoes which have spread in their range in the ionograms and are classified as range spread and frequency spread. The range spread which is the equatorial type spread F observed after sunset is seen to be influencing HF propagation. The irregularities are known to be magnetically field-aligned [Cohen and Bowles, 1961]. Recent observations have shown that both large-scale, non-field-aligned irregularities and small-scale field-aligned irregularities coexist in the F layer, when spread F is observed in the ionograms at equatorial latitudes [Bates, 1971; Cole and McNamara, 1975; Röttger, 1976].

The diurnal variation of range spread F is controlled by the sunset and the range spread F irregularities are seen normally after sunset and before midnight.

The seasonal variations show maxima of range spread F in the equinoxes. A longitudinal anomaly is seen in this case. Significant differences exist between the Far Eastern and American Equatorial region in the seasonal behaviour of spread F [Singleton, 1960].

The range spread F occurrence is positively correlated with sunspot number and indicates a negative correlation with magnetic activity [Huang, 1970].

Various workers have observed the same characteristics of range spread F as for equatorial flutter fading. Their observations are discussed in the next section.

4.2.2 *Experimental observations on flutter fading due to spread F in the Tropical Zone*

Flutter fading has been observed in India on All India Radio shortwave regional broadcast transmissions, ever since they were introduced in 1938. It was found that while flutter fading was very intense and annoying on shortwave transmissions from AIR Madras (Geomag. Lat. $3^{\circ}05' \text{ N}$) and Radio Ceylon, (Geomag. lat. $3^{\circ}38' \text{ S}$), it was considerably less on SW transmissions from AIR Bombay (Geomag. lat. $10^{\circ}00' \text{ N}$) and almost absent on transmissions from AIR Delhi (Geomag. lat. $19^{\circ}11' \text{ N}$). This indicates that flutter occurs nearer the geomagnetic equator. [Subba Rao and Somayajulu, 1949] called attention to the occurrence of equatorial flutter fading while studying field-strength variations of broadcasting stations of AIR in the 41 and 60 metre bands at Waltair in India. [Osborne, 1952] mentioned intolerable fading of ionospheric reflections at nearly vertical incidence associated with HF broadcast transmissions near the magnetic equator. [Yeh and Villard, 1958] have also described a high frequency fluctuation (up to 40 Hz) of signals observed at Stanford on BBC transmissions in the 9 and 21 MHz bands from Singapore, propagated on paths crossing the equator. They termed this phenomenon as "Doppler Fading". During the month of August 1957 they noticed this fading almost daily in the case of Singapore, but only sporadically from the transmissions in the same frequency range from Australia to Peking and to Buenos Aires. [Humby, 1959] reported similar behaviour of transequatorial Admiralty circuits from England to Colombo and England to Singapore during the period 1947 to 1958. [Chaman Lal, 1960] also reported rapid type of fading which is seen to be particularly pronounced in equatorial Southern India at Madras, Tiruchirapalli and Trivandrum. A rather similar observation was published by [Bennington, 1960] on the reception of United Kingdom transmissions in Johannesburg (South Africa) and Singapore during the period 1954 to 1958. Sunset fading effect on flutter fading has been investigated in Ghana since 1958. [Koster, 1963] gave a detailed analysis of the flutter fading observed on BBC (15.07 MHz) broadcast to West Africa and Accra and on a broadcast signal locally originating from Accra on 5 MHz at Kumasi (270 km north-west of Accra). [Davies and Bargaussen, 1966] recorded the effects of equatorial spread F on 5 paths in Africa near the magnetic equator, and observed flutter fading on the equatorial path. [McNamara, 1971] observed the evening type transequatorial propagation with deep flutter fading of the order of 5 to 15 Hz on the circuits between Okinawa and Yamagawa (Japan) and Townsville (Australia). The results of a study of night-time records of the field strength of radio signals on 11.8 MHz transmitted from Colombo and received at Ahmedabad indicate the presence of flutter fading [Chippa and Patel, 1973]. [Cole and McNamara, 1975] enumerated the effect of spread F on equatorial propagation. [Röttger, 1976] also observed flutter fading on transequatorial circuits between Lindau (Federal Republic of Germany) and Tsumeb (Republic of South Africa).

4.2.3 *Characteristics of flutter fading*

Based on the above observations, the characteristics of flutter fading are summarized below:

4.2.3.1 *Geographical extent*

Equatorial flutter fading appears to be most serious within a geographical area between $\pm 20^\circ$ geomagnetic latitude. Both the north-south circuits and east-west circuits are affected by this flutter fading.

4.2.3.2 *The diurnal variation of flutter fading*

Flutter fading is normally observed only between evening and midnight, starting almost around sunset and continuing for three to four hours thereafter. It is found to be most intense within two hours of local sunset at the point where the propagation path crosses the magnetic equator. The time of start is quite well-defined and sudden, but the time of disappearance is rather gradual. The fades are very deep almost completely drowned into noise, even though the mean signal strength remains high [Koster, 1963].

4.2.3.3 *Seasonal variation of flutter fading*

Seasonally, the phenomenon of post sunset flutter fading has been observed to be more pronounced during equinoctial months as compared to the other seasons of the year. It has been noted that definite maximum occurs during the two equinoctial periods well after the true equinox. The autumnal equinox shows significantly more flutter fading than the vernal equinox. The comparatively rapid falling-off of the phenomenon as the sunspot cycle approaches minimum is also observed [Koster, 1963].

4.2.3.4 *Solar-cycle-dependence of flutter fading*

Observations of [Osborne, 1951, 1952; Humby, 1959; Koster, 1963] tend to confirm that there is a positive correlation between mean sunspot number and amount of flutter fading. Equatorial flutter fading is most serious during sunspot maximum and becomes almost negligible during periods of sunspot minimum.

4.2.3.5 *Fading rates at various frequencies*

The observed fading rates are different for different wave frequencies. [Koster, 1963] analyzed fading on signals received in Ghana from London at frequencies approximately 7, 12, 15 and 21 MHz and concluded that the flutter fading rate was directly proportional to the wave-frequency. [Chaman Lal, 1960] also remarked that flutter increased with increase in operational frequency. Observations by [Cohen and Bowels, 1961] had shown that the effects of spread F on signals over transequatorial paths varied with frequency. [Davies and Barghausen, 1967] observed that the fading rate varied over a wide range, but a value of 10 fades per second was typical at a frequency of 15 MHz. A comparison of fading rates of signals at 10.1 and 20.2 MHz, observed over the same path from Monrovia to Accra, showed that the fading rates at 10 MHz were five to seven times faster than those at 20 MHz. This is, however, contrary to the observations of Koster and Chaman Lal, as mentioned above. [McNamara, 1971] observed the evening type transequatorial propagation (TEP) which had a high correlation with spread F with fading rates up to 15 Hz. Fading rates of transequatorial HF signals have been evaluated from observations on the paths Lindau to Rome and Tsumeb to Lindau which cross the equatorial zone of Africa [Carman *et al.*, 1974] and have been found to vary between 50 and 180 maxima per minute.

4.2.3.6 *Doppler fading*

Doppler fading of signals propagated on paths crossing the Equator noticed by [Yeh and Villard, 1958], has been observed by others also. [Calvert *et al.*, 1962], while measuring Doppler shifts of signals propagated from Tripoli to Accra, found that in the evening hours the spread in Doppler spectrum was of the order of 10 to 15 Hz. The systematic movement of a group of irregularities results in Doppler shift of the transmitted frequency up to 30 Hz at 20 MHz, while random motion of individual irregularities leads to Doppler spreading up to about 20 Hz [Bradley *et al.*, 1972]. [McNamara, 1975] also observed the evening type TEP with Doppler shift that sometimes exceed 40 Hz.

4.2.3.7 *Flutter fading and magnetic activity*

Flutter fading correlates negatively with magnetic activity [Wright *et al.*, 1956, Shimazaki, 1959; Briggs, 1965; Davies and Barghausen, 1966]. On quiet days flutter fading is noticed appreciably, whereas on magnetically disturbed days, flutter fading is absent [Chippa and Patel, 1973].

4.2.3.8 *Flutter fading and radio star scintillation*

In the equatorial region, observations of scintillation have been made at Accra in Ghana, at Ibadan in Nigeria and at Kodaikanal in South India. The temporal, seasonal, solar cycle and geomagnetic activity variations of scintillation have been found to be similar to spread F and flutter fading.

[Koster and Wright, 1960] pointed out the high correlation between the occurrence of flutter fading and radiostar scintillation. This was further confirmed by [Koster, 1963]. Radiostar scintillation also correlates negatively with magnetic activity.

[Kent, 1961] who conducted scintillation observations utilizing satellite signals, obtained similar results on scintillation correlation with spread F. [Bhargava, 1964] at Kodaikanal also found the same diurnal and solar cycle variation of scintillation but the maximum rate of scintillation was found to occur several hours before the maximum of spread F.

4.2.4 *Effect of flutter fading on broadcasting*

From the standpoint of degradation in communication circuits, flutter fading is one of the most important factors. It affects the overall merit of broadcast programmes to a considerable extent. Bennington's survey [1960] indicates that, in audio spectrum, voice is still somewhat intelligible in presence of flutter, whereas music becomes very disagreeable and jarring to listeners.

4.2.5 *Other types of fading observed in the Tropical Zone*

Another peculiar type of fading has been observed in India on the shortwave broadcast transmission of All India Radio. This type of fading, which is characterized by sudden and violent fluctuations of the received signal intensity, has been designated as "surge fading". As compared with flutter fading, "surge fading" is slower but a deeper form of fading accompanied by severe distortion. This peculiar type of fading gives the impression of the signal being received in powerful surges.

4.2.5.1 *Characteristics of surge fading*

Surge fading is experienced at its worst after sunset. Seasonally, surge fading has been noted to be more pronounced during winter and equinoctial months preceding winter. With surge fading, the signal varies over a wide range of amplitude with a recurrence rate of a few surges per minute. Surge fading may be due to phase interference or polarization changes of the received signal. The cause for this type of occurrence is not clearly known.

5. **Fading allowances to be provided for planning broadcasting services in the Tropical Zone**

Quantitative estimate of the fading range may be obtained from the statistical distribution of the signal, which can be characterized by indicating the levels exceeded for a number of specified time-percentages. The following Table I gives the levels for two time percentages derived theoretically from the distributions already discussed [Norton *et al.*, 1955].

TABLE I

Distribution	Level (dB) relative to median, exceeded for the following percentages of time	
	10%	90%
Rayleigh	5.21	- 8.18
Normal and log-normal (where σ is the standard deviation)	1.282 σ	- 1.282 σ

[CCIR, 1962a] serves as a preliminary basis for suggesting the values of fading allowances to be made for planning shortwave broadcasting services in the Tropical Zone. This document deals with two basic parameters associated with fading: the intensity fluctuation factor (IFF) and fading safety factor (FFS).

The intensity fluctuation factor, defined as the ratio (in dB) between the monthly median and the monthly lower decile values of the hourly-median field intensity, is considered to make allowance for day-to-day variations for 90% of the days. It is found that the values of IFF fluctuate widely between 1.0 dB and 15.4 dB, the overall average being 7.6 dB. The fading safety factor, defined as the ratio in (dB) between the median intensity of a received signal and the intensity exceeded 90% of the time, is estimated to make an allowance for instant-to-instant variation of the signal for 90% of time. The fading safety factor in summer varies from 2.4 to 27.0 dB, the most probable value being 11.2 dB and the corresponding figures for winter months are 1.6 to 14.4 and 7.0 dB respectively. The overall FSF is found to vary from 1.6 dB to 27.0 dB, the most probable value being 9.0 dB. The fading safety factor, calculated theoretically from the Rayleigh type of distribution which is predominant on short-term fading in the Tropical Zone, is 8.18 dB.

The overall fading allowance for planning may be obtained from the short-term and long-term fading allowance. Intensity fluctuation factor and fading safety factor, when referred to the received signal, take into account the variations of the wanted signal only. However, to arrive at the appropriate value of the fading allowance for planning any sound broadcasting service for a given service probability, it is important to take into account the character and variability of the interfering signal also. Considering this aspect, Recommendation 411 proposed certain values of fading allowance under three conditions of reception, as follows:

- radio frequency signal-to-interference ratio: 16 dB;
- wanted signal-to-atmospheric noise ratio: 17 dB;
- wanted signal-to-industrial noise ratio: 12 dB.

The above-recommended overall variability allowance must be made to ensure that the steady-state ratio is attained for 90% of the time.

There has not been any further documentation on this subject since the CCIR Recommendation 411 was adopted. However, it would appear that the due verification of this Recommendation for the Tropical Zone can be made only after further studies, especially, because it has been suggested that fading, referred to as instant-to-instant variations of field intensity, is more severe in the Tropical Zone than in the countries of the temperate zone [CCIR, 1962a].

6. Conclusion

In this Report, the nature, type and characteristics of fading encountered in the Tropical Zone have been discussed. Some of the special features of fading in the Tropical Zone for example flutter fading, surge fading and fading due to equatorial sporadic E, have also been described.

The fading records analyzed by various workers in different parts of the Tropical Zone show different types of distribution such as, Rayleigh, normal, log-normal and *m*-type. An idea of the allowance for short-term and long-term fading may be obtained from the distribution curves.

Propagation in the equatorial belt is highly influenced by q-type sporadic E during daytime. The fading rate of the radiowave reflected from the Es layer is observed to be more than in case of normal E or F region.

Flutter fading is a typical evening time phenomenon and depends upon the geographical area, local time, season, sunspot number and magnetic activity. Equatorial flutter causes circuit degradation and affects the music transmission appreciably. Presence of irregularities in the lower part of F region appears to be the cause of flutter fading. Hence a shift to higher frequencies is recommended wherever possible in the HF band; at least to alleviate the deterioration of circuit performance in the presence of spread F. [Davies, 1972] provided a scheme of frequency usage, designed to minimize as far as possible, the adverse propagation effects of spread F.

“Surge” fading occurring in this zone reduces the satisfaction value of the programme considerably. This type of fading is slower but deeper in form accompanied by severe distortion. The causes that lead to surge fading are not yet firmly established. Since the information available at present is too meagre, further studies on surge fading appear to be necessary.

The fluctuations in the field strength which occur primarily in HF broadcasting range due to interference and variations of absorption and polarization impair reception quality. These fading effects may be minimized by use of diversity systems. Depending upon the mechanism of propagation various diversity systems such as, space diversity, frequency diversity and polarization diversity are in use. It may be mentioned that the use of space diversity or polarization diversity does not help much in reducing the degrading effects in reception when the fluctuation is very rapid (e.g. in “flutter” and “Surge”). However, single-sideband reception may be used in minimizing the degrading effects of selective fading.

Sufficient data relating to the quantitative estimates of short-term and long-term fading in the Tropical Zone is not available. Further studies will have to be continued to arrive at specific values of fading allowances to be provided for planning sound broadcasting service. It would also be worthwhile to have detailed analysis of the fading characteristics on the types of fading especially those encountered in the Tropical Zone, and to make a study with a view to correlating the fading character and the fading allowance which should be provided to minimize annoyance to satisfactory listening.

REFERENCES AND BIBLIOGRAPHY

- BATEMAN, R., FINNEY, G. W., SMITH, E. K., TVETEN, L. H. and WATTS, J. M. [1959] IGY observations of F-layer scatter in the Far East. *J. Geophys. Res.*, **64**, 403.
- BATES, H. F. [1971] Aspect sensitivity of spread F irregularities. *J. Atmos. Terr. Phys.*, **33**, III.
- BENNINGTON, T. W. [1960] Equatorial ionospheric effects. *Wireless World*, **66**, 501-506.
- BHARGAVA, B. N. [1958] Observations of spread echoes from the F-layer over Kodaikanal – a preliminary study. *Indian J. Met Geophys.*, Vol 9, **1**, 35-40.
- BHARGAVA, B. N. [1964] Radio star scintillations in equatorial region. *J. Inst. Telecomm. Engrs.*, (India), **10**, 404-409.
- BHARGAVA, B. N. and SUBRAHMANYAN, R. V. [1964] A study of blanketing sporadic E in the Indian equatorial region. *Proc. Ind. Acad. Sci., A*, **60**, 271-285.
- BOOKER, H. G., RATCLIFFE, J. A. and SHINN, D. H. [1950] Diffractions from an irregular screen with applications to ionospheric problems. *Phil. Trans. Roy. Soc. (London)*, Series A, **242**, 579.
- BOWLES, K. L., COHEN, R., OCHUS, G. R. and BALSLEY, B. B. [1960] Radio echoes from field-aligned ionization above the magnetic equator and their resemblance to auroral echoes. *J. Geophys. Res.*, **65**, 1853.
- BOWMAN, G. G. [1975] Ionospheric spread F at Huancayo; sunspot activity and geomagnetic activity. *Planet. Space Sci.*, **23**, 899-903.
- BRADLEY, P. A., ECCLES, D. and KING, J. W. [December, 1972] Some effects of the equatorial ionosphere on terrestrial HF radio communication. *Telecomm. J.*, **39**, 717.
- BRIGGS, B. H. [1965] The relation of spread F echoes to magnetic disturbances. *J. Atmos. Terr. Phys.*, **27**, 991-994.
- CALVERT, W. and COHEN, L. [1961] The interpretation and synthesis of certain spread F configurations appearing on equatorial ionograms. *J. Geophys. Res.*, **66**, 3125-3140.
- CALVERT, W., DAVIES, K. and KOSTER, J. R. [1962] US NBS, Rep. No. 7276.
- CARMAN, E. H., HERAN, M. P. and RÖTTGER, J. [1974] Simultaneous observations of fading rates on two transequatorial HF radio paths. *Austral. J. Phys.*, **27**, 741-744.
- CHAMAN LAL [1960] Flutter fading of shortwave radio signals in equatorial regions and its connection with spread echoes, magnetic storms and the radiation belt. *J. Inst. Telecomm. Engrs. (India)*, **6**, 223-230.
- CHIPPA, C. M. and PATEL, B. M. [1973] Night-time changes in field-strength of 11.8 MHz radio signals over Colombo-Ahmedabad transmission path. *Indian J. Radio Space Phys.*, **2**, 148-152.
- CLEMESHA, B. R. [1963] Backscatter of radiowaves from the equatorial F region. *Nature*, **199**, 797-798.
- CLEMESHA, B. R. [1964] An investigation of the irregularities in the F-region associated with equatorial type spread F. *J. Atmos. Terr. Phys.*, **26**, 91.
- COHEN, R. and BOWLES, K. L. [1961] On the nature of equatorial spread F. *J. Geophys. Res.*, **66**, 1081.
- COHEN, R., BOWLES, K. L. and CALVERT, W. [1962] On the nature of equatorial slant sporadic E. *J. Geophys. Res.*, **67**, 965.
- COLE, D. G. and McNAMARA, L. F. [1975] Equatorial propagation and the occurrence of spread F. *Proc. IREE*, **36**, 39-43.
- CRACKNELL, R. G. [1959] Transequatorial propagation of VHF signal. *QST*, **43** (12) 11-17.
- DAS GUPTA, P. and VIJ, K. K. [1960] Statistical analysis of fading of a single downcoming wave. *J. Atmos. Terr. Phys.*, **18**, 265-275.
- DAVIES, K. [1965] Ionospheric Radio Propagation. NBS Monograph No. 80.
- DAVIES, K. and BARGHAUSEN, A. F. [1964] The effect of spread F on the propagation of radiowaves near the equator. AGARD ninth meeting of the Ionospheric Research Committee, Copenhagen, Denmark.
- DAVIES, K. and BARGHAUSEN, A. F. [1967] *Spread F and Its Effects Upon Radiowave Propagation and Communication*. Ed. Newman, London.
- DAVIES, R. M. [1972] The occurrence of spread F and its effect on HF propagation. Telecommunication Research and Engineering Report 28.
- FÜRTH, R. and MacDONALD, D. K. C. [1947] Statistical analysis of spontaneous electrical fluctuations. *Proc. Phys. Soc.*, **B 59**, 388-408.
- GANGULY, S. and SAMANTA, S. [1967] Studies on the fading of the radiowaves returned from the sporadic E region of the ionosphere. *Indian J. Phys.*, **41**, 908-918.
- HUANG, Chun-ming [1970] F-region irregularities that cause scintillations and spread F echoes at low latitude. *J. Geophys. Res.*, **75**, 4833-4841.
- HUANG, Yinn-Nien and CHUNG-YAUW, Yeh [1970] On the occurrence of spread F and the geomagnetic activity over Taipei, Taiwan. *J. Atmos. Terr. Phys.*, **32**, 1765-1772.
- HUMBY, A. M. [1959] Equatorial sunset effect. *Wireless World*, **65**, 342.
- JAGATH KUMAR, V. R. and RAO, B. R. [1965] Latitude effect on the variation of spread F occurring with sunspot number. *Nature*, **207**, 1083-1084.
- JAGATH KUMAR, V. R. and RAO, B. R. [1968] Latitude variation of time of maximum h'f and spread F occurrences. *Indian J. Pure Appl. Phys.*, **6**, 319.

- JANI, K. G. and CHIPPA, G. M. [1973] Field-strength measurements at Ahmedabad of shortwave radio signals from Radio Sri Lanka, Colombo on 11.8 MHz. *J. Inst. Telecomm. Engrs. (India)*, **19**, 525-530.
- JONES, J. and LYON, G. F. [1974] Focussing of radiowaves by large scale ionospheric irregularities. *J. Atmos. Terr. Phys.*, **36**, 461-473.
- KENT, G. S. [1961] High frequency fading of the 108 Mc/s wave radiated from an artificial earth satellite as observed at an equatorial station. *J. Atmos. Terr. Phys.*, Vol. 22, **4**, 255-269.
- KENT, G. S. and KOSTER, J. R. [1961] Height of night-time irregularities at equator. *Nature*, **191**, 1083-1084.
- KHASTAGIR, S. R., GANGULY, S. and SAMANTA, S. [1968] *Radio Sci.*, **3**, (New Series), 535.
- KING, G. A. M. [1970] Spread F on ionograms. *J. Atmos. Terr. Phys.*, **32**, 209-221.
- KNECHT, R. W. and McDUFFIE, R. E. [1962] *On the Width of the Equatorial Es Belt. Ionospheric sporadic E*. Ed. E.K. Smith, and S. Matsushita, 215-218, Pergamon Press, Oxford.
- KOSTER, J. R. [1958] Radio star scintillation at equatorial station. *J. Atmos. Terr. Phys.*, **12**, 100-109.
- KOSTER, J. R. [1963] Some measurements on the sunset fading effect. *J. Geophys. Res.*, **68**, 2571-2578.
- KOTADIA, K. M. [1959] Spread F in the ionosphere over Ahmedabad during the years 1954-57. *Proc. Indian Acad. Sci.*, **50A**, 259.
- KRISHNAMURTHY, B. V. [1966] Behaviour of topside and bottomside spread F at equatorial latitudes. *J. Geophys. Res.*, **71**, 4527-4533.
- LYON, A. J., SKINNER, N. J. and WRIGHT, R. W. H. [1960] The belt of equatorial spread F. *J. Atmos. Terr. Phys.*, **19**, 145-159.
- LYON, A. J., SKINNER, N. J. and WRIGHT, R. W. [1961] Equatorial spread F at Ibadan, Nigeria. *J. Atmos. Terr. Phys.*, **21**, 100-119.
- MATSUSHITA, S. [1962] *Lunar Tidal Variations of Sporadic E. Ionospheric Sporadic E*. Ed. E. K. Smith and S. Matsushita, 194-214, Pergamon Press, Oxford, UK.
- McNICOL, R. W. E. [1949] The fading of radiowaves of medium and high frequencies. *Proc. IEE*, Part III, **96**, 517-524.
- McNAMARA, L. F. [1971] Range spreading and evening type transequatorial propagation. *Nature*, (Phys. Sci.), **234**, 76.
- MITRA, S. N. and SRIVASTAVA, R. B. L. [1967] Fading and random motion of ionospheric irregularities. *Indian J. Phys.*, **31**, 20-42.
- MIYA, K. and SASAKI, T. [1966] Characteristics of ionospheric ES propagation and calculation of Es signal strength. *Radio Sci.*, **1**, 99-108.
- NAKAGAMI, M. [1943] Statistical character of shortwave fading. *J. Inst. Electron. Comm. Engrs. Japan*, **27**, 145.
- NAKAGAMI, M. [1960] *The M-distribution: A General Formula for Intensity Distribution of Rapid Fading: Statistical Methods in Radiowave Propagation*. Ed. W.C. Hoffman, 3-66, Pergamon Press, Oxford, UK.
- NORTON, K. A., VOGLER, L. E. MANSFIELD, W. V. and SHORT, P. J. [1955] The probability distribution of the amplitude of a constant vector plus a Rayleigh distributed vector. *Proc. IRE*, **43**, 1354-1361.
- OSBORNE, B. W. [1951] Ionospheric behaviour in the F2 region at Singapore. *J. Atmos. Terr. Phys.*, **2**, 66.
- OSBORNE, B. W. [1952] A note on ionospheric condition which may affect tropical broadcasting services after sunset. *J. Brit. IRE*, **12**, 110.
- OYINLOYE, J. O. [1971] A study of blanketing sporadic E in the equatorial region, *Planet. Space Sci.*, **19**, 1131-1139.
- PATEL, C. M. [1966] Speed of fading of radiowaves reflected from the ionosphere over Ahmedabad. *J. Inst. Telecomm. Engrs. (India)*, **12**, 511-515.
- RANGASWAMY, S. [1963] Backscatter of radiowaves from the equatorial F region, *J. Atmos. Terr. Phys.*, **25**, 545.
- RANGASWAMY, S. and KAPASI, K. B. [1963] A study of equatorial spread F. *J. Atmos. Terr. Phys.*, **25**, 721.
- RAO, B. C. N. [1966] Control of equatorial spread F by the F layer height. *J. Atmos. Terr. Phys.*, **28**, 1207-1217.
- RAO, C. V. S. and MITRA, S. N. [1962] Spread F and geomagnetic activity. *J. Geophys. Res.*, **67**, 127.
- RAO, P. S. K. and RAO, B. R. [1964] Fading analysis of ionospheric drift records. *J. Atmos. Terr. Phys.*, **26**, 841.
- RAO P. S. K. and RAO, B. R. [1967] Radiowave fading at Waltair during IGY. *Current Sci.*, **36**, 148-149.
- RASTOGI, R. G. and CHANDRA, H. C. [1970] Solar cycle anseasonal variation of spread F near the magnetic equator. *J. Atmos. Terr. Phys.*, **32**, 439-443.
- RASTOGI, R. G., KAUSHIKA, N. D. and DASGUPTA, M. R. [1966] Fading characteristics of radiowaves reflected from Es layer at Thumba. *Ann. Geophys.*, **22**, 380-384.
- RICE, S. O. [1944-1945] Mathematical analysis of random noise. *BSTJ*, **23**, 282; **24**, 46.
- RICE, S. O. [1958] Distribution of the duration of fades in radio transmissions: Gaussian noise model. *BSTJ*, **37**, 581.
- RÖTTGER, J. [1976] Influence of spread F on HF radio systems. AGARD Conf. Proc. No. 173 on radio systems and the ionosphere.
- SHIMAZAKI, T. [1959] A statistical study of world-wide occurrence probability of spread F, Parts I and II. *J. Radio Res. Labs. (Japan)*, **6**, 669-704.
- SINGLETON, D. G. [1960] The geomorphology of spread F. *J. Geophys. Res.*, **65**, 3615.
- SINGLETON, D. G. [November, 1962] Spread-F and the parameters of the F-layer of the ionosphere — IV. Causative mechanisms. *J. Atmos. Terr. Phys.*, Vol. 24, **11**, 909-919.
- SKINNER, N. J. and WRIGHT, R. W. H. [1962] *The reflection coefficient of fading characteristics of signals returned from Es layer at Ibadan. Ionospheric sporadic E*. Ed. E.K. Smith and S. Matsushita, 37-49 Pergamon Press, Oxford.
- SMITH, E. K. and FINNEY, J. W. [1960] Peculiarities of the ionosphere in the Far East: A report of IGY observations of sporadic E and F region scatter. *J. Geophys. Res.*, **65**, 885.

- SOUTHWORTH, M. P. [1960] Night-time equatorial propagation at 50 Mc/s first results from IGY amateur observing programme. *J. Geophys. Res.*, **65**, 601.
- SRIVASTAVA, S. K., PRADHAN, S. M. and TANTRY, B. A. P. [1972] Amplitude probability distribution of radiowaves reflected from travelling ionospheric disturbances. *Radio Sci.*, **7**, 563-569.
- STEIN, S. [1958] The role of ionospheric layer tilts in long-range high frequency radio propagation. *J. Geophys. Res.*, **63**, 217.
- SUBBA RAO, N. S. and SOMAYAJULU, T. V. [1949] A peculiar type of rapid fading in radio reception. *Nature*, **163**, 442.
- VENKATESWARLU, P. and RAMU, S. [1964] Some characteristics of sporadic E layer at low latitudes. *J. Atmos. Terr. Phys.*, **26**, 269.
- WATTS, J. M. and DAVIES, K. [1960] Rapid frequency analysis of fading radio signals. *J. Geophys. Res.*, **65**, 2295-2301.
- WRIGHT, R. W., KOSTER, J. R. and SKINNER, N. J. [1956] Spread F echoes and radiostar scintillation. *J. Atmos. Terr. Phys.*, **8**, 240.
- YEH, K. C. and VILLARD, O. G. [1958] A new type of fading observable in high frequency radio transmissions propagated over paths crossing the magnetic equator. *Proc. IRE*, **46**, 1968-1970.

CCIR Documents

- [1959] (Los Angeles): **a.** XII/8 (India); **b.** XII/5 (United Kingdom).
- [1962] (Bad Kreuznach): **a.** XII/12 (India); **b.** XII/17 (United Kingdom); **c.** XII/5 (USA).

RECOMMENDATION 215-2

MAXIMUM TRANSMITTER POWERS FOR BROADCASTING IN THE TROPICAL ZONE *

(Question 45/10, Study Programme 45A/10, Recommendation 214)

(1956-1978-1982)

The CCIR,

CONSIDERING

- (a) that the prolonged observations and studies which have been carried out confirm the existence of high noise levels in the Tropical Zone;
- (b) that good quality service presupposes the maintenance of a satisfactory value of signal-to-noise ratio in the entire coverage area;
- (c) that the high value of noise level observed in tropical regions during certain hours of the day and certain periods of the year, together with the need for signal-to-noise ratios such as to ensure a satisfactory service for practically all listeners within the specified coverage area, tends to suggest the use of high transmitter-power for sound-broadcasting services in the Tropical Zone. It is therefore advisable, when evaluating the powers to be used, to assume reasonable values for the average noise level and signal-to-noise ratio to reach practical values of transmitter powers, ensuring acceptable conditions of reception for a suitable percentage of transmission time at the limit of the coverage area;
- (d) that, when the coverage area is limited to 400 km, vertical incidence antennas may be used effectively to concentrate the energy in the coverage area and to reduce radiation beyond this zone;
- (e) that, for greater distances, it appears necessary to use types of antenna with low gain, such as a simple dipole, to obtain the required field strength at a distance of 800 km. Nevertheless, this type of antenna radiates at low angles of elevation and may give rise to interference at great distances;
- (f) that it is advisable to make a judicious choice of transmitting frequencies which, for a sound-broadcasting programme in the Tropical Zone may be located in the shared bands the upper limit of which is 5060 kHz and in band 7 (HF) at frequencies above 5060 kHz,

UNANIMOUSLY RECOMMENDS

1. that the upper carrier power limit for short-distance high frequency sound-broadcasting transmitters employing double-sideband (AM) emission, operating in the Tropical Zone in frequency bands below 5060 kHz but with the exception of the band 3900-4000 kHz, should be determined as follows:
 - 1.1 for a coverage area limited to 400 km, the carrier power of the transmitter should not exceed 10 kW;

* See Article 30 of the Radio Regulations.

- 1.2 for a coverage area limited to 800 km, the carrier power of the transmitter should not exceed 50 kW;
- 1.3 for frequencies above 5060 kHz, where sound-broadcasting services in the Tropical Zone use the same frequency bands as the HF broadcasting services, no carrier power limit, as in the case of the exclusive HF bands, shall apply.
2. that, within the above limits, administrations should use, as far as possible, lower powers, if these will ensure satisfactory service throughout the reception area;
3. that the frequency used should always be as near as possible to the optimum working frequency (provided that the frequency employed is within one of the permissible sound broadcasting bands), to provide as good a received signal-to-noise ratio as possible;
4. that, in conformity with the provisions of Recommendation 139, and to make the best possible use of the frequency bands which have been allocated, administrations should use appropriate antennas, so that radiations at low angles will be reduced to a minimum, to avoid all harmful interference outside the coverage area.

RECOMMENDATION 214-2

LIMITATION OF THE POWER OF TRANSMITTERS IN THE TROPICAL ZONE TO AVOID INTERFERENCE IN THE BANDS SHARED WITH BROADCASTING IN THE TROPICAL ZONE

(Question 45/10, Study Programme 45E/10)

(1951-1956-1978-1982)

The CCIR,

CONSIDERING

- (a) that the power of transmitters for radio services in the Tropical Zone, operating within the bands shared with tropical broadcasting (number 2669 of the Radio Regulations), should be determined to ensure full protection to broadcasting in the Tropical Zone;
- (b) that it is preferable to exploit the possibilities of "time sharing" between broadcasting services in the Tropical Zone and radiotelegraph services operating within the shared bands;
- (c) that, at sunspot minimum, when certain frequencies become useless for broadcasting in the Tropical Zone, such frequencies could be used by other services;
- (d) that Recommendation 215 recommends provisional power limitations for broadcasting stations in the Tropical Zone;
- (e) that the maximum power of radiotelegraph stations can best be determined in the light of the permissible "repetition distance";
- (f) that the protection ratio to be considered in the determination of the "repetition distance" will be that set forth in Recommendation 216 read in conjunction with Report 302;
- (g) that the factors governing the limitation of power for class of emission A3E by services other than broadcasting within the shared bands are similar to those for radiotelegraphy,

UNANIMOUSLY RECOMMENDS

1. that, for the particular cases not involving simultaneous operation of broadcasting and other services, no limitations should be imposed on the power of radiotelegraph stations operating within the shared bands, other than those necessary to comply with the provisions of numbers 1798-1846 of the Radio Regulations;
 2. that, for the general case involving the simultaneous operation of broadcasting and radiotelegraph services within the shared bands, the power of radiotelegraph stations in the Tropical Zone, should not be greater than that necessary to provide an adequate protection for the broadcasting services;
 3. that the limitations for fixed service stations in the Tropical Zone, employing class of emission A3E and operating within the shared bands, should be similar to those for radiotelegraph stations operating under like conditions.
-

RECOMMENDATION 139-1

**TRANSMITTING ANTENNAS FOR SOUND BROADCASTING
IN THE TROPICAL ZONE**

(Question 45/10, Study Programme 45F/10)

(1953-1978)

The CCIR,

CONSIDERING

- (a) that it is desirable to use transmitting antennas for sound broadcasting in the Tropical Zone that cause a minimum of interference outside the service area;
- (b) that the antennas should be economical in design and simple in operation;
- (c) that Report 301 and Annex I to this Recommendation give the principles on which antennas for sound broadcasting in the Tropical Zone should be designed and constructed;
- (d) that it is desirable to obtain as many operational data as possible on sound broadcasting in the Tropical Zone using antennas designed on these principles,

UNANIMOUSLY RECOMMENDS

1. that administrations and organizations operating sound-broadcasting services in the Tropical Zone should use antenna systems so designed that:
 - the power radiated is as large as possible at the high angles of elevation required to meet the needs of the service area,
 - a sufficient value of radiation should be maintained at angles of elevation necessary to serve the fringe of the service area,
 - the power radiated at angles of elevation lower than those used to serve the fringe of the service area is as low as possible;
2. that administrations and organizations should forward to the CCIR reports on the operation of such antennas, so that an addendum can be issued to Report 301 giving practical operational data concerning these antennas. The data and information should be forwarded in the following form:
 - type of antenna system used and its physical dimensions in relation to the frequency of operation;
 - electrical characteristics – polar diagram in the vertical and the horizontal planes;
 - power radiated by the antenna;
 - siting of the antenna with respect to the geographical configuration of the area to be served and the orientation of the antenna with respect to North;
 - hourly averages of field strength measured, whenever practicable, every 100 or 200 km, up to a maximum distance of 2000 km in all directions;
 - fading characteristics of the received signal;
 - influence, if any, of the orientation of the antenna with respect to the magnetic meridian;
 - ground conductivity in the vicinity of the antenna system;
 - any other information considered useful with respect to this Recommendation.

ANNEX I

1. Selection of site

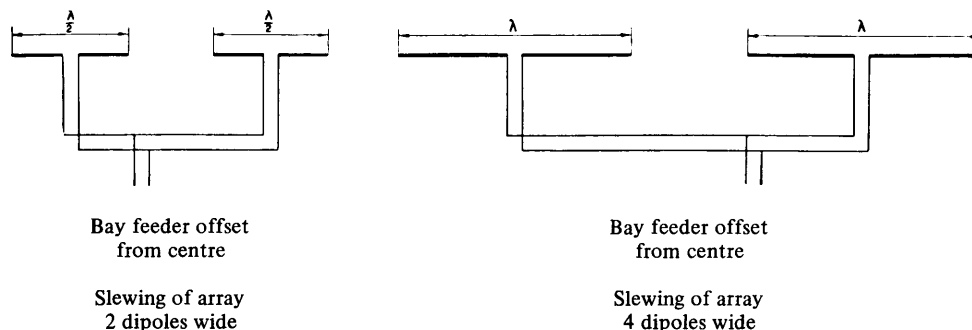
The transmitting antenna should be situated as near to the centre of the service area as possible. For antennas relying on ground reflection for their vertical directivity, the site should be chosen where the soil is of good conductivity. Where this is not possible, an earth mat can be used. This should consist of a number of paralleled wires spaced not more than one tenth of a wavelength apart, parallel to the dipoles and extending for half a wavelength beyond the extremities of the antenna array.

When it is not possible to locate the antenna at the centre of the service area, the beam should be suitably slewed using multi-element transmitting antenna to cover the desired service area. Angles of slew greater than about 15° often produce large side-lobes which may cause interference outside the reception area.

If there are no adjacent reception areas, for example, where the area to be served is an isolated island, a central location is less important.

2. Slewing

If it is desired to site a station away from the centre of the service area, the direction of vertical beam can be slewed, by dividing each row of dipoles of the array into two halves with currents in different phases. This method of slewing is most easily applicable to arrays of two or four dipoles per row and the following sketches indicate the method of feeding.



This method of slewing will result in the main-lobe being slewed in the plane containing the dipole whilst the polar diagram in the plane at right angles to the dipoles remains unchanged.

3. Antenna for services up to a radius of 350 km

Based on the studies carried out on a vertical incidence 4 half-wave element antenna, $1/4$ wavelength above ground end-fed (all elements fed in phase), it may be observed that this antenna would be suitable for sound broadcasting in the Tropical Zone up to a distance limited to about 350 km.

BIBLIOGRAPHY

ADORIAN, P. and DICKENSON, A. H. [February, 1952] High frequency broadcast transmission with vertical radiation. *J. Brit. IRE*, Vol. 12, 2.

AIR Research Report No. 382, A 2×2 Array at 0.2λ above ground.

CCIR Documents

[1956] (Warsaw): 470 (United Kingdom).

REPORT 301-3

TRANSMITTING ANTENNAS FOR SOUND BROADCASTING IN THE TROPICAL ZONE

(Question 45/10, Study Programme 45F/10)

(1953-1956-1963-1966-1970-1978)

1. Introduction

The radiated power of the transmitter is primarily decided by the minimum signal required to override the noise. In the Tropical Zone the atmospheric noise is the dominant factor for the purpose of planning. Accordingly, the main considerations in the design of antennas for sound broadcasting in the Tropical Zone are, that the antenna should be simple in operation and that the radiation from it should be fairly uniform in the service area and should cause minimum interference outside this area. Some antennas proposed for use in the Tropical Zone are briefly discussed below.

2. Antennas for vertical incidence

Some arrays used by different organizations for the purpose of sound broadcasting in the Tropical Zone have been described in [CCIR, 1956, and Adorian and Dickinson, 1952]. These include the Trinidad antenna, the Jamaica antenna and the 16-element array.

The Trinidad antenna consists of two half-wave dipoles in the same vertical plane, the lower of which is one quarter wave-length above the ground. The schematic of the antenna and its power density diagram are given in Figs. 20 and 21 of [CCIR, 1969]. It gives greater field strength near the transmitter and a lower value of field further away when compared to a dipole.

The Jamaica antenna consists of four half-wave end-fed dipoles in the same horizontal plane. All the elements are 0.2λ above ground. This parameter is not critical. The elements are fed with currents in the same phase and magnitude. The schematic of the antenna and its power density diagram are given in Fig. 16 of [CCIR, 1969]. This antenna is an improvement over the Trinidad antenna.

The 16-element array consists of sixteen half-wave dipoles all in the same horizontal plane. There are four rows, each consisting of four half-wave dipoles. The adjacent rows are separated by a distance of one half wave length. All the elements are a quarter-wavelength above the ground. But this is not critical. The elements are fed with currents in the same phase and magnitude. The schematic of the antenna and its power-density diagram are given in Fig. 17 of [CCIR, 1969].

3. High incidence array

[CCIR, 1962] describes a high incidence array which gives adequate high frequency coverage over a circular area of up to 1000 km radius. The array consists of four full-wave dipoles arranged in the form of a square and fed in such a manner that the currents in any two adjoining elements are in phase and are of the same magnitude. The average height above ground is 0.15λ but this does not seem to be critical. The radiating elements are built up of a four-wire cage, resulting in an impedance of 2200Ω each of which, when paralleled at the centre, gives a good match to a 550Ω feeder. A quarter-wave matching stub is included in the design. The schematic of the antenna and its power distribution diagram are given in Figs. 18 and 19 of [CCIR, 1969]. The gain of the array, relative to an isotropic radiator, is 8 dB.

It has been found that the low-angle radiation of the array is less than that of dipole ($h = 0.4 \lambda$) in all directions. At any angle of elevation below 30° , the radiation from the high incidence array is 16 dB below the maximum radiated by dipole at that elevation.

The high-angle radiation of the array is greater than that of dipole in broad-side direction at angles of elevation between 50° and 75° , representing improved signal strength between 100 and 400 km. In the end-on direction at angles of elevation between 25° and 75° , improved signal strength is available between 100 and 1000 km. The measurements of low-angle radiation (less than 30°) were made on a scale model of the array; the measurements at high angles were made in the field on an actual array.

4. H-1/2 array fed out-of-phase

[CCIR, 1963-66], describes an H-1/2, a simple two-tier dipole array with a standard 0.5λ spacing with a view to giving adequate coverage up to 800 km. An H-1/2/0.5 antenna fed out-of-phase, gives an angle of fire of 41° . Out-of-phase feeding can easily be arranged in such arrays because of the standard 0.5λ spacing between the elements. Theoretical investigations were first carried out and it was found that an H-1/2 array fed out-of-phase with the lower element at a height of 0.2λ above ground generally satisfied the requirements of a tropical broadcasting antenna. Figure 1 gives the polar diagram of H-1/2/0.2 fed out-of-phase antenna, a simple dipole 0.44λ ($7/16 \lambda$) above ground and an ideal antenna which shows cut-off at an angle of 36° above the horizon, so as to restrict radiation beyond 800 km. Scale model tests were carried out and these showed that a height of 0.40λ was more suitable than the theoretically computed height of 0.2λ . This was attributed to the mutual impedance effects due to the close proximity of the antenna to the ground.

Field trials were carried out on the full scale antenna system H-1/2/0.4 fed out-of-phase. The results show that at distances below 600 km the field strength laid down by the experimental antenna is higher than that from a single dipole. At distances above 600 km, the field strength laid down by the experimental antenna is low compared to the dipole (Fig. 2). It may be mentioned that the day-time values of the field strength need to be checked up by further measurements.

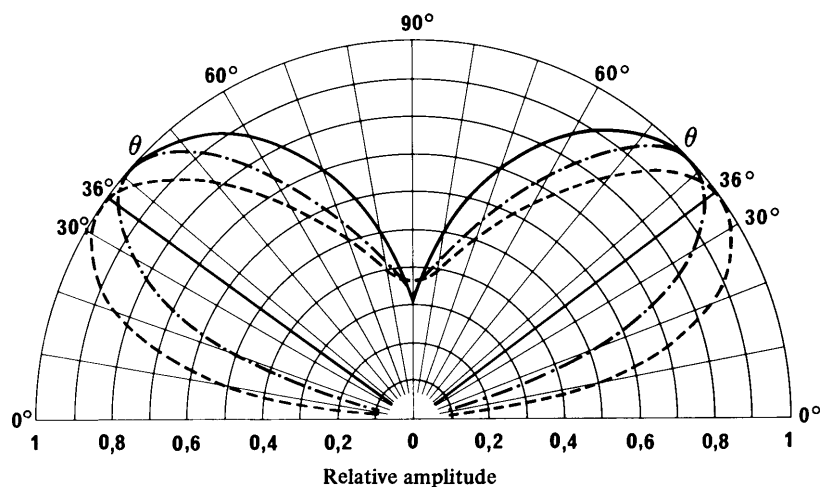


FIGURE 1 – Vertical radiation patterns—idealized for 800 km distance and those obtainable by simple dipole and dipole array

- Ideal diagram
- Dipole $7/16 \lambda$ above ground
- · - · - H-1/2/0.2 for out-of-phase feed

[CCIR, 1966-69] states that while designing antenna for night-time operation, the field due to higher order modes such as 2-F should be taken into account. During day-time, ionospheric absorption is considerable, resulting in propagation being limited to only 1-hop. The absorption also increases with the obliquity of the incidence and an antenna suitable for day-time should have maximum gain corresponding to the angle required at the fringe of the service area. At angles below this, there should be sharp cut-off. At night, however, multi-hop propagation is possible due to lower absorption. Fields due to 2-F mode should therefore be taken into account while designing such antennas systems (Fig. 3). Further measurements of field strength, both during the day-time and night-time, should be taken to assess the influence of different modes of propagation.

5. Conclusion

The transmitting antenna for broadcasting in the Tropical Zone is characterized by a fairly uniform field in the service area and a sharp cut-off thereafter. Among the different antennas tried by various administrations, an H-1/2, fed out-of-phase (Trinidad antenna) with lower elements at a height of 0.2λ can be used for service areas, having a radius of 300 to 400 km. However, a 2×2 array, fed in-phase (Jamaica antenna), gives improved performance for the same range. A 4×4 array, fed in-phase, can be used for service range of 150 to 200 km. The High-Incidence array, i.e. a four full-wave dipole placed along the side of a square can be used for serving distances between 100 to 1000 km only during the day-time. For designing the antenna for night-time operation, field due to higher modes should be taken into account.

It is considered necessary that further studies should be undertaken to optimize the design of the transmitting antenna for use in the Tropical Zone, by using computer techniques, and collecting data.

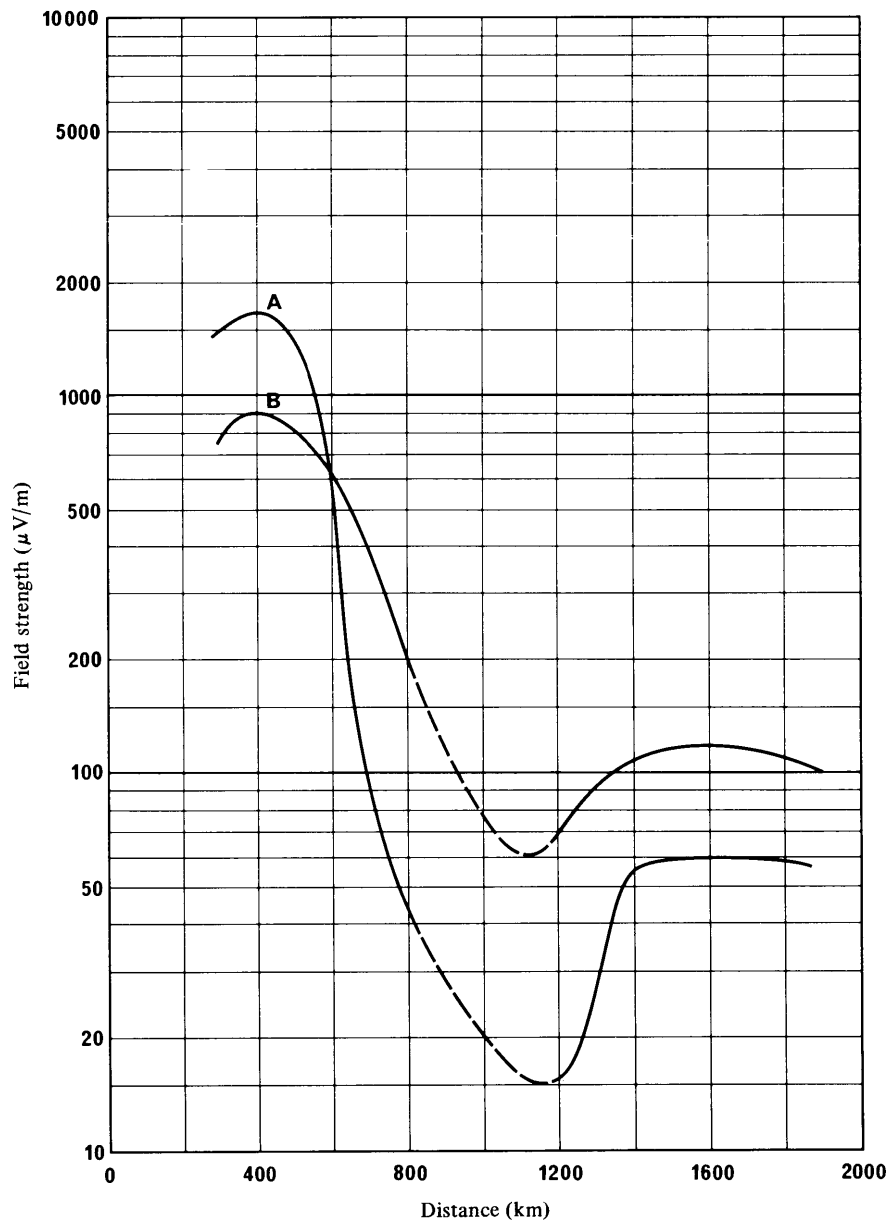


FIGURE 2 -- *Experimental antenna for broadcasting in the Tropical Zone:
field strength as a function of distance;
(transmitter power: 5 kW: λ : 49 m)*

Curve A : H-1/2/0.4 array, fed out-of-phase

Curve B : H-1/1/0.4 comparison dipole

----- interpolated regions

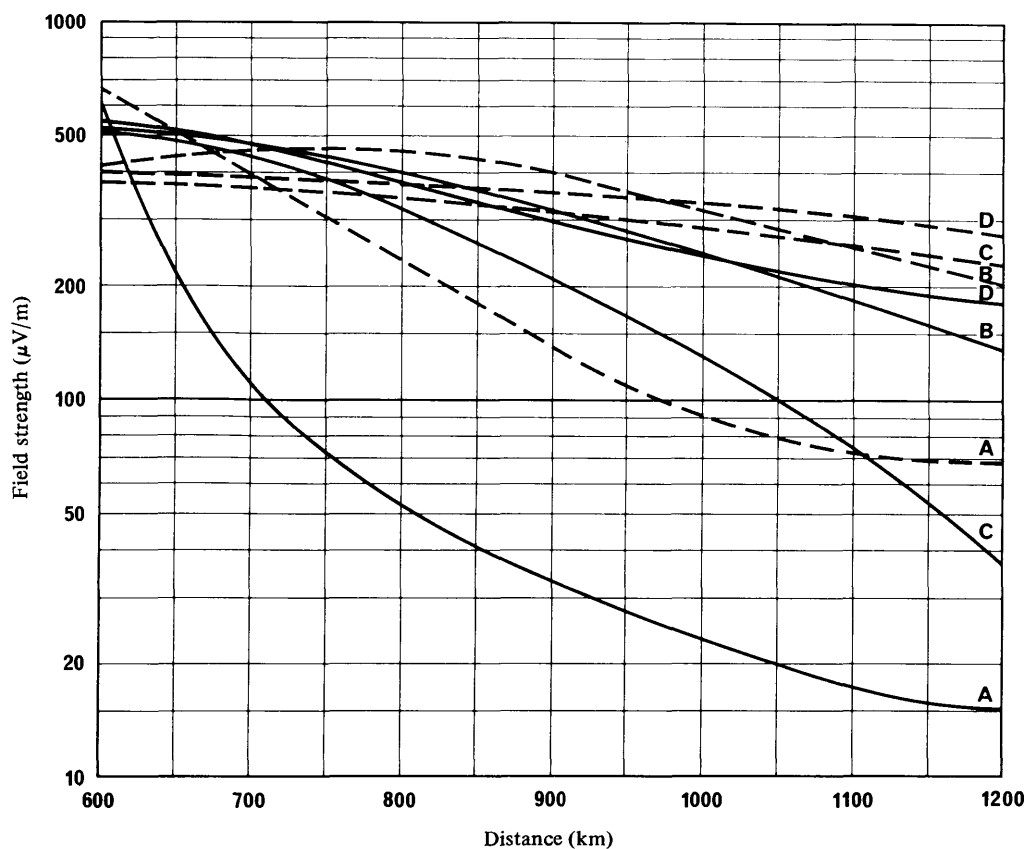


FIGURE 3 – Field strength as a function of distance for an experimental antenna for broadcasting in the Tropical Zone
(transmitter power: 5 kW)

— : H-1/2/0.4 array, fed out-of-phase
 - - - : H-1/1/0.4 dipole

Curves A: measured field strength: – day
 Curves B: – night
 Curves C: calculated field strength, night: – first hop field
 Curves D: night: – resultant field

REFERENCES

- ADORIAN, P. and DICKINSON, A. H. [1952] High frequency broadcast transmission with vertical radiation. *J. Brit. IRE*, Vol. 12, 2.
- CCIR [1969] Broadcasting in band 7 (HF) in the Tropical Zone.
- CCIR Documents*
- [1956] (Warsaw): 470 (United Kingdom).
- [1962] (Bad Kreuznach): XII/1 (Republic of South Africa).
- [1963-66]: XII/4 (India).
- [1966-69]: XII/6 (India).

BIBLIOGRAPHY

- CCIR [1978] Antenna diagrams.

RECOMMENDATION 140-1

**RECEIVING ANTENNAS FOR SOUND-BROADCASTING RECEPTION
IN THE TROPICAL ZONE**

(Question 45/10)

(1953-1978)

The CCIR,

CONSIDERING

- (a) that only simple antennas are practicable for the great majority of domestic broadcasting listeners in the Tropical Zone;
- (b) that the antenna must be both cheap and simple to install since it has to be used on a number of frequencies with fields at varying angles of incidence;
- (c) that the directivity of receiving antennas cannot be relied upon to improve the signal-to-noise ratio,

UNANIMOUSLY RECOMMENDS

that it is reasonable to assume that the antenna used by listeners will be an "L" type antenna with horizontal and vertical limbs, each 4.90 m (16 ft) long.

RECOMMENDATION 415-1

**MINIMUM PERFORMANCE SPECIFICATIONS FOR LOW-COST
SOUND-BROADCASTING RECEIVERS**

(1963-1982)

The CCIR,

CONSIDERING

- (a) that the advantages of broadcasting should be made more easily available to the populations of the countries where, at present, the density of receivers is particularly low due to economic, geographical or technical reasons;
- (b) that to this end, it is desirable that efficient broadcasting receivers should be available at prices low enough to secure their wide distribution in those countries;
- (c) that general agreement on the performance of suitable broadcasting receivers would prove most useful to radio receiver manufacturers by assisting them to produce suitable receivers, having an agreed adequate standard of performance, at the lowest possible cost,

UNANIMOUSLY RECOMMENDS

that the minimum performance specifications, contained in Annex I, be used to assist in the design and development of low-cost sound-broadcasting receivers suitable for production in large quantities.

ANNEX I

These specifications apply to the following types of receivers:

Type A : a low sensitivity receiver for operation in band 6 (MF),

Type B : a combined receiver for operation in bands 6 (MF) and 7 (HF),

Type C : a medium sensitivity frequency-modulation receiver for operation in band 8 (VHF).

1. General

1.1 Each of the three types of receiver should be available for either mains or battery operation. For battery operation, all three types of receiver should be fully transistorized to ensure economy of power consumption. For mains operation, either valves or transistors may be used, consideration of cost being the guiding factor.

1.2 For battery-operated receivers, the minimum performance specifications listed in this Recommendation should be achieved for the nominal battery voltage less 30% as specified in the relevant IEC publication.

1.3 The methods of measurement employed should be those recommended in the relevant IEC publications for amplitude-modulation receivers and frequency-modulation receivers.

1.4 The receivers should be simple, robust and well protected against dust. Those intended for use in regions of high temperature and humidity should be treated so that they can be used under the climatic conditions laid down by the administration concerned. The appropriate tests required by the administration procuring such receivers should comply with the relevant IEC publications.

1.5 If national regulations prescribe methods of measurement or tests differing from the standard IEC methods, administrations will, where necessary, draw attention to this.

2. Specification for Type A receivers

2.1	Frequency coverage (kHz)	526.5-1606.5 (Regions 1 and 3) 525-1705 (Region 2)
2.2	Sensitivity for 50 mW output 30% modulation at 400 Hz	5 mV/m (with a built-in antenna with facilities for using an external antenna)
2.3	Signal/noise ratio for input as under § 2.2	20 dB (mains-operated tube receivers) 26 dB (transistor receivers)
2.4	Power output, for less than 10% distortion	not less than 0.1 W
2.5	Overall selectivity at – 6 dB points at – 20 dB points	passband not less than ± 3 kHz passband not greater than ± 10 kHz
2.6	Image, intermediate frequency and spurious response ratio	not less than 30 dB
2.7	Overall fidelity including acoustic response of loudspeaker, or, Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be	250-3150 Hz, within 18 dB limits 100-4000 Hz within 12 dB limits (in a graphical presentation 400 Hz should be taken as the reference 0 dB level)

3. Specification for Type B receiver (the two types differing only in frequency range)

3.1	Frequency coverage (MHz)	B1 : 0.5265-1.6065; 2.3-15.6 (Regions 1 and 3) 0.5250-1.7050; 2.3-15.6 (Region 2) B2 : 0.5265-1.6065; 2.3-21.85 (Regions 1 and 3) 0.5250-1.7050; 2.3-21.85 (Region 2) The receiver shall be provided with adequate mechanical and/or electrical means for easy tuning.
3.2	Sensitivity for 50 mW output 30% modulation at 400 Hz	not worse than 150 μ V
3.3	Signal-to-noise ratio, for input as under § 3.2	20 dB (mains-operated tube receivers) 26 dB (transistor receivers)
3.4	Power output, for less than 10% distortion	not less than 0.1 W
3.5	Overall selectivity at – 6 dB points at – 20 dB points at – 40 dB points	passband not less than ± 3 kHz passband not greater than ± 10 kHz passband not greater than ± 20 kHz

3.6 Image, intermediate frequency and spurious response ratio	MF — not less than 30 dB
Intermediate frequency and spurious response ratio	HF — not less than 12 dB
Image response ratio	HF — not less than 5 dB
3.7 Overall fidelity including acoustic response of loudspeaker, or, Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be	250-3150 Hz within 18 dB limits 100-4000 Hz within 12 dB limits (in a graphical presentation 400 Hz should be taken as the reference 0 dB level)
3.8 A.g.c. performance: change in output when the input is reduced by 30 dB from 0.1 V	not greater than 10 dB
3.9 Frequency stability	must be such that the receiver does not require frequent retuning

4. Specification for Type C receivers

4.1 Frequency coverage (MHz)	87.5-108 (Region 1) 88 -108 (Region 2) 87 -108 (Region 3)
4.2 Signal-to-noise ratio	30 dB
4.3 Sensitivity (noise limited)	−75 dB rel. 1 mW (at a signal-to-noise ratio of 30 dB and 50 mW output power)
4.4 Intermediate frequency	10.7 MHz
4.5 Amplitude-modulation suppression ratio	20 dB
4.6 Power output	not less than 0.1 W
4.7 Overall selectivity	−30 dB at ± 300 kHz
4.8 Overall fidelity including acoustic response of loudspeaker, or, Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be	200-5000 Hz within 18 dB limits 100-5000 Hz within 6 dB limits (in a graphical presentation 400 Hz should be taken as the reference 0 dB level)
4.9 Radiation	the local oscillator radiation should be less than the limits specified by CISPR. However, where national regulations exist, the radiation should be less than the limits specified therein
4.10 Distortion	the distortion should be less than 5% for a frequency deviation varying between ± 15 kHz and ± 75 kHz with a modulation frequency of 400 Hz and an output power of 50 mW
4.11 Frequency stability	must be such that the receiver does not require frequent retuning.

RECOMMENDATION 416-1

**MINIMUM PERFORMANCE SPECIFICATIONS FOR LOW-COST
SOUND-BROADCASTING RECEIVERS FOR COMMUNITY LISTENING**

(1963–1982)

The CCIR,

CONSIDERING

that community receivers provide the easiest method of making broadcasting available to the population of those countries where, at present, the density of receivers is particularly low due to economic, geographical or technical reasons,

UNANIMOUSLY RECOMMENDS

that the minimum performance specifications, contained in Annex I, be used to assist in the design and development of low-cost community receivers.

ANNEX I

1. General

1.1 The receivers should be simple, robust and well protected against dust. They should also be strong enough to withstand transport and handling by unskilled persons.

1.2 The pre-set tuning controls should be available only to authorized persons. The controls should be robust and include a channel selection switch, a fine tuning control to facilitate accurate tuning and compensate for any frequency drift during operation, and a volume control.

1.3 Each of the two types of receiver considered in §§ 2 and 3 should be available for either mains or battery operation. For battery operation, the receivers should be fully transistorized to ensure economy of power consumption. For mains operation, either valves or transistors may be used, consideration of cost being the guiding factor.

1.4 For battery-operated receivers, the minimum performance specifications listed in this Recommendation should be achieved for the nominal battery voltage less 30% as specified in the relevant IEC publication.

1.5 The methods of measurement employed should be those recommended in the relevant IEC publications for amplitude-modulation and frequency-modulation receivers.

1.6 The receivers, which are intended for use in regions of high temperature and humidity, should be treated so that they can be used under the climatic conditions laid down by the administration concerned. The appropriate tests required by the administration procuring such receivers should comply with the relevant IEC publication.

1.7 If national regulations prescribe measuring methods or tests different from the standard IEC methods, the administrations will, where necessary, draw attention to this.

2. Specification for a community receiver operating in bands 6 (MF) and 7 (HF)

(Two types, differing only in frequency range)

2.1	Frequency coverage (MHz)	(a) 0.5265-1.6065; 2.3-21.85 (Regions 1 and 3) 0.5250-1.7050; 2.3-21.85 (Region 2)
		(b) 0.5265-1.6065; 2.3- 9.9 (Regions 1 and 3) 0.5250-1.7050; 2.3- 9.9 (Region 2).

2.1.1 Receiver tuning may be fully bandspread on the broadcast bands appropriate to the requirements of any administration or the receiver should be capable of being coarse pre-tuned to any spot frequency in:

- band 6 (MF) and
- each of the bands in band 7 (HF);

with the provision that a limited number of spot frequencies (e.g. three), selected from band 7 (HF) are made available for ready selection at any time, by the operator.

2.2	Sensitivity for 50 mW output 30% modulation at 400 Hz	not worse than 150 μ V.
2.3	Signal/noise ratio for input as under § 2.2	26 dB.

2.4	Power output for less than 10% distortion	not less than 900 mW (at nominal mains or battery voltage) and not less than 400 mW (at the nominal battery voltage less 30%)
2.5	Overall selectivity at – 6 dB points at – 20 dB points at – 40 dB points	passband not less than ± 3 kHz passband not greater than ± 10 kHz passband not greater than ± 20 kHz
2.6	Image, intermediate frequency and spurious response ratio	MF – not less than 30 dB
	Intermediate frequency and spurious response ratio	HF – not less than 12 dB
	Image response ratio	not less than 10 dB (HF up to 10 MHz)
	Image response ratio	not less than 5 dB (HF up to 21.75 MHz)
2.7	Overall fidelity including acoustic response of loudspeaker, or, Alternatively, since it may be more convenient for some manufacturers to consider only the electrical characteristics, these should be	250-3150 Hz within 18 dB limits 100-4000 Hz within 12 dB limits (in a graphical presentation 400 Hz should be taken as the reference 0 dB level)
2.8	Automatic gain control performance: change in output when the input is reduced by 30 dB from 0.1 V	not greater than 10 dB
2.9	Frequency stability	must be such that the receiver does not require frequent retuning
3.	Specification for a community receiver operating in band 8 (VHF)	
3.1	Frequency coverage (MHz)	87.5-108 (Region 1) 88 -108 (Region 2) 87 -108 (Region 3) (Provision must be made for one or more channels to be preselected)
3.2	Signal-to-noise ratio	30 dB
3.3	Sensitivity (noise limited)	– 85 dB rel. 1 mW (at a signal-to-noise ratio of 30 dB and 50 mW output power)
3.4	Intermediate frequency	10.7 MHz
3.5	Amplitude-modulation suppression ratio	24 dB
3.6	Power output	not less than 900 mW (at nominal mains or battery voltage) and not less than 400 mW (at the nominal battery voltage less 30%)
3.7	Overall selectivity	– 30 dB at ± 300 kHz
3.8	Overall fidelity including acoustic response of loudspeaker, or, Alternatively, since it may be more convenient for some manufacturers to consider only the electrical characteristics, these should be	200-5000 Hz within 18 dB limits 100-5000 Hz within 6 dB limits (in a graphical presentation 400 Hz should be taken as the reference 0 dB level)
3.9	Radiation	the local oscillator radiation should be less than the limits specified by CISPR. However, where national regulations exist, the radiation should be less than the limits specified therein

3.10	Distortion	the distortion should be less than 5% for a frequency deviation varying between ± 15 kHz and ± 75 kHz with a modulation frequency of 400 Hz and an output power of 50 mW
3.11	Frequency stability	must be such that the receiver does not require frequent retuning

REPORT 472-1

**SINGLE-SIDEBAND RECEPTION FOR RE-BROADCASTING APPLICATIONS
WITHIN THE TROPICAL ZONE**

Reduction of fading effects

(Question 45/10, Study Programme 45C/10)

(1970-1978)

1. Introduction

One of the most economical methods of re-broadcasting is the use of sky-wave signal from one broadcasting transmitter by another. In view of the simplicity and economy, it is of special importance to developing countries. The efficacy of this method, however, depends to a large extent on the quality of reception of the sky-wave signal at the re-transmission site. The quality is often impaired due to selective fading and "surge" and "flutter" fading peculiar to the Tropical Zone. In order to improve the quality of sky-wave reception by minimizing the adverse effects of the above types of fading, use of single-sideband reception may be considered as one of the effective means for re-broadcasting application.

2. Extent to which the use of single-sideband reception can improve the quality of HF broadcasting

2.1 Single-sideband (SSB) reception of a conventional double-sideband (DSB) amplitude-modulation emission has certain advantages, the principal ones being:

2.1.1 it is possible to select either of the sidebands of the received broadcasting signal, thereby rejecting the sideband most affected by adjacent channel interference;

2.1.2 the demodulation process is more linear at high levels of modulation and does not produce the objectionable audio distortion of an envelope detector, associated with selective fading of the carrier;

2.1.3 this system of reception has been reported to minimize other propagation impairments (e.g. flutter and surge fading) as discussed below. Preliminary studies reported in the CCIR texts have indicated the possibility of reducing the effects of selective, surge and flutter fading by the use of single-sideband reception technique.

2.2 The deterioration of the quality of sky-wave reception due to selective fading results from the non-linear harmonic distortion when envelope detector is adopted in DSB (AM) reception. However, in SSB system of reception, selective fading leads to only linear distortion which is less severe than non-linear distortion as in the DSB (AM) reception.

Studies in the Federal Republic of Germany [CCIR, 1966-69a] have led to the following broad conclusions:

For double-sideband AM emissions, selective fading near the carrier frequency causes an apparent increase in the depth of modulation. This gives rise to distortion as soon as the carrier voltage falls below the sum of sideband voltages. Besides, the amplitudes of the low frequency components of the modulating signal are attenuated — thereby affecting the dynamic range and the tonal quality of the programme. If selective fading occurs in one of the sidebands, an apparent phase modulation of the carrier occurs. This causes a frequency shift of the modulation. However, the change in the depth of modulation is not as pronounced as with selective fading of the carrier because of the retention of the second sideband.

For single-sideband emissions, the interfering effect of selective fading of the carrier is completely eliminated. Compared with the amplitude of the sideband, the amplitude of the carrier re-inserted in the receiver is very high and causes a reduction in the phase modulation of the vector sum of the carrier and sideband to a very low level. Consequently, the signal is not distorted by carrier fading.

Selective fading in the sideband changes the tonal quality of the signal. The effect is particularly noticeable when the low frequencies of a musical programme are affected by fading. This could be remedied by frequency diversity reception of the two sidebands. But this method fails if one sideband suffers interference from another transmitter. In this case, diversity reception is only possible when space or polarization diversity is applied to the undisturbed sideband but it requires more complex equipment. It may, however, be mentioned that the assessment of comparative merits of DSB (AM) and SSB reception by the Federal Republic of Germany was subjective. An experimental method for subjective comparisons developed in the Federal Republic of Germany is described in [CCIR, 1966-69a].

An HF-double-sideband emission (6 MHz band) was received on a receiver with 3 outputs:

- double-sideband;
- single-sideband;
- carrier signal strength measurement.

The signals from the first two outputs were recorded simultaneously on the two tracks of a tape-recorder while the signal from the third output was recorded on a paper chart-recorder. The counter on the tape-recorder was used to mark the paper-recording simultaneously. Switching from track 1 to track 2 and vice-versa of the tape-recorder allowed immediate comparison between the effects of fading on double-sideband and single-sideband reception. Different types of fading were recorded and could be compared with one another. Such comparative reproduction of characteristic passages indicated the improvement that could be obtained with SSB reception.

At the interim meeting of Study Group XII, Palma de Mallorca, 1968, the Federal Republic of Germany gave a demonstration using this experimental method. On the basis of this demonstration Study Group XII agreed unanimously that SSB reception led to a significant improvement in the quality of reception when selective fading occurred.

2.3 Some preliminary listening tests carried out in India [CCIR, 1966-69b] on spoken-word programmes have indicated that in the presence of surge and flutter fading, reception is worst while using DSB reception with automatic gain control (a.g.c.), but perceptible improvement is observed without a.g.c. When surge and flutter fading are severe, a noticeable improvement is obtained by the use of SSB reception even with a.g.c. The study concludes that reception on a single-sideband receiver with a.g.c. can apparently give acceptable quality of the spoken-word programmes when surge and flutter fading are present. In the experiment a commercially-built single-sideband adaptor was used, together with a standard HF communication receiver.

The single-sideband adaptor had the following main characteristics:

- sharply tuned bandpass filters to select either the upper or lower sideband of the emissions;
- carrier rejection filter (30 dB);
- stable, tunable local oscillator for carrier re-insertion;
- automatic frequency control of the local carrier re-insertion oscillator;
- oscilloscope indicator for correct tuning.

3. Preferred characteristics of SSB receiving system

At the interim meeting when the Federal Republic of Germany gave the demonstration, the former Study Group XII (incorporated into Study Group 10 by the XIIth Plenary Assembly, New Delhi, 1970) came to the conclusion that the characteristics of the single-sideband receiver would be important in determining the degree of observed improvement. A fairly high-class receiver is necessary with the following characteristics:

- The selectivity characteristics must be very sharp with steep flanks.
- The frequency stability of the receiver must be high, necessitating the provision of a “lock-in” circuit for automatic synchronization of the local oscillator with the frequency to be received.
- A built-in oscilloscope is most useful for tuning a receiver of this type.

It may specially be mentioned that the precision or accuracy of the local oscillator for carrier re-insertion is important and the frequency of the re-inserted carrier should be within a few hertz of the specified value. Any drift will produce an unpleasant modification of the reproduced sound for speech as well as musical programmes.

4. Conclusion

Studies on single-sideband reception have indicated that there is a considerable improvement in the quality of reception in the presence of selective fading.

Preliminary studies [CCIR, 1966-69b] have also shown the possibility of reducing the effect of surge and flutter by single-sideband reception. But there is a need for further detailed and extensive tests, both subjective and objective, to assess the extent of improvement that could be achieved and the determination of the preferred characteristics of such a system. It may be worthwhile to find out, whether the improvement in reception is due to the reduction of the effects of selective fading which may be associated with "surge" and "flutter".

The introduction of a suitable assessment scale is necessary when observed effects are subjective and are not open to exact measurement.

REFERENCES

CCIR Documents

[1966-69]: **a.** XII/7 (Federal Republic of Germany); **b.** XII/5 (India).

SECTION 10B: FREQUENCY-MODULATION SOUND BROADCASTING IN BANDS 8 (VHF) AND 9 (UHF)

Recommendations and Reports

REPORT 944

THEORETICAL NETWORK PLANNING

(Question 46/10, Study Programme 46L/10)

(1982)

1. Introduction

Broadcasting-transmitter networks should be planned in such a way that the required coverage of the area is provided using the minimum number of frequencies. From the purely technical standpoint, the coverage area of each transmitter depends upon a number of factors, for example: transmitter power, minimum usable field strength, radio-frequency protection ratio, the distance between transmitters sharing the same or adjacent channels, channel spacing, bandwidth of emission and other factors influencing wave propagation. It also depends on the channel distribution scheme.

When a large number of channels are to be planned or replanned for a particular AM or FM sound or television service, it has been found that effecting an efficient use of the spectrum can prove difficult when employing empirical methods only. For this reason, a theory of uniform transmitter networks was developed during the late 1950s and early 1960s [EBU, 1960]. This method can be applied with success when some uniformity of standards exists for the service to be planned. Furthermore, the frequency band to be planned should be constrained as little as possible, i.e. there should ideally be complete freedom in assigning any frequency to any transmitter.

The theory is not only useful in designing new or remodelling actual transmitter networks, but also provides a powerful tool for determining optimal technical parameters such as channel spacing, transmitter characteristics, etc., and identifying the best attainable coverage possible.

The method described below has already been used during the VHF/UHF European Broadcasting conference, Stockholm 1961, during the African VHF/UHF Broadcasting Conference, 1963, and helped in preliminary studies for the Geneva 1975 LF/MF Broadcasting Conference.

2. The theory of regular networks

It should be noted that the networks which will be studied in the present section are purely theoretical in the following sense:

- all the transmitters are identical: their power and antenna height are the same;
- they are equipped with non-directional antennas;
- propagation is isotropic and independent of frequency, at least within the band to be planned.
- for the purpose of calculating distances, the planning area is assumed to be flat and the population evenly spread over its surface; there are neither political nor natural boundaries.

In those conditions, and provided interference is negligible, the coverage area, i.e., the region where a good reception is achievable with a normal domestic receiver, is limited by a contour within which the electromagnetic field strength is greater than or equal to the value necessary to obtain a given signal-to-noise ratio. In the ideal situation described above, this contour is a circle whose radius depends on the type of service and the propagation laws valid for the frequency range considered. If it is desired to cover the whole of the planning area using such circular coverage areas, it is quite obvious that the number of transmitters per unit surface will be minimized if they are situated at the vertices of a lattice of equilateral triangles (Fig. 1). It should be noted that there is not one transmitter per triangle, but rather one transmitter for each pair of triangles forming a rhombus (shaded area of Fig. 1). This remark is of importance when computing the network efficiency.

With this configuration, every location on the planning area is served by at least one transmitter and overlapping of service areas is minimized. In what follows, we will take as a unit of length the side of the elementary equilateral triangle. The transmitter density is then one per elementary rhombus, the area of which is $\sqrt{3}/2$. The network efficiency can be expressed as the ratio of the total area where the service is acceptable (the area of the elementary rhombus) to the sum of the (overlapping) coverage areas. A regular lattice of equilateral triangles gives the optimum value, i.e., 0.83 (each transmitter has a coverage area of $\pi/3$ with a radius of $\sqrt{3}/3$). The ideal value would obviously be 1, but it is not attainable as it is impossible to cover a surface with circles without overlapping areas. A regular lattice of squares (or of isosceles right triangles) only achieves a ratio of 0.64 (each transmitter has a coverage area of $\pi/2$ with a radius of $\sqrt{2}/2$).

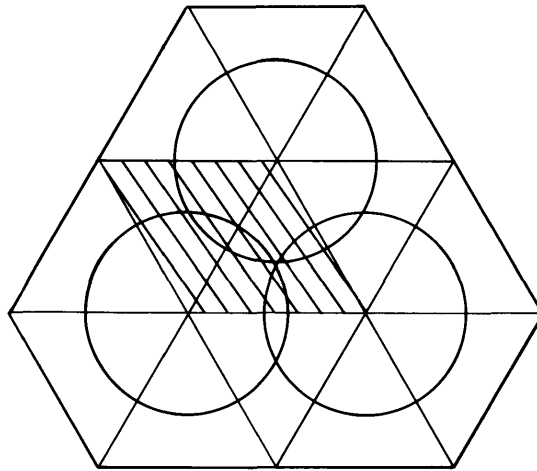


FIGURE 1 – Location and coverage areas of identical broadcasting transmitters in a regular network

It should be noted that actual transmitter networks are neither geometrically regular, nor do their technical characteristics correspond to those of the theoretical network. Deviations from geometrical regularity and from the power and antenna height of the theoretical network towards lower values will inevitably result in lower network efficiency. Nevertheless it is possible to derive, from the results of studies concerning theoretical networks, a fairly clear picture of the relationship between these factors and network efficiency.

3. An example of theoretical network

It is assumed first of all that the available frequency band has been divided, in an appropriate manner, into channels sufficiently wide for a sound or television programme to be located within its limits and adequately spaced (9 kHz for AM sound broadcasting; 100 or 200 kHz for FM sound broadcasting; 6 or 8 MHz for television (200 kHz and 6 MHz correspond to the American channels)) to make co-channel interference predominant vis-à-vis adjacent-channel interference.

It is then easy to derive, from this channel spacing, the number of channels that can be used when planning. As this number is obviously finite, it is inevitable that, at some more or less large distance from the starting point, the first channel assigned has to be re-used. The smaller the distance D , between two transmitters operating on the same channel, the smaller the number of channels needed to cover the whole planning area. But it is necessary that D be large enough for the two co-channel transmitters not to interfere unduly with each other.

It is not difficult to evaluate D . With the help of suitable propagation curves, field strengths of the wanted transmitter and of the interferer are computed, for given percentages of time (see Recommendations 368 and 370), on the circle defined in § 2, limiting the coverage area of the wanted transmitter. D is chosen sufficiently large so that the difference, expressed in dB, between the two field strengths is larger than the protection ratio which is to be found in the relevant Recommendations 560, 412, 418 and Report 306. The case of multiple interference will be dealt with later.

With N channels, it is possible to cover N elementary rhombi, that is an area equal to $N\sqrt{3}/2$, taking as unit area the surface of a square whose side is equal to the side of the elementary triangle. So another kind of network arises using rhombi consisting of N elementary rhombi, and it is logical to stick to the conclusion found in § 2: a given channel will be repeated at the nodes of a lattice of rhombi whose shorter diagonal is equal to the side, the area of which is $N\sqrt{3}/2$. This rhombus will be called the “co-channel rhombus” and the length D of its side is $\sqrt{N}$ ($\sqrt{N}$ times the side of the elementary triangle). The characteristics of rhombic lattices will be shown in a simple example, where $N = 13$ (see Fig. 2).

- *Period*: all the co-channel rhombi are identical. A two-dimensional periodicity appears. It may remind the reader of the theory of elliptical functions.
- *Channel distribution*: within a co-channel rhombus, channels might be distributed at random, but in every rhombus their locations should be identical. However, a random distribution is not suitable if it is necessary to take into account interference other than co-channel interference, which is usually the case. Assuming that a homogenous network leads to the most efficient utilization of the spectrum, it is necessary for the interfering signals on any channel to have the same strength, wherever the transmitter is.

Hence if, taking account of the protection ratio between adjacent-channel transmitters (referred to here as 1-channel transmitters; likewise 2-channel transmitters are spaced by 2 channels, etc.), channel 1 is placed at a point which is sufficiently far from channel 0, this defines for channel 1 a co-channel rhombic which is offset from the co-channel rhombic for channel 0, by the vector $\overline{01}$. To meet the requirement referred to above, for homogeneity, channel 2 will be placed such that $\overline{12} = \overline{01}$, and so on for the other channels. Channel N falls on channel 0. If we consider the 13 channel network in Fig. 2, it is seen that someone moving along the straight lines of the elementary triangle lattice will find the channel numbers are in an arithmetic progression, modulo 13. Starting from channel 0 and heading west, he will encounter channels: 2, 4, 6, 8, 10, 12, 1, 3, 5, 7, 9, 11, 0, etc. It is therefore very easy to define the entire network on the basis of the progression step in two distinct directions: + 2 towards the left and + 5 towards the top righthand corner.

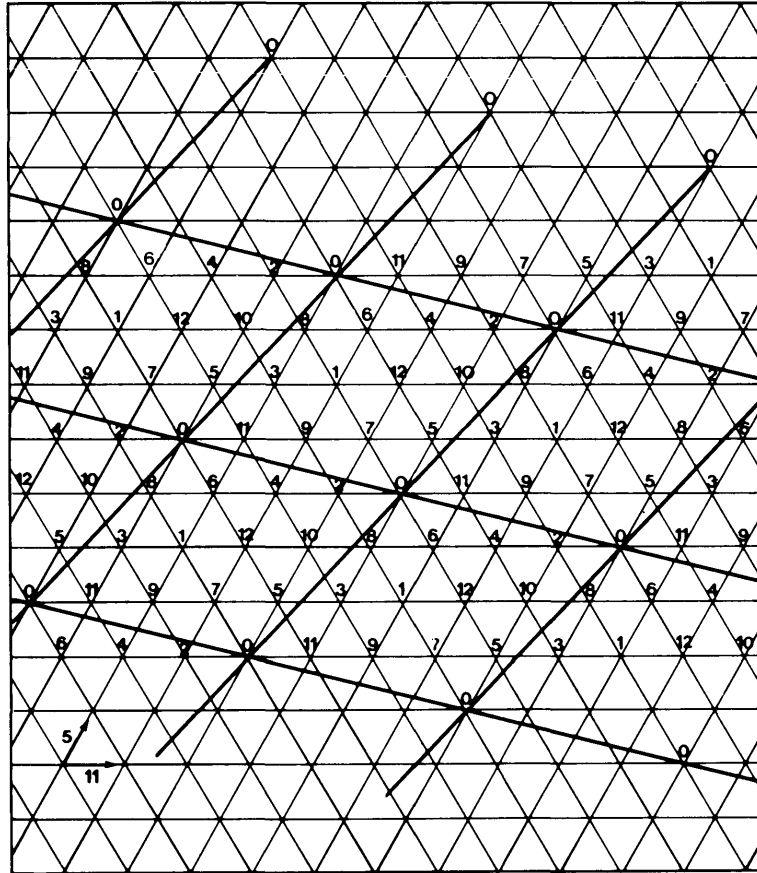


FIGURE 2 – Example of regular lattice for 13 channels

4. Ideal and non-ideal networks

To make the calculations easier, it is convenient to refer the plan to a system of two coordinate axes, bearing equal scales but making an angle of 60° rather than the conventional 90° (see Fig. 3).

We already know that the side of the co-channel rhombus has a length equal to $\sqrt{N}$, but it is necessary for the rhombus to coincide with the intersections of the elementary lattice. In the tilted coordinate system, the distance of any point (x, y) from the origin is:

$$(x^2 + xy + y^2)^{1/2} *$$

If two integers a and b can be found such that $a^2 + ab + b^2 = N$ (number of channels), then there is a co-channel rhombus whose vertices coincide with the intersections of the elementary lattice. $N = 13$ corresponds to the case where $a = 3$ and $b = 1$. In the following discussion, such numbers will be called “rhombic numbers”. Some of them are given on Fig. 4.

* All the distances in this section are calculated on the base of this formula and expressed in the multiples of units equal to the length of a side of an elementary triangle.

There are other conditions for the choice of a and b : they shall not have any common divisor, either between themselves or with N , and neither of them can be equal to zero. For instance, if they are both even numbers, only the even-numbered channels will appear. The other restriction will be given later. The theory still works if N is not exactly a rhombic number. The co-channel rhombus becomes a co-channel parallelogram, with an area equal to N . In this case, the sides of the parallelogram are not equal; one of them is shorter than $\sqrt{N}$ and as a consequence this co-channel distance is slightly smaller than for the rhombus.

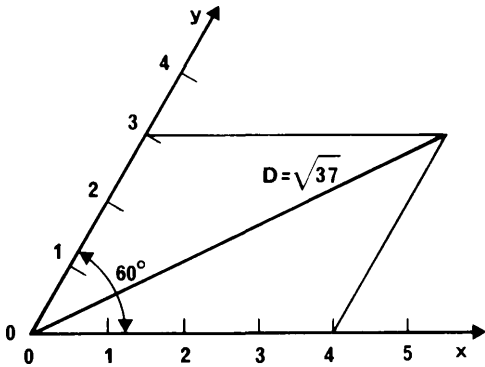


FIGURE 3 – Reference coordinates of regular lattices

$\begin{smallmatrix} a \\ b \end{smallmatrix}$	1	2	3	4	5	6	7	8	9	10	11	12
1	3	7	13	21	31	43	57	73	91	111	133	157
2			19		39		67		103		147	
3				37	49		79	97		139		
4					61		93		133			
5						91	109	129	151			
6							127					

FIGURE 4 – Table of rhombic numbers

Figure 5 shows a network with 26 channels, 26 not being a rhombic number. However, in this particular case, it is seen that the shortest co-channel distance is the shorter side of the parallelogram whose length equals 4.358. This is not much less than the distance $\sqrt{N} = 5.099$ which would have been obtained if 26 were a rhombic number. The lengths of other co-channel distances, e.g. the longer side of the parallelogram or the shorter diagonal of it, are 5.291 and 6.082 respectively. The next rhombic number is 31 an example of which is given in Fig. 6.

Figure 7 shows a network with 120 channels, 120 not being a rhombic number. However, in this particular case, it is seen that the shortest co-channel distance is the diagonal whose length equals 10.58. The lengths of the sides are 11.53 and 10.82, respectively. None of these numbers is much less than the distance $\sqrt{N} = 10.95$, which would have been obtained if 120 were a rhombic number. This lattice may not be optimum for VHF planning.

In the case of N not being a rhombic number, there are three possibilities:

- not to take note of this value N and consider the nearest rhombic number which could be used instead (e.g. 111; see Fig. 4);
- to consider the resulting regular lattice despite its consisting of co-channel parallelograms;
- to distort the lattice so as to transform co-channel parallelograms to rhombi. In these circumstances the elementary rhombi would become parallelograms, and network efficiency would decrease. This decrease will only be slight when N is fairly large.

The best choice among the three options depends on the circumstances to be taken into account.

It is not always easy to find the progression steps such that the channel assigned to the origin will reappear at the vertices of the co-channel rhombus or parallelogram. Referring Fig. 2 to the slant coordinate system of Fig. 3, the steps p along the x -axis and q along the y -axis must satisfy the following equations:

$$1 \cdot p + 3 \cdot q = kN \quad \text{and} \quad 4 \cdot p - 1 \cdot q = k'N$$

k and k' are integers.

In Fig. 2, $p = 11$, $q = 5$, $k = 2$, and $k' = 3$, for $N = 13$. These steps are indicated in Fig. 2. In the case of a non-rhombic number, there is more than one parallelogram and many attempts are necessary to find the best one [Arnaud, 1962]. Even in the case of rhombic numbers it may happen that two different co-channel rhombi exist, as it appears on Fig. 4 for 91 (9 and 1 or 6 and 5).

The case where a or $b = 0$ is a trivial one. If, for example, $b = 0$, the co-channel rhombus sides coincide with the x and y axes, and $a = \sqrt{N}$. The sum of steps along the axes from one vertex to the next must be N ; consequently their value is $\sqrt{N}$ and it is then only possible to write on the lattice channels that are multiples of $\sqrt{N}$.

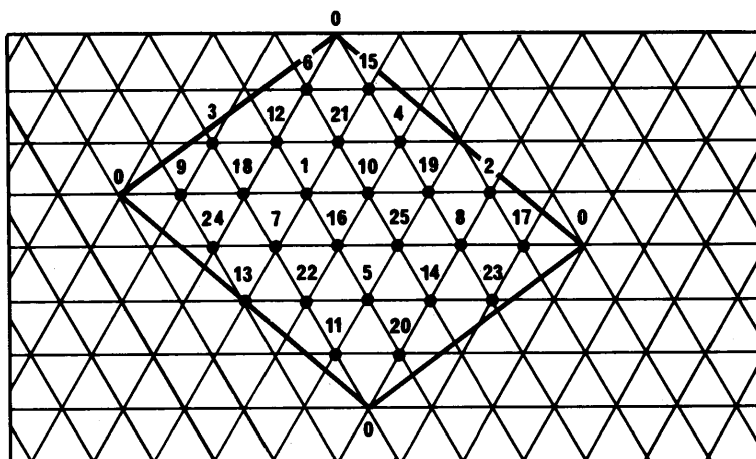


FIGURE 5 – Network with 26 channels

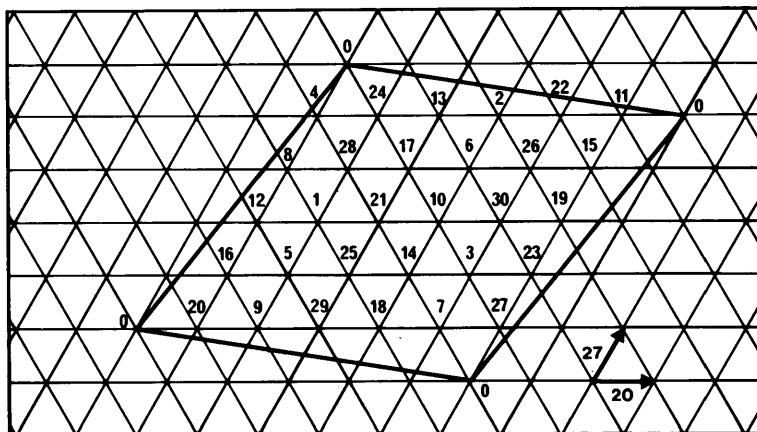


FIGURE 6 – Example of an optimum regular lattice for 31 channels

5. Evaluation of interference

5.1 Co-channel interference

It has been explained in § 3 how the minimum necessary number of channels derives from the consideration of propagation curves and protection ratios, but only one interfering transmitter has been taken into account. On Fig. 8 are drawn a few co-channel rhombi for a co-channel distance D , the wanted transmitter being at the centre and the eighteen others surrounding it are the interferers. In the case of VHF or UHF broadcasting, the coverage area is evaluated on the basis of the 50% or 1% of the time propagation curves of Recommendation 370 (for the wanted or interfering transmitter, respectively), taking due account of the characteristics of the transmitter (effective radiated power, antenna height, frequency) and the minimum usable field strength. (See

Recommendation 412). In § 2, the coverage area radius has been found to be $\sqrt{3}/3$ times the side of the elementary rhombus. So the scale of the lattice is known. The first six interfering transmitters are at a distance $D = \sqrt{N}$, and as a first approximation it will be assumed here that D is large enough and that the interfering field strength is almost the same at the wanted transmitter location and on the fringe of its coverage area. In a more accurate study, the ratio of wanted/interfering signals should be calculated at the limit of the coverage area, at least at the six locations shown by roman numerals I to VI on Fig. 8.

D has to be long enough for the difference (in decibels) between the wanted field strength exceeded for 50% of the time and the combined interfering field strengths exceeded for 1% of the time, to be greater or equal to the co-channel protection ratio. Then it should be checked whether the twelve transmitters located on the second hexagon (see Fig. 8) have any influence, but in general this is not the case unless D is very small.

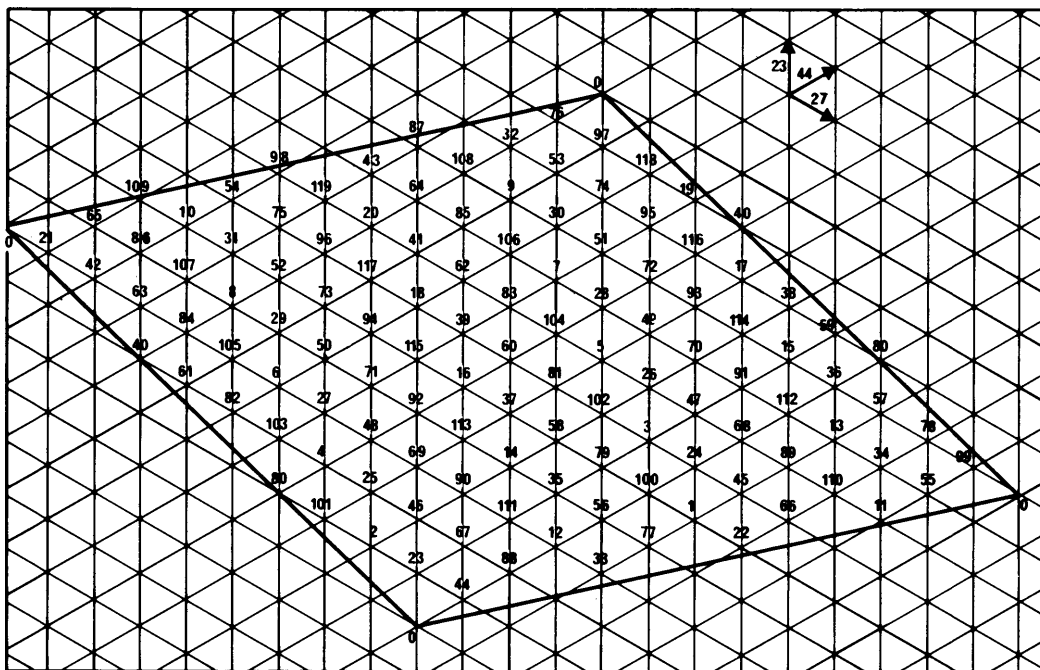


FIGURE 7 – Network with 120 channels

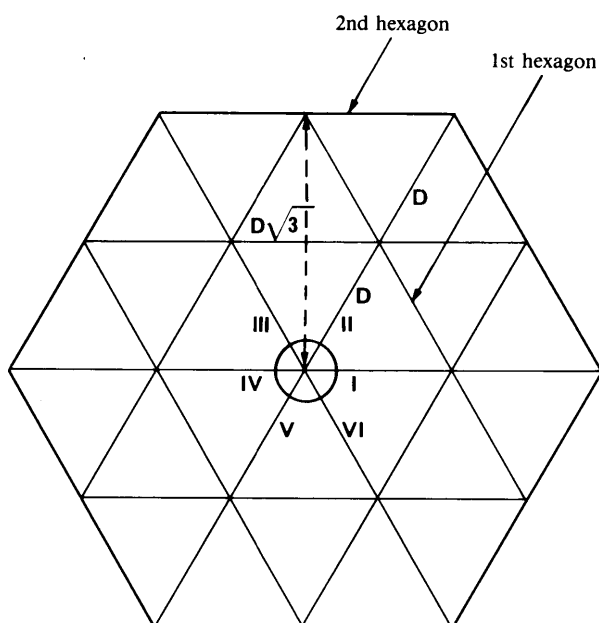


FIGURE 8 – Location of co-channel transmitters

5.2 *Adjacent channel interference*

The network of Fig. 2 will serve as a practical example. D is assumed to have been found to be equal to $\sqrt{13}$. By definition, the network is regular and any given channel can be studied. Take for instance channel 7. The adjacent channel distances are $\sqrt{3}$ and 2. There are 4 adjacent channel interfering transmitters. As in the case of co-channel interference, their total field strength will be evaluated at the transmitter location first, and then, if the wanted/interfering signal ratio is only slightly different from the protection ratio, at the most critical points at the limit of the coverage area. Other adjacent channel transmitters are much more remote. Their distances are $\sqrt{7}$, $\sqrt{12}$, $\sqrt{13}$, etc.

For a wanted transmitter on channel C , there are in each co-channel rhombus at least two adjacent channel interfering transmitters on channels $C + 1$ and $C - 1$. The further the transmitters $C + 1$ and $C - 1$ are from the corners of the co-channel rhombus of C , the better will be the network; the ideal positions will be the centres of gravity of the two equilateral triangles making up the rhombus. Hence if transmitter $C + 1$ is exactly at one of these centres of gravity, $C + 2$ will be exactly at the other and $C + 3$ will coincide with C which is absurd. This occurs with the network with $N = 21$ channels. If the coincidence of a point in the network with the centres of gravity is only approximate, channel $C + 2$ will be twice as far from the centre of gravity of the triangle, however channel $C + 3$ will be still fairly close to channel C which is unfavourable in FM sound broadcasting as this corresponds to a carrier spacing of 300 kHz (in parts of Europe) for which the protection ratio is only slightly negative (-7 dB).

5.3 *Multiple interference*

Both in theory and in practice more than one interfering transmitter has to be respected. At the site of the wanted transmitter in the network of Fig. 2 there are co-channel transmitters interfering with near identical signal strength and in addition there are four interfering adjacent-channel transmitters. It should not be overlooked that at least 2-channel and 3-channel transmitters will also need to be taken into account. In practice it has proved useful to compute the usable field strength on the basis of at least those interferers which cause the strongest interference potential. It cannot however be a matter for this description of a planning method to advocate one or the other method of computing multiple interference effects.

6. **Planning constraints**

When planning a particular type of service, some constraints have to be kept in mind and most of them result from the receiver design. It is useful to distinguish between internal and external constraints. Such constraints and their generating mechanisms are discussed in Report 946.

7. **Use of theoretical networks**

Theoretical networks may be of some help in trying to find the optimum characteristics of transmitters [Sauvet-Goichon, 1980] or the most suitable type of modulation parameters or channel spacing. There is a good probability that a solution found to be optimum in a regular network would be the best one for an actual network as well and in any event it will be far easier to study the former with the help of computerized methods.

7.1 *Simple network*

The allocated band, 16 MHz wide, is divided into 159 channels. Below 159 the largest rhombic number is 157 (12 and 1, see Fig. 4). Two channels are then left empty. They may replace channels whose use is precluded by some local constraints (see § 6) or fill gaps in mountainous areas or near borders. As a general rule, more than one programme is broadcast from a given location and some geographical neighbouring assignments will be moved to the same point. Figures 9 and 10 show two examples of channel clustering. Assignments made at the vertices of the shaded areas are concentrated to the centre of gravity of each area. It should be checked that this does not involve an unacceptable increase in interference.

Figure 11 gives the steps to build a 157 channel network. Their derivation is given in Annex I. The 1961 Stockholm Plan for UHF television has been based on a channel clustering C , $C + 3$, $C + 6$.

7.2 *Multiple networks*

When there is a large number of channels (more than about 50), and if, as is usual, each centre consists of several transmitters, it is possible to split the band into sub-bands, each of them including the same number of channels and possibly reserved for a separate programme. It should be noted that the African Plan has been designed on a channelling of 86 kHz, i.e. 185 channels in 16 MHz, for 6 networks of 31 channels or 5 networks of 37 channels (37 is a rhombic number).

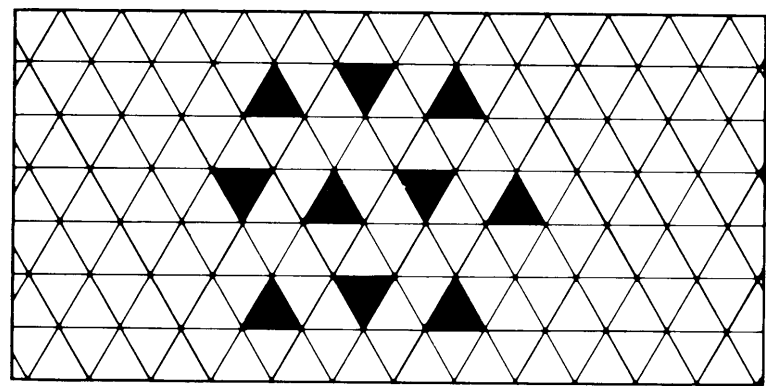


FIGURE 9 – Clustering of neighbouring channels

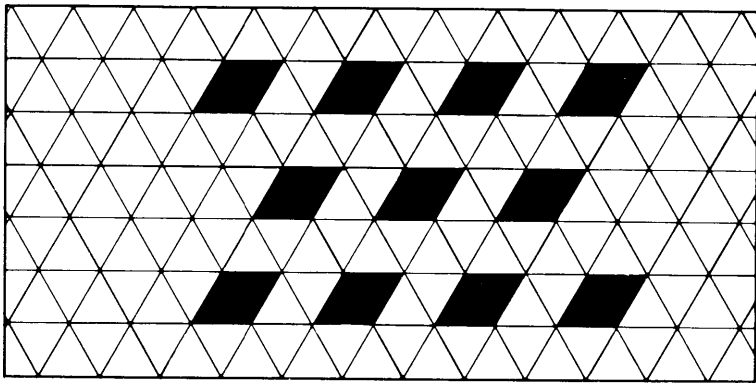


FIGURE 10 – Clustering of neighbouring channels

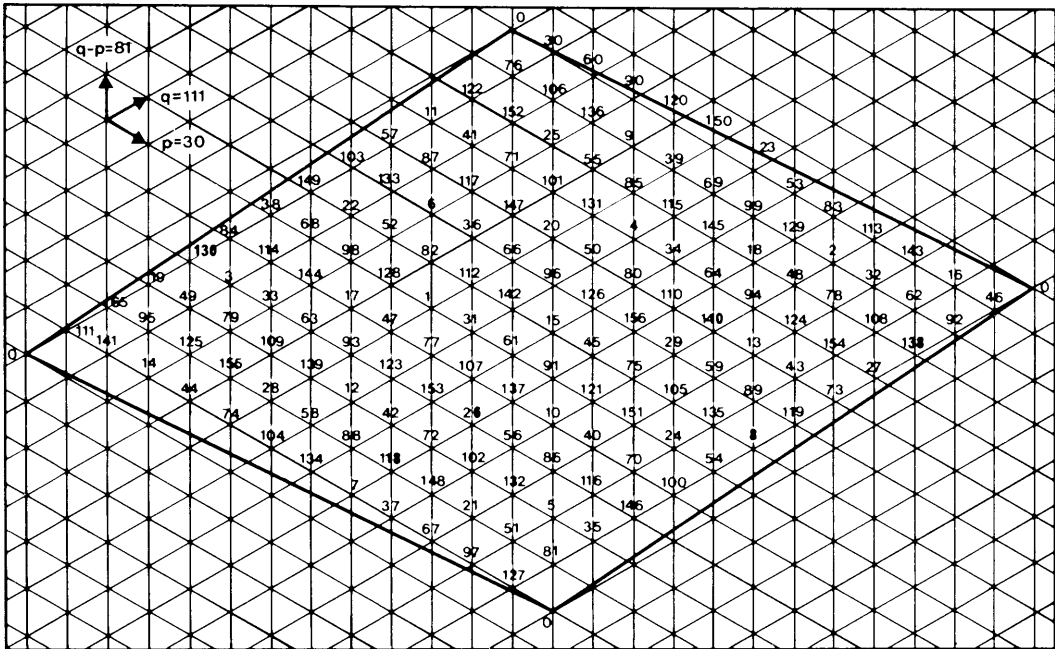


FIGURE 11 – Example of an optimum regular lattice for 157 channels

8. Number of channels needed for full area coverage with one programme in VHF sound broadcasting

8.1 General considerations

Based on the previously discussed method the number of channels needed for the dissemination of one programme in VHF sound broadcasting to provide full coverage was evaluated.

The investigations are made for different average distances between transmitters, two antenna heights, (300 m and 600 m), two coverage factors (90% and 100%) and an effective radiated power of 100 kW. Monophonic and stereophonic services were taken into account. The calculation of the interferences was carried out using the simplified multiplication method (see Report 945).

This method had previously been used during:

- the European Broadcasting Conference, Stockholm, 1961,
- the African Broadcasting Conference, Geneva, 1963.

8.2 Performance of the calculations

8.2.1 Basic assumptions

The investigations are based on idealized networks with a regular lattice of transmitters, linear distribution of channels and equilateral co-channel triangles. The so-called elementary triangles which are formed by three neighbouring transmitters are in this case not equilateral in general, but only for certain numbers of channels [EBU, 1960].

The calculations are based on the following conditions:

- field strength E (50,50) (Recommendation 370),
- field strength E (50,1) (Recommendation 370),
- protection ratios (Recommendation 412),
- local variation of field strength: 8.3 dB,
- receiving antenna,
 - monophony : omnidirectional,
 - stereophony : directional with 12 dB front-to-back ratio,
- minimum usable field strength (Recommendation 412)
 - monophony : 48 dB(μ V/m),
 - stereophony : 54 dB(μ V/m),
- channel spacing : 100 kHz.

8.2.2 Calculation of the usable field strength

8.2.2.1 Method of calculation

The calculation of these interferences was carried out using the simplified multiplication method.

Experience in some countries has shown that the coverage situation found in actual practice is, on average, in acceptable agreement with computation results obtained with the simplified multiplication method. In the subsequent sections only this method has been used for the determination of the required number of channels.

8.2.2.2 Number of interfering transmitters

For the calculation of interferences in the theoretical lattice, the 18 strongest interfering co-channel transmitters and the 40 strongest interfering adjacent channel transmitters having frequency separations up to 400 kHz were taken into account. (The relatively large number of interfering adjacent channel transmitters is only relevant with close channel spacings.)

8.2.3 Variation of parameters

The average distance of transmitters was varied between 40 and 120 km in steps of 10 km. For the effective height of the transmitter antenna, 300 and 600 m were chosen, because the average height values in many European countries fall into that range. The effective radiated power was set to 100 kW to ensure that interference rather than noise will limit the coverage area; this being a condition for efficient spectrum utilization (see Report 414 (Kyoto, 1978)). For small distances between transmitters however, considerably less power would provide equal percentage of coverage with the same number of channels.

8.2.4 Results

The number of channels needed in a theoretical network under different conditions can be found in Figs. 12 to 15. For a monophonic service with an omnidirectional receiving antenna and for a stereophonic service with a directional receiving antenna (12 dB front-to-back ratio), the number of channels required is almost equal.

In an idealized theoretical network based on the above assumptions with an effective transmitter antenna height of 300 m, an effective radiated power of 100 kW and an average distance between transmitters greater than 70 km:

- for 90% coverage about 25 channels are necessary (Fig. 12),
- for 100% coverage about 31 channels are necessary (Fig. 13).

Examples of possible channel distribution for corresponding numbers of channels are given in Figs. 5 and 6.

The number of channels needed for one programme in a theoretical network can only give an approximation to the number needed for a real network. The less the uniformity of the real network considered the more extra channels will be needed. As experience with existing networks in the range 87.5-100 MHz in continental Europe has shown, up to 4 programmes are possible in this range.

Based on theoretical study and practical experience, it may be assumed that for the entire frequency band 87.5-108 MHz:

- for 90% coverage about 7 programmes,
- for 100% coverage about 6 programmes,

should be practicable.

In practical networks, the power and the effective antenna height of any single transmitter should be set to the lowest possible value to obtain the intended coverage.

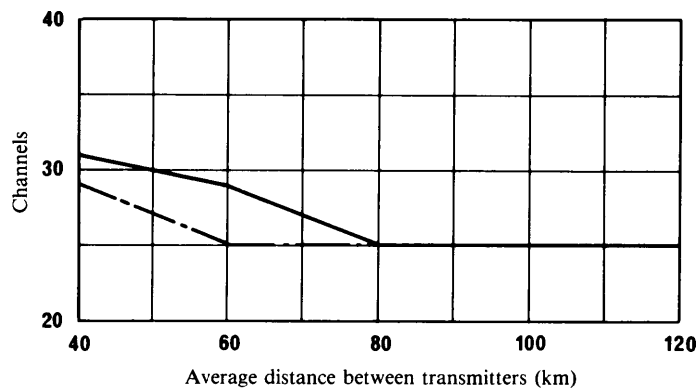


FIGURE 12 – Number of channels needed in a theoretical network for coverage 90 % and antenna height 300 m

— - — : monophony (0 dB - antenna gain)
 — : stereophony (12 dB - front-to-back ratio of the antenna)

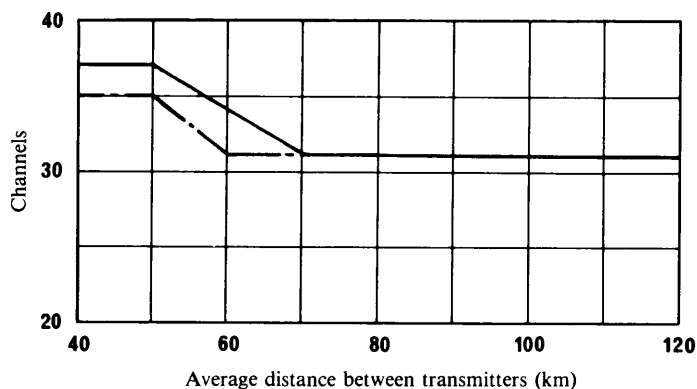


FIGURE 13 – Number of channels needed in a theoretical network for coverage 100 % and antenna height 300 m

— - — : monophony (0 dB - antenna gain)
 — : stereophony (12 dB - front-to-back ratio of the antenna)

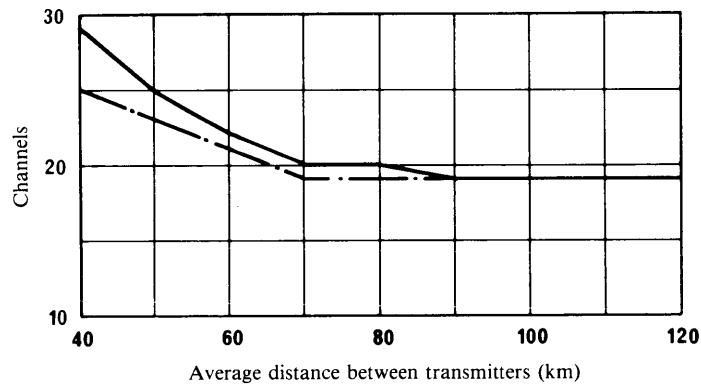


FIGURE 14 – *Number of channels needed in a theoretical network for coverage 90 % and antenna height 600 m*

— : monophony (0 dB - antenna gain)
 — : stereophony (12 dB - front-to-back ratio of the antenna)

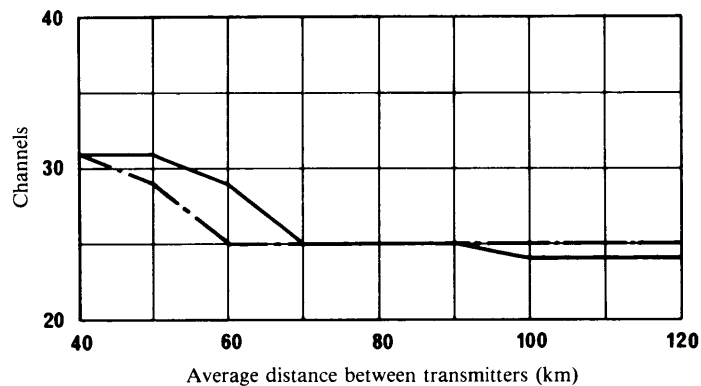


FIGURE 15 – *Number of channels needed in a theoretical network for coverage 100 % and antenna height 600 m*

— : monophony (0 dB - antenna gain)
 — : stereophony (12 dB - front-to-back ratio of the antenna)

9. Conclusions

When the number of channels is high, it seems difficult to achieve by purely empirical means the best use of the frequency spectrum. The theory of regular networks appears as an efficient tool to reach an optimum. Moreover, in an area where the surface of the earth is divided amongst many countries, it is a good way to assure them they have obtained a fair share of the spectrum. Consideration could also usefully be given to means of planning irregular networks in special cases where these may be more appropriate.

ANNEX I

CHOICE OF THE PROGRESSION STEPS IN AN OPTIMUM 157 CHANNEL LATTICE

A systematic study has been made of all the rhombic numbers less than 160, involving calculations of distance for 1-, 2- and 3- channel distances for all sets of values of p and q .

Those results that appear the most useful are shown below (Table I) (to simplify the presentation, the square of the distance is shown). The Table extends only to $N = 100$ to limit its size.

TABLE I

	p	q	Adjacent	2-channel	3-channel
$N = 19$ ($a = 3, b = 2$)	6	10	4	3	3
$N = 31$ ($a = 5, b = 1$)	7	27	7	7	3
$N = 37$ ($a = 4, b = 3$)	6	29	9	3	7
	9	25	9	7	3
$N = 39$ ($a = 5, b = 2$)	4	29	7	7	9
$N = 43$ ($a = 6, b = 1$)	5	13	12	7	3
$N = 49$ ($a = 5, b = 3$)	12	29	13	9	3
$N = 57$ ($a = 7, b = 1$)	11	37	13	7	9
$N = 61$ ($a = 5, b = 4$)	6	23	13	7	12
	15	27	16	13	3
$N = 67$ ($a = 7, b = 2$)	4	53	13	13	12
	8	39	19	13	3
	21	27	12	7	13
$N = 73$ ($a = 8, b = 1$)	5	33	19	7	12
	6	25	13	9	16
	7	17	19	19	3
	11	58	12	13	19
$N = 79$ ($a = 7, b = 3$)	4	17	13	19	21
	6	65	16	7	19
	11	27	19	9	12
	22	54	21	19	3
$N = 91$ ($a = 6, b = 5$)	4	68	16	19	21
	9	62	21	13	12
	15	73	25	21	3
$N = 91$ ($a = 9, b = 1$)	4	55	19	21	12
	6	37	19	9	21
	8	19	27	19	3
$N = 93$ ($a = 7, b = 4$)	5	61	25	13	9
	17	40	16	13	21
$N = 97$ ($a = 8, b = 3$)	6	81	19	13	21
	13	30	21	19	12
	26	60	28	21	3

As an example we give here the details of the calculations used to find the best progression steps for $N = 157$ channels.

As $157 = 12^2 + 12 \times 1 + 1^2$, the step p and q should be such that

$$12p + q = 0 \text{ modulo } 157$$

p and q must be greater than 3 so that transmitter coverages on channels C and $C + 1$, $C + 2$ or $C + 3$ do not overlap.

The first values to be tested are $p = 4$ and $q = 109$. Then $q - p = 105$ (see Fig. 11 for definition of p , q , $p - q$). The question now is to find out where channel 1 (or 156) falls, as here the co-channel rhombus of channel 0 is considered. As the lattice is homogeneous and regular, we can begin with any channel. The ideal location for channel 1 is at the centre of gravity of any of the two triangles which join up to form the co-channel rhombus. The adjacent channel distance would then be

$$\sqrt{157} \times \sqrt{3}/3 = 7.23$$

For $p = 4$ and $q = 109$, channel 1 will be found at three $(q - p)$ steps: $q - p = 105$; $3 \times 105 = 315 = 1 \text{ modulo } 157$. Adjacent channel distance is 3, which is far shorter than the maximum of 7.23.

For $p = 5$ and $q = 97$ ($q - p = 92$) channel 156 will be found at five $(q - p)$ steps plus two p steps: $5 \times 92 + 2 \times 5 = 470 = 156 \text{ modulo } 157$. Adjacent channel distance is $\sqrt{19}$. Hopefully a better solution exists.

For $p = 6$ and $q = 85$ ($q - p = 79$) channel 1 will be found at two steps, as $2(q - p) = 158 = 1 \text{ modulo } 157$. This is far too close.

For $p = 7$ and $q = 73$ ($q - p = 66$) channel 156 will be found at three p steps plus four q steps: $3 \times 7 + 4 \times 73 = 313 = 156 \text{ modulo } 157$. The 1-channel distance is $\sqrt{37} = 6.08$. Channels 156 and 1 are near the centres of gravity of the triangles as are channels 155 and 2; channels 154 and 3 at a distance of $\sqrt{12}$ from channel 0. A thorough search amongst all the pairs, p and q , shows that there are only a few sets of steps resulting in 1-channel distance greater than or equal to 6. They are given in the following Table II, together with the 2-channel and 3-channel distances.

TABLE II

p	q	Adjacent	2-channel	3-channel
7	73	$\sqrt{37}$	$\sqrt{39}$	$\sqrt{12}$
11	25	$\sqrt{48}$	$\sqrt{37}$	$\sqrt{3}$
20	74	$\sqrt{37}$	$\sqrt{21}$	$\sqrt{21}$
24	26	6	1 ⁽¹⁾	
30	111	$\sqrt{39}$	$\sqrt{19}$	$\sqrt{21}$
33	75	$\sqrt{39}$	$\sqrt{7}$	$\sqrt{48}$

(1) This eliminates the combination.

The final choice depends on the protection ratios for 2 and 3 channel interferences. The pair 24 and 26 will not be suitable.

If it were planned to cluster channels in groups of 3 or 4 (see Figs. 9 and 10) it would be more appropriate to have all steps greater than, say, 20 to avoid multiplexing problems (see [Arnaud, 1962]). Such a network is drawn on Fig. 11 ($p = 30$, $q = 111$). If no clustering is foreseen, or if a channel spacing of 20 is acceptable for colocated transmitters, then the network $p = 20$, $q = 74$ is slightly better.

REFERENCES

- ARNAUD, J. F. [March, 1962] Projets théoriques de répartition des fréquences de la bande II à un réseau d'émetteurs groupés en centre d'émission. *L'Onde électrique*, **420**, 208-218.
- EBU [May, 1960] New methods of producing television frequency assignment plans. Tech. Doc. 3080, European Broadcasting Union, Brussels.
- SAUVET-GOICHON, D. [November, 1980] Radiodiffusion sonore à modulation de fréquence. Etude théorique du nombre de canaux nécessaires en fonction du nombre et des caractéristiques techniques des émetteurs. Document TDF (DTR/11-0/80), **1015**.

BIBLIOGRAPHY

- ARNAUD, J. F. [December, 1980] Frequency planning for broadcast services in Europe. *Proc. IEEE*, Vol. 68, **12**, 1515-1522.
- ARNAUD, J. F. [April-May, 1981] Planification des fréquences pour la radiodiffusion en Europe. *Radiodif. Têlev.*, **67**.

REPORT 946

FREQUENCY-PLANNING CONSTRAINTS ON FM SOUND BROADCASTING IN BAND 8 (VHF)

(Question 46/10, Study Programme 46L/10)

(1982)

1. Introduction

In order to ensure effective planning of sound-broadcasting services in the frequency range 87.5-108 MHz, it may be necessary to take into account certain constraints on the use of frequencies in order to avoid interference to other sound-broadcast transmissions within this band and to ensure compatibility with television broadcasts in the frequency ranges 47-68 MHz and 174-230 MHz.

This Report identifies the various possible interference mechanisms resulting from the technical limitations of receiver design, and also those due to constraints resulting from the transmission of several broadcast programmes from the same site.

A listing of the main interference mechanisms generated in the radio receiver is provided in § 2, and § 3 specifies those which are of importance in planning. No account is taken of interference resulting from radiation of harmonics and intermodulation products at transmitter sites, on the assumption that the broadcaster can take the necessary precautions to reduce such spurious radiation to acceptable levels.

2. Listing of interference mechanisms generated in broadcast receivers

2.1 Local oscillator radiation

In the following, consideration is given only to the case where the local oscillator frequency is 10.7 MHz above that of the wanted transmission, this representing the condition for the great majority of current receivers. The following interference mechanisms may occur:

2.1.1 Radiation at the fundamental frequency

Radiation from VHF-FM receivers may affect VHF-FM reception at frequency separations of 10.7 ± 0.2 MHz. This occurs if adjacent receivers are in use, tuned to transmissions separated by this frequency difference.

Radiation from television receivers in the range 47-68 MHz may affect VHF-FM reception. This may occur when the television oscillator frequency, which is equal to the intermediate frequency (IF) plus the frequency of the vision carrier, lies near the carrier frequency of a VHF-FM transmission. VHF-FM frequencies which may suffer possible interference are given in Table I below.

TABLE I

System	Channel	Channel limits (MHz)	Vision carrier (MHz)	IF video channel (MHz)	VHF-FM frequencies which may be interfered with (MHz)
B	3	54 – 61	55.25	38.9	94.1; 94.2
B	4	61 – 68	62.25	38.9	101.1; 101.2
D	R1	48.5 – 56.5	49.75	38	87.7; 87.8
D	R2	58 – 66	59.25	38	97.2; 97.3
I	1B	52.5 – 60.5	53.75	39.5	93.2; 93.3
I	1C	60.5 – 68.5	61.75	39.5	101.2; 101.3

2.1.2 Harmonic radiation

Second harmonics of local oscillators of VHF-FM receivers may interfere with reception of television on all channels in the range 196-230 MHz. The interfering VHF-FM frequency can be calculated using the formula

$$2(f_{FM} + 10.7) = f_{TV} \quad \text{MHz} \quad (1)$$

2.2 Harmonic conversion

In a VHF-FM receiver the second harmonic of the local oscillator may combine with television sound and vision carriers in the range 174-230 MHz to produce a frequency difference of 10.7 MHz, thereby causing interference to radio reception. The interfered VHF-FM frequency can be calculated using the formula

$$2(f_{FM} + 10.7) = f_{TV} \pm 10.7 \quad \text{MHz} \quad (2)$$

2.3 Harmonics and intermodulation products generated under overload conditions in the receivers

High input signal levels can lead to non-linearities in the input stage of receivers, giving rise to the generation of harmonics and intermodulation products. The following cases may occur:

- second harmonics of television transmissions in the range 47-54 MHz fall in the range 94-108 MHz;
- second harmonics of VHF-FM transmissions in the range 87.5-108 MHz fall in the range 175-216 MHz;
- third-order intermodulation products due to reception of more than two VHF-FM transmissions separated by equal frequency spacings occur on the frequencies of these transmissions. For example, with three frequencies f_1, f_2, f_3 such that:

$$f_2 = f_1 + \Delta f; f_3 = f_1 + 2\Delta f \quad (3)$$

where Δf is the frequency spacing,

$$\text{then } 2f_2 - f_1 = 2(f_1 + \Delta f) - f_1 = f_1 + 2\Delta f = f_3 \quad (4)$$

There exist additional possibilities of double or triple beats.

- The second harmonic of an interfering VHF-FH transmission separated by 5.3 or 5.4 MHz from the wanted transmission can combine with the second harmonic of the local oscillator to produce a frequency difference of 10.6 or 10.8 MHz, thereby causing interference to radio reception.
- Two transmissions with a frequency separation of 10.7 ± 0.2 MHz may give rise to interference as a result of intermodulation processes in a receiver.

2.4 Harmonics of the intermediate frequency

Non-linearities in the output intermediate frequency stage can produce harmonics of 10.7 MHz. The ninth and tenth harmonics (96.3 MHz and 107.0 MHz respectively) fall within the VHF-FM broadcasting band 8, and interference may result from feedback to the input stages of receivers tuned to these frequencies.

3. Relevance of the various interference mechanisms to frequency planning

3.1 Main constraints

3.1.1 The use of VHF-FM transmission frequencies separated by 10.7 ± 0.2 MHz in the same area should be avoided to the extent possible (see §§ 2.1.1 and 2.3).

3.1.2 It is common practice to radiate several VHF-FM transmissions from a single site using either a common antenna or separate antennas. In the former case the minimum possible frequency separation is determined by the design limitations of combiner units. Whereas it may be technically feasible to design such units to operate at spacings down to 1 MHz, this is very costly, particularly for high powers.

For planning purposes therefore the minimum frequency spacings should not be in general less than 2 MHz, with a reduction down to 1.5 MHz accepted in special cases.

With separate antennas for each transmission, frequency spacings of less than 1 MHz may be feasible.

3.2 *Constraints of less importance*

3.2.1 It is suggested that those interference mechanisms which depend on the generation of the second harmonic of the unwanted transmission in the VHF-FM receiver need not in general be taken into account in planning. In general, such interference is only likely to occur in areas close to the unwanted transmitter, and the problem may be overcome either with improved receiver selectivity or by providing appropriate filters in the antenna lead. In the case of portable VHF-FM receivers it will often be possible to reduce the probability of overload by retracting the receiving antenna should wanted signal levels allow this.

3.2.2 Although some earlier experience has indicated that significant interference to stereo reception of transmission on 96.3 MHz may result from the mechanism described in § 2.4, a number of European countries now operate such services on this frequency with little complaint. This may also apply to the frequency 107.0 MHz.

3.2.3 The use of VHF-FM transmission frequencies for which the second harmonic of the local oscillator falls within the band occupied by a television transmission operating in the range 196-230 MHz within the same area should be avoided. In view of the severe limitations it would impose on the use of frequencies for the VHF-FM service, it is probably impractical to take this into account in planning (see § 2.1.2).

3.2.4 Although the use of equal frequency spacings can in principle cause problems as described in § 2.3 (third inset), one European country provides three stereo transmissions at equal spacings from nearly all sites providing national network services at VHF-FM. It could be desirable to avoid using equal spacings for transmitters listed close to areas of high population density.

3.3 *Conclusions for the planning procedure*

In the planning procedure the main constraints (§ 3.1) should be taken into account generally. Other constraints may be taken into account only in individual cases.

BIBLIOGRAPHY

CCIR Documents

[1978-82] : a. 10/232 (Yugoslavia (Socialist Federal Republic of)); b. 10/240 (EBU).

REPORT 947 *

RADIO-FREQUENCY PROTECTION RATIO REQUIRED BY FM SOUND BROADCASTING IN THE BAND BETWEEN 87.5 MHz AND 108 MHz AGAINST INTERFERENCE FROM D/SECAM TELEVISION TRANSMISSIONS

(Question 46/10, Study Programme 46J/10)

(1982)

1. Introduction

In some areas of Europe the part below 100 MHz of the VHF band II is used for television broadcasting. For planning of sound broadcasting in that band it is, therefore, necessary to know to what extent the reception of sound broadcasting signals is interfered with by television transmissions.

2. Measurements

To study the radio-frequency protection ratios required by sound broadcasting reception against interference from D/SECAM television transmissions, measurements have been made in the Federal Republic of Germany and Finland.

* This Report should be brought to the attention of Study Group 11.

2.1 In Finland five representative domestic sound broadcasting receivers were measured making use of a D/SECAM television signal generator as the unwanted transmitter. The measurements were performed in accordance with Report 796 and Recommendation 468.

The D/SECAM television signal generator used was modulated by a 13×17 grid electronic test pattern signal with 90% modulation depth. The sound carrier was at a level of -10 dB with respect to the vision carrier and was modulated by a 1000 Hz signal with ± 50 kHz deviation. The wanted reference signal was 1000 Hz with ± 75 kHz deviation. The input level was 66 dB(1 μ V) into 75 Ω . The signal-to-noise ratio required was 50 dB measured according to Recommendation 468.

In the range of wanted signal frequencies from 0.5 MHz to 4 MHz above the vision carrier, the required protection ratio values were found to be greatly dependent on picture content. The worst interference with varying degrees of frequency dependence was produced by test patterns. In this range, therefore, an envelope curve has been taken to represent the interference potential of commonly-used test pictures.

The results obtained on the basis of these measurements are given in Table I and Figure 1. The effect of offset frequency operation should be taken into account separately especially near the carriers.

TABLE I – *Radio-frequency protection ratio required by frequency modulation sound broadcasting at frequencies between 87.5 MHz and 108 MHz against interference from D/SECAM television transmissions*
(Steady interference)

Wanted signal frequency relative to vision carrier (MHz)	RF-protection ratio (dB)	
	Mono	Stereo
-2.0	-30	-12
-1.0	-2	18
-0.5	0	20
-0.15	19	25
-0.1	24	35
-0.05	30	50
0.0	35	45
0.05	30	50
0.1	24	35
0.15	19	31
0.25	10	25
0.5	0	20
1.0	-1	20
2.0	-3	18
3.0	-4	17
4.0	-5	15
4.18	8	25
4.25	10	26
4.41	10	26
4.48	8	25
4.7	-5	15
5.0	-15	0
6.0	-25	-5
6.25	-13	-6
6.3	-5	5
6.4	6	26
6.45	15	40
6.475	25	43
6.5	28	35
6.525	25	43
6.55	15	40
6.6	6	26
6.7	-3	0
7.0	-30	-13

Note 1. – For tropospheric interference (protection 99% of the time) these values may be reduced by 8 dB.

Note 2. – Values for frequencies from 0.5 to 4 MHz are greatly affected by picture content. The figures given are for a test pattern and are representative of the on-the-air test picture transmissions.

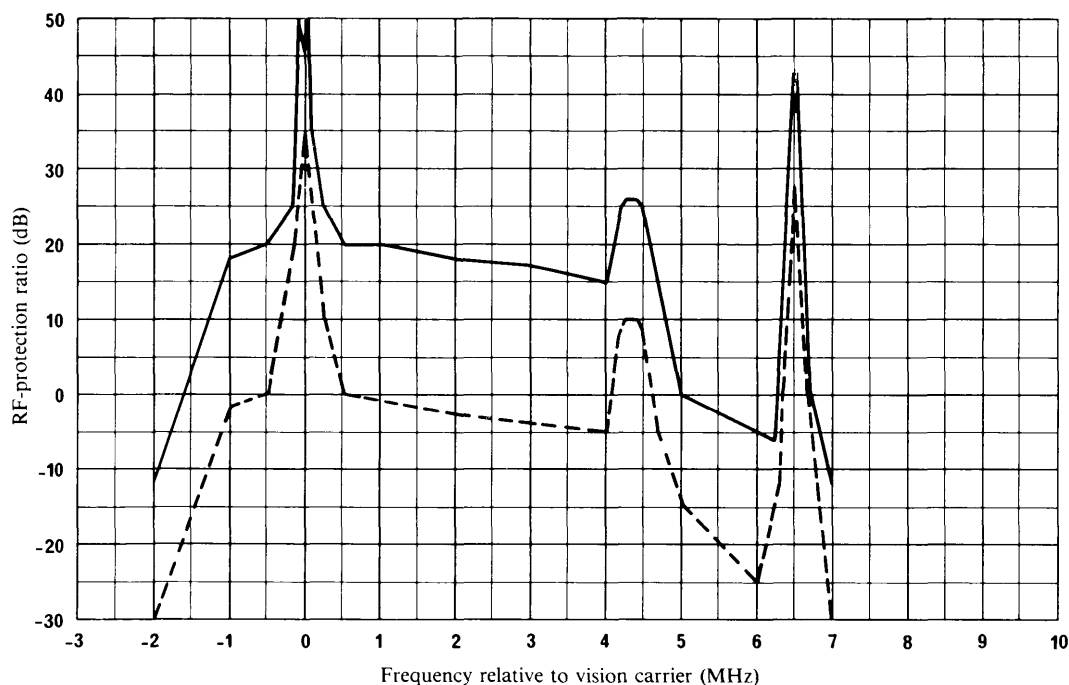


FIGURE 1 – *Radio-frequency protection ratio required by frequency modulation sound-broadcasting at frequencies between 87.5 MHz and 108 MHz against interference from D/SECAM television transmissions*

(Steady interference)

— : stereo
- - - : mono

The results of the laboratory measurements are for steady interference. According to Recommendation 412 these values may be reduced by 8 dB for tropospheric interference (protection 99% of the time).

2.2 In the Federal Republic of Germany the RF wanted-to-interfering signal ratios were measured using one re-broadcast receiver and one domestic sound broadcast receiver of medium quality which meets the RF protection ratio curves of Recommendation 412 fairly well.

The measurements were made using a PAL transmitter but with a vision-sound-carrier spacing of 6.5 MHz. The vision-to-sound-carrier ratio was chosen as 10 dB. Taking account of the greater video bandwidth of the D/SECAM standard the interference in the frequency range between 5 MHz and 6 MHz was extrapolated from the results at lower frequencies.

The frequency of the chrominance sub-carrier was at about 4.433 MHz according to PAL standard but when evaluating the results, the special conditions of the D/SECAM standard using two sub-carriers at frequencies 4.25 MHz and 4.4 MHz were taken into account.

The measurements were made according to Report 796 using the D/SECAM television signals as the interfering signal. However, the interfering sound carrier was only modulated with a quasi-peak deviation of ± 24 kHz, thereby taking account of the smaller maximum deviation of ± 50 kHz for the sound in television systems. For the video signal, different test patterns were used.

3. Comparison of the results

The results obtained in the measurements effected in the Federal Republic of Germany generally confirm those given in Table I and Fig. 1. As a result of the different measuring methods and equipment used, the radio-frequency protection ratios differ below -1 MHz relative to the vision carrier and around the colour sub-carrier frequencies above 4 MHz. The results obtained in the Federal Republic of Germany require lower protection ratios below -1 MHz for stereophonic reception and above 4 MHz for monophonic reception.

4. Conclusions

The radio-frequency protection ratio values given are based on a preliminary series of measurements and slight modifications are possible when further measurements are carried out. The numerical values of Table I and Figure I could, however, be used provisionally until results based on other measurements are available.

BIBLIOGRAPHY

CCIR Documents

[1978-82]: 10/236 (Finland); 10/235 (Poland (People's Republic of)); 10/239 (Germany (Federal Republic of)).

REPORT 796-1

DETERMINATION OF RADIO-FREQUENCY PROTECTION RATIO FOR FREQUENCY-MODULATION SOUND BROADCASTING

Objective two-signal method of measurement

(Question 46/10, Study Programme 46L/10)

(1978-1982)

1. Introduction

In frequency planning the radio-frequency protection ratio, which is a function of the frequency spacing between the wanted and unwanted signal, is of great importance. This RF protection ratio depends mainly on the selectivity characteristics of the receiver, but also on the characteristics of the limiter and the decoder and on the RF input voltage. It is obvious, therefore, that the selectivity and the protection ratio curve of a receiver do not coincide. It should be noted that, in contrast to the measurement of a selectivity curve, the determination of a protection-ratio curve is by far more complex.

The method used for the measurement of RF protection ratios is essentially a psophometric two-signal method in which the interfering transmitter is modulated by a standard coloured-noise signal with a given frequency deviation. The interference effect is measured at the audio-frequency output of the receiver by means of an international standard noise voltmeter (psophometer). The reference value used to define the audio-frequency signal-to-interference ratio is that which is measured at the audio-frequency output of the receiver with the same noise voltmeter, when the wanted transmitter is modulated with a sinusoidal tone of 500 Hz, while the interfering transmitter is switched off.

2. Psophometer

The noise voltmeter used to measure the wanted and interfering signals at the output of the receiver consists of a quasi-peak voltmeter with defined dynamic characteristics and an added filter which modifies the interfering frequencies according to their subjective interference effect (see Recommendation 468). As the noise voltmeter is also used to determine the reference level and to adjust the frequency deviation, it must be possible to disconnect the weighting network. If, instead of the noise voltmeter, only a peak programme meter is available, it should have the same dynamic performance.

3. Noise signal for modulating the interfering signal generator

The standardized coloured noise is described in detail in Recommendation 559 (see Note).

The spectrum beyond the required bandwidth of the standardized coloured noise should be restricted by a low-pass filter having a cut-off frequency of 15 kHz and a slope of 60 dB/octave. The audio-frequency amplitude/frequency characteristic of the modulation stage of the signal generator should not vary by more than 2 dB up to the cut-off frequency of the low-pass filter.

Note. — Recommendation 571 proposes a different coloured noise signal. The effect which would result from the use of that signal instead of the one proposed in Recommendation 559 is discussed in [CCIR, 1978-82].

4. Measuring arrangement

Figure 1 shows a schematic diagram of the measuring arrangement.

The arrangement is suitable for monophonic and stereophonic transmissions. With stereophonic operation, channel A or B should be measured. The unwanted transmitter is always operated in the monophonic mode, because this gives the more critical disturbing effect.

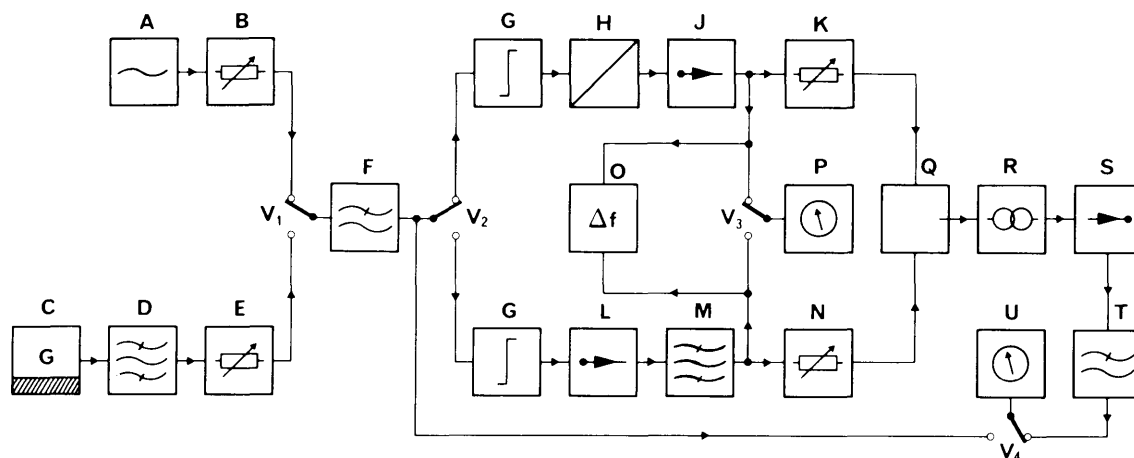


FIGURE 1 – Diagram of the measuring apparatus

A: 500 Hz AF generator (for transmitter line-up procedure)	K: calibrated RF attenuator	T: 15 kHz low-pass filter
B: calibrated AF attenuator	L: signal generator (unwanted signal)	U: psophometer (switchable weighting network)
C: noise generator	M: RF band-pass filter (tuneable)	V ₁ : selector switch for the modulation
D: noise shaping filter complying with Recommendation 559	N: calibrated RF attenuator	V ₂ : selector switch for modulating one or other of the signal generators
E: calibrated AF attenuator	O: frequency-meter for measuring the frequency difference between signal generators J and L	V ₃ : selector switch for the frequency-deviation meter (J and L generators)
F: 15 kHz low-pass filter	P: frequency-deviation meter	V ₄ : selector switch for measuring the AF signal levels
G: pre-emphasis network	Q: coupling device	
H: stereo coder	R: matching network	
J: signal generator (wanted signal)	S: receiver under test	

It is important that the unwanted transmitter should be relatively free from spurious emissions. For this reason, a tunable bandpass filter with a 3 dB bandwidth of approximately 300 kHz, follows the signal generator. Care should be taken to avoid any interaction between the output stages of the two signal generators. A directional coupler may be used.

The audio-frequency signal-to-interference ratio should be measured at the audio-frequency output of the receiver ahead of the tone-control. If this is not possible, the tone-control should be in a position to assure a flat amplitude/frequency response.

The 19 kHz pilot-tone must be sufficiently suppressed at the audio-frequency output. It is necessary to add to the receiver output a low-pass filter with a 15 kHz cut-off frequency having an attenuation at 19 kHz of at least 40 dB.

5. Frequency deviation of the signal generators

The accuracy of the measurement depends very much on the precision with which frequency deviation of the signal generator can be set; this is especially true for the unwanted transmitter. The line-up procedure therefore should be carried out very carefully.

For the determination of the reference level, the wanted transmitter J is frequency modulated with the aid of the tone-generator A, using a sinusoidal tone of 500 Hz. Attenuator B is then adjusted to obtain a deviation of ± 75 kHz, including the pilot-tone in stereophonic operation. The reading of the noise-meter U, with the weighting network filter switched off, indicates the reference level. During the remaining measurements, the wanted transmitter is unmodulated. In stereophonic operation, only the pilot-tone has to be transmitted.

The unwanted transmitter L is then modulated with a 500 Hz sinusoidal tone obtained from audio-frequency generator A. Attenuator B is then adjusted to obtain a deviation of ± 32 kHz. The audio-frequency level at the input of the unwanted transmitter before the pre-emphasis is now measured by means of the noise voltmeter U. The noise-weighting network is switched off. Next, a noise signal C + D replaces the sinusoidal tone, and attenuator E is adjusted to obtain the same peak-reading as before at the noise voltmeter. The (quasi) peak-deviation is thus equal to ± 32 kHz. Since the pre-emphasis has not been included in the level measurement, the actual peak deviation is higher. The described adjustment corresponds to the present-day broadcasting practice.

6. Radio-frequency wanted-to-interfering signal ratio

By means of attenuator K, the radio-frequency level of the wanted transmitter J is kept as low as possible to avoid non-linear effects in the receiver input stages. However, the level should be such that with the unwanted signal switched off, the audio-frequency signal-to-interference ratio is at least 56 dB.

Attenuator N at the output of the unwanted transmitter is adjusted to obtain an audio-frequency signal-to-interference ratio of 50 dB at the audio-frequency output of the receiver S. In this case, the weighting network at the noise voltmeter U must be switched in. The ratio between the radio-frequency levels of the wanted and unwanted transmitters is the required radio-frequency wanted-to-interfering signal ratio.

The measurement is carried out for channel spacings ranging from 0 to 400 kHz between the wanted and unwanted transmitters. The results should be given in a table or a diagram. If a diagram is drawn, the measuring points should be connected by straight lines. The radio-frequency level of the wanted transmitter and the receiver input impedance should be stated.

REFERENCES

CCIR Documents

[1978-82]: 10/51 (Germany (Federal Republic of)).

REPORT 464-3

POLARIZATION OF EMISSIONS IN FREQUENCY-MODULATION BROADCASTING IN BAND 8 (VHF)

(Question 46/10, Study Programme 46C/10)

(1970-1974-1978-1982)

1. Introduction

From the outset of broadcasting in band 8 (VHF), the provision of high quality was a key feature and was given further impetus by the introduction of stereo transmissions. Thus, during the planning of these new services, consideration was given primarily to properly installed receiving installations employing roof-mounted antennas where studies had shown some advantage in the use of horizontal polarization.

The advent of the transistor has led to the mass production of cheap portable VHF/FM radio sets of high sensitivity and capable of satisfactory operation from built-in rod antennas. Also, the use of VHF/FM with car radios, although not universally accepted as satisfactory at the present time, may well increase in popularity. Generally, these newer categories of receivers enable a mass audience to be reached and, although they are not able to derive the fullest benefit from high-quality transmissions, they are used in such numbers that they cannot be ignored by broadcasters. It must also be mentioned that there is generally a continuing increase in demand for receivers giving high-quality reception, including stereo.

The evidence available suggests that for the type of antenna used with portable and car receivers, there is, in some circumstances, a signal-strength advantage to be gained through the transmission of a vertically polarized component. Recently, the use of a vertically polarized component transmitted in addition to the existing horizontal component has become popular in North America and new services frequently use circular polarization. This has been found to offer advantages for car reception in filling in the standing-wave pattern as well as providing generally higher signal strength in open areas. In Ireland, contrary to practice elsewhere, all band-8 transmissions are vertically polarized, while in the United Kingdom some BBC local radio stations use slant polarization and most IBA local radio stations are being planned with the use of circular polarization. Tests carried out in Sweden [CCIR 1978-82a] also show that car-radio reception is improved in built-up areas close to the transmitter by using circular or vertical polarization rather than horizontal. However, work in the Federal Republic of Germany and in Italy has shown that horizontally-polarized transmissions are less susceptible to multipath distortions in certain types of terrain, and that this is especially important for stereo or other multiplexed signals.

Experience in the United Kingdom [CCIR 1978-82b], particularly as a result of tests carried out in the London area showed that, compared with horizontal polarization, mixed polarization (see § 2) provided an improved service to listeners using portables or car radios without causing a significant degradation to stereo listeners using properly installed, horizontally polarized, outside antennas. Using an e.r.p. of 400 W the measurements were made within a range up to 25 km from the transmitter site and it was found that the addition of a vertical component (of equal power) to an existing horizontally polarized transmission led to an effective increase in signal for portable and car receivers of between 5 and 7 dB.

This Report is intended to provide broadcasters with data from which they may more easily choose the most appropriate polarization to use for any new service, according to the individual circumstances.

2. Forms of polarization for broadcast services

The polarization employed for broadcast services may take several forms, and these are defined as follows:

Horizontal polarization: with the electric vector in the horizontal plane.

Vertical polarization: with the electric vector in the vertical plane.

Slant polarization: with the electric vector inclined at 45° to the horizontal. This may be considered as the result of equal-amplitude vertically- and horizontally-polarized components combined in the same phase.

The polarization is said to be right or left slant when the electric vector of the propagating wave has been rotated clockwise, or anti-clockwise, respectively, 45° from the vertical position, as seen from the transmitting point.

Elliptical polarization: with the electric vector rotating in a circular motion. This may be considered as the result of vertically- and horizontally-polarized components differing in phase and/or amplitude.

The polarization is said to be right-hand or left-hand elliptical when the electric vector of the propagating wave rotates clockwise, or anti-clockwise, respectively, as seen from the transmitting point.

Circular polarization: with the electric vector rotating in a circular motion. This may be considered as a special case of elliptical polarization where equal-amplitude vertically- and horizontally-polarized components are combined in phase quadrature.

The polarization is said to be right-hand or left-hand circular when the electric vector of the propagating wave rotates clockwise, or anti-clockwise, respectively, as seen from the transmitting point.

Dual polarization: when substantially equal-amplitude vertically- and horizontally-polarized components are radiated without particular control of the phase relation between them. Typically, the vertically- and horizontally-polarized sources may be displaced one from the other so that the resultant polarization varies between circular and slant, according to azimuth angle.

Mixed polarization: the collective term applied when both vertical and horizontal components are radiated, embracing slant, elliptical (including circular) and dual polarization.

In practice, because of the types of antenna employed for domestic reception, one type of mixed polarization is unlikely to have any significant advantage over another.

When the broadcaster wishes to use mixed rather than horizontal or vertical polarization, the choice may be made with regard to the most convenient arrangement for realisation of the transmitting antenna. In such cases, it is necessary to increase the transmitting power by 3 dB when it is intended to provide the same input voltage to receivers employing horizontally- or vertically-polarized receiving antennas. It is to be noted that, where directional antenna patterns are employed, the specified form of polarization is likely to be obtained only within the main beam.

An important factor is that, where mixed polarization is used, the opportunity is generally lost for the provision of mutual protection between services through the use of orthogonal polarization (vertical and horizontal). In the case of mixed polarization, no advantage in polarization discrimination can be gained over horizontal or vertical polarization by using, at the receiving site, the same type of antenna as at the site of the wanted transmitter. This would also apply for right and left circular polarization, because the direction of rotation of a signal coming from the back of an antenna is opposite to that of a signal coming from the front.

3. Definition of effective radiated power for interference calculations in the case of mixed polarization [CCIR, 1978-82c]

Any kind of mixed polarization can be represented by a horizontally- and a vertically-polarized component which, depending on the type of receiving antenna used, may provide different input voltages to the receiver. Because of the general loss of mutual protection between services through the use of orthogonal

polarization — as mentioned above — it is not important to take the phase relationship between the two components into account when carrying out interference calculations. However, the effective radiated power (e.r.p.) has to be clearly defined. It is therefore appropriate to specify the two components of the e.r.p. in the horizontal and vertical plane separately, and not merely to indicate the value of the total e.r.p. only.

4. Propagation factors

4.1 *Direct or diffracted component*

Broadcast signals arriving at a receiving point are normally made up of several components, the strongest of which is either a direct wave or a diffracted wave. The magnitude of this direct or diffracted wave is substantially independent of polarization, except where diffraction occurs over smooth rounded hills (without vegetation or obstructions higher than about one metre), in which case a vertically-polarized wave will be attenuated less than a horizontally polarized wave. Another special case is where propagation is over hills wooded with coniferous trees, as the greater tendency of trees to scatter the vertically-polarized component contributes to a greater loss for this polarization. Close to the ground, the boundary conditions favour a vertically-polarized component, as any horizontally-polarized component is attenuated. Thus, at low antenna heights, vertical polarization will give the stronger signal.

4.2 *Reflected component*

In addition to the direct or diffracted component there will generally be one or more reflected signals, and these may arise from a number of causes which may be categorised into the following three groups:

4.2.1 *Grazing reflections from the ground in front of the receiving point*

The path difference between direct and reflected signals is normally very small, and the echo, in consequence, does not contribute to distortion but only to variation in field strength. In most cases where the grazing angle is not more than a degree or so, the effect is substantially independent of polarization; however, if transmission is between high transmitting and receiving points, e.g. across a valley or bay, the echo delay time may become significant, and horizontal polarization will normally give a rather larger echo.

4.2.2 *Reflections from the side of the path, where the reflecting object may be a man-made structure, trees, hills or mountains*

When the reflections are from vertical or near-vertical surfaces, their magnitude will generally be significantly greater for vertically-polarized transmissions as compared with horizontally-polarized ones. It is this factor which is likely to make vertically-polarized transmissions rather more liable to multipath effects when compared with horizontally-polarized transmissions. In practice, the effect is more pronounced when the direct path is obscured and there are strongly illuminated structures or topographical features to the side of the path. The effect can become important where the path difference between direct and reflected signals exceeds about 3 km (10 μ s). With this path delay, perceptible distortion may occur at an echo amplitude of about 15% for stereo or 40% for mono, although the actual value will depend upon the amount of AM suppression in the receiver.

4.2.3 *Reflections from behind the receiving point and occurring from vertical or near-vertical surfaces such as buildings, trees or mountains*

Where dimensions of the reflecting object are large in both the vertical and horizontal plane, then polarization is often found to be unimportant, although some evidence has been found in the Federal Republic of Germany that buildings tend to reflect vertically-polarized band 8 signals more than those which are horizontally polarized. Where the reflecting object is a tree, particularly of the coniferous type, vertically-polarized signals will be reflected more strongly. As in § 4.2.2 the effects are important only when the path difference exceeds about 3 km.

4.3 *Summary of propagation factors*

It is evident, therefore, that transmissions of a vertical component can result in an increased signal strength where receiving antennas are essentially vertically polarized and used at low heights. Offset against this advantage is the possibility of an increase in multipath distortion in certain types of terrain. This distortion is the more serious when multiplexed signals are transmitted.

Present evidence shows that, in flat or rolling country, multipath effects are minimal, while the increase in received signal strength obtainable by transmitting a vertical component is the greatest. At the other extreme, in rugged mountainous country, the increase in received signal strength is small, whereas multipath effects may be severe, especially when reflections are from mountains with coniferous trees.

Thus, in these extreme cases, it is possible to make a decision as to the most suitable polarization to employ for transmission. For the more general intermediate cases, the decision may be less clear-cut and be dependent upon the type of service the broadcaster is attempting to provide.

5. Man-made interference

The main source of interference is from vehicle-ignition systems, and experience seems to show that the magnitude of the interference differs from one country to another. The explanation for this is not known with certainty, but it may be due to the different standards adopted for vehicle electrical system suppression.

Interference radiated from vehicles has a semi-random polarization but with a preponderant vertical component. Thus, where receiving antennas are well above ground level and of the same polarization as the transmissions, it is advantageous to use horizontal polarization. Where the receiving antenna is used near ground level and responds primarily to vertically polarized signals, as is the case at present for portable and car receivers, the signal-to-interference ratio can be improved only by the radiation of a vertical component.

6. Existing services

It is important to know whether services already exist in the area to be served. If so, it will presumably be necessary to employ a polarization of transmission such that existing receiving systems can, in most cases, provide satisfactory results. Generally, this is likely to mean that where existing services use horizontal or vertical polarization, the new service should use either the same or mixed polarization.

7. Discussion

The various factors affecting the choice of polarization for new services in band 8 (VHF) have been reviewed. It appears that certain advantages exist for the use of horizontal, vertical or mixed polarization, and that these advantages take on a different weight according to the type of terrain, the type of receiving installation and the type of service being provided. No one type of polarization is best for all circumstances.

Table 1 is intended, with this in mind, to assist the broadcaster in making a choice according to circumstances.

TABLE 1 – *Choice of polarization appropriate for new services*

Type of service intended	Polarization of existing services	Type of terrain	Preferred polarization for new services
Primarily for high-quality receiving installations, probably with stereo, with no improvement to reception conditions for portable or car sets envisaged.	nil	any	horizontal
	horizontal	any	horizontal
	vertical	flat or rolling	vertical
	vertical(1)	rugged	mixed(2)
Primarily to reach the largest audience, especially those using portable or car sets. Account to be taken of those installations already equipped to receive any existing transmissions.	nil or horizontal	flat or rolling	mixed
		rugged	horizontal
	vertical	flat or rolling	vertical
	vertical(3)	rugged	mixed

(1) It would be preferable to change any existing services to horizontal polarization.

(2) Horizontal, if existing services can be changed to horizontal polarization.

(3) It would be preferable to change any existing services to mixed polarization.

REFERENCES

CCIR Documents

[1978-82]: a. 10/61 (Sweden); b. 10/195 (United Kingdom); c. 10/240 (EBU).

BIBLIOGRAPHY

EBU [February, 1976] Choice of polarisation for new Band-II services. *EBU Rev. Tech.*, **155**, 21-24.

REPORT 122-3

**ADVANTAGES TO BE GAINED BY USING ORTHOGONAL WAVE
POLARIZATIONS IN THE PLANNING OF BROADCASTING SERVICES
IN BANDS 8 (VHF) AND 9 (UHF)**

Sound and television

(Question 46/10, Study Programme 46C/10)

(1956-1959-1970-1974-1982)

Investigations have been conducted in several countries to ascertain the advantages which can be obtained in sound and television broadcasting by using polarization discrimination in reception. The results of extensive studies made in Europe by the Federal Republic of Germany, France, Italy and the United Kingdom and also in the United States of America, have been made available in documents at Warsaw, 1956 and Geneva, 1958; and a reasonably definite answer may now be given to the question.

1. Band 8 (VHF)

In this band of frequencies, between 30 and 300 MHz, the median value of discrimination that can be achieved at domestic receiving sites by the use of orthogonal polarization may be as much as 18 dB, and under these conditions, the values exceeded at 90% and 10% of the receiving sites are about 10 dB and 25 dB respectively.

The values of discrimination are likely to be better in open country and worse in built-up areas or places where the receiving antenna is surrounded by obstacles. For domestic installations in densely populated districts, the median values of 18 dB will usually be realized only at roof level; and this value may be reduced to 13 dB or less at street level.

No significant changes in the polarization of waves in band 8 due to transmission through the troposphere have been observed over distances exceeding 200 km. Furthermore, there have been no reports of systematic change in polarization effects with frequency in the metric band, neither with distance nor with type of terrain.

It must be emphasized, however, that to realize the discrimination ratios mentioned above, certain precautions are necessary at both the transmitting and receiving installations; cases have been reported in which, for a transmitter of horizontally polarized waves, some 7% of the radiated power was vertically polarized. It is clear that if the best discrimination is to be obtained for co-channel operation, the transmitters and antenna systems must be designed and installed so as to radiate as much as possible of the total power on the assigned polarization.

In the same way, to achieve the desired discrimination at the home receiving installation, the reception of the undesired orthogonally polarized waves on the antenna feeder and on the receiver itself must be reduced to the minimum practicable value.

It should, however, be noted that the above-mentioned advantage from the use of orthogonal polarizations can only be obtained when, in general, the polarization of the receiving antennas conforms to that of the wanted signal. In cases where the polarization of the receiving antennas is random, e.g. when in VHF/FM sound broadcasting, antennas for domestic and car reception have different polarization, no general advantage can be expected from making systematic use of orthogonal polarization and this may be detrimental to reception under these conditions.

2. Band 9 (UHF)

Experiments have been conducted in the United Kingdom to determine the polarization discrimination in band 9 (UHF) of receiving antennas at typical urban and rural sites. The results of measurements showed that for orthogonally polarized signals arriving in the direction of main response of the antenna, the discrimination obtained is similar to that already described above for frequencies in band 8 (VHF), although the factor exceeded for 90% of receiving sites was only 8 dB (as compared with 10 dB for band 8 (VHF)). In the case of discrimination against orthogonally polarized signals arriving within the arc $180^\circ \pm 90^\circ$ relative to the direction of main response, measurements confirmed that at least 20 dB discrimination is achieved at 90% of receiving sites. As a result of these investigations, for television planning purposes in band 9 (UHF), the United Kingdom uses values of antenna discrimination for orthogonal transmissions which exceed the values for co-planar transmissions given in Recommendation 419, by 8 dB (total value: 8 dB) in the range of 0° to 20° relative to the direction of main response and by 4 dB (total value: 20 dB) in the range 60° to 180° . Linear interpolation is applied for the range 20 to 60° as in the existing curve for discrimination between co-planar transmissions.

As in band 8, care is necessary to ensure that the transmitter and receiver respectively do not emit or receive radiation of the undesired polarization. Apart from this, however, experience indicates that in band 9 (UHF), the use of horizontal polarization offers advantages, because of the greater directivity obtainable at the receiving antennas; this reduces the effect of reflected waves, particularly in town areas. The European Broadcasting Union, therefore, considers that frequency assignments in these bands should be based on the general use of horizontal polarization, though exceptions may be made in cases where orthogonal polarization is necessary to achieve the desired protection.

3. Conclusion

From the studies described above, it is clear that the use of orthogonal polarization for broadcasting stations operating in the same frequency channel is of material assistance in discriminating against the reception of undesired signals. Worth-while advantages are obtainable over the whole band of frequencies from 40 to 500 MHz and within the normal broadcasting service ranges. From the uniformity of the discrimination obtained over these frequencies, it is considered to be almost certain that the advantages will extend to the top of the broadcasting band in band 9 at nearly 1000 MHz.

However, in VHF/FM sound broadcasting, no advantage should be expected in cases where the polarization of the receiving antennas are random and, hence, do not necessarily conform to that of the wanted transmission.

BIBLIOGRAPHY

CCIR Documents

[1956]: Warsaw 267, 435 and 512.

[1958]: Geneva V/1, V/6, V/12, V/23 and V/27.

[1970-74]: 11/267 (United Kingdom).

RECOMMENDATION 412-3 *

PLANNING STANDARDS FOR FM SOUND BROADCASTING AT VHF

(Question 46/10, Study Programme 46L/10)

(1956-1959-1963-1974-1978-1982)

The CCIR

UNANIMOUSLY RECOMMENDS

that the following planning standards should be used for frequency-modulation sound broadcasting in band 8 (VHF):

* The Director, CCIR, is requested to bring this Recommendation to the attention of the IEC, so that it may inform manufacturers of FM receivers accordingly. Serious difficulties have been encountered in introducing stereophonic FM services planned according to the standards given in this Recommendation. Special attention should be directed to § 2.3 which sets out the problems which will arise if the required design characteristics of such receivers are not met.

1. Minimum usable field strength

In the presence of interference from industrial and domestic equipment (for limits of radiation from such equipments refer to Recommendation 433, which gives the relevant CISPR recommendations) a satisfactory service requires a median field strength (measured 10 m above ground level) of at least:

1.1 *for the monophonic service:*

48 dB(μ V/m) in rural areas,
60 dB(μ V/m) in urban areas,
70 dB(μ V/m) in large cities;

1.2 *for the stereophonic service:*

54 dB(μ V/m) in rural areas,
66 dB(μ V/m) in urban areas,
74 dB(μ V/m) in large cities.

Note. — In the absence of interference from industrial and domestic equipment, a field strength (measured 10 m above ground level) of at least 34 dB(μ V/m) or 48 dB(μ V/m) can be considered to give an acceptable monophonic or stereophonic service, respectively. These field-strength values apply when an outdoor antenna is used for monophonic reception, or a directional antenna with appreciable gain for stereophonic reception (pilot-tone system, as defined in Recommendation 450).

2. Protection ratios

2.1 The radio-frequency protection ratios required to give satisfactory monophonic reception for 99% of the time, in systems using a maximum frequency deviation of ± 75 kHz, are those given by the Curve M2 in Fig. 1. For steady interference, it is desirable to provide the higher degree of protection, shown by the Curve M1 in Fig. 1 (see Annex I).

The protection ratios at important values of the frequency spacing are also given in Table I.

The corresponding values for monophonic systems using a maximum frequency deviation of ± 50 kHz are given in Fig. 2.

2.2 The radio-frequency protection ratios required to give satisfactory stereophonic reception for 99% of the time, for transmissions using the pilot-tone system and a maximum frequency deviation of ± 75 kHz, are given by Curve S2 in Fig. 1. For steady interference (see Annex I), it is desirable to provide a higher degree of protection, shown by Curve S1 in Fig. 1. The protection ratios at important values of the frequency spacing are also given in Table I.

2.3 The protection ratios for stereophonic broadcasting assume the use of a low-pass filter following the frequency-modulation demodulator in the receiver designed to reduce interference and noise at frequencies greater than 53 kHz in the pilot-tone system and greater than 46.25 kHz in the polar-modulation system. Without such a filter or an equivalent arrangement in the receiver, the protection-ratio curves for stereophonic broadcasting cannot be met, and significant interference from transmissions in adjacent or nearby channels is possible.

2.4 Data systems or other systems providing supplementary information, if introduced, should not cause more interference to monophonic and stereophonic services than is indicated by the protection-ratio curves in Fig. 1 (see Report 463). It is not considered practicable in the planning to provide additional protection to data services or other services providing supplementary information signals.

Note 1. — The protection-ratio curves in Fig. 1 were originally determined by subjective evaluation of interference effects. As subjective tests are rather time-consuming an objective measuring method was developed (see Report 796) and found to yield results which are in fair agreement with those of subjective tests.

Note 2. — In determining the characteristics of the filters whose phase response is important in the preservation of channel separation at high audio frequencies, reference should be made to Report 293, particularly Table I and Figs. 2, 3 and 4.

Note 3. — The protection ratios for steady interference provide approximately 50 dB signal-to-noise ratio. (Weighted quasi-peak measurement according to Recommendation 468, with a reference signal at maximum frequency deviation.) See also Report 796.

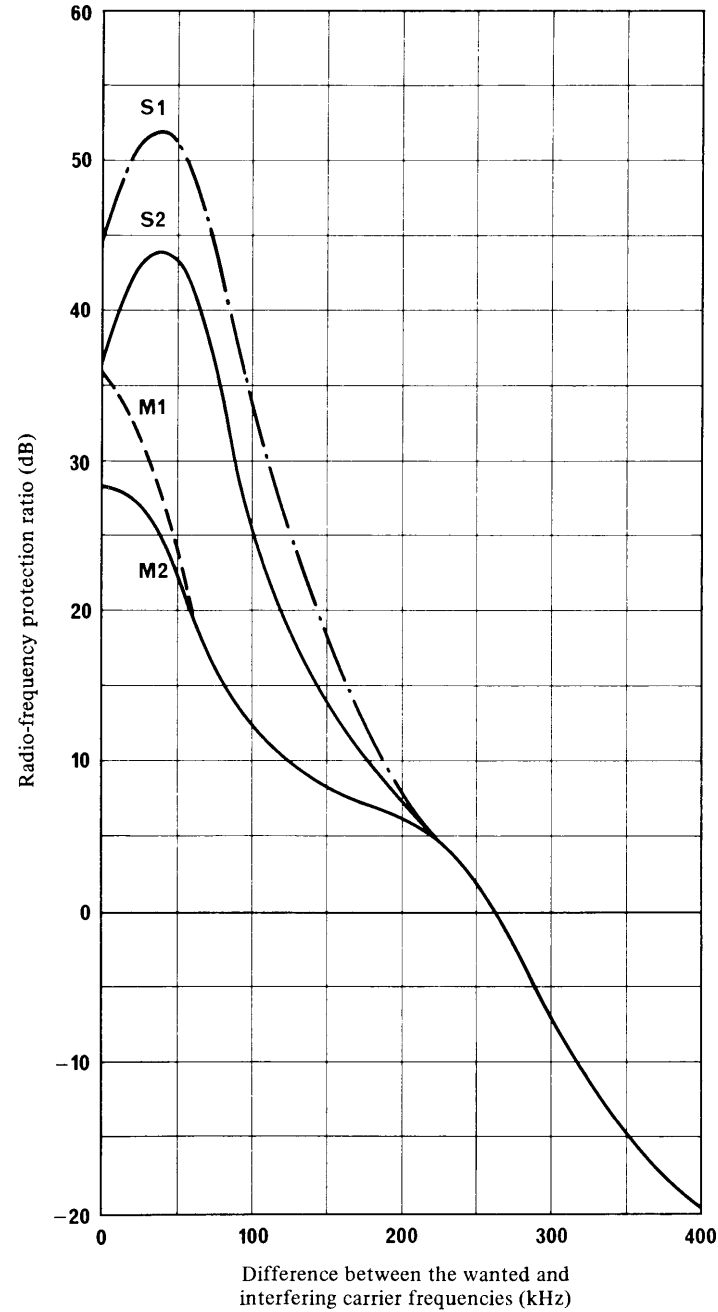


FIGURE 1 – Radio-frequency protection ratio required by broadcasting services in band 8 (VHF) at frequencies between 87.5 MHz and 108 MHz using a maximum frequency deviation of ± 75 kHz

- Curve M1 : monophonic broadcasting; steady interference
- Curve M2 : monophonic broadcasting; tropospheric interference (protection for 99% of the time)
- Curve S1 : stereophonic broadcasting; steady interference
- Curve S2 : stereophonic broadcasting; tropospheric interference (protection for 99% of the time)

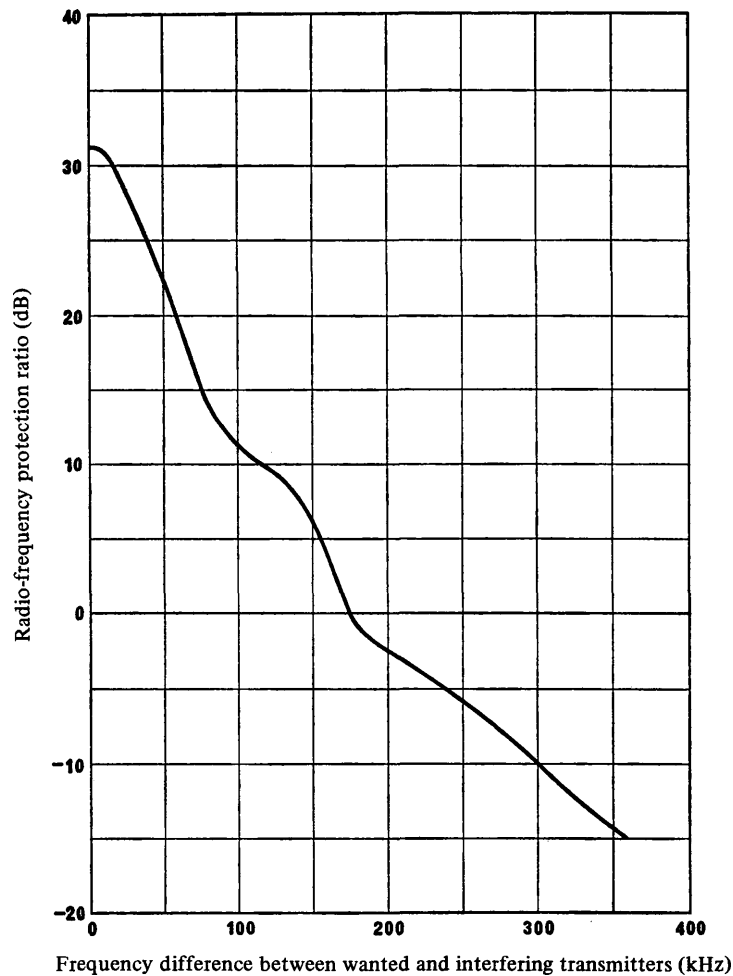


FIGURE 2 – Radio-frequency protection ratios for monophonic sound broadcasting in band 8 (VHF) using a maximum frequency deviation of ± 50 kHz

Tropospheric interference (protection for 99% of the time)

TABLE I

Frequency spacing, (kHz)	Radio-frequency protection ratio (dB)			
	Monophonic		Stereophonic	
	Steady interference	Tropospheric interference	Steady interference	Tropospheric interference
0	36	28	45	37
25	31	27	51	43
50	24	22	51	43
75	16	16	45	37
100	12	12	33	25
150	8	8	18	14
200	6	6	7	7
250	2	2	2	2
300	- 7	- 7	- 7	- 7
350	-15	-15	-15	-15
400	-20	-20	-20	-20

3. Channel spacing

Channels are to be assigned in such a way that:

3.1 the carrier frequencies which define the nominal placement of the RF channels within the band are integral multiples of 100 kHz;

3.2 a uniform channel spacing of 100 kHz applies for both monophonic and stereophonic transmissions.

Note. — In those cases where a 100 kHz channel spacing would be difficult to implement, the use of a spacing which is an integral multiple of 100 kHz would also be acceptable, provided that the carrier frequencies are chosen in accordance with § 3.1 above.

ANNEX I

To apply the protection-ratio curves of Fig. 1 it is necessary to determine whether, in the particular circumstances, the interference is to be regarded as steady or tropospheric [CCIR, 1978-82]. A suitable criterion for this is provided by the concept of “nuisance field” which is the field strength of the interfering transmitter (at its pertinent e.r.p.) enlarged by the relevant protection ratio.

Thus, the nuisance field for steady interference:

$$E_s = P + E(50,50) + A_s$$

and the nuisance field for tropospheric interference

$$E_t = P + E(50, T) + A_t$$

where

P : e.r.p. (dB(1 kW)) of the interfering transmitter;

A : radio-frequency protection ratio (dB);

$E(50, T)$: field strength (dB(μ V/m)) of the interfering transmitter, normalized to 1 kW, and exceeded during $T\%$ of the time,

and where indices s and t indicate steady or tropospheric interference respectively.

The protection-ratio curve for steady interference is applicable when the resulting nuisance field is stronger than that resulting from tropospheric interference,

i.e. $E_s \geq E_t$

This means that A_s should be used in all cases when:

$$E(50,50) + A_s \geq E(50, T) + A_t.$$

REFERENCES

CCIR Documents

[1978-82]: 10/241 (Yugoslavia (Socialist Federal Republic of)).

RECOMMENDATION 450-1

TRANSMISSION STANDARDS FOR FM SOUND BROADCASTING AT VHF

(Question 46/10)

(1982)

The CCIR

UNANIMOUSLY RECOMMENDS

that for FM sound broadcasting in band 8 (VHF) the following transmission standards should be used:

1. Monophonic transmissions

1.1 RF signal

The radio-frequency signal consists of a carrier frequency-modulated by the sound signal to be transmitted, after pre-emphasis, with a maximum frequency deviation equal to:

± 75 kHz or ± 50 kHz.

Note 1. — In the West European countries and the United States, the maximum deviation is ± 75 kHz. In the U.S.S.R. and in some other European countries, it is ± 50 kHz.

1.2 *Pre-emphasis of the sound signal*

The pre-emphasis characteristic of the sound signal is identical to the admittance-frequency curve of a parallel resistance-capacitance circuit having a time constant of:

50 μ s or 75 μ s.

Note 2. — In Europe, the pre-emphasis is 50 μ s. In the United States, it is 75 μ s.

2. **Stereophonic transmissions**

2.1 *Polar-modulation system*

2.1.1 *RF signal*

The radio-frequency signal consists of a carrier frequency-modulated by a baseband signal, known in this case as the “stereophonic multiplex signal”, with a maximum frequency deviation equal to:

± 75 kHz or ± 50 kHz (see Note 1, § 1).

2.1.2 *Stereophonic multiplex signal*

This signal is produced as follows:

2.1.2.1 A signal M is formed equal to one half of the sum of the left-hand signal, A , and the right-hand signal, B , corresponding to the two stereophonic channels. This signal, M , is pre-emphasized in the same way as monophonic signals (see § 1).

Note 1. — M is a “compatible” signal in the sense that the stereophonic transmission may be received by a monophonic receiver equipped for the same maximum frequency deviation and the same pre-emphasis.

2.1.2.2 A signal S is produced equal to one half of the difference between signals A and B mentioned above. This signal, S , is pre-emphasized in the same way as signal M . The pre-emphasized signal, S , is used for the amplitude modulation of a sub-carrier at 31.25 kHz; the spectrum of the amplitude-modulated sub-carrier is formed so that the sub-carrier amplitude is reduced by 14 dB and the spectral components of the given modulating signal appear to be transformed as follows:

$$\bar{K}(f) = \frac{1 + j 6.4 f}{5 + j 6.4 f}$$

where f is equal to each frequency component in kHz.

2.1.2.3 The stereophonic multiplex signal is the sum of:

- the pre-emphasized signal, M ;
- the sideband spectral components which are the product of amplitude-modulated unsuppressed carrier by a pre-emphasized signal S additionally transformed from the law $\bar{K}(f)$;
- the sub-carrier with the amplitude reduced by 14 dB.

2.1.2.4 The amplitudes of the various components of the stereophonic multiplex signal, referred to the maximum amplitude of that signal (which corresponds to the maximum frequency deviation) are:

- signal M : maximum value 80% (A and B being equal, and in phase);
- signal S : maximum value 80% (A and B being equal but of opposite phase);
- reduced sub-carrier at 31.25 kHz; maximum residual amplitude 20%.

2.1.2.5 The frequency modulation is arranged in such a way that positive values of the multiplex signal correspond to a positive frequency deviation of the main carrier and negative values to negative frequency deviation.

2.2 *Pilot-tone system*

2.2.1 *RF signal*

The radio frequency signal consists of a carrier frequency-modulated by a baseband signal, known in this case as the “stereophonic multiplex signal”, with a maximum frequency deviation equal to:

± 75 kHz or ± 50 kHz (see Note 1, § 1).

2.2.2 *Stereophonic multiplex signal*

This signal is produced as follows:

2.2.2.1 A signal M is formed equal to one half of the sum of the left-hand signal, A , and the right-hand signal, B , corresponding to the two stereophonic channels. This signal, M , is pre-emphasized in the same way as monophonic signals (see § 1) (see Note 1, § 2).

2.2.2.2 A signal S is produced equal to one half of the difference between signals A and B mentioned above. This signal, S , is pre-emphasized in the same way as signal M . The pre-emphasized signal, S , is used for the suppressed-carrier amplitude modulation of a sub-carrier at $38\text{ kHz} \pm 4\text{ Hz}$.

Note 2. — The same effect is obtained by pre-emphasizing the left-hand signal A and the right-hand signal B before encoding. For technical reasons this procedure is sometimes preferred.

2.2.2.3 The stereophonic multiplex signal is the sum of:

- the pre-emphasized signal, M ;
- the sidebands of the suppressed sub-carrier amplitude modulated by the pre-emphasized signal, S ;
- a "pilot signal" with a frequency of 19 kHz exactly one-half the sub-carrier frequency.

2.2.2.4 The amplitudes of the various components of the stereophonic multiplex signals referred to the maximum amplitude of that signal (which corresponds to the maximum frequency deviation) are:

- signal M : maximum value 90% (A and B being equal and in phase);
- signal S : maximum value of the sum of the amplitudes of the two sidebands: 90% (which corresponds to A and B being equal and of opposite phase);
- pilot signal: 8 to 10%;
- sub-carrier at 38 kHz suppressed: maximum residual amplitude 1%.

2.2.2.5 The relative phase of the pilot signal and the sub-carrier is such that, when the transmitter is modulated by a multiplex signal for which A is positive and $B = -A$, this signal crosses the time axis with a positive slope each time the pilot signal has an instantaneous value of zero. The phase tolerance of the pilot signal should not exceed $\pm 3^\circ$ from the above state. Moreover, a positive value of the multiplex signal corresponds to a positive frequency deviation of the main carrier.

2.2.3 *Baseband signal in the case of a supplementary signal transmission*

If, in addition to the monophonic or stereophonic programme, a supplementary monophonic programme and/or supplementary information signals are transmitted and the maximum frequency deviation is $\pm 75\text{ kHz}$, the following additional conditions must be met:

2.2.3.1 The insertion of the supplementary programme or signals in the baseband signal must permit compatibility with existing receivers, i.e. these additional signals must not affect the reception quality of the main monophonic or stereophonic programmes.

2.2.3.2 The baseband signal consists of the monophonic signal or stereophonic multiplex signal described above and having an amplitude of not less than 90% of that of the maximum permitted baseband signal value, and of the supplementary signals having a maximum amplitude of 10% of that value.

2.2.3.3 For a supplementary monophonic programme, the sub-carrier and its frequency deviation must be such that the corresponding instantaneous frequency of the signal remains between 53 and 76 kHz.

2.2.3.4 For supplementary information signals, the frequency of any additional sub-carrier must be between 15 and 23 kHz or between 53 and 76 kHz.

2.2.3.5 Under no circumstances may the maximum deviation of the main carrier by the total base signal exceed $\pm 75\text{ kHz}$.

REPORT 300-5

STEREOPHONIC BROADCASTING

(Question 46/10, Study Programme 46D/10)

(1963–1966–1970–1974–1978–1982)

1. Introduction

Since the XIth Plenary Assembly of the CCIR, Oslo, 1966, certain administrations and broadcasting organizations have conducted theoretical and experimental work relating to stereophonic broadcasting.

As a result of this work, stereophonic transmissions intended for the public, using single frequency-modulation transmitters, were introduced in a number of countries.

This Report summarizes the situation concerning stereophonic broadcasting systems on the basis of the documents listed in Annex I.

2. Desirable basic characteristics

2.1 *Stereophonic broadcasting systems*

The principal desirable characteristics of any system for stereophonic broadcasting using a single radio-frequency channel, are as follows:

- 2.1.1 the system should be compatible; that is to say, it should be possible to obtain monophonic reception of a stereophonic transmission, without reduction of quality in comparison with the reception of a normal monophonic transmission;
- 2.1.2 the system should provide high-quality stereophonic reproduction (see Report 293);
- 2.1.3 it should be possible to construct stereophonic receivers at reasonably economic prices;
- 2.1.4 the introduction of stereophonic transmissions, at an existing monophonic broadcasting station, should not significantly reduce the service area of the station for monophonic reception;
- 2.1.5 the service area of the broadcasting station for stereophonic reception should be as near as possible equal to that required for monophonic reception;
- 2.1.6 the protection against interference required for stereophonic reception should not be substantially greater than that required for monophonic reception;
- 2.1.7 the introduction of stereophonic transmissions should not necessitate extensive changes to existing frequency assignment plans;
- 2.1.8 according to some administrations, the system should be capable, when not used for stereophonic broadcasting, of transmitting two separate monophonic programmes such as, for example, speech in two different languages. However, other administrations, while agreeing that this characteristic is desirable, do not consider it to be essential.

2.2 *Multi-dimensional sound-broadcasting systems*

The principal desirable characteristics of any system providing 3 or more output sound signals from a single radio-frequency channel, are as follows:

- 2.2.1 the system should be compatible: that is to say, it should be possible to obtain both stereophonic and monophonic reception of a multi-dimensional sound transmission without reduction of quality in comparison with the reception of normal stereophonic or monophonic transmissions;
- 2.2.2 the system should provide high-quality multi-dimensional sound reproduction;
- 2.2.3 it should be possible to construct multi-dimensional sound receivers at reasonably economic prices;
- 2.2.4 the introduction of multi-dimensional sound transmissions at an existing stereophonic broadcasting station, should not significantly reduce the coverage area of the station for stereophonic or monophonic reception;
- 2.2.5 the coverage area of the broadcasting station for multi-dimensional sound reception should be substantially equal to that required for stereophonic reception;
- 2.2.6 the protection against interference required for multi-dimensional sound reception should not be significantly greater than that required for stereophonic reception;
- 2.2.7 the introduction of multi-dimensional sound transmissions should not necessitate extensive changes to existing frequency assignment plans.
- 2.2.8 any system adopted should, as far as possible, acknowledge the existence of non-ideal receivers in the market and be so designed as to minimize the effect of any resulting cross-modulation on their monophonic and stereophonic performance.

3. Results of tests on stereophonic systems

3.1 *Polar-modulation system*

The system of stereophonic broadcasting, using polar-modulation with partly suppressed sub-carrier, was developed in the U.S.S.R. and has been in service in that country since 1959. The system ensures a high quality of sound reproduction and good compatibility with monophonic broadcasting.

For the period 1959 to 1964, additional studies and experiments have been carried out and new decoding circuits have been developed, as a result of which there has been further improvement of the system. Moreover, this system has been tested within the framework of the OIRT and found to provide high-quality monophonic and stereophonic reception. The Technical Commission of the OIRT, in its Recommendation No. 45, suggested the use of the polar-modulation system in the OIRT member countries.

The polar-modulation system can be used with maximum frequency deviations of ± 50 kHz and ± 75 kHz. It is defined by the specifications in Recommendation 450.

[CCIR, 1978-82a] describes an automatic level controller of the channel-signals $M = A + B$ and $S = A - B$ which is used in the U.S.S.R. to avoid the sub-carrier and main-carrier overmodulation in FM transmitters which can be caused by level variations of these signals.

3.1.1 *Compatible monophonic reception*

As a result of tests, compatible monophonic reception by the polar-modulation system may be characterized by the test results given below, as observed at the output of a typical domestic receiver.

3.1.1.1 Audio-frequency response: the same as for monophonic service.

3.1.1.2 Intermodulation S to M : -44 dB.

3.1.1.3 Total harmonic distortion: equal to, or slightly greater than, the value for monophonic transmission.

3.1.1.4 Non-linear cross-talk S to M : better than -39 dB.

3.1.1.5 Signal-to-noise (weighted) ratio: 1 to 2 dB worse than for monophonic transmission.

3.1.1.6 Radio-frequency protection ratio: almost equal to that required for the reception of a monophonic transmission, whether the interfering transmission is monophonic or stereophonic.

3.1.2 *Stereophonic reception*

Stereophonic reception by the polar-modulation system may be characterized by the following results observed at the output of a typical domestic receiver.

3.1.2.1 Audio-frequency response: the same as for monophonic service.

3.1.2.2 Linear cross-talk between A and B :

between 300 Hz and 5 kHz: better than -30 dB,

between 60 Hz and 300 Hz and 5 kHz and 10 kHz: better than -20 dB,

between 30 Hz and 60 Hz and between 10 kHz and 15 kHz: better than -12 dB.

3.1.2.3 Total harmonic distortion: not greater than 1%.

3.1.2.4 Non-linear cross-talk between A and B : better than -39 dB.

3.1.2.5 Signal-to-noise (weighted) ratio: 9 to 19 dB worse than for monophonic service.

3.1.2.6 Radio-frequency protection ratios relative to the values used for monophonic transmission: for a deviation of ± 50 kHz as a function of the separation Δf of the carrier frequencies:

$\Delta f = 0$: increase of about 10 dB;

$\Delta f = 30$ to 60 kHz: increase of about 18 dB;

$\Delta f = 135$ kHz: no change.

3.2 *Pilot-tone system*

During the period 1959 to 1966, detailed studies of a system of stereophonic broadcasting, the service performance characteristics of which are given in §§ 3.2.1 to 3.2.5, were carried out independently in many countries. These studies have comprised theoretical analyses, laboratory tests, actual service trials and listening tests, before and after high-frequency transmission, with the object of evaluating not only the subjective quality of stereophonic reception, but also, that of compatible monophonic reception. The results and conclusions drawn from these tests are given in the documents listed in Annex I.

In the United States of America, the tests were carried out by the National Stereophonic Radio Committee with the collaboration of many industrial firms. The tests were carried out on six systems from which only the pilot-tone system was retained and put into regular service in 1961.

In Europe, the tests were co-ordinated by the EBU and were carried out by five broadcasting organizations; in addition, seven industrial laboratories took part in the first series of measurements. Tests were made on ten systems and, of these, the pilot-tone system was considered to be the best. More detailed tests on this system have been continued to date. Tests have also been made on this system within the framework of the OIRT, the Technical Commission of which in its Recommendation No. 45 suggested the use of this system in the OIRT member countries.

Nine countries have commended a regular stereophonic service using the pilot-tone system because they considered that this system best complied, on the whole, with the conditions set out in § 2 of this Report.

The pilot-tone system has been tested with maximum frequency deviations of ± 75 kHz and ± 50 kHz. It is defined by the specifications in Recommendation 450.

3.2.1 *Compatible monophonic reception*

As a result of tests, compatible monophonic reception by the pilot-tone system may be characterized by the test results given below, as observed at the output of a typical domestic receiver.

3.2.1.1 Audio-frequency response: the same as for monophonic service.

3.2.1.2 Linear cross-talk: *S* to *M*: -60 dB below 1 kHz, -44 dB from 1 to 15 kHz.

3.2.1.3 Intermodulation: *S* to *M*: equal to, or better than, -40 dB.

3.2.1.4 Total harmonic distortion: equal to, or slightly greater than, the value for monophonic transmission.

3.2.1.5 Non-linear cross-talk *S* to *M*: better than -40 dB.

3.2.1.6 Signal-to-noise (weighted) ratio: 66 to 76 dB for an input level of -54 dBmW.

3.2.1.7 Beat-frequency interference: better than -50 dB.

3.2.1.8 Radio-frequency protection ratio: 0 to 3 dB higher than for monophonic reception for a carrier frequency separation of between 0 and 300 kHz.

3.2.1.9 Multipath propagation effects: almost equivalent to those of monophonic transmission.

3.2.1.10 Sensitivity to impulse noise: almost equivalent to that of monophonic transmission.

3.2.2 *Stereophonic reception*

Stereophonic reception by the pilot-tone system may be characterized by the following results, as observed at the output of a typical domestic receiver.

It is possible, however, to improve on most of the following results by using better receiving installations, notably by using a decoder containing:

- a low-pass filter inserted in the multiplex channel, having a relatively sharp cut-off above 53 kHz;
- a filter to attenuate unwanted frequencies close to 19 kHz;
- an amplitude-modulation limiter for the pilot signal in the sub-carrier reconstitution circuits.

The figures in parentheses refer to these improved receivers.

3.2.2.1 Audio-frequency response: the same as for monophonic service.

3.2.2.2 Linear cross-talk between *A* and *B*: better than -35 dB between 100 Hz and 3 kHz, and better than -20 dB at frequencies between 50 Hz to 100 Hz, and from 3 kHz to 15 kHz independent of the receiver input level.

3.2.2.3 Intermodulation between *A* and *B*: -45 dB at 1 kHz; -30 dB at 15 kHz (-45 dB from 50 Hz to 15 kHz).

3.2.2.4 Total harmonic distortion: equal to, or slightly greater than, the value for monophonic transmission.

3.2.2.5 Non-linear cross-talk between *A* and *B*: better than -40 dB.

3.2.2.6 Signal-to-noise (weighted) ratio: 58 to 64 dB for an input level to the receiver of -54 dBmW.

3.2.2.7 Beat-frequency interference: better than -50 dB.

3.2.2.8 Radio-frequency protection ratio as a function of the separation Δf of the carrier frequencies:

- $\Delta f = 0$: of the same order as the value 36 dB adopted for monophonic transmission;
- $\Delta f = 50$ kHz : between 50 and 55 dB (42 dB); it is clearly desirable to avoid the use of frequency separation of 50 kHz for stereophonic services;
- $\Delta f = 100$ kHz : between 25 and 30 dB (17 dB), value for monophonic transmission being 12 dB;
- $\Delta f = 200$ kHz : equal to, or less than, the value of 6 dB adopted for monophonic transmission.

3.2.2.9 Multipath propagation effects: satisfactory if the signal-to-echo ratio, at the receiver input, is equal to, or greater than, 16 dB. (It is possible to achieve an improvement of 20 dB relating to the distortion, if a 53 kHz low-pass filter is fitted immediately following the discriminator output in the receiver.)

3.2.2.10 Sensitivity to impulse noise: satisfactory reception, if the field-strength is greater than a value of between 250 μ V/m and 1 mV/m, depending on the regulations in different countries which apply to the suppression of interference.

3.2.3 *Transmission and reception of independent monophonic programmes in the M and S channels having an audio-frequency bandwidth of 15 kHz and equal maximum modulation depths.*

3.2.3.1 Overall cross-talk (linear and non-linear) *S* to *M*: -45 dB.

3.2.3.2 Overall cross-talk (linear and non-linear) *M* to *S*: –55 dB.

The presence of multipath propagation can degrade these figures by 10 dB or more.

3.2.4 *Direct rebroadcasting of stereophonic programmes*

No difficulties were encountered in transmitting over three links in tandem.

It was also found to be possible, with the pilot-tone system, to provide for the international exchange of high quality stereophonic programmes using a communications space satellite system.

3.2.5 *Variants of the pilot-tone system*

A variant of the pilot-tone system has been investigated in the Netherlands using a single-sideband modulation of the sub-carrier, having a vector amplitude twice that of the sidebands generated in the case of normal sub-carrier modulation, making it compatible for stereophonic receivers having a synchronous type of decoder. The variant could offer interesting applications in certain circumstances, while maintaining the normal receiving and decoding principles.

3.3 *The FM-FM system using a compressor/expander in the S-channel*

In the Documents listed in Annex I to Report 300 (Geneva, 1974) (see also the Note in Annex I to this Report), results are given of tests on a number of systems using a compressor for the *S* channel in the transmitter and a corresponding expander in the receiver. These tests were carried out with an FM-AM system, a pilot-tone system and an FM-FM system. The results obtained have shown that noise in the *S*-channel is considerably suppressed by the compressor/expander. Recent tests have shown furthermore that, when transmitting two independent monophonic programmes, only the FM-FM system can give sufficiently low cross-talk from the *S*-channel, into the *M*-channel. The FM-FM system is defined by the following specifications:

3.3.1 a compatible signal *M* produces a deviation of the main carrier of not more than 80% of the maximum frequency deviation for monophonic transmissions; in the case of two-programme transmission, the deviation is equal to that of the first programme signal. In the case of stereophonic transmissions, it is equal to one half the sum of the left-hand signal *A* and the right-hand signal *B*;

3.3.2 a signal *S* produces frequency-modulation of a sub-carrier; in the case of two-programme transmissions equal to the second programme signal and, in the case of stereophonic transmissions, equal to one half the difference between the left-hand signal *A* and the right-hand signal *B*;

3.3.3 the frequency of the sub-carrier is 33.3 kHz $\pm$ 100 Hz;

3.3.4 the maximum frequency deviation of the sub-carrier is $\pm$ 10 kHz;

3.3.5 the sub-carrier produces a deviation of the main carrier of between 18% and 20% of the maximum frequency deviation for monophonic transmissions;

3.3.6 the pre-emphasis of the *S*-signal is identical to that of the compatible *M*-signal;

3.3.7 a compressor with transfer ratio 2/1 (in dB) is inserted in the *S*-channel of the transmitter before the pre-emphasis network. This compressor has time-constants respectively equal to 2 ms for the rise-time and 20 ms for the decay-time;

3.3.8 an expander with characteristics reciprocal to those of the compressor, is inserted in the *S*-channel of the receiver after the de-emphasis network;

3.3.9 in stereophonic transmissions, an *A*-signal produces a frequency deviation in the same direction for the sub-carrier and the main carrier.

3.4 *Stereophonic systems in AM broadcasting*

[CCIR, 1974-78a] describes four methods of stereophonic broadcasting for use in bands 5 and 6. All systems described in this Document use conventional amplitude modulation for the stereophonic sum signal and angle modulation of the same carrier frequency for the stereophonic difference signal. They differ in the way the modulations are generated and in the resulting distribution of the audio information in the various radio frequency sidebands.

4. *The use of compandor systems*

The use of compandor systems for transmissions in VHF sound broadcasting permits an improvement in reproduction quality throughout the coverage area. This improvement depends on the degree of compression at the transmitter and on whether or not expanders are used at the receiver. The reason for this improvement is the higher energy content of the compressed signal which makes the signal less susceptible to both noise and interference which may be added to the wanted signal on the transmission path. Subsequent expansion of the wanted together with the unwanted signals once again contributes to obtain improved reproduction quality [CCIR, 1974-78b; 1978-82b].

When a compandor system is introduced in an existing network not all transmitters and receivers can be equipped simultaneously with compressors and expanders, respectively. It can be expected that the duration of the transition period will mainly be determined by the situation at the receiving end. Therefore, the compatibility aspect is of paramount importance. In this context "compatibility" does not only mean that it should be possible to receive, without expander, compressed and unaffected sound broadcasting transmissions with acceptable quality; it also means that, in areas of high transmitter density, transmitters operating in the same channel or in adjacent channels should not be adversely affected by the higher amount of energy contained in compressed signals.

Extensive subjective listening tests with different compandor versions were performed in the Federal Republic of Germany to investigate the impairment of quality when no expanders are used.

From the results obtained, the conclusion can be drawn that to maintain compatibility at the receiving end, the degree of compression should not exceed approximately 10 dB. It should, however, be stressed that this amount of compression is only acceptable when the quality of the programme source is sufficiently high, i.e. when the noise level of tape recordings is low enough.

To obtain limit values for the compandor, gain measurements were performed with a compandor system of high compression gain (20 dB) of the type used in tape-recorder techniques. The results showed a considerable improvement in the AF signal-to-interference ratio, amounting during modulation pauses, to something in the order of the compression gain. This improvement decreases with higher programme levels, due to the lesser compression and expansion of those levels.

By using a compandor system the RF-protection ratios can also be improved. This is especially true in the case of stereophonic reception with up to 100 kHz channel spacing. In the case when only the unwanted transmitter uses a compression factor of 20 dB and no expansion is applied in the receiver, the RF-protection ratio will not be influenced for frequency separations of up to 100 kHz. A slight deterioration occurs at frequency separations above 100 kHz, increasing up to 2 dB at about 300 kHz.

Since the improvement of the AF signal-to-interference ratios varies with programme level and the RF protection ratios are also based on a certain AF signal-to-interference ratio (see Recommendation 412), it seems difficult to predict to what extent the coverage area will be improved if compandor systems were used.

5. Results of tests on multi-dimensional sound systems

[CCIR, 1970-74a] describes a variant of the pilot-tone system in which quadrature modulation is used for an additional sound channel *C* combined with the two stereophonic channels *A* and *B*. By so doing, the system is capable of transmitting three separate sound signals which can be demodulated in the same way as the pilot-tone system. With a baseband width the same as that required for stereophony and by a correct choice of signal levels, the radio-frequency bandwidth remains unchanged and hence, also, the radio-frequency protection ratios. This system is in accordance with Recommendation 450.

Subjective tests have shown that with three separate channels and matrixing signals *A*, *B* and *C* corresponding with the positions of the studio microphones feeding four loudspeakers, no significant subjective differences occur when compared with reproduction in four separate channels.

A third variant of the pilot-tone system is described in [CCIR, 1970-74b], in which four separate channels are transmitted by one transmitter. The system uses quadrature modulation of the normal suppressed sub-carrier of 38 kHz but additionally modulates a fourth audio-frequency signal onto a second suppressed sub-carrier of 76 kHz. Two possibilities of dividing the four signals into the different sub-carrier channels are given and with a sub-carrier frequency of 76 kHz, either double-sideband or single (lower) sideband modulation may be used.

[CCIR, 1974-78c] outlines the work that has been carried out involving the study of some of the fundamental properties of hearing involved in the subjective aspects of multi-dimensional sound systems. It includes a proposal for a quadraphonic broadcasting system known as Matrix H, which encodes the incoming audio signals into two audio channels for distribution and transmission. At the receiver these signals can be reproduced directly as stereophony (or monophony) and can be decoded to give quadraphony. A considerable number of tests and calculations carried out in the United Kingdom have shown that Matrix H meets the basic characteristics as listed in § 2.2.

[CCIR, 1978-82c] describes surround-sound systems used experimentally in the United Kingdom for broadcasting. It is acknowledged that while all systems require an artistic compromise to be made between surround-sound and stereophonic balances, a broad distinction can be made between hierarchical and non-hierarchical systems. In hierarchical systems surround-sound decoding is possible with two or two and a half channels, and it achieves a similar coverage area to the stereophonic service at the expense of reducing the sharpness of sound images because of phase differences occurring in the audio band. In non-hierarchical three channel systems the stereophonic sound image can be excellent, but with the penalty of a reduced surround-sound coverage area.

[CCIR, 1978-82d] describes the stereophonic and monophonic compatibility of various multi-dimensional sound systems which utilize an N-2-N matrix format. This describes five such systems: SQ (CBS), HJ (BBC/NRDC), H (an earlier BBC system), BMX (Cooper/Nippon Columbia) and QS (Sansui). As described in this document, these characteristics differ significantly under conditions of ordinary stereophonic and monophonic reception.

6. Conclusions

Bearing in mind the desirable characteristics of a system of stereophonic broadcasting as set out in § 2.1 of this Report, and taking into account the results contained in the Documents listed in Annex I, it would appear that the polar-modulation system and the pilot-tone system meet, in service, the requirements of § 2.1.1 (compatibility), § 2.1.2 (quality), § 2.1.4 (monophonic coverage), § 2.1.5 (stereophonic coverage), § 2.1.6 (protection against interference) and § 2.1.7 (frequency assignment plans). Experience of industrial manufacturing in countries where these systems are operating has shown that the corresponding stereophonic receivers meet the requirements of § 2.1.3 (reasonable cost).

For these reasons, although some difficulties remain concerning the condition of § 2.1.8 (transmission of independent programmes), Study Group 10 is of the opinion that either the polar-modulation system or the pilot-tone system, as indicated in Recommendation 450, can be used for a stereophonic broadcasting service.

ANNEX I

RECENT DOCUMENTS CONCERNING STEREOPHONIC BROADCASTING SYSTEMS

Note. — A complete list of CCIR Documents on stereophonic broadcasting from the periods between 1963 and 1970 is to be found in Volume X of the XIIIth Plenary Assembly, Geneva 1974, pages 124 and 125.

REFERENCES

CCIR Documents

[1970-74]: a. 10/52 (Netherlands); b. 10/44 (USA).

[1974-78]: a. 10/279 (USA); b. 10/114 (Sweden); c. 10/266 (United Kingdom).

[1978-82]: a. 10/60 (U.S.S.R.); b. 10/255 (Germany (Federal Republic of)); c. 10/20 (United Kingdom); d. 10/27 (USA).

BIBLIOGRAPHY

BAUER, B. B. [December, 1976] Quadraphony: Matrixing and compatibility. *EBU Rev. Tech.*, **160**, 268-274.

MIDDLEKAMP, L. C., *et al.* [August, 1977] A subjective evaluation of FM quadraphonic reproduction systems — listening tests. United States Federal Communications Commission, Lab. Div., Project No. 2710-1.

MIELKE, E. J. [1981] Der Einsatz von Kompondersystemen im UKW-Hörrundfunk (The use of compandor systems in VHF/FM sound broadcasting) (in German), Institut für Rundfunktechnik, Technischer Bericht, **291**.

ROBINSON, D. P. [June, 1973] Dolby B-type noise reduction for FM broadcasts. *J. Audio Eng. Soc.*, Vol. 21, **5**, 351.

RECOMMENDATION 467

TECHNICAL CHARACTERISTICS TO BE CHECKED FOR FREQUENCY-MODULATION STEREOPHONIC BROADCASTING

Pilot-tone system

(Question 46/10, Study Programme 46F/10)

(1970)

The CCIR

UNANIMOUSLY RECOMMENDS

1. that during programme transmission instruments should indicate the percentage of peak-modulation in the main carrier by the following:

1.1 the main channel, *M*;

1.2 the stereophonic sub-carrier, *S*;

- 1.3 the pilot signal;
- 1.4 all signals specified in Recommendation 450, simultaneously;
- 2. that in addition, the following characteristics should be measured during periods of test and adjustment:
 - 2.1 the frequency response of the *M* and individual *A* and *B* channels;
 - 2.2 harmonic distortion in the individual *A* and *B* channels;
 - 2.3 the signal-to-noise ratio in the individual *A* and *B* channels;
 - 2.4 the crosstalk attenuation between the *A* and *B* channels;
 - 2.5 the crosstalk from the main channel, *M*, into the stereophonic sub-channel, *S*, and from the stereophonic sub-channel, *S* into the main channel;
 - 2.6 the frequency of the pilot signal;
 - 2.7 the degree of suppression of the sub-carrier;
 - 2.8 the phase of the sub-carrier relative to the pilot signal;
 - 2.9 the total unintentional amplitude-modulation of the main carrier.

REPORT 620

COMPATIBILITY OF A MONOPHONIC SIGNAL OBTAINED FROM A STEREOPHONIC SOURCE

(Question 46/10, Study Programme 46E/10)

(1974)

[CCIR, 1970-74] indicates some of the difficulties which may arise when a monophonic signal is obtained by combining the *A* and *B* channels of a stereophonic tape source. Gap scatter and tape skew, for example, may cause phasing errors which will result in a complete loss of the monophonic signal at higher frequencies. Gap scatter may be compensated for, to some degree, by a compromise in the azimuth alignment of tape heads.

It is suggested that further study be given to possible solutions to the problem.

The same problem is discussed in Report 293 [Hoeg and Arnold, 1963].

REFERENCES

HOEG, W. and ARNOLD, P. [1963] On the question of the effect of level and phase differences between two-stereo channels (in German). *Techn. Mitt. RFZ*, **4**, 171.

CCIR Documents

[1970-74]: 10/9 (USA).

REPORT 463-3

TRANSMISSION OF SEVERAL SOUND PROGRAMMES OR OTHER SIGNALS WITH A SINGLE TRANSMITTER IN FREQUENCY-MODULATION SOUND BROADCASTING

(Question 46/10, Study Programme 46D/10 and 46E/10)

(1970-1974-1978-1982)

1. Introduction

The growing need for more programmes in almost all parts of the world makes it desirable to examine the present broadcasting standards to determine what changes are possible to provide a better utilization of the available frequency bands. The frequency-modulation service uses a large bandwidth to provide a programme service of exceptional quality. However, it has been found that some additional broadcasting services can be added without significant deterioration of the programme quality. This is an important consideration when the need for additional broadcasting services might make a reconsideration of the standards a necessity.

2. Requirements for monitoring and test instruments

The basic purpose of the supplementary sub-carrier monitoring instruments is:

- to provide equipment for use in the routine operation and adjustment of the broadcasting station in its day-to-day operations;
- to provide the instrumentation necessary to test and prove the integrity of the transmitting system.

In keeping with the above requirements, the following parameters become subjects of interest:

- the degree of modulation of the main carrier by the sub-carrier;
- centre frequency of the sub-carrier;
- spectrum of the modulated sub-carrier;
- cross-talk and noise;
- distortion, frequency response, or error rate, as applicable.

3. Systems using one or more sub-carriers for supplementary sound programmes

The analysis of supplementary sub-carrier operation in [CCIR, 1966-69a], shows that the use of a frequency-modulated sub-carrier provides the best signal-to-noise ratio for a given sub-carrier amplitude. Although the theoretical analysis of cross-talk is omitted, qualitative analysis, borne out by experience with sub-carrier operation, indicates that the system of modulation with the best signal-to-noise ratio also has the least cross-talk when other system parameters are the same.

Although the choice of the lowest possible sub-carrier frequency will provide the best signal-to-noise ratio in the supplementary sub-carrier channel, the sub-carrier frequency should be high enough to prevent audible beats. The use of a still higher sub-carrier frequency reduces the probability of cross-talk but unnecessarily reduces the signal-to-noise ratio.

3.1 An FM-FM system using a compressor/expander in the *S* channel is described in Report 300.

3.2 An FM-FM system is described in [CCIR, 1966-69b]. In this instance, the frequency of the sub-carrier was 67 kHz with a maximum deviation of the main carrier by the sub-carrier of ± 7.5 kHz during stereophonic broadcasting and a maximum deviation of the main carrier by the sub-carrier of ± 11.25 kHz during monophonic broadcasting. The maximum audio frequency of the supplementary channel is restricted to 6 kHz.

3.3 [CCIR, 1966-69c] gives the results of tests showing that it is possible to transmit simultaneously a main channel programme and a second programme using a supplementary sub-carrier. The frequency response is as good and the distortion as low, for the supplementary sub-channel as for the main channel. A sub-carrier frequency of 58 kHz was used. The deviation of the main carrier by the sub-carrier was ± 15 kHz and the deviation of the sub-carrier ± 12 kHz. The cross-talk figures were -70 dB or better, for the main channel and about -50 dB for the sub-channel.

3.4 A system for the transmission of four supplementary sound programmes in frequency-modulation broadcasting is described in [CCIR, 1966-69d]. In this instance four sub-carriers with frequencies of 70.75 kHz, 55.25 kHz, 39.75 kHz and 24.25 kHz are used. The maximum deviation of the main carrier by all four sub-carriers simultaneously, is 22.5 kHz. The maximum audio frequency of each sub-carrier is 3 kHz.

3.5 A similar FM-FM system providing two supplementary programmes is described in [CCIR, 1966-69e]. The first sub-carrier has a frequency of 33.3 kHz and carries the second programme as described in Report 300. A third programme is carried on a second sub-carrier having a frequency of 66.6 kHz. This second sub-carrier, which has a deviation of ± 8 kHz, determines the deviation of the main carrier which is ± 3 kHz. The audio-frequency range is 40 to 5000 Hz. The system includes a compressor/expander with the same characteristics as mentioned in § 3.1. The cross-talk figures are better than -70 dB for the first and second channels and better than -60 dB for the third channel (when modulated at 100% in the third channel, and at 30% in the others, the cross-talk figure was better than -45 dB).

3.6 [CCIR, 1970-74a] describes a two sound programme system, the supplementary channel intended to be received with high-grade receivers for feeding wired distribution systems. The maximum deviation of the main carrier caused by the first channel programme is ± 40 kHz (80% of the maximum system deviation). The sub-carrier frequency is 62.5 kHz and is frequency modulated with a maximum deviation of ± 30 kHz. The sub-carrier level is varied, deviating the main carrier ± 15 kHz during periods of no modulation and is reduced to

a minimum value of ± 6 kHz (8 dB) at 100% modulation. The cross-talk figure for the first channel from the second channel is better than 55 dB and better than 50 dB for the second channel from the first channel. The difference in immunity to interference between the two channels is calculated to be 18 dB. This value can be reduced to 5 dB if the audio bandwidth of the second channel is reduced from 15 kHz to 6 kHz and highly directional antennas are used. More details are given in the bibliography.

3.7 [CCIR, 1974-78a] describes a two-sound programme system, the supplementary programme intended to be received with FM receivers equipped with a simple additional discriminator. While the main compatible programme signal deviates the carrier by 80% of the maximum system deviation, the deviation by the 41 kHz sub-carrier can be up to 20%.

The second programme signal is restricted in audio bandwidth to 6.5 kHz; with a pre-emphasis of 100 μ s it deviates the sub-carrier ± 7 kHz. While the cross-talk to the main programme channel is negligible, the cross-talk into the supplementary channel is regarded as sufficiently low for special broadcasting services. The system described occupies only modulation frequencies up to 54.5 kHz enabling additional applications using frequencies above this limit.

3.8 A frequency division multiplex broadcasting system is described in the first five pages of [CCIR, 1966-69f]. This system uses a single-sideband type of modulation of the sub-carrier and a pilot tone of 20.8 kHz.

In one of the experiments, four channels are provided, the first two having audio frequencies up to 15 kHz, the third channel up to 10 kHz and the fourth (speech channel) up to 6 kHz.

Results are also given for an existing system of two-channel transmission which has a main (first) channel and a second channel using a sub-carrier frequency of 31.25 kHz using ordinary radio broadcasting receivers equipped with decoders for both channels.

3.9 [CCIR, 1970-74b] describes a system providing for a maximum of eight supplementary low-quality channels, in each of which suppressed carrier single-sideband modulation is employed. The corresponding eight frequencies are chosen within the band 64 kHz to 100 kHz, so as to avoid interference with the stereophonic signal within the frequency band up to 53 kHz.

3.10 Tests in the UK [Whyte, 1977] have shown that a subsidiary programme using a 41 kHz sub-carrier at any worthwhile level of injection caused unacceptable impairment to reception of a monophonic main programme. When a 67 kHz sub-carrier was used, at 15% or less injection, the subsidiary programme was found to be acceptably compatible with reception of a monophonic main programme. The quality of reproduction of the subsidiary programme was found to be markedly inferior to that of the main programme.

4. Systems using one or more sub-carriers for supplementary information

A number of applications are foreseen for the transmission of various types of information in addition to the main programme and which may, or may not, be related to that programme. Such applications include the control of receivers, operation of display devices built into the receiver or operation of a separate display device such as a television receiver. Additionally, the broadcaster may make use of the system for monitoring purposes.

Earlier work has shown that the transmission of sound is best accomplished through the use of frequency-modulation of a sub-carrier. Whilst this method may also be used for other types of information, more recent work [CCIR, 1974-78b and c] has shown that if the information can be digitally coded, other forms of modulation may be preferred. Further studies should be undertaken in order to examine any possibility for the use of a common transmission standard for different applications.

4.1 An automatic receiver volume control device would be useful for achieving a satisfactory level of loudness for different programmes and individual preference. Preliminary ideas have been reported in [CCIR, 1970-74c], in which a supplementary sub-carrier with suitable modulation is proposed to give a programme identification signal.

4.2 For individual regulation of the reproduced dynamic range, which would often be useful considering the differences in ambient noise at the receiving locations (e.g. in the home or in a car), the programme signal could be transmitted accompanied by a separate control signal indicating the amount of compression. Receivers could be designed to use this signal for performing the degree of expansion required by individual listeners. Preliminary ideas for the application of such a system have been reported in [CCIR, 1970-74c] and [CCIR, 1970-74d].

4.3 [CCIR, 1970-74e] describes an identification system, which is used in a broadcasting network, transmitting traffic information. Results of field trials are given. The traffic information is broadcast in the normal way. Those listeners wishing to operate their receiver automatically, have three different control signals available. A sub-carrier at 57 kHz (see § 5.3) is used as an identification signal for networks transmitting traffic information. This sub-carrier is amplitude modulated. One of six possible modulation frequencies in the range 23 Hz to 54 Hz indicates the traffic area. A modulation frequency of 125 Hz is used for receiver muting and is present only during traffic announcements. Operational practice has shown that even under difficult receiving conditions a high degree of reliability was obtained, of both the control functions and the sound reception. No mutual interference was observed between the identification signals and either monophonic or stereophonic channels.

4.4 [CCIR, 1974-78b] and [CCIR, 1974-78d] describe a transmission system suitable for different applications. The characteristics of the system are as follows:

Sub-carrier frequency: 57 kHz, phase-locked to the pilot-tone and crossing the time axis simultaneously.

Modulation method: Differentially bi-phase coded binary data at 1187.5 baud phase-shift-keying the sub-carrier.

Peak frequency deviation of main carrier: ± 3 kHz.

Frame structure: Blocks containing sixteen information bits and ten control bits (permits correction of one error burst per block of maximum length five bits).

Synchronization: An eight-bit word (at least once per ten blocks) to initiate the synchronization procedure in the receiver.

Protection ratio: The figure specified in Recommendation 412 for stereophony is in all aspects, with broad margin, valid for reliable reception of the radio-data transmission. Nor is the protection ratio required to give satisfactory sound reception affected by introducing the data channel.

Measurement [CCIR, 1978-82a] shows that reliable reception of the supplementary information is possible within at least the same coverage area as monophonic sound transmissions. In this case the mobile receiving installation is operated with a minimum input signal of about 30 dB (1 μ V) open circuit voltage.

Field tests with the radio data system [CCIR, 1978-82b] show that by using an error-correcting code it is possible to improve considerably the probability of satisfactory reception. The tests have shown that the following qualities are important:

- short blocklength,
- error correcting capability of short bursts ≤ 2 bits,
- error detection of longer burst.

One code which fulfils this requirement is a shortened cyclic block code with a length of 26 bits of which 16 bits are for information and the remaining 10 bits are used for error-correction. This concept is used in the radio data system.

4.5 [CCIR, 1974-78c] describes a method for the supplementary transmission of a digital “station programme identification” (SPI) signal in FM broadcasting. This SPI signal is transmitted by using phase-shift keying of a sub-carrier frequency at 16.625 kHz, which is exactly 7/8 that of the pilot-tone and is phase-locked to it; the sub-carrier falls about midway between the highest audio range and the pilot-tone. The deviation of the phase-shift keyed signal on the main carrier is chosen as ± 250 Hz, being 30 dB below the recommended value for the pilot-tone. For receiver input voltages above 6 μ V (across 60 Ω) and a bit rate of 600 bit/s, experimental results indicate that a reliable display of the alphanumeric SPI data was obtained and no audible interference for mono and stereo reception was found. In order to have SPI for monophonic transmissions it is necessary to maintain the pilot-tone as a reference for demodulation; however, a reduction of the deviation to ± 2.5 kHz is possible.

[CCIR, 1978-82c] provides additional information on the SPI system which was designed for reception in accordance with Recommendation 412 and in particular for reception in the home on stationary receivers. Operational tests in the Netherlands have shown that the system is fully compatible with the stereophonic service, both for direct reception and also reception via a cable distribution system. The message repetition rate of five messages per second has been chosen for manual and search tuning for stationary receivers. Under severe multipath conditions which are not changing rapidly with time, the reception of the data signal on a visual display could be detected for input voltages as low as 4 μ V across 60 Ω with a deviation of the phase-shift keyed signal on the main carrier of ± 250 Hz, owing to the operation of the error-correction circuitry. The system is not

intended for mobile receivers because quite different requirements prevail in that service. In mobile reception, the continuity in reception of the chosen programme is of primary importance and this requires fast and automatic changes in the tuning of the receivers. There are various ways to realize this using supplementary information. More details of both applications, stationary and mobile, are given in the Bibliography.

4.6 [CCIR, 1978-82d] describes a data transmission system in frequency modulation broadcasting providing 600 bit/s on a 58.3 kHz sub-carrier. The choice of this sub-carrier frequency results from field tests on mobile reception where the level of noise in two 600 Hz-wide frequency bands was recorded, one centred around 16.6 kHz and the other around 57 kHz. Under these circumstances, the level of the spurious components around 57 kHz is only 6 dB greater than that measured around 16.6 kHz (thermal noise alone will lead to 10 dB). The other parameters chosen for the system refer principally to compatibility. The 58.3 kHz frequency, determined by subjective tests, corresponds to a minimum impairment on phase lock loop stereo decoders. In addition two level differential phase-shift keying leads to a narrow spectrum. Synchronous demodulation is achieved mainly by digital processes which are well suited for integrated circuits. With a sub-carrier level corresponding to a ± 1.5 kHz deviation, the coverage area, as defined for a BER of 10^{-2} , is obtained with an RF level of 4 μ V across 50 Ω and, on mobile reception, in a zone extending over the stereophonic coverage area. Under the same circumstances the protection ratio of the system, measured in the same channel or in an adjacent channel, is less than that specified for monophony (about 10 dB). As for compatibility, bringing the system into operation on a transmitter of the French network did not result in any audible interference signal.

4.7 [CCIR, 1978-82e] describes a new transmission method for additional binary information at a rate of 593.75 bit/s in connection with stereo transmissions. The method is based on amplitude modulation of the pilot signal with a frequency-shift keyed data signal. The FM carrier deviation caused by the additional information is varied from 0.7 kHz to 3.5 kHz in accordance with the programme material.

4.8 [CCIR, 1970-74f] describes the use of a supplementary sub-carrier for the simultaneous transmission of voice and a graphic display. The graphic display portion of the system is designed for the transmission of handwritten messages, diagrams, maps, and sketches at the time when written. The co-ordinates are frequency determined in ranges from 1310 to 1490 Hz and 2060 to 2340 Hz for vertical and horizontal travel respectively. Actual writing causes one of the co-ordinate signals to become modulated in amplitude with double the power line frequency. Frequency modulation on a carrier of 5100 Hz makes it possible to achieve frequency division multiplex of an audio-frequency channel from 200 to 2000 Hz from the writing channel. The sum signal is used for modulating a frequency-modulation sub-carrier as mentioned in Recommendation 450. The voice transmission can be related to the graphic display or not, as the user wishes. The system is especially useful for educational purposes. The entire information can be stored on audio quality magnetic tape.

4.9 [CCIR, 1970-74g] describes the transmission of television picture signals using a frequency-modulation sub-carrier with sampling scan conversion techniques to reduce the video bandwidth to the audio-frequency range. The transmission system consists of a source of composite video from a Vidicon camera, a scan converter, a sub-carrier generator, and a frequency-modulated transmitter. The receiver consists of a sub-carrier demodulator, a scan converter and a video monitor. The bandwidth of the output signal will correspond to one half of the line rate of the wide-band input signal. A line rate of 15 750 Hz will give a bandwidth of approximately 8 kHz. The picture rate for a bandwidth of 8 kHz is 7 s. If the picture rate is increased to 14 s, a bandwidth of only 4 kHz will be required.

5. Cross-talk into the stereophonic channels caused by supplementary sound programmes or other signals

5.1 [CCIR, 1974-78e] gives typical test results of measurements of supplementary sub-carrier cross-talk into the *M*-channel and the *S*-channel in the transmission chain. It suggests that the deviation of the 67 kHz sub-carrier should be limited to ± 4 kHz when used with stereophonic transmissions.

5.2 [CCIR, 1970-74h] underlines the difficulty in avoiding cross-talk caused by sub-carrier channels similar to the specifications given in Recommendation 450. Receivers with insufficient filtering between the stereophonic multiplex-signal and the supplementary signals will incur cross-talk in the stereophonic programme. Those administrations not at present using supplementary broadcasts should be alert to this interference possibility before commencing such services.

5.3 [CCIR, 1970-74h] indicates that a supplementary carrier could be tolerated having a frequency of three times the pilot tone frequency and being phase-locked to it. In this case, only the deviation of the main carrier by the sub-carrier may be quite high (± 7.5 kHz). This sub-carrier, for example, can be used as a means of identification for a particular transmitter programme (e.g. a road traffic information programme).

5.4 [CCIR, 1974-78d] and [CCIR, 1974-78b] show results from tests with various sub-carrier frequencies and types of modulation. The Documents indicate that a supplementary sub-carrier having a frequency of three times the pilot-tone frequency and being phase-locked to it, causes minimum interference in existing stereophonic receivers. The Documents also indicate that with that choice of sub-carrier frequency there can be interference in receivers utilizing the phase-lock loop technique for the 38 kHz carrier regeneration. The phase of this carrier is altered by the modulated supplementary sub-carrier unless the spectrum of the modulating signal lies above the loop-bandwidth of the filter in the phase-lock loop. Such phase changes cause a change in amplitude of the demodulated *S*-signal resulting in an increase in *A* to *B* cross-talk and an intermodulation between the demodulated *S*-signal and the modulating signal of the supplementary sub-carrier.

5.5 Tests in the U.K. [Whythe, 1977] have shown that a subsidiary programme using a 67 kHz sub-carrier at any worthwhile level of injection caused unacceptable impairment to reception of a stereophonic main programme on at least 50% of existing stereo receivers. The use of a highly compressed main programme signal could, to some extent, conceal the interference from the subsidiary programme. The quality of reproduction of the subsidiary programme was found to be markedly inferior to that of the main programme.

6. Radio frequency problems

When additional signals are multiplexed onto the main monophonic or stereophonic programme, account must be taken of certain radio-frequency effects. These effects include a possible change in the required protection ratio and a possible increase in susceptibility to the deleterious effects of multipath. Administrations proposing systems requiring the use of additional sub-carriers are, therefore, urged to include this information.

Investigations into possible protection ratio changes should explore the case where the wanted transmission is stereophonic and the unwanted transmission includes additional sub-carriers, also the case where both transmissions include additional sub-carriers. Results are needed for co-channel and for adjacent channel protection ratios, noting that in different parts of the world channel spacings of 100 kHz and 200 kHz are used.

REFERENCES

WHYTHE, D. J. [February, 1977] The transmission of two programmes from Band-II transmitters: an assessment of "store-casting". *EBU Rev. Tech.*, **161**, 20-28.

CCIR Documents

[1966-69]: **a.** X/43 (USA); **b.** X/44 (USA); **c.** X/158 (USA); **d.** X/37 (USA); **e.** X/154 (Sweden); **f.** X/66 (U.S.S.R.).

[1970-74]: **a.** 10/81 (U.S.S.R.); **b.** 10/52 (Netherlands); **c.** 10/47 (Oy. Yleisradio AB); **d.** 10/240 (Oy. Yleisradio AB); **e.** 10/198 (Germany (Federal Republic of)); **f.** 10/13 (USA); **g.** 10/40 (USA); **h.** 10/30 (Germany (Federal Republic of)).

[1974-78]: **a.** 10/72 (Netherlands); **b.** 10/342 (Sweden); **c.** 10/364 (Netherlands); **d.** 10/129 (Sweden); **e.** 10/40 (USA).

[1978-82]: **a.** 10/81 (Sweden); **b.** 10/251 (Sweden); **c.** 10/23 (Netherlands); **d.** 10/69 (France); **e.** 10/206 (Oy. Yleisradio AB).

BIBLIOGRAPHY

KOTIKOVA, R. A. and SAVITSKY, V. I. [1968] Peredacha nezavisimyykh programm v odnom UKV ChM kanale (Transmission of independent programmes over a single VHF FM channel). *Trudy NIIR*, **2**.

PEEK, J. B. H. and SCHMIDT, J. M. [September, 1978] A station programme identification (SPI) system for FM sound broadcasting. Proc. International Broadcasting Convention (IBC 78) London. IEE Conf. Publ. **166**, 321-323.

GIELIS, G. C. M., PEEK, J. B. H., and SCHMIDT, J. M. [1980] Station and programme identification in FM sound broadcasting. *Philips Tech. Rev.* Vol. 39, **8**, 216-225.

SAVITSKY, V. I. [1966] O pomekhoustoichivosti priema uplotnennogo UKV ChM kanala (Immunity to interference in reception of a multiplexed VHF FM channel). *Sb. trudov Gos. NIIR Min svyazi U.S.S.R.*, **3**, 48.

RECOMMENDATION 599

**DIRECTIVITY OF ANTENNAS FOR THE RECEPTION OF
SOUND BROADCASTING IN BAND 8 (VHF)**

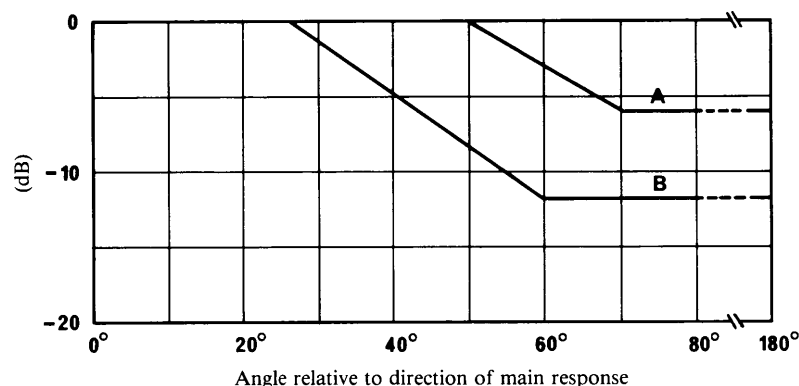
(Question 46/10, Study Programme 46L/10)

(1963–1982)

The CCIR

UNANIMOUSLY RECOMMENDS

that the characteristics of directivity of the receiving antennas of Fig. 1 can be used for planning sound broadcasting in band 8 (VHF). However, for portable or mobile reception of sound broadcasts, no directivity of the reception antenna should be applied in planning.

FIGURE 1 – *Discrimination obtained by the use of directional receiving antennas*

Curves A: monophonic-sound broadcasting
B: stereophonic-sound broadcasting

Note 1. — It is considered that the discrimination shown will be available at the majority of antenna locations in built-up areas. At clear sites in open country, slightly higher values will be obtained.

Note 2. — The curves in Fig. 1 are valid for signals of vertical or horizontal polarization, when both the wanted and the unwanted signals have the same polarization.

Note 3. — The Special Regional Conference, Geneva, 1960, and the European VHF/UHF Broadcasting Conference, Stockholm, 1961, and the African VHF/UHF Broadcasting Conference, Geneva, 1963, did not take the directional characteristics of antennas into consideration for sound broadcasting.

REPORT 795-1

**TRANSMISSION OF TWO OR MORE SOUND PROGRAMMES OR
INFORMATION CHANNELS IN TELEVISION**

(Question 47/10, Study Programme 47A/10)

(1978–1982)

1. Introduction

In broadcasting systems there is sometimes spare capacity that can be utilized to improve the subjective effect of a programme. The spare capacity can also be used to broadcast two or more programmes or to broadcast information that is of a different nature than sound; for example, alphanumerical or graphical information. This information may, or may not, be associated with the main programme.

Since 1959, certain administrations and broadcasting organizations have been conducting studies of systems for simultaneously transmitting two sound channels in television. As a result of these studies, several systems, such as FM-FM, FM-AM, two carrier and time-division multiplex systems and their variants, have been developed. So far sufficient results have been obtained only for systems using the sound transmitter of a television transmitting station, and further studies are required of systems multiplexing the sound and video signals.

It seems at present from results of some laboratory and field tests carried out in Japan and by the EBU, that, of the various systems mentioned above, the FM-FM system and the two-carrier system are the most promising, particularly if it is necessary to have high quality for both sound channels. The principal parameters to be taken into account in these two systems are given in Annex I for television systems B, G, M and H.

Regular and/or occasional broadcasting tests of the FM-FM system have been conducted in Japan, the Federal Republic of Germany and Switzerland, and broadcasting tests of the two-carrier system have been carried out in the Federal Republic of Germany, Finland and Switzerland.

Since October 1978, a public service of bilingual and stereophonic television programmes using the FM-FM system has been operational in Japan. The two-carrier system has become operational in September 1981 for transmission of stereophonic or two separate sound signals in television in the Federal Republic of Germany.

Transmission of other information than sound, e.g. subtitles to the television programmes and written messages has been studied.

Transmission by multiplexing with the picture signal is not dealt with in this Report, as this is a subject for Study Group 11.

2. Characteristics of the systems

2.1 Specifications of the first sound channel and the vision channel in any system are the same as, or close to, those of the standard television system considered.

The FM-FM system makes use of a sub-carrier in the normal sound channel. The frequency of the sub-carrier, which is frequency-modulated by the second sound signal, is chosen to be the second harmonic of the picture line frequency, because this reduces interference from the picture into the second sound channel.

A compressor/expander method can be used for reducing interference from the picture and the first sound signal into the second sound channel. In an FM-FM system developed in Sweden, the dynamic range of the second sound signal is compressed at the transmitter in the ratio 2 : 1 (in dB) with defined time constants and expanded to the original range in reception. In the Japanese system, a similar method but with different characteristics was tested, but it is not in use in the operational service.

The two-carrier system provides an additional sound carrier for the second sound signal. The additional sound carrier is located at a higher frequency than the normal sound carrier and is set at a level lower than that of the first sound carrier. The compressor/expander method is not necessary for the two-carrier system.

In the two systems, the second sound channel has an audio-frequency response of up to 14 kHz (FM-FM) or of 15 kHz (two-carrier), respectively. Hence, both systems can be used for high quality transmission of either two independent programmes or one stereophonic programme. The details of the characteristics of the systems are given in Tables I and II.

A combination of these systems has the capability to transmit three or four sound signals, but as yet there has been no report of experimental studies nor is the transmission of more than two sound signals envisaged in either of the two countries where there is a regular service.

Four additional FM sound carriers may be transmitted in the unused 1 MHz of television system G [band 9 (UHF)].

2.2 It seems appropriate to transmit, by television, information that is associated with the television programme being broadcast. Moreover, because in many countries television receivers are available in most households, it is an attractive display device for alphanumerical or graphical information not associated with the programme.

3. System requirements

In addition to the capacity requirements of the additional sound or information channels, the following requirements should be fulfilled:

- the system should be compatible with existing receivers and networks;
- the system should not involve any increase in the bandwidth of a television channel;
- the additional sound or information channel should have at least the same coverage area as that of the picture channel;

- the system for an additional sound channel should provide high-quality reproduction of both channels and stereophony;
- for receiving the additional sound channel, an ordinary receiver and a relatively simple adapter can be used.

4. System proposed for additional sound channels

4.1 Receivers

4.1.1 Adaptation to existing receivers

For both systems, the second sound signal can be demodulated by adding a simple adapter to a conventional television receiver. If two independent sound channels and stereophonic transmissions are to be transmitted, a switching facility may be provided in the adapter for changing the reception mode. The cost of the adapter is considered to be low compared with that of the receiver. Receivers should be designed to facilitate the attachment of suitable adapters.

4.1.2 Inter-carrier or split-carrier receivers *

Both inter-carrier and split-sound receivers are suitable for the two-carrier system.

Tests carried out in Sweden, the Federal Republic of Germany and Switzerland showed that, in the FM-FM system, high quality reception with an audio-frequency response up to 15 kHz was only possible with a split-carrier receiver. Laboratory and broadcasting tests made in Japan however, showed that, with suitable design of the sound intermediate-frequency circuits, inter-carrier receivers were suitable for reception of a second sound channel having an audio-frequency response of up to 14 kHz.

Investigations [CCIR, 1974-78a] were carried out in Switzerland using an intercarrier-type receiver modified to include a separate IF stage for the four additional sound carriers (at 20 dB below picture-carrier level). These investigations showed that this form of reception would be feasible without significant loss of coverage area.

4.2 Stereophony

In either system, compatibility with existing standards necessitates modulation of the first and the second channels by the signals M and S , respectively, as defined in Recommendation 450.

Another possibility for transmitting stereophonic sound in television has been tested in France [CCIR, 1974-78b]. Experimental broadcasts under real operating conditions, whose duration has been intentionally limited, have proved that it is possible to transmit stereophonic sound in television using the pilot-tone system as defined in Recommendation 450. During the transmissions, the multiplex signal frequency-modulated the television sound carrier. To achieve good stereophonic sound quality, it is necessary to use “split-carrier reception”.

4.3 Coverage area

In the FM-FM system, the first sound channel has the same coverage area as the ordinary monophonic transmission and the second sound channel has the same coverage area as that of the picture channel. In the two-carrier system, both sound channels are expected to cover an area larger than the picture channel.

Even when propagation conditions are unfavourable (long-distance multipath propagation), both systems are still satisfactory for stereophony. For two independent sound signals, the performance of the FM-FM system deteriorates more rapidly than that of the two-carrier system, due to cross-talk from the first into the second sound channel. However, too much importance should not be placed on this disadvantage of the FM-FM system, because even under these conditions the subjective quality of the second sound channel is of the same order as that of the picture.

Both, the FM-FM and the two-carrier systems were examined with respect to the effects on the audio-frequency signal-to-noise ratio under the conditions of line and precision-offset [CCIR, 1978-82a, b].

4.4 Quality of the second channel

4.4.1 Signal-to-weighted noise ratio, including buzz

Typical results for good propagation conditions, are as follows:

* Split-carrier receivers are receivers where the channels for vision and sound are independent of one another, that is to say, the difference frequency between the local oscillators is not synchronized, as in the case of inter-carrier systems.

4.4.2 *Two-carrier system*

Characteristics as given in Table II:

- 56 dB (split-carrier receiver),
- 44 dB (inter-carrier receiver).

4.4.3 *FM-FM system*

Variant as given in Table I, Column 2 with compandor:

- with a split-carrier receiver, the same as that of the main channel at 1% modulation; 20 dB less than the main channel at 100% modulation because of the action of the compandor.

Variant as given in Table I, Column 2 without compandor:

- 34 dB (inter-carrier receiver).

Variant as given in Table I, Column 1 without compandor.

- 51 dB (inter-carrier receiver).

These results were observed to vary from receiver to receiver. The figures were also affected by the picture content by up to 10 dB in inter-carrier receivers.

4.4.4 *Cross-talk from the main sound channel into the second sound channel*

Under normal operation, the cross-talk attenuation from the first sound channel into the second sound channel was found to exceed 55 dB for the two-carrier system and for all variants of the FM-FM system.

The field tests made in mountainous regions in the Federal Republic of Germany and Switzerland showed the following results, using split-carrier receivers:

4.4.5 *Two-carrier system*

Characteristics as given in Table II:

- 68 dB at 1 kHz,
- 57 dB at 5 kHz.

4.4.6 *FM-FM system*

Variant as given in Table I, Column 2 without compandor:

- 47 dB at 1 kHz,
- 32 dB at 5 kHz.

Practical tests with the FM-FM system carried out in mountainous regions in Japan showed that the subjective quality of the second sound channel was better than, or equal to, picture quality at over 90% of the test sites where the picture suffered from the long-distance multipath echoes. In laboratory tests with the FM-FM system carried out in Sweden, the subjective quality of the second sound channel was better than, or equal to, that of the picture channel, in cases of a multipath echo with a delay time of less than or greater than 5 μ s respectively.

4.4.7 *Harmonic distortion*

For sound channel No. 2, with a modulation frequency of 1 kHz, the following typical figures were obtained in the tests in the Federal Republic of Germany, Switzerland and Japan:

4.4.8 *Two-carrier system*

Characteristics as given in Table II:

- 46 dB (split-carrier receiver).

4.4.9 *FM-FM system*

Variant as given in Table I, Column 2, without compandor:

- 32 dB (split-carrier receiver).

Variant as given in Table 1, Column 1, without compandor:

- 44 dB (inter-carrier receiver).

4.5 *Stereophonic quality*

Typical figures for the attenuation of the cross-talk between the stereophonic signals *A* and *B* for the tests in the Federal Republic of Germany, Switzerland and Japan were:

4.5.1 *Two-carrier system*

Characteristics as given in Table II:

- 41 dB.

4.5.2 *FM-FM system*

Variant as given in Table I, Column 2, without compandor:

- 31 dB.

There was no measurable deterioration in these figures when the signals were passed through a rebroadcasting chain comprising up to three transposers in cascade.

Variant as given in Table I, Column 1, without compandor:

- better than – 30 dB (0.4 to 7 kHz) (inter-carrier receiver).

4.6 *Compatibility (vision and sound)*

4.6.1 *Compatibility with existing receivers*

In the FM-FM system, investigations made in Sweden showed that with older receivers the risk of sound interference into the first sound channel was minimized when the sub-carrier frequency was close to a harmonic of the picture line frequency.

In the operational service in Japan, no complaint concerning interference into the picture channel has been reported and very few complaints of interference into the first sound channel were received. Since it is estimated that twenty million viewers watch the programmes every day, the compatibility of the FM-FM system is said to be good.

For the two-carrier system, results of broadcasting tests carried out in the Federal Republic of Germany showed that cross-talk attenuation of the second sound channel into the first sound channel was over 65 dB and 57 dB at 1 kHz and 10 kHz respectively. Laboratory tests in the Federal Republic of Germany, Sweden and Italy, made with 39 domestic receivers, showed cross-talk attenuation values of 24 to 78 dB *. In Italy, no disturbance in the picture was observed, with the second sound carrier at its nominal level of – 16 dB relative to the vision carrier in the case of four of the seven receivers tested.

The tests in the laboratory and under operational conditions carried out in Finland on the two-carrier system, showed that the results can vary substantially from one receiver to another. The same effect had already been observed previously. During the course of a series of experimental transmissions during programme hours in Finland, using a second channel carrier amplitude 16 dB below that of the vision carrier, numerous complaints were received from the public. In a second series of experimental transmissions, the level of the second carrier was reduced to – 20 dB; the complaints were then less numerous. The reason for such cross-talk appears to be always associated with incorrect adjustment of the sound intermediate-frequency stages of the receiver. On the occasion of some experimental transmissions in the Federal Republic of Germany, no complaint was received when there was no modulation of the second sound channel or when the two sound channels were modulated with the same programme (this latter condition is very similar to the case of a stereophonic programme). On the other hand, however, with different modulations in the two sound channels, there were a few complaints. When the homes of the viewers in question were visited, it was found in every case that the adjustment of the sound intermediate-frequency stages of the receiver was defective; readjustment of these stages rendered the cross-talk inaudible in every case. During the course of the experimental transmissions in the Federal Republic of Germany, there were no complaints about the quality of the pictures. On the other hand, however, difficulties of that kind were reported on the occasion of the experimental transmission in Finland, particularly with community-antenna receiving systems. Some degradation of the picture-quality caused by the second sound channel became evident when the output level of the distribution amplifiers of such systems exceeded the normal value, even if the excess was only about 1 dB. The compatibility of the two-carrier system should be satisfactory, provided that care is taken to tune the intermediate-frequency sound amplifier stages of the receiver correctly and to avoid overloading the amplifiers used in common-antenna and cable-distribution installations. The need to readjust a proportion of the receivers already in service is said to be a disadvantage, it is, however, significant as a receiver deficiency rather than questioning the compatibility of the two-carrier system.

* The reasons for the poor cross-talk figures obtained with some receivers are not known.

TABLE I – Transmission characteristics of the FM-FM system

Characteristics	Television system	
	M (Japan)	B, G, H (PAL)
	1	2
1. <i>The first channel</i> (the same as the monophonic channel)		
Maximum frequency deviation of the main carrier (kHz)	± 25	± 40
Audio-frequency range (Hz)	50 to 15 000	40 to 15 000
Pre-emphasis (μ s)	75	50
2. <i>The second channel</i>		
Sub-carrier frequency	second harmonic of the line frequency	the same
Maximum frequency deviation of the sub-carrier (kHz)	± 10	± 10
Frequency deviation of the main carrier by the sub-carrier (sub-carrier level) (kHz)	± 15	± 10 to ± 20
Audio-frequency range (Hz)	50 to 14 000	40 to 15 000
Pre-emphasis (μ s)	75	50
Compressor: Compression ratio (dB)		2: 1 ⁽¹⁾
Attack time (ms)		2
Recovery time (ms)		20
3. <i>Stereophony</i>		
(A + B) channel	the same as the first channel	the same as the first channel
(A – B) channel	the same as the second channel except the sub-carrier level	the same as the second channel
Frequency deviation of the main carrier by the sub-carrier (sub-carrier level) (kHz)	± 20	± 10 to ± 20
The left-hand signal produces a deviation in the same direction in both the sub-carrier and the main carrier		
Compensation for receiver delay time (μ s)	20	none
4. <i>Control signal</i>		
Sub-carrier frequency	3.5 times the line frequency	
Modulation frequency:	two sound programmes: 922.5 Hz stereophonic programme: 982.5 Hz	
Modulation	60% (AM)	
Maximum frequency deviation of the main carrier by the control signal sub-carrier (kHz)	± 2	

(1) The figures given for system B, G, H (PAL) are based on a Swedish proposal, not finally defined; further study seems to be appropriate.

TABLE II – *Transmission characteristics of the two-sound carrier system*
(Television systems B, G and H)

Characteristics	Sound carrier 1	Sound carrier 2
<i>RF-sound carriers</i>		
Frequency referred to vision carrier (MHz)	5.5(1)	$5.5 + 0.2421875(1)$
Power referred to peak vision (dB)	– 13	– 20
Modulation	MF	MF
Frequency deviation (kHz)	± 50	± 50
Audio-bandwidth (Hz)	40 to 15 000	40 to 15 000
Pre-emphasis (μ s)	50	50
<i>AF-signals</i>		
Monophonic	Monophonic 1	Monophonic 1
Stereophonic	$(A + B)/2$	B
Double sound	Monophonic 1	Monophonic 2
<i>Identification signals</i>		
Sub-carrier frequency (kHz)		$54.6875(2)$ $(3.5 \times \text{line frequency})$
Modulation		AM
Modulation depth (%)		50(3)
Modulation frequency:(2) (Hz)		
Monophonic		0
Stereophonic		117.5 (line frequency/133)
Double sound		274.1 (line frequency/57)
Frequency deviation of the second sound carrier by the sub-carrier (kHz)		± 2.5

- (1) The frequency difference between both sound carriers is $15.5 \times \text{line frequency} = 242.1875 \text{ kHz}$. Phaselocking of both sound carriers with the line frequency gives improvements, but is not absolutely necessary.
- (2) The sub-carrier and identification frequencies are phaselocked with the line frequency.
- (3) The residual 50% AM modulation depth is reserved for future identification of audio-frequency companding.

Laboratory tests in Japan on the two-carrier system made with 70 domestic receivers, showed that compatibility with existing receivers could be maintained only when the power level of the second sound carrier was kept at -30 dB referred to the vision carrier, and with such a low level, high quality sound could not be obtained.

4.6.2 Compatibility with existing networks

In Japan, with rebroadcasting by 1355 stations operated using the FM-FM system, no interference to the picture and the first channel was detected even when five rebroadcasting stations were operated in cascade. Interference from the picture signal into the second sound channel did not increase significantly with inter-carrier reception.

During the broadcasting tests carried out in the Federal Republic of Germany with the two-carrier system using 17 rebroadcast transmitters, no interference in the first sound channel was observed. Laboratory tests made in Italy with the two-carrier system showed that the demand for linearity of the rebroadcasting transmitter is slightly more stringent than for colour television.

In broadcasting the FM-FM system operating in Japan no increase in interference to the picture and the first sound channel from adjacent channels and co-channels was observed.

4.7 Subjective tests

A large number of subjective quality assessments have been made for the two-carrier system and for the FM-FM system, during tests in Switzerland in mountainous regions. The systems used were the FM-FM variant as given in Table 1, Column 2 without compandor, and the two-carrier system as given in Table II. In these tests the two sound channels were modulated by two musical programmes, except for the cross-talk assessments, in which case the wanted channel was unmodulated. The vision channel was in all cases modulated by an electronic test pattern. The results are given in the attached Fig. 1. They suggest that the dual-carrier system is slightly better than the FM-FM system, and that in most unfavourable conditions the vision and sound have approximately the same quality.

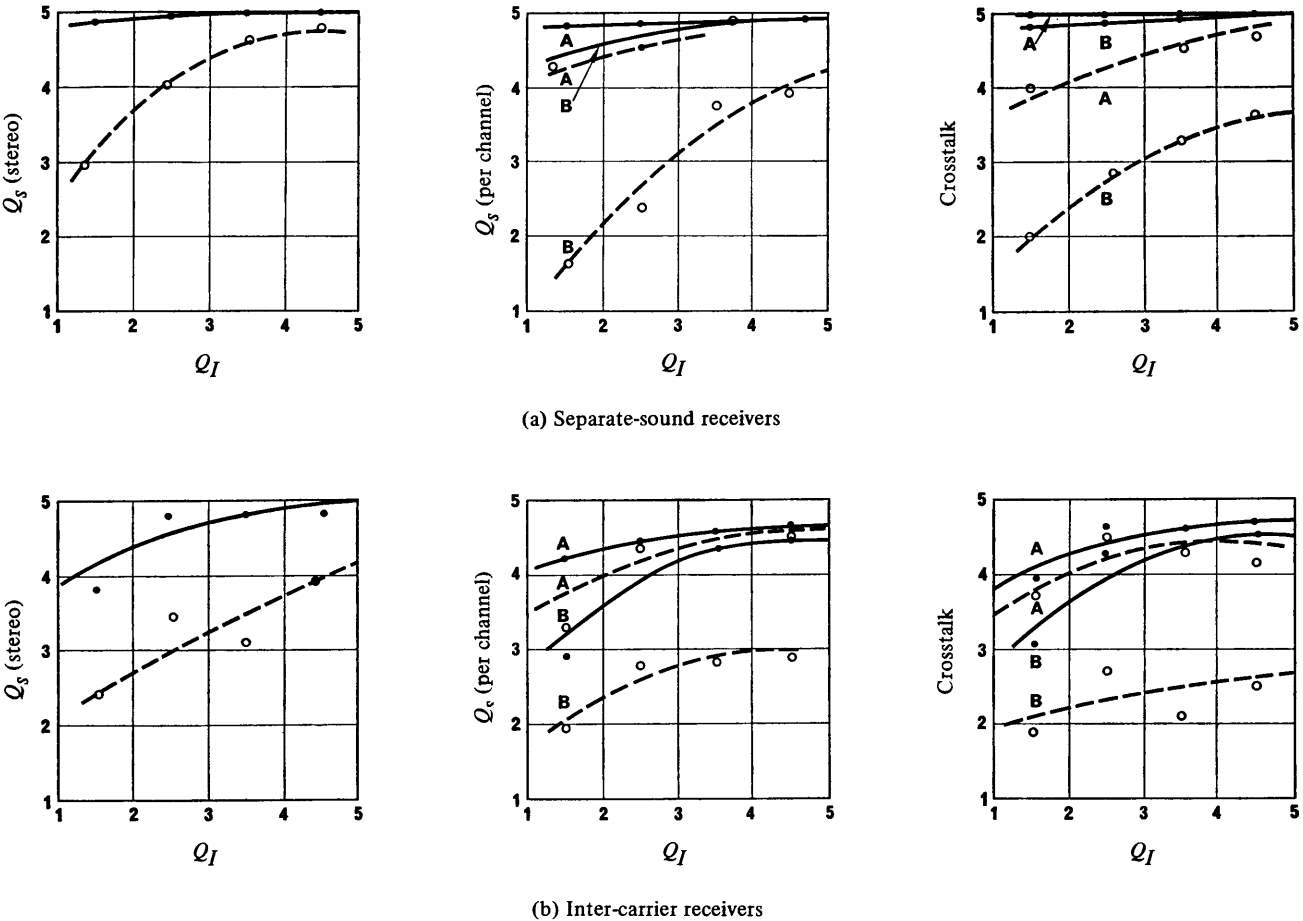


FIGURE 1 – Subjective-quality evaluations of picture and of both sound channels made during field-tests over mountainous terrain in Switzerland

— : dual-carrier system
- - : FM-FM system

A: sound channel No. 1
B: sound channel No. 2

Q_s : sound quality
 Q_I : picture quality

REFERENCES

CCIR Documents

[1974-78]: a. 10/278 (Switzerland); b. 10/331 (France).
[1978-82]: a. 10/57 (Germany (Federal Republic of)); b. 10/77 (Japan).

BIBLIOGRAPHY

- ANDO, H., KANEKI, T., HARADA, S. and FUJIWARA, M. [March, 1973] Graphic transmission in FM sound broadcasting. *NHK Lab. Note*, No. 160.
- GELUK, J. J. [March, 1973] Scribosonly. EBU Doc. Com. T(S) 132.
- NUMAGUCHI, Y. [December, 1979] Present status of multichannel-sound television broadcasting in Japan. *IEEE Trans. Broadcasting*, Vol. BC-25, 4, 128-136
- SUNDIN, L. and VERRI, B. [1973] TV subtitles for viewers with defective hearing. TELE No. 2 (Swedish Telecommunications Administration).
- CCIR Documents*
[1978-82]: 10/24 (Japan); 10/26 (Germany (Federal Republic of)).

ANNEX I

PRINCIPAL PARAMETERS OF THE FM-FM SYSTEM
AND THE TWO-CARRIER SYSTEM

Specifications common to both systems

Specifications of the first sound and vision channels are the same as, or close to, those of the standard television system considered.

1. FM-FM system

- 1.1 The second sound signal is transmitted by frequency-modulating a sub-carrier in the normal sound channel.
- 1.2 The centre frequency of the sub-carrier is twice the line frequency of the vision signal.
- 1.3 The maximum frequency deviation of the sub-carrier is ± 10 kHz.
- 1.4 The frequency deviation of the main carrier by the sub-carrier is between ± 15 kHz and ± 20 kHz.
- 1.5 Pre-emphasis of the second sound signal is identical with that of the first sound signal.
- 1.6 In stereophonic transmission, the first sound channel is modulated by signal *M*, equal to one half of the sum of the left-hand signal *A* and the right-hand signal *B*, and the second sound channel by signal *S*, equal to half the difference between signals *A* and *B*. The left-hand signal produces deviations of the same percentage and in the same direction in both the main carrier and the sub-carrier.
- 1.7 Control signals are provided for distinction between two-sound and stereophonic programmes. These signals are transmitted by amplitude-modulating an additional sub-carrier in the normal sound channel.
- 1.8 The frequency of this additional sub-carrier is 3.5 times the line frequency of the vision signal.
- 1.9 The frequency deviation of the main carrier by the additional sub-carrier is ± 2 kHz.

2. Two-carrier system

- 2.1 The second sound signal is transmitted by using an additional sound carrier, the frequency of which is chosen 15.5 times the line frequency of the vision signal from the conventional sound carrier to the upper limit of the television channel. The level of the second carrier is 20 dB below that of the vision carrier.
- 2.2 Pre-emphasis of the second sound signal is identical with that of the first sound signal.
- 2.3 In stereophonic transmission, the first sound channel is modulated by signal *M*, equal to one half of the sum of the left-hand signal *A* and the right-hand signal *B* and the second channel by signal *B* only.
- 2.4 Control signals are provided for distinction between two-sound and stereophonic programmes. These signals are transmitted by amplitude-modulating a sub-carrier in the second sound carrier.
- 2.5 The frequency of the sub-carrier is 3.5 times the line frequency of the vision signal.
- 2.6 The frequency deviation of the second sound carrier by the sub-carrier is ± 2.5 kHz.

Note. — It may be possible to provide three sound channels by adding another sub-carrier to the FM-FM system or by combining the FM-FM and the two-carrier systems.

BIBLIOGRAPHY

- CCIR Documents*
[1978-1982]: 10/186 (Japan); 10/229 (Germany (Federal Republic of)).

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

SECTION 10C: AUDIO-FREQUENCY CHARACTERISTICS OF SOUND-BROADCASTING SIGNALS

Recommendations and Reports

RECOMMENDATION 562-1 *

SUBJECTIVE ASSESSMENT OF SOUND QUALITY

(Question 50/10, Study Programme 50C/10)

(1978-1982)

The CCIR,

CONSIDERING

- (a) that subjective listening tests permit assessment of the degree of annoyance caused to the listener by any impairment of the wanted signal during its transmission between the originating source and the listener;
- (b) that such an assessment implies that a programme sequence which has been subjected to impairment should be compared with the original sequence, which should be of "excellent quality" or with "imperceptible impairment";
- (c) that to make these assessments comparable one with the other, the conditions of listening and the composition of the team of assessors should, as far as possible, be standardized;
- (d) that it would be desirable for a single scale of assessment to be available for both sound and television programmes,

UNANIMOUSLY RECOMMENDS

1. that the grading scales given below should be used for the subjective assessment of the quality or of the impairment, of the quality of sound in broadcasting (for television pictures, see draft Recommendation 500. The nature and object of the tests will determine which of the two scales is the more appropriate:

1.1 *Five-grade quality and impairment scale ***

TABLE I

Quality	Impairment
5 Excellent	5 Imperceptible
4 Good	4 Perceptible, but not annoying
3 Fair	3 Slightly annoying
2 Poor	2 Annoying
1 Bad	1 Very annoying

* This Recommendation is of interest to the CMTT.

** In view of the large number of documented results which have been obtained using a six-grade scale, it is desirable to have a means of converting these results to the above five-grade scales so that the data can still be used. Uncertainties arise in attempting to convert results obtained with one scale into another. However, as a first approximation, the following linear relationship can be used to convert a grade, A_6 , obtained in an experiment using a six-grade scale (Report 405, Notes 7 and 9) into a grade, A_5 , in the corresponding five-grade scale:

$$A_5 = 5.8 - 0.8 A_6$$

When results which have been converted by means of the above equation are presented, it should be stated that this conversion has been carried out.

1.2 Seven-grade comparison scale

For certain types of subjective tests it may be more convenient to use a comparison scale, in which case the following seven-grade scale should be used:

TABLE II

3	Much better
2	Better
1	Slightly better
0	The same
-1	Slightly worse
-2	Worse
-3	Much worse

2. Presentation of results

The results obtained by the use of expert listening panels should be presented separately from those provided by non-expert panels. Details should be given of listening conditions and sound levels; any statistical methods used to analyse the test results should be described.

Note. — The general considerations governing the assessment procedure, the listening conditions, the selection of assessors, etc., are given in Annex I.

ANNEX I

1. General

Programme sequences used for testing should include silent intervals so that, in the absence of the wanted signal, the subjective assessment of the impairment caused by noise in the system is not excluded. On the other hand, the tests should exclude any assessment of defects, the audible effects of which might, in certain cases, not be objectionable and which might even give a subjective impression of improved quality. The programme sequences should, therefore, be free of any audible defects similar to those produced in the system under test, but where this is impracticable the consequent limitations on the validity of the results should be clearly indicated.

For tests using the five-point grading scale mentioned in § 1.1 of the Recommendation, a system of lights should be used to indicate to the listener the source (impaired or unimpaired) of the programme he is hearing. To test the listener's attention and consistency, some tests in which the impaired condition would be replaced by the unimpaired condition should be included randomly, without informing the listener. For tests involving the use of the seven-grade comparison scale, no indication should be given which may bias the judgement of the listener. However, for the comparison tests, it could be useful from time to time to give a reference condition which may be the unimpaired source, and this reference condition may be indicated by a light.

The amount of data which needs to be collected depends upon such interrelated factors as the degree of statistical confidence which is needed in the result, the standard deviation of the measurements, and the relative magnitude of the effect which it is required to detect. The following suggestions are intended as guide-lines to assist in formulating a considered experimental design.

2. Selection of listening panel

Although in a normal listening audience there will be some expert listeners *, the proportion of them is likely to be so small that it is proper to concentrate the objective of laboratory tests on the opinions of non-experts, because the use of experts could lead to results which are much more critical than would be obtained with non-expert listeners. The choice of test listening conditions should be more critical than average, but not unduly so. As tests with non-expert listeners tend to be lengthy, it is often desirable that a quick test should be carried out by experts. In this case, a smaller number of listeners can be used. However, it should be noted that in certain circumstances tests carried out with expert listeners may not be a satisfactory substitute for tests carried out by non-experts. In cases of doubt, the relationship between expert and non-expert opinion should be investigated.

* The term "expert listeners" is considered to apply to listeners who have had recent extensive experience of assessing sound quality or impairment, particularly of the type being studied in the subjective tests.

The minimum number of non-expert listeners should normally be twenty whilst the minimum number of expert listeners should normally be ten. In all cases, the number and category of listeners and the duration of the tests should be stated. Whenever the system is intended for high-quality sound broadcasting or reproduction, expert listeners should be used exclusively.

3. Test procedure and duration

Because of the extreme unreliability of the long or medium-term aural memory, the instantaneous comparison method should always be used.

For tests using the five-grade quality or impairment scales each process involves the repetition, four times consecutively, of the same programme sequence in the following order:

1. original sequence,
2. same sequence, impaired
3. original sequence (repeated),
4. same sequence, impaired (repeated).

Each programme sequence should not last longer than 15 to 20 s; it may be very short (a few seconds) for some tests. In the case where the sequence is a musical item, the phrase should not appear to be interrupted. The interval between presentation 1 and 2 and between 3 and 4 should be about 0.5 to 1 s, while the interval between 2 and 3 should be somewhat longer, for example 1.5 s. The exact time should depend upon the type of programme. The switching device should not introduce audible interference.

The programme sequences and impairments should be presented in random order subject to the condition that the same sequence should never be presented on two successive occasions with the same or different levels of impairment.

No session with any one listener should last for more than about 15 to 20 min without interruption. If the sessions must be consecutive, they should be separated by rest periods of roughly the same length.

For tests with the seven-grade comparison scale involving two impaired conditions, a similar set of presentations can be used, the order being:

1. Condition 1,
2. Condition 2,
3. Condition 1 (repeated),
4. Condition 2 (repeated).

Conditions 1 and 2 should be interchanged on a random basis. In addition, a reference condition may be presented at the beginning of each four presentations and, in this case, a definite indication (such as the use of a light signal) should be given, that this item is the reference condition.

4. Choice of programme sequences

Depending on the precise objective fixed and in particular on the category of the sound-programme transmission or reproduction system tested, the following programme sequences should be used:

- either a representative selection of typical programme material,
- or, a selection of a few sequences picked deliberately for their highly critical behaviour with respect to the impairments introduced by the system being tested. For example, when assessing protection ratios, a suitably critical test sequence would be speech on the wanted programme impaired by “pop” music on the unwanted programme.

Whenever the system is intended to carry high-quality sound, the second type of programme sequence should be used.

In any event, the artistic or intellectual content of a programme sequence should be neither so attractive nor so disagreeable or wearisome that the listener is distracted from his purpose.

5. Sound level

When using a wanted signal of high peak level, the sound level should be measured with a sound level meter with no weighting and the “slow” time constant standardized by the IEC (Publication 123). For other signals, and for measuring room noise, the level should be measured with a sound level meter with weighting *A* and the “slow” time constant standardized by the IEC (Publication 123). For measurement of the sound level of a programme sequence in the special conditions of the test and at a given position in the listening room, the sound level will be taken by definition as equal to the maximum value shown by the sound level meter during each sequence. In case of assessments of high-quality high-level signals, a listening sound level of 80 to 90 dB should be used.

The sound level considered in defining exactly the conditions in which the tests have been carried out will be the mean of the sound levels measured at the various positions occupied by the listeners. The difference from this mean value for any position must be as small as possible. A value of ± 4 dB might be reasonable. All measurements should be made with the listeners present.

6. Listening conditions

Whenever the tests are conducted with loudspeakers, all the essential information concerning the dimensions and the reverberation time of the listening room *, the arrangement of listeners in the room and their distance from the loudspeaker or loudspeakers should be given.

Generally speaking, an effort should be made to minimize the masking effect due to room noise, particularly when establishing tolerances for high-quality sound transmission.

The mean level of the room noise should always be indicated and, when it is manifestly likely to have a noticeable masking effect, the mean spectrum should also be indicated.

Furthermore, precautions should be taken to prevent as far as possible the listener(s) from being annoyed or distracted by certain features of the surroundings (temperature, light, moving objects or persons, etc.).

Technical requirements for the loudspeaker characteristics, which are in use in the U.S.S.R., are described in [CCIR, 1978-82a].

7. Assessment of special characteristics of equipment **, programmes, studios, etc.

7.1 Protection ratios

The assessment of protection ratio requires a slightly different testing procedure. In this case, the unimpaired programme sequence used for comparison should be such that the sound quality reproduced by the receiver is appropriate to the broadcasting system for which the receiver is designed.

7.2 Recorded programmes, studios

For the assessment of recordings no uniform method exists. The OIRT suggests [CCIR, 1978-82b] special working methods for assessing recordings intended for the international exchange of programmes (OIRT, Recommendations Nos. 63/1; 91), and [CCIR, 1974-78a] methods of assessing the acoustical properties of studios and concert halls (OIRT, Recommendation No. 68). [CCIR, 1974-78b] gives information on requirements for high-quality subjective assessment which are applied in the U.S.S.R. (listening conditions, choice of method, number of listeners and their selection).

REFERENCES

CCIR Documents

[1974-78]: a. 10/26 (OIRT); b. 10/311 (U.S.S.R.).

[1978-82]: a. 10/45 (U.S.S.R.); b. 10/35 (OIRT).

REPORT 292-5

MEASUREMENT OF PROGRAMME LEVEL IN SOUND BROADCASTING

(Question 50/10, Study Programme 50E/10)

(1963-1966-1970-1974-1978-1982)

The CCIR and CCITT have considered for many years: "by what methods and by means of what equipment should the programme level be controlled in connection with recording, reproduction and transmission over lines or radio links?" (Former Question 151.)

* For acoustical properties of listening rooms, see Report 797.

** For example, apparatus such as compressors, compandors, recorders, etc.

As far as transmission over lines or radio links is concerned, CCITT Recommendations J.14, J.15 and N.13 apply and should be respected (see Annex I).

It has not been possible to reach agreement on the use of a single type of meter. It is not possible, therefore, to do more than to state the present practices. Table I shows the fundamental characteristics of meters recommended at present by the CCITT, EBU, OIRT and IEC.

It is hoped that further contributions will be submitted which will make it possible to recommend uniform fundamental characteristics of the meters.

TABLE I – *Principal characteristics of the various instruments used for monitoring the volume or peaks during programme transmissions*

Type of instrument	Rectifier characteristics (Note 3)	Time to reach 99% of final reading (ms)	Integration time (ms) (Note 4)	Time to return to zero (value and definition)
1) CCITT – “Speech voltmeter” British type 3 (S.V.3) identical to the speech power meter of the ARAEN	2	230	100 (approx.)	equal to the integration time
2) CCITT – V.U. meter (United States of America) C 16.5 – 1954 ASA (Note 1)	1.0 – 1.4	300	165 (approx.)	equal to the integration time
3) CCITT – Speech power meter of the “SFERT” volume indicator	2	around 400 – 650	200	equal to the integration time
4) CCITT – Peak indicator for programme transmission used by the BBC (B.B.C. Peak Programme Meter) (Note 2). Type IIa of IEC Publ. 268-10A	1	around 12	10	3 s for the pointer to fall 26 dB
5) CCITT – Maximum amplitude indicator used by the Federal Republic of Germany (U 21), Type I of IEC Publ. 268-10.	1	around 80	5 (approx.)	1.7 s from 100% to 10% of the reading in the steady state
6a) OIRT Programme level meter (OIRT Recommendation (N. 59))	1	less than 300	5	1.75 ± 0.25 s for the pointer to fall 20 dB
6b) Level meter for international programme exchange over lines or links between OIRT and EBU (OIRT Recommendation (N. 69))	1	less than 300	5 and 1000	2.5 to 4 s for the pointer to fall 20 dB
7) EBU Standard peak programme meter (Note 5) EBU Tech. 3205 and Type IIb of IEC Publ. 268-10A	1	—	10	2.8 s for the pointer to fall 24 dB

Note 1. – In France, a meter has been standardized which is similar to that defined in item (2) of Table I.

Note 2. – In the Netherlands, a meter has been standardized (Type NOS-SN-411) which is similar to that defined in item (4) of Table I.

Note 3. – The number given in this column of the Table is the exponential n in the formula $V_{out} = (V_{in})^n$ applicable for each half-cycle.

Note 4. – The “integration time” was defined by the CCIF as the “minimum period during which a sinusoidal voltage should be applied to the instrument for the pointer to reach to within 0.2 N, or nearly 2 dB of the deflection which would be obtained if the voltage applied indefinitely”. A logarithmic ratio of 2 dB corresponds to 79.5% and a ratio of 0.2 N to 82%.

Note 5. – This meter is intended specifically for use in monitoring sound signals transmitted internationally, and therefore incorporates a scale conforming with CCITT Recommendation N. 15, calibrated in dB from –12 to +12 relative to a level marked “TEST” corresponding to 0 dBm at a zero relative level point. In addition to the normal mode of operation having the characteristics shown above, the meter may be operated temporarily in a “slow” mode facilitating the comparison of observations made at widely separate points. The peak values indicated in this mode have no absolute significance, and may only be used for such comparisons.

ANNEX 1

dBm0s + dBrs TERMINOLOGY *

1. This Report specifies that transmission over lines or radio links should be in accordance with CCITT Recommendation J.14.

2. CCITT Recommendation J.14 uses terminology that is not always familiar in broadcasting practice. As a result transmission over lines and radio links has not always been satisfactory (CCITT Recommendation J.31). In some cases the peak programme levels exceed the maximum permissible levels producing overload distortion, and in other cases the programme levels have been too low leading to poor signal-to-noise ratios.

Report 820 details conditions to be observed by Method A (vu meters) and Method B (ppm) users to ensure optimum performance in programme exchange.

Terms used in CCITT practice are introduced in Report 820. These are frequently misunderstood or used in a different context by broadcasters.

3. This Annex describes the terms in broadcasters' terms, but at the same time maintaining compatibility with CCITT usage.

These terms are:

3.1 *dBm0s*

3.1.1 The term dBm0s is used to describe test or line-up signal levels and should not be used for programme levels. For broadcasting systems the line-up signal should be defined in terms of a sine wave having a frequency of 1 kHz.

3.1.2 A level of 0 dBm0s corresponds to the nominal line-up level of the system concerned and will be 8 dB to 10 dB below the maximum level allowable at points of interconnection between broadcasting organizations.

In broadcasting practice, the line-up level corresponds to 40% to 32% of the maximum allowable modulation of a broadcast transmitter (if no compression and/or pre-emphasis is used). The 8 to 10 dB (40% to 32% modulation) takes account of programme peak levels assumed by different countries. The description is acceptable for operational use during international programme exchange.

3.1.3 A test or line-up signal is the level of the signal measured in dB, relative to an 0 dBm0s signal, e.g. -10 dBm0s.

3.2 *dBrs*

3.2.1 The term dBrs is used to describe the designed electrical level of any point throughout a transmission path relative to a defined reference point (point of zero relative level, 0 dBrs) and therefore specifies the gain or loss designed through the path.

3.2.2 An 0 dBrs point is a point where a line-up or test signal of 0 dBm0s level has a power level of 0 dBm.

3.2.3 The dBrs value of a point is the power level of that point referred to a point of zero relative level (0 dBrs point). Zero gain or loss exists between the different 0 dBrs points throughout the transmission path.

Note 1. — The term dBm0s is a *normalized* test signal level. The normalizing factor is the dBrs value of the point at which a measurement is to be made. This factor will allow the *absolute power* level of the signal at any point throughout the transmission path to be determined.

* CCITT Study Group XV has recently proposed that the suffix "s" be added to the terms dBm0 and dBrs when these refer to sound programme circuits. This text has adopted the proposed practice.

Note 2. — From the descriptions of the dBm0s and dBrs above, it will be evident that:

- $\text{dBm (power level)} = \text{dBm0s (normalized test signal level)} + \text{dBrs (normalizing factor)}$;
- the dBrs value is determined by circuit gain or loss;
- the addition sign must be taken to indicate algebraic addition.

Note 3. — It is necessary to clearly distinguish between the normalized *test signal level* as expressed in dBm0s, and the *power level* of the test signal at the measuring point in dBm. Thus, a meter will measure the *power level* of a signal in dBm (i.e. as a power ratio expressed in dB relative to 1 mW), but this information *alone* tells nothing about the relationship of the measured level of the level which one would expect to have at that point when a nominal test signal (e.g. nominal line-up signal) had been applied to some other point.

On the other hand, one requires a clear unambiguous way of describing the *level* of a given test signal. The *power level* is not adequate, because for a given test signal, the power level will vary with the amplification and losses which occur throughout a transmission system. The term dBm0s is such a means of describing a normalized test signal.

Thus, if one is applying the nominal, standard line-up level at a reference point, then this is an 0 dBm0s *test signal level* regardless of the *power level* in dBm. Furthermore, regardless of the variations of power level resulting from normal circuit gains or losses, this remains an 0 dBm0s *test signal level* even though its *power level* varies from point to point.

If one applied a test signal which was 8 dB below the nominal line-up level at that point, then this would be an -8 dBm0s signal regardless of its actual power level as read on a meter (in dBm).

Note 4. — It is the practice in the United Kingdom and some other countries, to allow a margin of 8 dB, and in most of Europe, to allow a margin of 9 dB. 0 dBm0s then corresponds to 40% modulation or 35% modulation, respectively. There is agreement between members of EBU to ignore the 1 dB discrepancy, as it makes no difference operationally. In North America it is general practice to allow a margin of 10 dB corresponding to 32% modulation.

Note 5. — It is desirable to restrict the use of dBm0s to test signals.

Note 6. — It is desirable that the frequency of the test signal should not be too high, to avoid difficulties with equipment containing pre-emphasis etc.. One kHz has been nominated because it is the CCIR preferred reference frequency and is the reference used on most source test material (standard discs, tapes and film). Where test signals at other frequencies are required, such as for frequency response tests, the result should be expressed as “x dB below 0 dBm0s” or “x dB” with respect to 0 dBm0s”. For example, “a 3 kHz tone 20 dB below 0 dBm0s” would be satisfactory.

Note 7. — Definitions of “relative power level” and “transmission reference point” are given in §§ 1.3.1 and 1.3.2 of Appendix I to Recommendation 574.

Examples of the special notations used to indicate absolute power level in various cases are contained in § 2.10 of the same Recommendation.

REPORT 465-3

DETERMINATION OF THE SUBJECTIVE LOUDNESS OF A BROADCASTING PROGRAMME

(Question 50/10, Study Programme 50A/10)

(1970-1974-1978-1982)

1. Question 4/X was adopted subsequent to the Interim Meeting of Study Group X, Vienna, 1965, and Docs. [CCIR, 1963-66a, b, c and d] were considered at the XIth Plenary Assembly, Oslo, 1966, resulting in Doc. [CCIR, 1963-66e].

2. During the Interim Meeting of Study Group X, Palma de Mallorca, 1968 and the Final Meeting, Geneva, 1969, the following documents were considered:

2.1 [CCIR, 1966-69a] suggests as an interim solution, the use of a standard loudness reference recording with which programmes may be compared.

2.2 [CCIR, 1966-69b] describes a programme loudness meter which uses a loudness contour filter and selected attack and decay times to indicate units of loudness.

2.3 [CCIR, 1966-69c] describes a unit which also uses a loudness contour filter and selected attack and decay times to adjust automatically the programme level so as to avoid abnormal loudness variations.

2.4 [CCIR, 1966-69d] describes a new programme loudness indicator which measures the contents of several frequency bands over the audio-frequency spectrum. It is designed to measure the relative loudness levels of various programme sequences. The document points to the possibility of automatic control of programme loudness.

3. Study Group 10 agrees that a standard reference loudness tape should be produced for the use of the administrations taking part in this Study Programme. This tape should contain as a minimum, a variety of material from different programmes and using different languages, recorded with a constant peak level.

The BBC has produced a provisional loudness tape with a comprehensive range of programme material having different subjective loudness characteristics. This has been published by the CCIR Secretariat for study purposes leading to the possible production of a CCIR standard reference loudness tape. Resolution 57, New Delhi, 1970, established Interim Working Party 10/1 with this object.

4. Further to the work carried out by Interim Working Party 10/1, set up by Resolution 57, the following documents were examined at the Interim Meeting in Geneva, 1972:

4.1 [CCIR, 1970-74a]. This gives conclusions drawn from tests carried out with the tape recorded by the BBC. It is accepted that in view of the subjective element even an automatic adjustment of the level would not satisfy all listeners, considering the wide spread of individual results in the assessments.

4.2 [CCIR, 1970-74b]. Tests carried out in Finland over a number of years have shown the loudness preference of the broadcasting public to be dependent on many individual factors, such as the listener's age, the ambient noise level and the attention given to the programme. It is therefore proposed to transmit programme identification signals which would control the sensitivity of the receivers (see Report 463).

4.3 [CCIR, 1970-74c] contains a synthesis of the results obtained by six members of the Working Party using the tape produced by the BBC. The values obtained by the different countries were fairly similar and it was noted that musical programmes and sound effects are louder than speech. However, in all countries, the values given by some observers vary as much as 15 dB from the mean.

A number of countries carried out complementary tests with measuring apparatus which should correspond more closely to a subjective impression, such as the apparatus mentioned in [CCIR, 1966-69d] and a loudness analyser (of laboratory quality), but the results were not entirely satisfactory and the high cost of such devices excludes their routine use.

4.4 At the Final Meetings, Geneva, 1974, [CCIR, 1970-74d] was examined. This document provides additional information on the subject.

5. As the determination of subjective loudness of programmes depends on too many imponderables, broadcasting organizations seem to be favouring the idea of giving directives to transmission staff to the effect that the dynamic range should be compressed for speech and the level deliberately attenuated by as much as 10 dB for greatly compressed musical recordings.

Consequently, the XIIIth Plenary Assembly decided that Interim Working Party 10/1 was dissolved.

6. [CCIR, 1974-78a and b] give additional information concerning further studies on the subject. OIRT members consider that an improvement of speech-music loudness ratios cannot be completely solved by manual regulation of signal level in the studios. The OIRT decided to examine this subject [CCIR, 1974-78b] in conjunction with automated programme emissions. As a result of the discussion on these documents, Study Programme 50B/10, § 4, concerning automatic regulation was drafted.

7. [CCIR, 1978-82a] describes the design and tests of a new loudness indicator for monitoring an audio broadcast programme. The new device is an improved version of the device originally described in [CCIR, 1966-69d].

[CCIR, 1978-82b] describes studies on level regulation of sound broadcasting signals.

Various level regulation procedures have been evaluated subjectively under studio and home reception conditions. The results indicate that an improvement of the programme regulation is not achieved when a fixed loudness value serves as level regulation criterion. A great number of listeners can already be satisfied by a correct quasi-peak level regulation with a differentiation between music and speech sequences as a function of the type of programme. A single level regulation of the programme which appears to be satisfactory for all listeners proves to be impossible.

For those reception conditions, which differ widely from the average value, corrections in the receivers are necessary.

REFERENCES

CCIR Documents

- [1963-66]: **a.** X/127 (Federal Republic of Germany); **b.** X/130 (Canada); **c.** X/137 (USA); **d.** X/154 (OIRT); **e.** X/198 (Chairman, Study Group X).
 [1966-69]: **a.** X/8 (USA); **b.** X/38 (USA); **c.** X/34 (USA); **d.** X/151 (USA).
 [1970-74]: **a.** 10/29 (Germany (Federal Republic of)); **b.** 10/47 (Finnish Broadcasting Company); **c.** 10/63 (Chairman, Interim Working Party 10/1); **d.** 10/211 (USA).
 [1974-78]: **a.** 10/336 (OIRT); **b.** 10/337 (OIRT).
 [1978-82]: **a.** 10/28 (USA); **b.** 10/75 (German Democratic Republic).

RECOMMENDATION 468-3 *

MEASUREMENT OF AUDIO-FREQUENCY NOISE VOLTAGE LEVEL IN SOUND BROADCASTING

(Question 50/10)

(1970-1974-1978-1982)

The CCIR,

CONSIDERING

- (a) that it is desirable to standardize the methods of measurement of audio-frequency noise in broadcasting, in sound-recording systems and on sound-programme circuits;
- (b) that such measurements of noise should provide satisfactory agreement with subjective assessments,

UNANIMOUSLY RECOMMENDS

that the noise voltage level be measured in a quasi-peak and weighted manner, using the measurement system defined below:

1. Weighting network

The nominal response curve of the weighting network is given in Fig. 1b which is the theoretical response of the passive network shown in Fig. 1a. Table I gives the values of this response at various frequencies.

The permissible differences between this nominal curve and the response curve of the measuring equipment, comprising the amplifier and the network, are shown in the last column of Table I and in Fig. 2.

Note 1. — When a weighting filter conforming to § 1 is used to measure audio-frequency noise, the measuring device should be a quasi-peak meter conforming to § 2. Indeed, the use of any other meter (e.g. an r.m.s. meter) for such a measurement would lead to figures for the signal-to-noise ratio that are not directly comparable with those obtained by using the characteristics that are described in the present Recommendation.

Note 2. — The whole instrument is calibrated at 1 kHz (see § 2.6).

* This Recommendation is also of interest to the CMTT.

TABLE I

Frequency (Hz)	Response (dB)	Proposed tolerance (dB)
31.5	− 29.9	± 2.0
63	− 23.9	± 1.4 (1)
100	− 19.8	± 1.0
200	− 13.8	± 0.85
400	− 7.8	± 0.75
800	− 1.9	± 0.55
1 000	0	± 0.5
2 000	+ 5.6	± 0.5
3 150	+ 9.0	± 0.5 (1)
4 000	+ 10.5	± 0.5 (1)
5 000	+ 11.7	± 0.5
6 300	+ 12.2	0
7 100	+ 12.0	± 0.2 (1)
8 000	+ 11.4	± 0.4 (1)
9 000	+ 10.1	± 0.6 (1)
10 000	+ 8.1	± 0.8 (1)
12 500	0	± 1.2 (1)
14 000	− 5.3	± 1.4 (1)
16 000	− 11.7	± 1.6 (1)
20 000	− 22.2	± 2.0
31 500	− 42.7	{ + 2.8 (1) − ∞

(1) This tolerance is obtained by a linear interpolation on a logarithmic graph on the basis of values specified for the frequencies used to define the mask, i.e., 31.5, 100, 1 000, 5 000, 6 300 and 20 000 Hz.

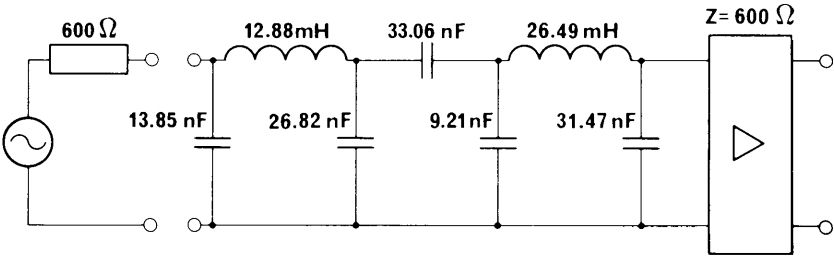


FIGURE 1a – *Weighting network, simple form*

(A constant-resistance realization is described in Annex I)

(A tolerance of at most 1 % on the component values and a *Q*-factor of at least 200 at 10 000 Hz are sufficient to meet the tolerances given in Table I)

(The difference between the responses at 1000 Hz and 6300 Hz may be adjusted more precisely by a small adjustment of the 33.06 nF capacitor)

2. Characteristics of the measuring device

A quasi-peak value method of measurement shall be used. The required dynamic performance of the measuring set may be realized in a variety of ways (see Note). It is defined in the following sections. Tests of the measuring equipment, except those for § 2.4, should be made through the weighting network.

Note. — After full wave rectification of the input signal, a possible arrangement would consist of two peak rectifier circuits of different time constants connected in tandem [CCIR, 1974-78].

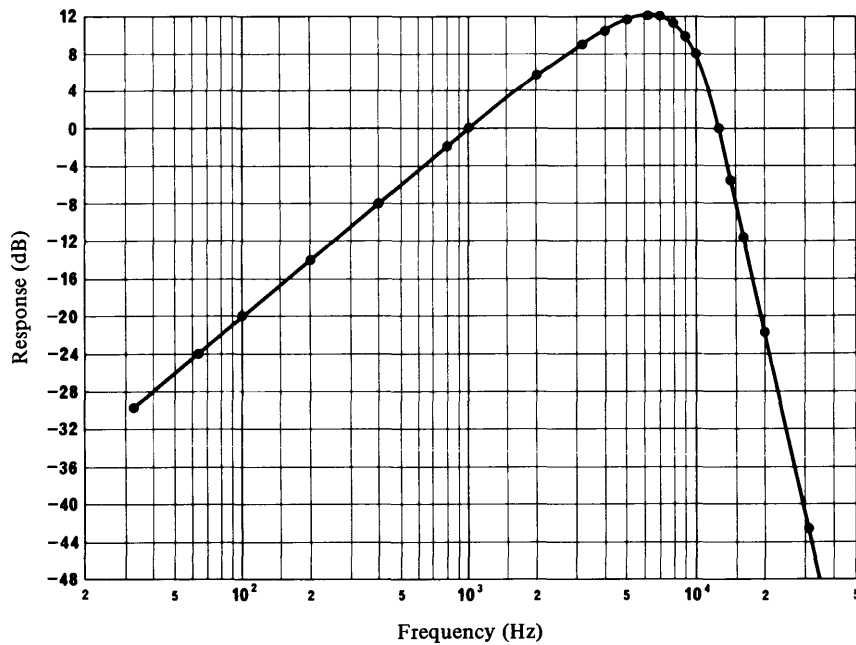


FIGURE 1b – Frequency response of the weighting network shown in Fig. 1a

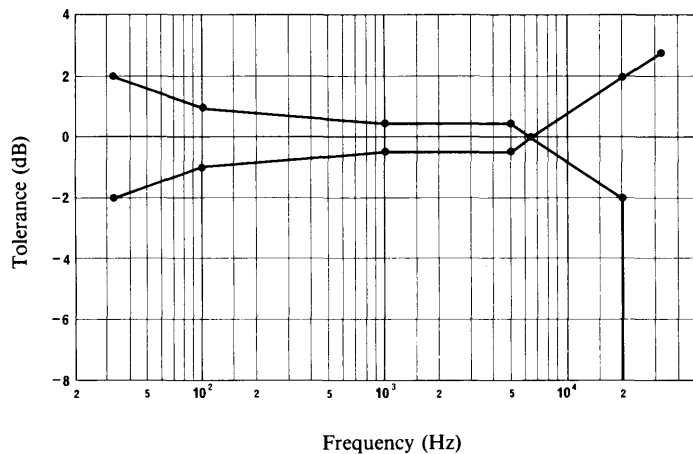


FIGURE 2 – Maximum tolerances for the frequency response of the weighting network and the amplifier

2.1 Dynamic characteristic in response to single tone-bursts

Method of measurement

Single bursts of 5 kHz tone are applied to the input at an amplitude such that the steady signal would give a reading of 80% of full scale. The burst should start at the zero-crossing of the 5 kHz tone and should consist of an integral number of full periods. The limits of reading corresponding to each duration of tone burst are given in Table 11.

The tests should be performed both without adjustment of the attenuators, the readings being observed directly from the instrument scale, and also with the attenuators adjusted for each burst duration to maintain the reading as nearly constant at 80% of full scale as the attenuator steps will permit.

TABLE II

Burst duration (ms)	1 ⁽¹⁾	2	5	10	20	50	100	200
Amplitude reference steady signal reading (%) (dB)	17.0 -15.4	26.6 -11.5	40 -8.0	48 -6.4	52 -5.7	59 -4.6	68 -3.3	80 -1.9
Limiting values								
– lower limit (%) (dB)	13.5 -17.4	22.4 -13.0	34 -9.3	41 -7.7	44 -7.1	50 -6.0	58 -4.7	68 -3.3
– upper limit (%) (dB)	21.4 -13.4	31.6 -10.0	46 -6.6	55 -5.2	60 -4.4	68 -3.3	78 -2.2	92 -0.7

(1) The Administration of the U.S.S.R. intends to use burst durations ≥ 5 ms.

2.2 Dynamic characteristic in response to repetitive tone-bursts

Method of measurement

A series of 5 ms bursts of 5 kHz tone starting at zero-crossing is applied to the input at an amplitude such that the steady signal would give a reading of 80% of full scale. The limits of the reading corresponding to each repetition frequency are given in Table III.

The tests should be performed without adjustment of the attenuators but the characteristic should be within tolerance on all ranges.

TABLE III

Number of bursts per second	2	10	100
Amplitude reference steady signal reading (%) (dB)	48 -6.4	77 -2.3	97 -0.25
Limiting values			
– lower limit (%) (dB)	43 -7.3	72 -2.9	94 -0.5
– upper limit (%) (dB)	53 -5.5	82 -1.7	100 -0.0

2.3 Overload characteristics

The overload capacity of the measuring set should be more than 20 dB with respect to the maximum indication of the scale at all settings of the attenuators. The term “overload capacity” refers both to absence of clipping in linear stages and to retention of the law of any logarithmic or similar stage which may be incorporated.

Method of measurement

Isolated 5 kHz tone-bursts of 0.6 ms duration starting at zero-crossing are applied to the input at an amplitude giving full scale reading using the most sensitive range of the instrument. The amplitude of the tone-bursts is decreased in steps by a total of 20 dB while the readings are observed to check that they decrease by corresponding steps within an overall tolerance of ± 1 dB. The test is repeated for each range.

2.4 *Reversibility error*

The difference in reading when the polarity of an asymmetrical signal is reversed shall not be greater than 0.5 dB.

Method of measurement

1 ms rectangular d.c. pulses with a pulse repetition rate of 100 pulses per second or less are applied to the input in the unweighted mode, at an amplitude giving an indication of 80% of full scale. The polarity of the input signal is reversed and the difference in indication is noted.

2.5 *Overswing*

The reading device shall be free from excessive overswing.

Method of measurement

1 kHz tone is applied to the input at an amplitude giving a steady reading of 0.775 V or 0 dB (see § 2.6). When this signal is suddenly applied there shall be less than 0.3 dB momentary excess reading.

2.6 *Calibration*

The instrument shall be calibrated such that a steady input signal of 1 kHz sine-wave at 0.775 V r.m.s., having less than 1% total harmonic distortion, shall give a reading of 0.775 V, 0 dB. The scale should have a calibrated range of at least 20 dB with the indication corresponding to 0.775 V (or 0 dB) between 2 and 10 dB below full scale.

2.7 *Input impedance*

The instrument should have an input impedance ≥ 20 k Ω and if an input termination is provided then this should be $600 \Omega \pm 1\%$.

3. **Presentation of results**

Noise voltage levels measured according to this Recommendation are expressed in units of dBqps.

Note 1. — If, for technical reasons, it is desirable to measure unweighted noise, the method described in Annex II should be used.

Note 2. — The influence of the weighting network on readings obtained with different spectra of random noise is discussed in Report 496.

REFERENCES

CCIR Documents

[1974-78]: 10/28 (United Kingdom).

BIBLIOGRAPHY

BBC [1968] Research Department Report No. EL-17. The assessment of noise in audio-frequency circuits.

DEUTSCHE NORMEN DIN 45 405.

STEFFEN, E. [1972] Untersuchungen zur Geräuschspannungsmessung (Investigations into the measurement of noise voltage). *Techn. Mitt. RFZ*, Heft 3.

WILMS, H. A. O. [December, 1970] Subjective or psophometric audio noise measurement: A review of standards. *J. Audio Eng. Soc.*, Vol. 18, 6.

CCIR Documents

[1978-82]: 10/9 (EBU); 10/31 (LM Ericsson); 10/38 (OIRT); 10/225 (German Democratic Republic).

ANNEX I

CONSTANT RESISTANCE REALIZATION OF WEIGHTING NETWORK

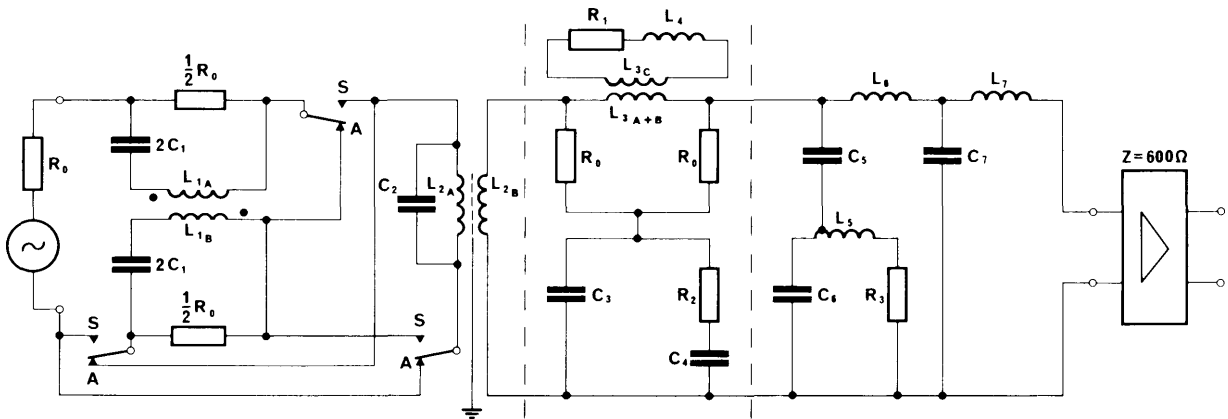


FIGURE 3 – Constant resistance realization of weighting network

R (Ω)	C (nF)	L (mH)
R ₀ : 600	2C ₁ : 83.7	L ₁ : 12.70 (for both windings in series)
½ R ₀ : 300	C ₂ : 35.28	L ₂ : 15.06 (for each of two windings separated by electrostatic shield)
R ₁ : 912	C ₃ : 38.4	L _{3A+B} : 16.73 (two equal windings in series)
R ₂ : 3340	C ₄ : 7.99	L _{3C} : 4.18 (one winding, turns half L _{3A+B} , can have large d.c. resistance, absorbed in R ₃)
R ₃ : 941	C ₅ : 23.8	L ₄ : 20.1 (can have large d.c. resistance, absorbed in R ₃)
	C ₆ : 13.94	L ₅ : 31.5 (with tap 20.1 at 0.798 of total turns)
	C ₇ : 35.4	L ₆ : 13.29
		L ₇ : 8.00
A: unbalanced		
S: balanced		

BIBLIOGRAPHY

AUSTRALIAN BROADCASTING COMMISSION Engineering Development Report No. 106 – Constant resistance realization of CCIR noise weighting network, Recommendation 468.

ANNEX II

UNWEIGHTED MEASUREMENT

It is recognized that unweighted measurements outside the scope of this Recommendation may be required for specific purposes. A standard response for unweighted measurements is included here for guidance.

Frequency response

The frequency response shall be within the limits given in Fig. 4.

This response serves to standardize the measurement and ensure consistent readings of noise distributed across the useful spectrum. When out-of-band signals, e.g. carrier leaks, are present at a sufficient amplitude, they may produce readings that are inconsistent between measuring equipments whose responses are different but still fall within the tolerance template of Fig. 4.

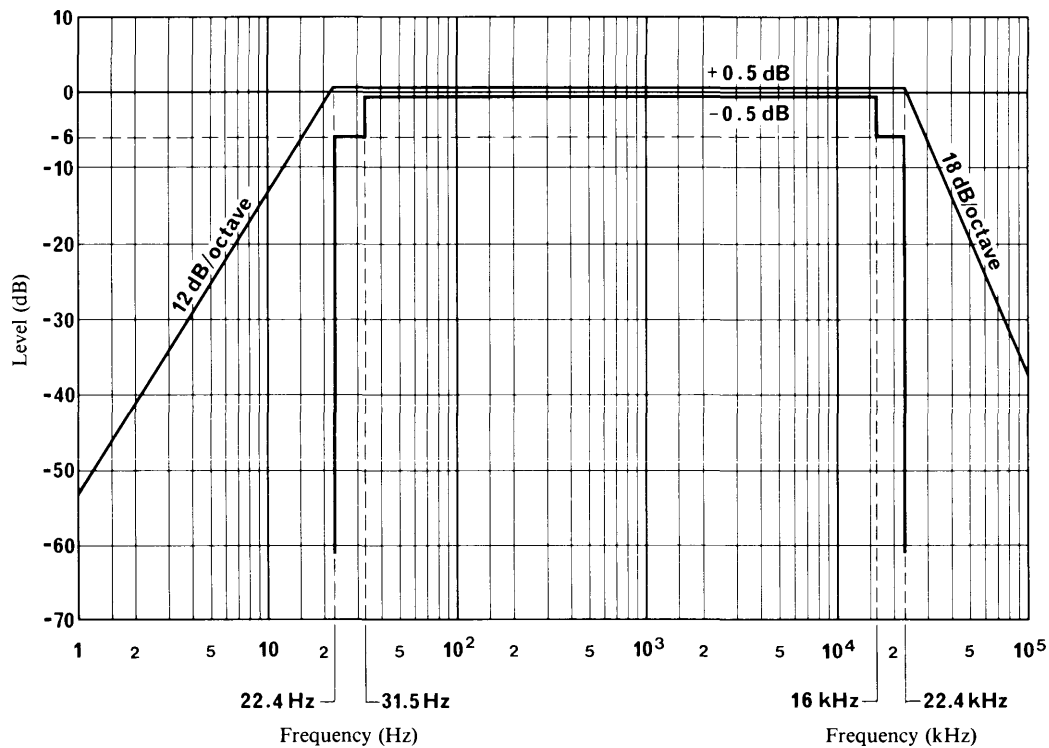


FIGURE 4

BIBLIOGRAPHY

CCIR Documents

[1978-82]: 10/76 (CMTT/14) (Canada).

REPORT 798-1

SIMULATED PROGRAMME SIGNALS

(Question 44/10, Study Programme 44A/10)

(1978-1982)

1. Present situation

Noise signals simulating programme signals are specified in Recommendation 559, Report 497, and Recommendation 571. It is also known that this subject is under discussion in the IEC (SC 29 B/SSGB), and a draft proposal exists.

It has been proposed that there should be only one such signal but before standardization can be achieved it is necessary to study the differences between the signals as specified at present, and the reasons for these differences.

2. Characteristics of the signals

The signals proposed at present differ significantly in the high-frequency regions of their spectra. The signal in the IEC draft proposal has the least high-frequency energy, while the CMTT signal has the greatest amount.

Table I shows the main differences between the noise signals in terms of their purpose and their relationship with real programme signals.

TABLE I

Characteristic	CCIR		IEC
	Recommendation 559	Recommendation 571 Report 497	Draft proposals SC 29 B/SSGB
Type of signal which is simulated by the noise spectrum	Modern dance music (1967)	Average of all types (1976?)	Average of all types (1975-77)
Derivation of spectrum from measurements on actual programme signals	In each 1/3 octave band, the level which was exceeded for between 20% and 40% of the time was measured	The spectrum is typical of signals whose levels lie between those exceeded for 1% and 10% of the time, over a period of 1 min.	The spectrum is typical of signals whose levels are equal to that exceeded for 50% of the time
Purpose	Measurement of selectivity of AM and FM receivers for frequency planning and determination of protection ratios	Measurement of cross-talk and cross-intermodulation in circuits and multiplex systems, excluding measurements of non-linearity within a channel	Specifying the performance of amplifiers and loud-speakers. Measurement of non-linearity within a channel

3. Conclusions

It should be noted in particular that the noise signals specified in Recommendation 559 are used to determine radio-frequency protection ratios. The effect of a change in the characteristics of the noise signals used is discussed in [CCIR, 1978-82].

It is not possible at present, considering the differences shown in Table I, to recommend the adoption of any one of the signals for *all* purposes. It is necessary for further studies to be carried out (see Opinion 59).

REFERENCES

CCIR Documents

[1978-82]: 10/51 (Germany (Federal Republic of)).

REPORT 293-5 *

AUDIO-FREQUENCY PARAMETERS FOR THE STEREOPHONIC TRANSMISSION AND REPRODUCTION OF SOUND

Principal audio-frequency characteristics

(1963-1966-1970-1974-1978-1982)

1. Introduction

Extensive studies have been carried out in several countries with regard to Study Programme 15B/10 (Geneva, 1974), which is concerned with the study of the subjective aspects of stereophonic sound transmission and reproduction.

2. Tolerances of the quality parameters for stereophony

The fundamental documents which served as a basis for establishing quality characteristics for stereophony are given in the Bibliography.

* This Report is a provisional answer to Study Programme 15B/10, which is hereby deleted.

[CCIR, 1970-74] gives additional and more accurate information regarding the overall tolerances defined earlier. It also proposes specific tolerances applicable to the transmission circuit, to the chain “transmission circuit + stereophonic encoder + transmitter” and to tape-recorders.

The values proposed for the transmission circuit have been taken into consideration by the CMTT in Recommendation 505 which specifies the characteristics of high-quality circuits for sound programme transmissions.

Relevant tape-recorder tolerances are given in Recommendation 408, which specifies the standards of sound recording for the international exchange of programmes.

The tolerances applicable to the chain “circuit + encoder + transmitter” are considered to apply to the “broadcast signal”; i.e. to all the elements in the chain, for the operation and quality maintenance of which the programme transmitting and broadcasting organizations are responsible.

2.1 *Significance of the tolerances*

The values shown in the “overall values” column in Table I define the conditions that must be met by a complete stereophonic transmission chain, to ensure good quality reproduction. They therefore apply in principle to a transmission chain extending from the microphone output to the input of the loudspeakers, i.e. including the studio equipment, the links and the stereophonic transmitter and receiver. The receiver considered is a monitoring receiver such as may be used in the studio for subjective monitoring of the broadcast programme.

The EBU and the OIRT are aware that, in certain cases, the limitations of the performance of the equipment will imply the possibility of relaxing tolerances; however, it is desirable for future technological progress to accept the overall tolerances indicated.

The values in the “broadcast signal” column in Table I relate to the part of the chain extending from the studio output to the transmitter output. In this case, it is understood that all characteristics are measured in accordance with standard practice, using a high-quality apparatus (demodulator and measuring decoder) normally having a very slight if not negligible effect on the value measured. The measuring signals applied to the chain input are also assumed to be flawless.

2.2 *General conditions of measurement*

Values of individual parameters are measured with standard operational conditions at individual points in the transmission chain.

Ideal transmitter-to-receiver radiation, propagation and receiving conditions are assumed in the path between the transmitter and the receiver.

2.3 *Notes on the individual parameters*

2.3.1 *Bandwidth*

The EBU and the OIRT particularly stress the danger of limiting the bandwidth of the *S* signal in those parts of the transmission chain where that signal is effectively present.

2.3.2 *Amplitude/frequency response*

It is preferable for the acceptable *A* and *B* channels tolerance limits to be defined by a profile. Figure 1 shows these tolerances referred to a level of 0 dB. The area within this profile can be used as a mask within which an acceptable response curve should fit.

Below 40 Hz and above 15 kHz, the curve should have a falling characteristic, the slope of which has yet to be determined.

2.3.3 *Difference in gain between the A and B channels*

The acceptable tolerance for the difference in gain between *A* and *B* channels is also given in the form of a profile (Fig. 2). The tolerated difference in gain for a particular frequency is, therefore, equal to the maximum deviation between the absolute values of the amplitude/frequency curves of the *A* and *B* channels, both of which should, nevertheless, fall within the profile specified in § 2.3.2.

2.3.4 *Difference in phase between the A and B channels*

The proposed tolerance profiles for this parameter are given in Fig. 3.

2.3.5 *Linear crosstalk between the A and B channels*

The proposed tolerance profiles for this parameter are given in Fig. 4.

2.3.6 *Weighted signal-to-noise ratio*

The proposed value represents the difference in level between the weighted noise measured in accordance with Recommendation 468 and a signal, where amplitude corresponds to the maximum frequency deviation at 1000 Hz.

2.3.7 *Non-linearity distortions*

This tolerance for non-linearity distortions applies to the most unfavourable result obtained by applying to the stereophonic system of maximum level, the following three combinations of signals:

$$A = B; \quad A = -B; \quad A \text{ or } B = 0.$$

This characteristic is measured by a device (total harmonic distortion factor meter), which suppresses the measuring frequency, to obtain the r.m.s. value of the sum of the non-linearity products within the frequency range of 40 Hz to 15 kHz. The reference level is the measured signal after de-emphasis.

For measuring frequencies in the range of 40 Hz to 7.5 kHz the specified values apply to the harmonics of the measuring signal.

For measuring frequencies in the range of 7.5 kHz to 15 kHz the specified value applies only to non-harmonic products which are generated in the stereophonic decoder by combination with the sub-carrier frequency.

It is to be noted that the tolerances given for non-linearity distortions apply to both "non-linearity distortion" and "non-linear crosstalk" which appear simultaneously when both *A* and *B* signals are present.

3. **Table of quality tolerances in stereophony**

Table I summarizes the tolerances applicable to the quality parameters of stereophonic reproduction.

The diagrams following the Table show some of these tolerances in graphical form.

4. **Further work**

The documents [CCIR, 1974-78a and b] were considered, which contain information on "Parameters of the sound transmission channel at the input of the international transmission channel" and on methods used in the OIRT for the summation of the numerical values of transmission parameters. Both documents can be used for further work; the document [CCIR, 1974-78b] was extensively considered by the CMTT, see [CCIR, 1974-78c].

The OIRT applies recommendations for the international programme exchange per lines and/or radio links between different broadcasting houses. It should be considered whether in CCIR also such recommendations are advisable.

The values in this Report are valid only for the national broadcasting organizations, as mentioned in the introduction of § 2. Nevertheless it must be examined, whether the values could be applied also for the broadcast-signal, i.e. for direct transmission from satellite.

Study Group 10 is aware that the parameters and values listed in Table I need to be extended to take account of digital techniques in connection with Question 51/10 and Study Programmes 51A/10 to 51E/10 and Study Programme 52B/10, which were established at the Interim Meetings, 1980.

Documents [CCIR, 1978-82a and b] submitted in answer to Question 51/10, have supported and confirmed the value of 15 kHz for the upper cut-off frequency in Table I.

When the documents [CCIR, 1978-82c, d and e] were considered, however, it could be recognized that the different opinions on level characteristics (e.g. test tone level, reference level, modulation rate, etc.) made the interpretation of some important values more and more difficult.

The discussions at the Interim Meetings on documents [CCIR, 1978-82a, b and c] showed that further studies are necessary before a Recommendation can be prepared. For that purpose, Question 50/10 and Study Programme 50A/10 were established.

Further contributions on this subject are therefore requested.

TABLE I

Characteristics and signals(1)	Frequencies (kHz)	Broadcast signal(2)	Overall tolerances
Bandwidth <i>A</i> , <i>B</i> , <i>M</i> and <i>S</i>		0.04 to 15 kHz	0.04 to 15 kHz
Amplitude/frequency response profile (Fig. 1) <i>A</i> and <i>B</i> (dB)	0.04 to 0.125 0.125 to 0.630 0.630 to 1.25 1.25 to 10 10 to 14 14 to 15	+0.7 to -2.5 +0.7 to -0.7 +0.5 to -0.5 +0.7 to -0.7 +1 to -2.5 +1 to -3	+2 to -3 +1 to -1 +0.5 to -0.5 +1 to -1 +2 to -3 +2 to -3
Gain difference(3) (Fig. 2) <i>A</i> and <i>B</i> (dB)	1 0.04 to 0.125 0.125 to 10 10 to 14 14 to 15	1 2 1 2 3	1 2 1.5 3 3
Phase difference(3) (Fig. 3) <i>A</i> and <i>B</i> (degrees)	0.04 0.04 to 0.2 0.2 to 4 4 to 15 15	40° oblique segment 20° oblique segment 45°	90° oblique segment 45° oblique segment 90°
Linear crosstalk(3) (Fig. 4) <i>A</i> and <i>B</i> (dB)	0.04 to 0.3 0.3 to 4 4 to 15	-36 -36 oblique segment 6 dB per octave	oblique segment 6 dB per octave -30 oblique segment 6 dB per octave
Weighted signal-to-noise ratio <i>A</i> , <i>B</i> and <i>M</i> (dB)	—	50(4)	46(4)
Non-linearity distortion <i>A</i> , <i>B</i> and <i>M</i> (dB)			
Total harmonic distortion	{ 0.04 to 0.125 0.125 to 7.5	-37 -43	-34 -40
Non-harmonic products	7.5 to 15	-40	-30

(1) *A* is the signal on the left and *B* the signal on the right. $M = \frac{1}{2} (A + B)$ and $S = \frac{1}{2} (A - B)$.

(2) The broadcast signal tolerances apply to the chain circuit + encoder + transmitter. The circuit taken is the reference circuit defined in Recommendation 502.

(3) This concerns only differences of gain, differences of phase or linear crosstalk, which are introduced unintentionally between the *A* and *B* channels owing to imperfections in the transmission chain.

(4) The values indicated are adequate in most cases. However, for some types of programme (e.g. piano music) it would be desirable to increase these values by about 10 dB.

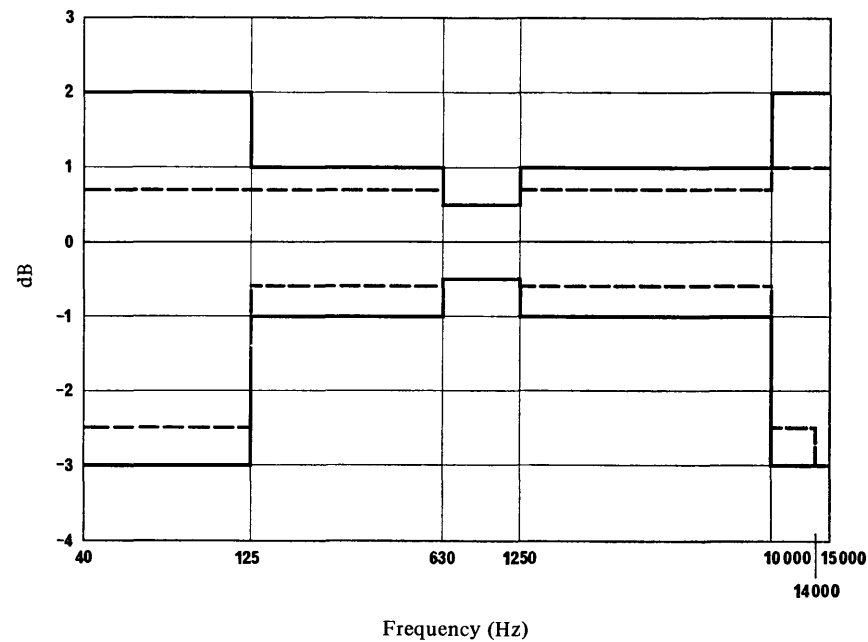


FIGURE 1 – Amplitude/frequency response profile of the A and B channels

—— overall tolerances
----- broadcast signal

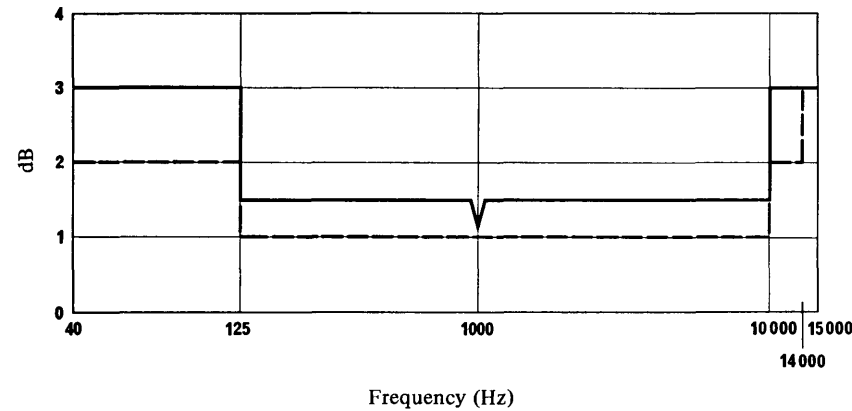


FIGURE 2 – Gain difference between the A and B channels

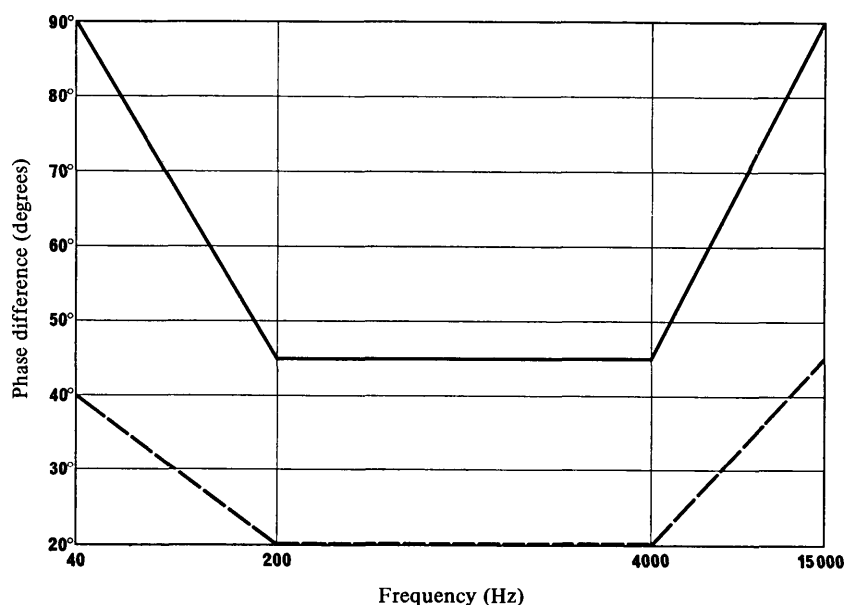


FIGURE 3 – Phase difference between the A and B channels

— overall tolerances
 - - - broadcast signal

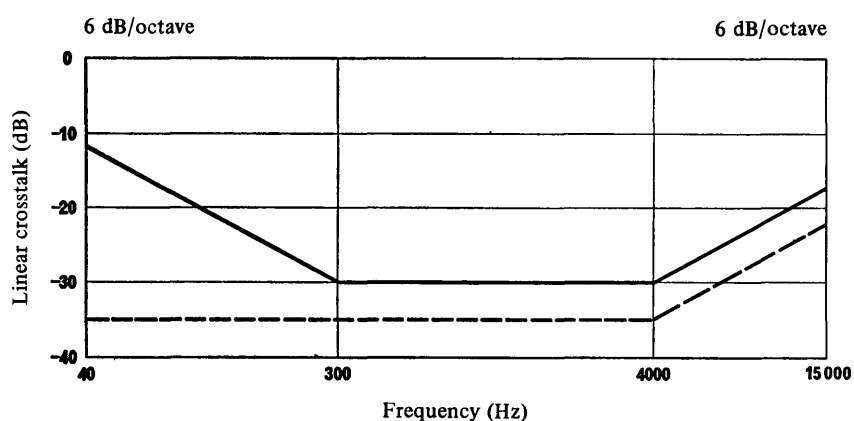


FIGURE 4 – Linear crosstalk between the A and B channels

REFERENCES

CCIR Documents

[1970-74]: 10/222 (EBU).

[1974-78]: a. 10/44 (OIRT); b. 10/333 (OIRT); c. CMTT/309 (CMTT).

[1978-82]: a. 10/13 (EBU); b. 10/49 (Germany (Federal Republic of)); c. 10/36 (OIRT); d. 10/42 (Sweden); e. 10/95 (LM Ericsson).

BIBLIOGRAPHY

PLENGE, G., JAKUBOWSKI, H. and SCHÖNE, P. [1980] Which bandwidth is necessary for optimal sound transmission?
J. Audio Eng. Soc., Vol. 28, 3, 114-120.

Note. — A complete Bibliography from the periods between 1963 and 1974, is to be found in Volume X of the XIIIth Plenary Assembly, Geneva 1974, page 212.

REPORT 797-1

DETERMINATION OF THE ACOUSTICAL PROPERTIES OF CONTROL ROOMS AND HIGH-QUALITY LISTENING ROOMS IN BROADCASTING

(Question 50/10, Study Programme 50D/10)

(1978-1980-1982)

1. Control rooms

In control rooms, the conflicts between the acoustic and operational requirements have not been optimally resolved. It is therefore not appropriate to specify a standard control room.

The principal requirements for control rooms have been the subjects of contributions from several countries (see also Annex I):

1.1 During the Interim Meeting of Study Group 10, Geneva, 1976, the document [CCIR, 1974-78a] was considered. Another document [CCIR, 1978-82a] updating the information given by the first one was considered at the Final Meeting, Geneva, 1981. These documents describe Canadian practices and experience regarding the acoustics of control rooms and listening rooms in broadcasting.

Room parameters appropriate for monophony and stereophony:

- *Ambient noise level* in the room with air conditioning or ventilation equipment working and technical equipment in stand by position should not exceed noise curve 25 [Beranek, 1957].
- *Reverberation time*: 0.25 to 0.4 s (above 100 Hz)
- *Room proportions*: dimensions whose ratios are integral powers of $2^{1/3}$ (1; 1.26; 1.59; 2.00; 2.52; 3.17; ...) have proven to be very satisfactory for this purpose, provided the ratio 1 : 2 between any two dimensions is avoided. Irregular shaped rooms are often used.
- *Volume*: a desirable volume for a control room or listening room is in the order of 40 m³ and volumes less than 30 m³ are to be avoided.
- *Acoustical defects* due to the room and/or the equipment therein, like flutter echo and standing waves should be eliminated.
- *Location of sound sources* as related to listening position:
 - Monophony: the sound source should be located in front of the listener at a height such that the elevation angle relative to the head of the listener be in the range 0°-30°;
 - Stereophony: the two sound sources should be equally displaced on each side of the position for the monophonic source so that the horizontal angle subtended by the sources should at the listener position be between 60° and 90°. The elevation angle requirement should be as in the monophonic case.

In all cases, the listener ought to be located near the centre of the room.

1.2 At the Interim Meeting of Study Group 10, Geneva, 1980, the EBU also submitted a document [CCIR, 1978-82b] suggesting similar requirements for the acoustics of control rooms.

1.3 United Kingdom engineers studied this subject [CCIR, 1978-82c] and reached the following conclusions:

For monophony and stereophony, the following acoustical parameters of listening rooms and control rooms are vital (they are not given in any specific order of importance):

- *Volume of the room*: not less than 30 m³, preferably greater than 40 m³.
- *Shape of the room*: such that isolated eigentones or groups of eigentones are avoided.
- *Reverberation time*: 0.2 to 0.4 s, the maximum deviation from the design value between frequencies of 160 Hz and 6.3 kHz being less than $\pm 10\%$. In addition, adjacent 1/3 octave bands should not differ by more than 10%.
- *Diffusion of the sound energy*: the sound energy field should be rendered diffuse by the proper location of reflecting and absorbing surfaces distributed in relatively small patches on opposing wall surfaces which need not be non-parallel.

- *Background noise level*: should be low enough to avoid masking of the quietest signal levels. This level will depend on the type of programme material being assessed and the absolute reproduced level.
- *Acoustic isolation from other areas*: the sound insulation surrounding the room should be sufficient to reduce extraneous noise to a level below that at which the listeners become distracted.
- *Symmetry of the room*: for stereophony the room should be acoustically perfectly symmetrical about the line between the listener and the point midway between the loudspeakers (see also § 2.3).

2. Listening rooms

2.1 At the Final Meeting, Geneva, 1977, the OIRT proposed that the CCIR prepare a draft Recommendation on standardized listening rooms to obtain comparable results of high-quality unified monophonic and stereophonic listening.

The OIRT proposes, as a basis for this work, the document [CCIR, 1974-78b] which contains the OIRT Recommendation on “Standard listening rooms of the OIRT”, based on the results of the research work and the experience regarding the control rooms and listening rooms of the OIRT member countries. Table I shows the most important values of Documents [CCIR, 1974-78c and b].

At the Interim Meeting, Geneva, 1980, the OIRT submitted, for information, a document [CCIR, 1978-82d] on a new edition of the OIRT Recommendation “Standard listening rooms of the OIRT” (OIRT Recommendation No. 86/1). (The values, given in Table I, do not differ in the new edition, but more details are standardized.)

2.2 A U.S.S.R. document [CCIR, 1978-82e] described some additional requirements for listening conditions which have been adopted in the U.S.S.R.:

- the listening equipment (acoustical centre) should be placed at a distance of at least 1 m from the side walls and 0.7 m from the back wall;
- the axis of the listening equipment should pass at a height of more than 1.25 m from the floor through the centre of the listener seating area;
- the acoustic treatment of the surfaces in the listening room should be arranged so that, at each end of the room, the end walls, (behind and facing the listeners’ seating area) the side walls and the ceiling for about one-third of the length of the room, are sound reflecting compared with the remainder of the walls and ceiling. The floor should, if possible, be carpeted.

TABLE I – *Main parameters of listening rooms for high-quality monophonic and stereophonic listening*
(See [CCIR, 1974-78d and e])

Parameters	Values
1. Volume (V)	$120 \pm 30 \text{ m}^3$ (1)
2. Optimum side ratio (central part of the Bolt range; other recommended ratios, see [CCIR, 1974-78c])	1.9 : 1.4 : 1.0
3. Reverberation time (T) (tolerance $\pm 0.05 \text{ s}$ in frequency range 125 to 6300 Hz about the chosen nominal value)	0.25 s ... 0.40 s
4. Optimum base angle	70°
5. Width of base (b)	3.0 to 4.5 m
6. Listening distance (h)	1.5 to 6.7 m preferable: $3 \pm 0.5 \text{ m}$
Optimum, i.e. reference listening point	$h \approx 0.7 b$

(1) 90 m^3 is allowed for monophonic use only.

Flutter echoes should be suppressed by means of sound absorbent and sound scattering objects randomly distributed on opposite parallel surfaces (see IEC draft Publication 268-13: Electro-acoustic (sound) system features. Part 13, Listening test on loudspeakers. Document IEC 29B (Secretariat) 162, January 1980).

2.3 At the Final Meeting, Geneva, 1981, the United Kingdom [CCIR, 1978-82c] informed on studies of their engineers, which differ partly from the opinions in Table I.

Accordingly, whilst the items in § 1.3 and Annex I should be regarded as necessary in the specification of the parameters for listening rooms, the following aspects also need to be taken into account:

- *Loudspeaker types*: given two acoustically identical rooms, significant differences in reproduced sound quality will occur if different types of loudspeakers are used in each room. Far from being susceptible to standardization, many of the factors giving rise to audible differences between loudspeakers have not yet been quantified. The position of the loudspeakers is also important.
- *Other variables*: other variables may also give rise to audible differences between nominally identical rooms. Most of these measurements have not been quantified to the degree necessary for laying down standards.

2.4 The Final Meeting of Study Group 10, Geneva, 1981, after examination of the newly presented documents [CCIR, 1978-82c and a], agreed that a satisfactory Recommendation on the acoustical properties of control rooms could not be drafted. It was decided to amend the title and the aim of the existing Report in such a way that each administration could consider whether the specification of a special listening room with uniform conditions, as a reference room should be attempted.

It is hoped that further contributions will be submitted which will make it possible to prepare such a Recommendation.

REFERENCES

BERANEK, L. L. [1957] Revised criteria for noise in building. *Noise Control*, Vol. 3, 1, 19-27.

CCIR Documents

[1974-78]: a. 10/60 (Canada); b. 10/356 (OIRT); c. 10/312 (U.S.S.R.).

[1978-82]: a. 10/207 (Canada); b. 10/8 (EBU); c. 10/196 (UK); d. 10/37 (OIRT); e. 10/44 (U.S.S.R.).

BIBLIOGRAPHY

LEBEDJEV, V. and RESVYAKOWA, Z. [1977] On the standardization of listening rooms. *Radio Telev.* (OIRT), 2, 15-24.

LOUDEN, M. M. [February, 1971] Dimension ratios of rectangular rooms with good distribution of eigenpoints. *Acustica*, Vol. 24, 2, 101-104.

ANNEX I

1. Reverberation time

Ideally, the reverberation time of listening rooms should be the same as the average of the best domestic listening conditions, so that the perceived sound is as those listeners with the best acoustic conditions would hear it. Work done some years ago [BBC, 1954] showed that such domestic conditions had a reverberation time of around 0.4 s, reasonably independent of the frequency. This work also concluded that for “diagnostic” listening, that is when the listener is attempting to analyse and possibly correct defects in the sound quality, a reverberation time of virtually zero enables differences to be perceived more easily, although it was found to be almost impossible to establish an order of preference under these conditions. The optimum reverberation time is, therefore, a compromise between these two factors (leaving aside the cost factors inherent in reducing the reverberation time to a very low value), and a reverberation time of about 0.3 s has been found satisfactory in the usual sizes of rooms.

In control rooms, the influence of the necessary apparatus such as equipment bays, tape and gramophone machines and particularly, the control desk and the observation window, may affect the value of the optimum reverberation time. For some years the average value of reverberation time in control rooms has been getting shorter and averages of about 0.2 s are now common. No significant number of specific complaints have been received about the acoustics being too “dead”. It therefore seems that the optimum reverberation time in control rooms is slightly shorter than in listening rooms. From the reports and complaints received, the average reverberation time is a much less sensitive parameter than the variation of reverberation time with frequency. The effect of a trend in the reverberation time as a function of frequency, such as a depression in the middle frequencies, can have a very significant effect. Over the range 160 Hz to 6.3 kHz, the reverberation time should not differ by more than $\pm 10\%$ from the design value. In addition, adjacent $\frac{1}{3}$ octave frequency bands should not differ by more than 10%.

2. Size of the room

The size of a control room will usually be dictated by the conflict between having sufficient space for acoustic reasons and for the necessary equipment and the cost of providing this space. Acoustically, it should be large enough to give closely spaced eigentones in the critical frequency range (up to about 300 Hz) [BBC, 1958].

In the case of listening rooms, there is more freedom of choice in the size of the room as the amount of equipment contained is generally small, although space and seating may have to be provided for a number of people. However, a listening room designed for just one or two people and very little equipment would generally be acoustically too small, resulting in prominent isolated room modes within the critical frequency range. In addition, the average reverberation time may be significantly affected by the number of room occupants unless the seating is permanent and of a type which has a similar sound absorption property whether occupied or not.

3. Shape of the room

The shape of the room, particularly of a small room, will undoubtedly give rise to acoustic problems if care is not taken to design the proportions correctly. This point is discussed in detail in [BBC, 1958] and the general results are summarised here. It was found that of the three types of possible room modes, only the axial modes, that is, those propagating normally between a pair of walls, are acoustically significant in the majority of cases. In small rooms (30 m³ to 120 m³) the reverberation time is so short that the effects of irregularities are manifest only in the frequency domain as colorations. Although a number of "optimum" ratios for the dimensions of rooms have been suggested, each case must be considered individually by listing the first few axial room modes (up to about 300 Hz) in order of frequency. The bandwidth of these modes is generally of the order of 10 to 20 Hz and any mode or group of modes separated from neighbouring modes by more than this amount can be regarded as isolated and the room dimensions should be altered so as to remove all isolated modes in the critical frequency range.

4. Diffusion

Ideally, the sound energy in a room should be perfectly diffuse but this characteristic becomes meaningless as the reverberation time is reduced to zero. Diffusion is almost impossible to measure absolutely and it is difficult to achieve this perfectly in practical rooms occupied by equipment and personnel. However, a reasonable degree of diffusion can usually be achieved. A rough guide to actual diffusion can be obtained from the spread of reverberation times at different measuring positions. There is no evidence that making the walls of the room non-parallel is more beneficial than other methods. The most practical method of diffusing the sound energy is by arranging the different types of acoustic treatment in relatively small patches, equally intermixed on the wall and ceiling surfaces.

5. Early reflections

Although it is relatively easy to measure, the average reverberation time is a poor guide to acoustic quality. Early reflections can significantly affect the perceived sound quality. At low and middle frequencies, the reflections from large surfaces near to the loudspeakers for example, the walls, sides of equipment bays and casing of ventilation trunking, can cause interference effects resulting in an acoustic response consisting of a series of regularly spaced maxima and minima. These effects are reduced by spacing the loudspeakers away from such surfaces and covering the surfaces with acoustic absorbers which are effective at low and middle frequencies.

At higher frequencies, direct specular reflections can occur from quite small areas, for example the faces of cable trunking, flush-faced lighting fittings and the top of the control desk. These types of reflections can be serious and all such surfaces must either be avoided (particularly vertical reflecting surfaces at the height of the head of the listener) or be covered with an acoustic absorber which is effective at high frequencies.

6. Background noise level

The background noise level should, ideally, be near to or at the threshold of hearing at all frequencies. However, the cost of providing suitable ventilation and low-noise equipment (such as tape recorders and gramophone turntables) and the noise made by the occupants of the room mean that less stringent criteria are unavoidable [BBC, 1980].

Whatever the actual internal background noise level, the sound insulation surrounding the room should reduce the interference from other areas to a level below that of the internal background noise of the room, in all frequency bands [BBC, 1981]. It is rarely sufficient to specify a single figure noise level, such as "A"-weighted, for these criteria. The cost implications of specifying an unnecessary low background noise level must include the consequences on the insulation requirements.

7. Room symmetry

All the above applies equally to both monophonic and multichannel operation. In addition, for stereo-phony the room should be symmetrical, both physically and acoustically, about the axis from the head of the listener to the mid-point between the loudspeakers. This requirement is so restrictive that it is rarely satisfied in practice in control rooms, but may be achieved in listening rooms. The main feature of control rooms which causes difficulties in this respect is the observation window. For symmetry, this can only be positioned between the loudspeakers. This restricts the field of view to less than 60° and is usually operationally unacceptable.

The requirement for acoustic symmetry should include all features of the room which have an acoustic effect. These particularly include the distribution of the acoustic treatment, the equipment, the doors and the windows.

8. Quality and position of the loudspeakers

The loudspeaker is probably the most important source of differences in auditive quality. Experienced listeners, familiar with the room in which they are working have a facility for ignoring or allowing for the acoustic effects of the room. Ideally, a loudspeaker should be acoustically transparent, that is, it should introduce nothing of its own to the sound quality. Such a loudspeaker has not yet been developed. Objective measurements on loudspeakers are limited to the free-field frequency response, both steady-state and measured with time as an additional variable. This second technique can be of assistance in identifying colorations. As loudspeakers are all imperfect, a judgement has to be made on which imperfections are the most objectionable. There is some evidence that, although within any one organization there is a preference for a characteristic loudspeaker sound, there are significant differences between organizations. These differences can account for a large part of the differences in sound quality when a programme made by one organization is reproduced by the equipment of the second organization. The only solution to this problem would be to standardise the kind of loudspeaker used – an obviously impracticable solution.

The position of a loudspeaker can significantly affect the perceived sound quality. For example, if a loudspeaker with a uniform free-field frequency response is placed near a corner of a room then at low frequencies where the loudspeaker is omni-directional, there will be an emphasis of the low frequencies because the loudspeaker is radiating into a smaller solid angle than that for which it was equalised. Also, it is impossible to space the loudspeaker so close to the wall as to avoid the interference effects described above (see § 5) unless it is built into the wall. However, placing the loudspeaker in the corner of a room will stimulate all of the room modes to an equal degree and thus reduce the probability of exciting a few isolated room modes. This second requirement is clearly in conflict with the first.

REFERENCES

- BBC [1954] The influence of listening conditions on the quality of reproduced speech. BBC Research Department Report 1954/27.
- BBC [1958] The acoustic design of talks studios and listening rooms. BBC Research Department Report 1958/28.
- BBC [1980] Revised background noise criteria for broadcasting studios. BBC Research Department Report 1980/8.
- BBC [1981] Revision of sound insulation requirements in studio centres. BBC Research Department Report 1981/1.

BIBLIOGRAPHY

- BBC [1958] Acoustics in the BBC. BBC Research Department Report 1958/29.
- BBC [1960] The influence of reverberation on the loudness of programmes. BBC Research Department Report 1960/16.
- BBC [1963] The influence of loudspeaker directivity and orientation on the effective audience area in 2-channel stereophonic reproduction. BBC Research Department Report 1963/1.

BBC [1967] The subjective significance of secondary reverberation. BBC Research Department Report 1967/58.

BBC [1969] The measurement of sound diffusion index in small rooms. BBC Research Department Report 1969/16.

BBC [1970] Permissible bass rise in talks studios. BBC Research Department Report 1970/10.

BBC [1974] The subjective performance of various quadraphonic reproduction systems. BBC Research Department Report 1974/29.

BBC [1974] Properties of hearing related to quadraphonic reproduction. BBC Research Department Report 1974/38.

REPORT 948

DIGITAL AUDIO TECHNIQUES FOR STUDIOS AND QUALITY MEASUREMENT

(Question 51/10, Study Programme 51B/10)

(1982)

This Report is intended to bring together information on digital audio techniques with the aim of making appropriate Recommendations in the next CCIR study period. At the Final Meetings of the CCIR Study Groups, 1981, two topics were considered: the interface used for digital audio equipment for broadcast use and methods of measuring the distortion caused by bit errors in a digital audio data-stream.

1. Studies on a standard digital audio interface for studios in broadcasting

There would be cost savings and simpler arrangements if there were a common data-frame used inside studios. The following proposal reflects the present status of studies by the EBU [CCIR, 1978-82a].

Significant features are (see Fig. 1):

- a two-channel format (believed to be the most useful for broadcasting studios); a single channel could occupy the frame with redundancy;
- a serial data-stream which is self-clocking (to reduce interconnection requirements);
- a major allocation of data for control purposes, which could also be used to extend the coding range/resolution of the signal, or other uses including error protection;
- the format is independent of the sampling frequency used; but, for example, if this were 32 kHz, the total bit rate would be 2048 kbit/s;
- a coding/resolution range of up to 20 bit/sample (and beyond by use of the auxiliary block).

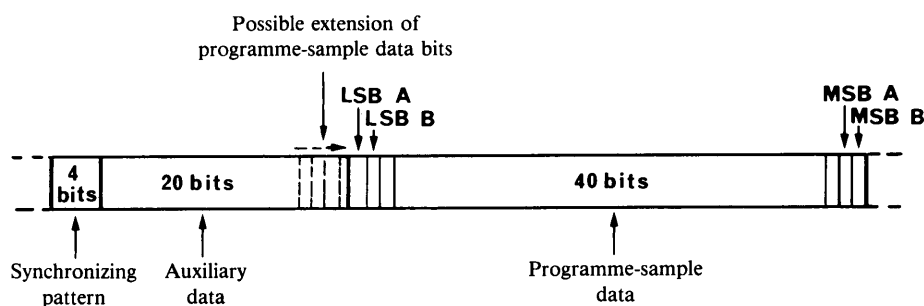


FIGURE 1 – Basic bit stream for two audio channels, A and B

MSB A } most significant bits when interface
MSB B } is used for two audio channels, A and B

LSB A } least significant bits when interface
LSB B } is used for two audio channels, A and B

The least significant bits are transmitted first to facilitate serial processing operations.

A four-frame repetition pattern for the synchronizing word is suggested as follows (see Fig. 2):

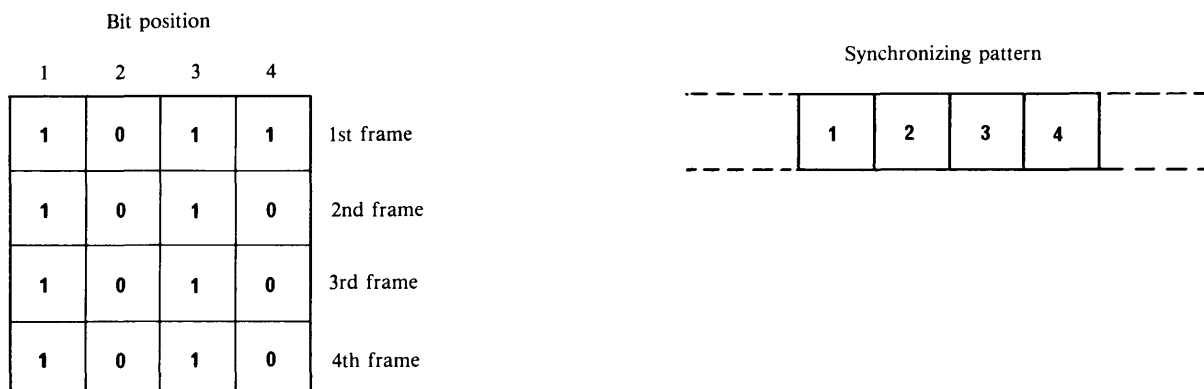


FIGURE 2

The channel coding would ideally have no d.c. components, and a practical choice would be bi-phase coding.

Administrations are requested to consider during the next study period any modifications or refinements which might make the interface suitable for world-wide adoption.

2. Methods for measuring distortion caused by bit errors

A bit error in a data-stream causes an interference pulse, and for linear (uniform) coding and magnitude depends only on where it occurs in the code group. However, when companding is used the audio signal itself has an effect on the magnitude, so in this case a method of measuring distortion in the presence of programme material is needed.

A method of this kind is applicable to both companded and linear systems; the major benefit in this latter case is that it allows measurements during the course of normal programme operations.

One method which is described in [CCIR, 1978-82b] suggests measuring the energy in a window above an audio band limit. Here the energy would be almost solely due to the interference pulses. For more complete details, see CMTT Report 968.

REFERENCES

CCIR Documents

[1978-82]: a. 10/190 (EBU); b. 10/191 (EBU).

REPORT 949

SAMPLING FREQUENCY FOR DIGITAL SOUND SIGNALS IN BROADCASTING STUDIOS

(Question 51/10, Study Programme 51B/10)

(1982)

1. Introduction

Study Programme 51B/10 recognizes the need of different sampling frequencies for studio, transmission and broadcasting applications.

This Report summarizes the information received on this subject. The text in Annex I could become a new Recommendation in future.

2. During the Final Meeting of CCIR, Geneva, 1981, Docs. [CCIR 1978-82a and b] were considered.

After discussion of the practical, theoretical and economical aspects of a common sampling frequency for the various applications in broadcasting studios, Study Group 10 decided to prepare a proposal for a draft Recommendation (Annex I) which is intended to stimulate further studies and contributions during the next CCIR study period.

REFERENCES

CCIR Documents

[1978-82]: **a.** 10/185 (Japan); **b.** 10/233 (Italy).

ANNEX I

The following text is proposed:

SAMPLING FREQUENCY FOR DIGITAL SOUND
SIGNALS IN BROADCASTING STUDIOS

The CCIR,

CONSIDERING

- (a) that the introduction of digital techniques in the studio for broadcasting applications should improve quality as well as operational facilities;
- (b) that there is a need to define a common sampling frequency for sound only and for sound accompanying a TV programme in studio applications;
- (c) that this sampling frequency should be simply related to 32 kHz sampling frequency recommended for transmission links (and for satellite broadcasting) in order to reduce the cost of transcoding equipment;
- (d) that it is advisable that this sampling frequency should allow an audio bandwidth nominally flat to 20 kHz which cannot be provided by the 32 kHz sampling frequency;
- (e) that the choice of a particular sampling frequency for general studio applications does not prejudice the use of different sampling frequencies for particular equipment or applications;
- (f) that for some of these particular applications, including consumer applications, further studies are being carried out in the framework of the IEC,

RECOMMENDS

1. that the sampling frequency for the digital encoding of sound signals in broadcasting studio applications including recording should have a nominal value of 48 kHz;
2. that the sampling frequency for the digital encoding of sound signals in television applications should have the same value.

REPORT 799-1 *

**SUBJECTIVE ASSESSMENT OF QUALITY OF SOUND IN
BROADCASTING USING DIGITAL TECHNIQUES**

(Question 51/10, Study Programme 51A/10)

(1978-1982)

1. Decision 18 co-ordinates the studies undertaken by the CCIR in the field of digital systems. It has allocated responsibility for the following studies to Study Group 10:
 - study of encoding methods (including reduction of redundancy), transmission over various transmission media (including methods of monitoring), measurement of operational quality and test signals; these studies should apply in the field of sound studio equipment (including recording) and sound broadcasting from terrestrial transmitters and satellites;
 - study of methods for protection against impairments associated with digital transmission in the field of sound studio techniques;

* This Report should be brought to the attention of Interim Working Party CMTT/1.

- study of the subjective quality of encoded and digitally transmitted signals for sound broadcasting;
- study of the problems of switching, mixing and special effects in sound studios.

2. During the Final Meeting (Geneva, 1977), the following documents were considered: [CCIR, 1974-78a, b, c, d, e and f].

These documents were studied by the CMTT but they did not provide a sufficient basis to formulate solutions to the problems given to Study Group 10 and listed above and also in Study Programme 51A/10. They have been used for information only.

Study Programme 51A/10, the aim of which is subjective assessment of the quality in digital sound broadcasting systems, should, in particular, provide an answer to the question raised by the CMTT, with regard to whether a subjective impairment of grade 4.5 is appropriate for a reference circuit including digital sections (Decision 18, Annex I; Report 647; [CCIR, 1974-78e]). The lack of detailed studies concerning the addition of the specific impairments associated with the digital systems does not, at the present time, make it possible to define a precise limit for the subjective impairment acceptable to the reference circuit.

Further studies are therefore necessary. They would allow definition of quality characteristics for intermediate or short distance transmission circuits (such as between production centres).

3. [CCIR, 1978-82a and b] report listening tests which have been carried out to determine the upper cut-off frequency of the audio signal. To reduce the bit rate, this frequency should be as low as possible without deteriorating the quality of the audio signal.

The result of these tests shows that, for the listener, a bandwidth of 15 kHz is sufficient and an extension of the frequency range up to 20 kHz gives an insignificant improvement in quality even taking into account future developments in sound systems because the result is related to the hearing ability of the listener.

REFERENCES

CCIR Documents

[1974-78]: a. 10/347 (Italy); b. 10/353 (EBU); c. 10/360 (France); d. 10/361 (France); e. CMTT/301 (Rev. 1); f. CMTT/349.
[1978-82]: a. 10/13 (EBU); b. 10/49 (Germany (Federal Republic of)).

BIBLIOGRAPHY

PLENGE, G., JAKUBOWSKI, H. and SCHÖNE, P. [1980] Which bandwidth is necessary for optimal sound transmission?
J. Audio Eng. Soc., Vol. 28, 3, 114-120.

REPORT 953

DIGITAL CODING FOR THE EMISSION OF HIGH-QUALITY SOUND SIGNALS IN SATELLITE BROADCASTING (15 kHz NOMINAL BANDWIDTH)

(Question 51/10, Study Programmes 51C/10, 2F/10 and 11)

(1982)

This text may be found in Part 2 of Vol. X and XI.

SECTION 10D: RECORDING OF SOUND PROGRAMMES

Recommendations and Reports

RECOMMENDATION 407-2

INTERNATIONAL EXCHANGE OF RECORDED SOUND PROGRAMMES

(Question 52/10)

(1951-1953-1956-1959-1963-1966-1970)

The CCIR

UNANIMOUSLY RECOMMENDS

that the international exchange of recorded sound programmes, both monophonic and stereophonic, between broadcasting organizations should be by means of:

1. magnetic recording on tape as specified in Recommendation 408;
2. recording on discs of Types III, IV, V and VI as specified in the current edition of IEC Publication 98.

RECOMMENDATION 408-4 *

STANDARDS OF SOUND RECORDING ON MAGNETIC TAPE
FOR THE INTERNATIONAL EXCHANGE OF PROGRAMMES

(Question 52/10, Study Programme 52A/10)

(1951-1953-1956-1959-1963-1966-1970-1974-1982)

THE CCIR

UNANIMOUSLY RECOMMENDS

that monophonic and stereophonic recordings on magnetic tape for the international exchange of programmes should be made in accordance with the current edition of IEC Publication 94, and amendments thereof, with the following additional requirements:

1. **Speed of tape**

Only two speeds should be used: 38.1 cm/s (15 in./s) nominal value
19.05 cm/s (7½ in./s) nominal value.

2. **Width of tape**

$$6.3 \text{ mm } \begin{matrix} +0 \\ -0.06 \end{matrix} \left(0.248 \text{ in. } \begin{matrix} +0 \\ -0.003 \end{matrix} \right)$$

3. **Strength of tape**

The tape should be suitable for use on a machine exerting a maximum (transient) stress of 10 N.

4. **Maximum diameter of a full spool**

For Type I: 290 mm (11.5 in.)
(In France, the maximum diameter is 270 mm)
For Type II: 267.5 mm (10.5 in.).

* This Recommendation should be brought to the attention of the International Electrotechnical Commission (IEC).

5. Additional information on the tape container

MONO or STEREO in Latin characters.

Width of track. (For stereophony only.)

MAXIMUM RECORDED LEVEL (in nWb/m).

6. Additional requirements for stereophonic recordings

The minimum width of a recorded track should be 2 mm.

The outside limits of both tracks should coincide with the edges of the tape.

The distance between the tracks, situated symmetrically with respect to the central axis of the tape should be at least 0.75 mm. (The central axis is defined as a line situated at a distance of 3.125 mm from the reference edge.)

The edge of Track No. 1 is taken as the reference edge.

7. Beginning of a programme

The programme material should be preceded by a reference signal of 1000 Hz recorded at a level of 9 dB below maximum permitted programme peaks.

On monophonic tapes, this reference signal should have a duration of about 10 s, with a pause of about 5 s before the start of the programme modulation.

On stereophonic tapes, this reference signal should be recorded in the *A*-(left) channel for about 5 s, then in both channels for about 10 s, with a pause of about 5 s before the start of the programme modulation.

Note. — The recording of the reference signal in both channels may be followed by the recording of a signal for testing frequency response and phase, in accordance with Report 622.

8. For reference purposes, a hypothetical recording-duplicating chain is specified. It is expected that exchanged recordings will be made by using a chain similar to the hypothetical reference recording-duplicating chain here described.

The hypothetical reference recording-duplicating chain consists of a master recorder and the duplicating replay-recorder equipment. The input of the recording-duplicating chain is the input of the master recorder. The output of the recording section of the duplicating equipment, i.e. the short-circuit flux of the magnetic tape for the exchange, is the output of the recording-duplicating chain.

The preferred performance characteristics of the hypothetical reference recording-duplicating chain are detailed hereunder.

8.1 *Amplitude/frequency response of the two channels **

The tolerances on the amplitude/frequency response of the two channels *A* and *B* shall be as follows:

40	to 125 Hz	: +2	to -3	dB
125	to 630 Hz	: +1	to -1	dB
630	to 1250 Hz	: +0.5	to -0.5	dB
1250 Hz	to 10 kHz	: +1	to -1	dB
10	to 15 kHz	: +2	to -3	dB.

8.2 *Difference in recorded level between tracks **

In the frequency range of 125 to 10 000 Hz, a difference in level of 1.5 dB is admissible. Beyond these limits, a progressive increase up to 2 dB is admissible at 40 and 16 000 Hz.

8.3 *Phase difference between tracks **

In the frequency range from 250 to 4000 Hz, the maximum phase difference should be 15°. Outside these frequency limits, a progressive increase of this value is admissible; it can reach 30° at 40 Hz and 65° at 16 000 Hz.

* For the special case of quadraphonic matrix recording, stricter specifications may be required, particularly in level and phase differences between tracks.

8.4 *Crosstalk*

In the frequency range from 250 to 4000 Hz, crosstalk should not exceed -35 dB. Outside these frequency limits, a progressive increase up to -20 dB at 40 Hz and -25 dB at 16 000 Hz is admissible.

8.5 *Weighted signal-to-noise ratio*

The weighted signal-to-noise ratio of the *A*, *B* and *M* signals should be at least 51 dB.

Note. — This value represents the difference in level between the noise measured with the meter and weighting network defined in Recommendation 468 and a signal, the amplitude of which corresponds to the maximum level of programme peaks indicated.

8.6 *Non-linearity distortions*

The total percentage harmonic distortion of the *A*, *B* and *M* signals should be less than or equal to the following values:

- 2% from 40 Hz to 125 Hz
- 1.6% from 125 Hz to 8 kHz.

REPORT 800

STANDARDS OF SOUND RECORDING ON MAGNETIC TAPE FOR THE INTERNATIONAL EXCHANGE OF PROGRAMMES

Recording-duplicating chain for the production of sound programmes

(Question 52/10, Study Programme 52A/10)

(1978)

1. Introduction

[CCIR, 1974-78a] and [CCIR, 1974-78b] report studies carried out to specify more exactly the standards for international exchange of programmes on tape.

The above documents propose that Recommendation 408 should specify the technical requirements of the "recording-duplicating chain", used for the production of monophonic and stereophonic sound programmes for international exchange.

2. Description of recording-duplicating chain

The recording-duplicating chain consists of a master recorder and the duplicating replay-recorder equipment. The input of the recording-duplicating chain is the input of the master recorder. The output of the recording section of the duplicating equipment, i.e. the short-circuit flux of the magnetic tape for the exchange, is the output of the recording-duplicating chain.

3. Measuring the characteristics of the recording-duplicating chain

The chain should be considered as a complete system. The chain's overall characteristics are measured by feeding electronic test signals to the input of the reference recorder and measuring the output tape recording produced by the duplicating equipment. This measurement is carried out by means of a test reproducing chain. The amplitude/frequency response of the chain should conform to that of the reproduction chain characteristic for professional equipment as specified in IEC Publication 94.

The performance characteristics of the test reproducing chain should be good enough not to introduce significant distortion into the measurement.

4. Administrations are invited to consider the usefulness of these new concepts.

REFERENCES

CCIR Documents

[1974-78]: a. 10/43 (OIRT); b. 10/254 (U.S.S.R.).

REPORT 622-2

**SOUND RECORDING ON MAGNETIC TAPE
FOR THE INTERNATIONAL EXCHANGE OF PROGRAMMES**

**Use of special section for checking the technical
parameters of stereophonic tapes**

(Question 52/10, Study Programme 52A/10)

(1974-1978-1982)

1. Extensive studies carried out in the OIRT, in Australia and some other countries have shown that the quality of the international exchange of programmes recorded on stereophonic tapes can be improved, if the recordings have at the beginning a special section containing alignment test signals.

2. It is advisable from the point of view of the OIRT [CCIR, 1978-82], that such a special section contains alignment test signals as described in Table I, so that each tape will contain, in the following order (see Fig. 1):

2.1 the tape identification strip for the beginning of the tape, as specified in IEC Publication 94; the leader should preferably be coloured or annotated;

2.2 a special section for the alignment of the reproducing equipment, recorded under the same conditions as those applying to the programme itself. For this purpose, sinusoidal test signals, identical in phase, should be fed to the inputs of both recording channels.

In general, these test signals will be generated electronically and recorded directly onto the master copy * of the programme intended for international exchange. This section consists of three parts as listed in Table I.

2.3 A second leader for stereophonic recordings following the special alignment section, for operational purposes:

2.4 the stereophonic programme section of the tape;

2.5 the red identification strip marking the end of the tape (as specified in IEC Publication 94, Third Edition 1978).

3. Further studies are necessary so that during the next period a special section with uniform levels can be recommended which will allow § 7 of Recommendation 408 to be replaced.

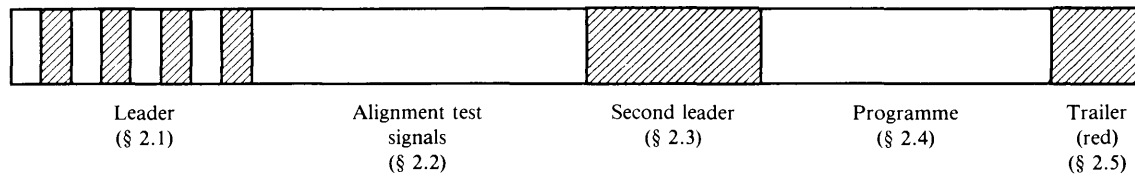
TABLE I – *Special section*

Recorded signal	Frequency (Hz)	Level ⁽¹⁾ (⁽²⁾ (dB)	Duration (s)	Channel
1. Signal for testing, or adjusting, level and balance of channels	1000	– 10	10 $\begin{pmatrix} +1 \\ -0 \end{pmatrix}$	A, B
2. Signal for testing frequency response and phase	40	– 10	5 $\begin{pmatrix} +1 \\ -0 \end{pmatrix}$	A, B
	10 000	– 10	10 $\begin{pmatrix} +1 \\ -0 \end{pmatrix}$	A, B

(1) According to the present practice in the OIRT, this is 10 dB below the nominal value of the maximum recorded level.

(2) [CCIR, 1974-78] proposes that these test tone levels should be in accordance with CCITT practice (CCITT Recommendation N.13, Geneva, 1981).

* *Master copy*: in the assembly of a recorded programme by editing techniques, the first tape produced which contains all the intended programme durations and sequences.

FIGURE 1 – *Different parts of a tape*

REFERENCES

CCIR Documents

[1974-78]: 10/351 (Australia).

[1978-82]: 10/34 (OIRT).

REPORT 950

DIGITAL RECORDING OF AUDIO SIGNALS

(Question 52/10, Study Programme 52B/10)

(1982)

1. Introduction

Two elements must be defined when specifying a digital audio magnetic tape recorder: the digital audio interface standard used at the recorder input and output, and the recording standard.

1.1 The digital audio interface used at the recorder input and output should conform with the digital audio interface to be adopted by the CCIR for digital audio studio equipment.

1.2 The recording standard includes the specification of the tape format, including channel coding, modulation methods, the error protection system and the distribution of the recorded signals on the surface of the tape.

Contributions are invited, particularly on the problems connected with the definition of the recording standard, including those associated with the provision of necessary operational facilities.

2. Systems under investigation

In [CCIR 1978-82], basic parameters for digital sound recording, as used in an experimental stationary-head magnetic tape recorder at NHK are described. The NHK equipment had four channels: two digital audio channels derived from eight magnetic tracks, one auxiliary analogue audio channel and one time and control code channel. The audio bandwidth was 20 kHz in the digital channels, and the signals were uniformly quantized with 16-bit encoding. A sampling frequency of 50.4 kHz was used in the prototype equipment. It was subsequently acknowledged, however, that this sampling frequency might not be compatible with other classes of service that might use sampling frequencies of 32 or 48 kHz. The equipment required redundancy of about 30% of the total channel capacity for error correction and synchronization codes.

REFERENCES

CCIR Documents

[1978-82]: 10/185 (Japan).

RECOMMENDATION 564 *

**USE OF MAGNETIC TAPE CARTRIDGES AND CASSETTES
FOR SOUND BROADCASTING**

(Question 52/10, Study Programme 52A/10)

(1978)

The CCIR,

CONSIDERING

- (a) That the cartridge **, an endless loop device, is mainly used for broadcasting short sequences, for example, station identification, or for short and medium programme inserts;
- (b) that the cassette, as standardized in IEC Publication 94A, is in increasing use in outside-broadcast applications;
- (c) that pre-recorded cassettes of this type are commercially available and broadcasting organizations will need equipment to reproduce them;
- (d) that there is growing interest among broadcasters to have available a special professional cassette-system that could provide a quality and playing time comparable to the present reel-to-reel standards (Recommendation 408); such a cassette could use a tape of nominal width of 6.25 mm, but transported at a speed lower than 19.05 cm/s (7.5 in/s);
- (e) that it is desirable that the dimensions and characteristics of this professional cassette-system should be standardized,

UNANIMOUSLY RECOMMENDS

1. that, at the present time and for internal operation, only cartridges and cassettes as standardized by the IEC should be used; they should not be used for the international exchange of programmes, except by mutual agreement;
2. that a future professional cassette should use a tape of nominal width of 6.25 mm transported at a speed of 9.5 cm/s (3.75 in/s). The cassette should use the full tape width for one programme *** only and have a playing time capability of up to 30 minutes.

RECOMMENDATION 563

**MEASUREMENT OF THE CHARACTERISTICS OF SOUND SIGNALS
RECORDED ON MAGNETIC TAPE**

(Question 52/10, Study Programme 52A/10)

(1978)

The CCIR

UNANIMOUSLY RECOMMENDS

that the short-circuit flux per unit track width should be used in accordance with the recommendations of IEC Publication 94, for measuring the characteristics of sound signals recorded on magnetic tape.

* This Recommendation replaces Report 467, which is hereby cancelled. The Director, CCIR, is requested to draw the attention of the IEC to this Recommendation.

** This cartridge is now being standardized in IEC and will be the subject of Publication 94-5, part 4.

*** The programme consists of one monophonic or two stereophonic tracks and possibly one cue track.

RECOMMENDATION 409-3

**MEASUREMENT OF WOW AND FLUTTER IN RECORDING EQUIPMENT
AND IN SOUND REPRODUCTION**

(Study Programme 52A/10)

(1956-1963-1966-1970-1978)

The CCIR

UNANIMOUSLY RECOMMENDS

that the method of measurement of wow and flutter in recording equipment and in sound reproduction should be in accordance with IEC Publication 386.

REPORT 468-2

**METHODS OF SYNCHRONIZING VARIOUS RECORDING
AND REPRODUCING SYSTEMS**

(Questions 18/10 and 40/11)

(1970-1974-1978-1982)

This report is published in Vol. XI

PAGE INTENTIONALLY LEFT BLANK

PAGE LAISSEE EN BLANC INTENTIONNELLEMENT

SECTION 10E: BROADCASTING SERVICE (SOUND) USING SATELLITES

The texts will be found in Part 2 of Vol. X and XI.

QUESTIONS AND STUDY PROGRAMMES, RESOLUTIONS, OPINIONS AND DECISIONS

QUESTION 44/10 *

LF, MF, AND HF SOUND BROADCASTING

(1982)

The CCIR,

CONSIDERING

- (a) that any sound broadcasting system should specify the essential emission and reception characteristics taking into account the effects of propagation;
- (b) that the system, or systems, chosen should permit efficient use of the frequency bands available, whilst maintaining reasonable receiver costs;
- (c) that apart from the double-sideband amplitude-modulation system, other systems may be used;
- (d) that sky-wave and/or ground-wave reception may be required;
- (e) that the WARC-79, in its Resolutions and Recommendations, invited the CCIR to study this problem, with specific reference to:

- *Resolution No. 508*: Convening of a World Administrative Radio Conference (HF broadcasting planning);
- *Recommendations*:

No. 8: Automatic identification of stations,

No. 64: Protection ratios and minimum field strengths required in the various services,

No. 69: Frequency tolerances of transmitters,

No. 70: Studies of the technical characteristics of equipment, bandwidths and channel spacing,

No. 500: Preparation of technical information for the WARC (HF broadcasting),

No. 501: Introduction of single-sideband techniques in the HF broadcasting bands in preparation for the WARC (HF broadcasting),

No. 503: Studies of “out-of-band spectrum” in the HF bands,

No. 504: Preparation of broadcasting plans for the band 1605 to 1705 kHz in Region 2,

with a view to presenting the results of the studies to the World Administrative Radio Conference (HF broadcasting planning), 1984, and the Regional Administrative Radio Conference (broadcasting in the band 1605 to 1705 kHz in Region 2), 1986;

- (f) that the band 1625 to 1705 kHz is allocated on a shared basis to sound broadcasting in Region 2,

UNANIMOUSLY DECIDES that the following question should be studied:

1. what sound broadcasting systems should be standardized;
2. what should be the characteristics of these systems with respect to:
 - the emission (type of modulation, audio-frequency bandwidth and necessary bandwidth of emission, dynamic compression, pre-emphasis, limiting, channel spacing, etc.);
 - reception (principle of demodulation, audio-frequency response, dynamic expansion, de-emphasis, intermediate frequency, etc.);
 - the transmission of supplementary information;

* Formerly Question 25/10.

3. should a system differing from the present system be chosen, what are the consequences resulting from that choice during any transition period on:

- existing receivers;
- receivers constructed in conformity with the new system;

4. what are the criteria for sharing between sound broadcasting and other services?

Note. — See Reports 299, 457, 458, 461, 616, 619 and Recommendations 205, 410, 411, 498, 499, 597, 598.

STUDY PROGRAMME 44A/10 *

PROTECTION RATIOS IN LF, MF AND HF BROADCASTING

(1982)

The CCIR

UNANIMOUSLY DECIDES that the following studies should be carried out:

the determination of radio-frequency protection ratios under conditions which take account simultaneously of the following items, which may vary independently of each other:

1. **Fading** (see Study Programme 44C/10);
 - 1.1 wanted signal and unwanted signal stable; **
 - 1.2 wanted signal stable, and unwanted signal fluctuating; **
 - 1.3 wanted signal and unwanted signal fluctuating; **
 - 1.4 wanted signal fluctuating and unwanted signal stable; **
2. **Frequency separation** from 0 to 30 kHz between the wanted and unwanted carrier;
3. **Broadcasting programmes**
 - 3.1 wanted and unwanted signals modulated with the same programme; **
 - 3.2 wanted and unwanted signals modulated with different programmes; **
4. **Class of emission** (the characteristics should be stated in each case)
 - 4.1 double-sideband amplitude modulation:
 - 4.1.1 with current-type receivers;
 - 4.1.2 with receivers with characteristics adapted to the defined double-sideband transmission;
 - 4.2 single-sideband or vestigial-sideband, including compatible single-sideband modulation; ***
 - 4.2.1 with current-type receivers;
 - 4.2.2 with receivers specially adapted to the system considered;
 - 4.3 any other class of emission;

* Formerly Study Programme 25A-1/10.

** Tests should also be made with several unwanted signals.

*** A transmission is said to be "compatible" if it can be received on an existing conventional receiver, without any modification whatsoever to the receiver, and then gives a quality of reception at least as satisfactory as that obtained at present in a double-sideband system.

4.4 coexistence of two systems as follows:

TABLE 1

Wanted emission	Unwanted emission
Double-sideband amplitude-modulation Class of emission as under §§ 4.2 or 4.3	Class of emission as under §§ 4.2 or 4.3 Double-sideband amplitude-modulation

5. frequency band (5 (LF), 6 (MF) or 7 (HF));
6. minimum usable field strength;
7. modulation processing (compression and pre-emphasis);
8. necessary bandwidth.

Note 1. — See also Recommendation 560, Annex II.

Note 2. — See Reports 457, 516, 794, 798 and Recommendations 447, 559, 560, 597.

STUDY PROGRAMME 44B/10 *

MINIMUM USABLE FIELD STRENGTH IN LF, MF AND HF BROADCASTING

(1982)

The CCIR

UNANIMOUSLY DECIDES that the following studies should be carried out:

the minimum usable field strength for broadcasting in bands 5 (LF), 6 (MF) and 7 (HF), taking account of:

- the characteristics of the system;
- whether ground-wave or sky-wave reception is envisaged;
- atmospheric noise;
- man-made noise.

Note. — See Recommendation 499.

* Formerly Study Programme 25C-1/10.

STUDY PROGRAMME 44C/10 *

SKY-WAVE RECEPTION IN LF, MF AND HF BROADCASTING

(1982)

The CCIR

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the nature of the distortion due to the effects of the ionosphere at distances beyond the ground-wave coverage area;
2. the degradation of the subjective quality of the sky-wave signal when received beyond the limit of the ground-wave coverage area, according to the system envisaged and as a function of distance and other possible factors, such as the geographical location of the transmitter, the frequency, the season of the year and the characteristics of the transmitting antenna;
3. the degree of distortion for a given percentage of time that would, after demodulation at the receiver, provide satisfactory sky-wave reception;
4. the reduction in distortion, due to the effects of the ionosphere, that can be secured by improvements in methods of reception, for example, replacing envelope detectors by other detection devices.

Note 1. — See also Study Programme 44D/10.*Note 2.* — See Report 619.

STUDY PROGRAMME 44D/10 **

REDUCTION OF SKY-WAVE IN MF BROADCASTING

(1982)

The CCIR,

CONSIDERING

- (a) that, under certain circumstances, a substantial reduction in the field strength of sky-wave transmission in band 6 (MF) is produced by transmitting an elliptically polarized wave in a manner referred to as orthogonal transmission (see Note 1);
- (b) that this type of transmission is expected to reduce sky-wave interference and to extend the primary coverage area of broadcasting stations restricted by fading, due to such interference;
- (c) that these improvements may be produced without altering the horizontal radiation pattern of the transmitting antenna;
- (d) that more transmitter power than that at present employed at night is required to operate this system;

Note 1. — Orthogonal transmission refers to a system in which the radiated waves are polarized for maximum ionospheric absorption (see Report 431, Vol. VI and with respect to ionospheric cross-modulation, Study Programme 44E/10),

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the improvement in reception which can be obtained with orthogonal transmission, and the extent to which it depends on:
 - 1.1 the transmission frequency relative to the gyro-frequency;
 - 1.2 the magnetic dip between the mid-point of the path and the transmitter;

* Formerly Study Programme 25D-1/10.

** Formerly Question 11-2/10.

- 1.3 the magnetic bearing of the path;
- 1.4 the distance;
- 2. the types of transmitting antennas which can be used;
- 3. the effect of time of day, season and sunspot cycle.

Note 2. — See Report 461.

STUDY PROGRAMME 44E/10 *

**IONOSPHERIC CROSS-MODULATION — LIMITATION OF RADIATED
POWER IN LF AND MF BROADCASTING**

(1982)

The CCIR,

CONSIDERING

that ionospheric cross-modulation and, consequently, harmful interference can result from excessive radiation towards the ionosphere,

UNANIMOUSLY DECIDES that the following studies should be carried out:

the maximum permissible radiated power in bands 5 (LF) and 6 (MF), as a function of the angle of elevation, to ensure that the effects of ionospheric cross-modulation are not disturbing.

Note 1. — See Study Programmes 44D/10 and 44G/10.

Note 2. — See Recommendation 498.

STUDY PROGRAMME 44F/10 **

COVERAGE IN LF, MF AND HF BROADCASTING

(1982)

The CCIR

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the dependence of ground-wave and sky-wave sound broadcasting coverage on:
 - the characteristics of the system;
 - the radio-frequency protection ratios;
 - the channel spacing;
 - the minimum usable field strength;
 - the radiated power;
 - the geographical distribution of the transmitters;
 - the distribution of population density;
 - the use of directional transmitting antennas;
 - the use of groups of synchronized transmitters;

for bands 5 (LF), 6 (MF) and 7 (HF);

2. methods for calculating the minimum number of channels required for the coverage for broadcasting in bands 5 (LF) and 6 (MF), for each of the systems envisaged, taking into account the points listed under § 1 above and the possibility of using computers.

* Formerly Study Programme 25E-1/10.

** Formerly Study Programme 25F-1/10.

Note 1. — The results of Study Programmes 44A/10, 44B/10, 44C/10 and 44E/10 and the propagation data worked out by Study Groups 5 and 6 should be taken into account.

Note 2. — See Report 616 and Recommendation 598.

STUDY PROGRAMME 44G/10 *

TRANSMITTING ANTENNAS IN LF AND MF BROADCASTING

(1982)

The CCIR,

CONSIDERING

- (a) that there is a general tendency to increase the size of the coverage area of broadcasting transmitters operating in bands 5 (LF) and 6 (MF) by increasing the transmitter power;
- (b) that, especially with high-power transmitters, it is preferable to increase the size of the coverage area by the use of high-efficiency antennas, especially when the size of the coverage area is limited by interference between the sky- and the ground-waves,

UNANIMOUSLY DECIDES that the following studies should be carried out:

the types of antennas that can be used in practice, to increase the area covered either by the ground-wave or the sky-wave, taking into account the effects of the E and F regions of the ionosphere.

Note. — See Report 401.

STUDY PROGRAMME 44H/10 **

DIRECTIONAL ANTENNAS IN HF BROADCASTING

(1982)

The CCIR,

CONSIDERING

- (a) the extensive and increasing use of highly directional antenna systems for broadcasting in band 7 (HF);
- (b) that the use of appropriate and well-designed directional antenna systems can lead to improved coverage and reduced interference;
- (c) that such antenna systems can produce strong subsidiary radiation lobes, particularly when fed asymmetrically to produce a horizontal slew of the main beam;
- (d) the need to share frequencies wherever possible to permit the most efficient use of the broadcasting bands in band 7 (HF);
- (e) that the WARC-79, in its Resolutions and Recommendations, invited the CCIR to study this problem, with specific reference to:
 - *Resolution No. 508*: Convening of a World Administrative Radio Conference (HF broadcasting planning);
 - *Recommendation No. 500*: Preparation of technical information for the WARC (HF broadcasting planning);
 with a view to presenting the results of these studies to the World Administrative Radio Conference for HF broadcasting planning, 1984,

* Formerly Question 13/10.

** Formerly Question 14-1/10.

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the type of directional antennas most suitable for use for broadcasting in band 7 (HF) and their influence on coverage and interference;
2. the methods whereby the formation of strong subsidiary radiation lobes can be avoided, particularly when directional antenna systems are operated in the slewed condition;
3. the extent to which the theoretical protection can be obtained in practice when using the usual types of directional antenna systems.

Note 1. — It is suggested that field-strength measurements should be obtained to verify the nominal gain in the main beam and the validity of Recommendation 80.

Note 2. — Tests should be arranged in such a way as to eliminate to the greatest possible extent the effects of changing ionospheric conditions.

Note 3. — See Report 32 and Recommendations 80, 414.

STUDY PROGRAMME 44J/10

TRANSMISSION OF SUPPLEMENTARY INFORMATION IN AMPLITUDE MODULATION SOUND BROADCASTING

(1982)

The CCIR,

CONSIDERING

- (a) that, in addition to the normal sound programme, it is technically possible to transmit supplementary information in an amplitude-modulation sound-broadcasting channel;
- (b) that such supplementary signals can have various applications, having no direct relationship to the normal sound programme;
- (c) that the systems used must be compatible with existing services,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. possible applications for the supplementary signals in the various frequency bands, band 5 (LF), band 6 (MF) and band 7 (HF);
2. characteristics of the supplementary transmission channel, such as: information rate, access time, acceptable error rate, coverage compared to that of the normal programme;
3. usable transmission systems; in particular, type of modulation, methods of demodulation and methods of error detection and/or correction;
4. compatibility with existing broadcasting services, notably increases in interference and application to synchronized networks.

STUDY PROGRAMME 44K/10

SINGLE-SIDEBAND (SSB) SYSTEM FOR BROADCASTING (HF)

(1982)

The CCIR,

CONSIDERING

- (a) that the application of single-sideband technique allows for more efficient utilization of the radio spectrum;
- (b) Recommendation No. 501 of the WARC-79,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. specifications of the technical characteristics of a single-sideband HF sound-broadcasting system (see Report 458);
2. the economies in spectrum utilization to be expected from the use of SSB in HF sound broadcasting;
3. the technical and economic problems concerning transmitters and receivers that can arise with the introduction of single-sideband technique in the HF bands allocated to broadcasting.

Note. — Some of the technical studies required for the transition period when both SSB and DSB systems will be in operation include the following:

- channel spacing;
- co-channel and relative radio-frequency protection ratios;
- equivalent sideband power;
- SSB carrier reduction;
- receiver compatibility;
- statistical characteristics of the SSB signal, in particular the spectral distribution of energy.

STUDY PROGRAMME 44L/10

SYNCHRONIZED TRANSMITTERS IN HF SOUND BROADCASTING *

(1982)

The CCIR,

CONSIDERING

- (a) that the use of synchronized-frequency transmitter operation is likely to lead to improved efficiency in the use of the spectrum;
- (b) that improved knowledge of these techniques is of importance to the World Administrative Radio Conference for HF broadcast planning, 1983,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the technical conditions under which synchronized transmitters (i.e. on the same frequency and modulated by the same programme) may be used for sound broadcasting in band 7 (HF);
2. the extent to which the coverage areas of synchronized transmitters may overlap in practice;
3. the combination(s) of suitable types of antennas that may be used for synchronized operation.

STUDY PROGRAMME 44M/10 **

COMPATIBILITY BETWEEN THE MF SOUND-BROADCASTING SERVICE AND OTHER SERVICES USING THE SAME BAND

(1982)

The CCIR,

CONSIDERING

- (a) that the WARC-79 allocated the band 1605 to 1625 kHz exclusively and the band 1625-1705 kHz on a shared basis to sound broadcasting in Region 2;
- (b) that these bands are allocated to the fixed, mobile, radiolocation, and radionavigation services in Region 3 and to some of these services in Region 1;

* See Recommendation 205.

** This Study Programme should be brought to the attention of Study Groups 3 and 8.

(c) that in its Recommendation No. 504, WARC-79 invited the CCIR to perform the necessary studies for sharing criteria,

UNANIMOUSLY DECIDES that the following studies should be carried out:

the criteria for sharing between the sound-broadcasting service and the following services:

- the fixed and mobile services operating in the same or another Region;
- the radiolocation service operating in other Regions;
- the radionavigation service operating in Region 3.

QUESTION 45/10

SOUND BROADCASTING IN THE TROPICAL ZONE *

(1982)

The CCIR

UNANIMOUSLY DECIDES that the following question should be studied:

what are the preferred characteristics of amplitude modulation sound-broadcasting services operating in the Tropical Zone?

Note. — See Reports 302, 303, 304, 472 and Recommendations 48, 49, 139, 215, 216.

STUDY PROGRAMME 45A/10 **

SHORT-DISTANCE BROADCASTING IN BAND 7 (HF) IN THE TROPICAL ZONE

(1982)

The CCIR,

CONSIDERING

- (a) that few data exist on the determination of the power required for a given grade of short-distance broadcasting service (defined in Annex I) in the Tropical Zone;
- (b) that it would be helpful in the planning of new broadcasting services in the Tropical Zone to have more reliable data;
- (c) that more reliable data would be helpful in the organization of services in the bands shared with broadcasting in the Tropical Zone (see No. 2669 of the Radio Regulations),

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the experimental determination of the signal-to-noise ratio and the radio-frequency wanted-to-interfering signal ratio that should be adopted as representative of an acceptable broadcasting service in the Tropical Zone. The observations should be made with antennas and receivers that are representative of those normally used for broadcasting reception in the Tropical Zone. The reports on this study should be made in conformity with Recommendation 560, Annex II.

2. a practical examination of whether the power limits in Recommendation 215 are satisfactory or whether they should be changed to give an acceptable broadcasting service in the Tropical Zone. The reports on this study should include all the relevant factors concerned and, in particular, information on the following points:

- the area and the hour, day, month and year for which observations are made;
- the distance from the transmitter to the point of observation;

* See No. 2668 of the Radio Regulations.

** This Study Programme replaces Study Programme 27A-1/10.

- the carrier power of the transmitter and its depth of modulation;
- the details of the transmitting and receiving antennas;
- the characteristics of the receiver used.

Information on the signal-to-noise ratio and the radio-frequency wanted-to-interfering signal ratio (if possible in a statistical form) would also be helpful (see also § 1 above). Any conditions peculiar to the area concerned and which have an important bearing on the transmitted power required, should also be stated;

3. the study of natural noise in the Tropical Zone, with particular reference to broadcasting conditions. The aim should be to provide noise data (in a statistical form if possible), which could be used in problems concerning the field strength or radiated power required to produce a given grade of broadcasting service. The method of measurement used should be clearly defined, particularly as concerns the bandwidth of the measuring equipment. Particular attention should be paid to those frequency bands allocated to broadcasting below 16 MHz, which could be used for broadcasting in the Tropical Zone, and also, to the normal broadcasting listening hours (approximately 0600 to 2400 h local time);

4. study of the field strength produced by broadcasting transmitters in the Tropical Zone. Reports should, if possible, be evaluated on a statistical basis, and should give, in particular, the following information:

- method of measurement employed;
- methods of analysis;
- location of the transmitter;
- distance from the transmitter at which measurements are made;
- radiated carrier power;
- polar diagram of the transmitting antenna (or equivalent data);
- period during which measurements are made;
- radio-frequency used.

It might be convenient to carry out this study in conjunction with those outlined in §§ 1 and 2 above. If it is possible to make measurements of the field strength produced outside the coverage area of the tropical broadcasting station, the resulting information would also be helpful in determining the degree of interference produced to other services which share frequency bands with broadcasting in the Tropical Zone.

ANNEX I

A short-distance broadcasting service in band 7 (HF) is an indirect-ray service in which the incident ray meets the reflecting layer at a considerable angle to the horizontal and there is no appreciable skip distance between the transmitter and the coverage area. Technically, the outer limit of a short-distance service is considered as being 800 km.

(Taken from former Question 27, which was terminated in 1951 by Recommendation 84, subsequently replaced in 1956 by Recommendation 215.)

Note. – See also Recommendations 48, 49, 214, 216.

STUDY PROGRAMME 45B/10 *

FADING CHARACTERISTICS OF SOUND BROADCASTING IN THE TROPICAL ZONE

(1982)

The CCIR,

CONSIDERING

- (a) that Study Programme 1A/3 concerns allowances for the protection of fading signals in general;
- (b) that sound broadcasting in the Tropical Zone has special characteristics which differ from those of HF sound broadcasting for long distances;

* This Study Programme replaces Question 30-1/10 and Study Programme 30A/10.

- (c) that the fading of sound-broadcast emissions under tropical conditions has special characteristics due to equatorial type sporadic E and F region irregularities (e.g. spread F);
- (d) that "surge" and "flutter" types of fading * are observed in the Tropical Zone;
- (e) that the nature and origin of "surge" fading have not yet been established;
- (f) that sufficient data are not available on the quantitative estimates of short-term and long-term fading in the Tropical Zone,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the different types and characteristics of fading encountered in the Tropical Zone;
2. the allowances to be provided for planning sound-broadcasting services in the Tropical Zone;
3. determination of the nature and occurrence of "surge" and "flutter" fading affecting reception;
4. determination of the various statistical parameters for short-term and long-term fading of signals;
5. quantitative evaluation of the fading allowances based on § 3 and § 4 above.

Note. — See Report 304.

STUDY PROGRAMME 45C/10 **

SINGLE-SIDEBAND RECEPTION FOR REDUCTION OF FADING EFFECTS FOR RE-BROADCAST APPLICATIONS WITHIN THE TROPICAL ZONE

(1982)

The CCIR,

CONSIDERING

- (a) that the quality of broadcasting in band 7 (HF) within the Tropical Zone suffers greatly from the ill-effects of selective fading and peculiar types of "surge" and "flutter" fading (Report 304);
- (b) that development of techniques to reduce the ill-effects of these types of fading will improve the quality of re-broadcast services within the Tropical Zone;
- (c) that results of these studies will also be of interest to Study Groups 1, 3 and 6,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the extent to which the use of single-sideband reception can improve the quality of broadcasting in band 7 (HF) for re-broadcast applications within the Tropical Zone by way of:
 - reduction in selective fading,
 - reduction in "surge" and "flutter" fading;
2. determination of a suitable scale for assessing the extent of improvement in the quality of broadcasting by the use of single-sideband reception;
3. determination of the preferred system characteristics of single-sideband reception intended for re-broadcast applications.

Note. — See Report 472.

* As compared with "flutter fading", "surge fading" is a slower but deeper form of fading accompanied by severe distortion. This peculiar type of fading gives the impression of the signal being received in powerful "surges".

** This Study Programme replaces Study Programme 33A-1/10.

STUDY PROGRAMME 45D/10 *

**DETERMINATION OF THE EFFECTS OF ATMOSPHERIC NOISE
ON THE GRADE OF RECEPTION IN THE TROPICAL ZONE**

(1982)

The CCIR,

CONSIDERING

that the determination of the transmitter power required depends in part upon the value of the signal-to-atmospheric noise ratio, regarded as being the minimum for an acceptable broadcasting service in the Tropical Zone,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the characteristics of atmospheric noise that are important in determining the response of a typical broadcast receiver and the extent to which they affect the grade of reception;
2. the average value of signal-to-atmospheric noise ratio required to ensure satisfactory reception for at least 90% of the total time.

Note. — See Report 303.

STUDY PROGRAMME 45E/10 **

**INTERFERENCE FROM OTHER SERVICES TO SOUND BROADCASTING
IN THE TROPICAL ZONE**

(1982)

The CCIR,

CONSIDERING

- (a) Recommendation No. 64 of the World Administrative Radio Conference (Geneva, 1979) and the studies pursued at the Plenary Assemblies of the CCIR;
- (b) that Recommendation 216 is based on non-exhaustive information obtained in the studies of Study Programme 45A/10 and that further studies are necessary to determine finally a value for the radio-frequency protection ratio for sound-broadcasting services operating in the Tropical Zone in the shared bands;
- (c) that comprehensive data could be obtained by the use of objective methods as described in Recommendation 559 besides the subjective methods used hitherto,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. experimental determination of the radio-frequency protection ratio to be provided for a sound-broadcasting service, operating in the shared bands in the Tropical Zone, against interference from telegraphy (A1A/A1B and A2A/A2B) and telephony (A3E) emissions when:
 - the interference is caused by one of these three types of emission;
 - the interference is caused by two or more types of emission at the same time;
- 1.1 this study should be carried out taking into account transmitter frequency variations (up to and including those equal to the sum of the permissible frequency tolerances) of the sound-broadcasting service in the Tropical Zone and other services sharing the bands as laid down in the Radio Regulations;
- 1.2 measurements should be carried out at the output of a receiver fitted with a simple filter having an audio-frequency cut-off of 5 kHz (the characteristics of the filter employed should be given);

* This Study Programme replaces Question 31/10.

** This Study Programme replaces Question 27/10 and Study Programme 27C-1/10.

- 1.3 measurements should be carried out for carrier frequencies separated by 0, 1, 2, ... 10 kHz;
- 1.4 the results should be expressed in terms of percentage of listener satisfaction, as well as of percentage of time during which the satisfaction is achieved;

2. experimental determination of the minimum usable field strength to which a protection ratio, (to be determined under different conditions as stated in § 1 above and as stipulated in § 1 of Recommendation 216), should relate (taking into account the nature, intensity and distribution of noise levels in different parts of the Tropical Zone).

Note. — See Recommendations 48, 49, 216 and Report 302.

STUDY PROGRAMME 45F/10 *

**TRANSMITTING ANTENNAS FOR SOUND BROADCASTING
IN THE TROPICAL ZONE**

(1982)

The CCIR,

CONSIDERING

- (a) that the maximum limit of a sound-broadcasting coverage area in the Tropical Zone is about 800 km;
- (b) the necessity for further study of the design of transmitting antennas for sound broadcasting in the Tropical Zone including the use of various computer programmes using synthesis methods, etc., for the purpose of concentrating the energy transmitted by reflection from the ionosphere as much as possible into the desired coverage area;
- (c) that the use of efficient antennas for transmission would permit the use of transmitters of lower power;
- (d) the importance of reducing interference to a minimum between services which share frequency bands, as provided by Nos. 2669-2671 of the Radio Regulations;
- (e) the provisions of Nos. 1805-1809 of the Radio Regulations,

UNANIMOUSLY DECIDES that the following studies should be carried out:

- 1. the factors that determine the best position of the transmitting antennas, with respect to the area to be covered, to concentrate the energy received by reflection from the ionosphere within the desired coverage area and to reduce to a minimum the amount of energy received outside the sound-broadcasting coverage area;
- 2. the practical improvements, confirmed by measurement, that can be made in the design of transmitting antennas for sound broadcasting in the Tropical Zone, to concentrate the energy received by reflection from the ionosphere within the desired coverage area and to reduce to a minimum the energy received outside the sound-broadcasting coverage area; in particular, the steps that can be taken to reduce low-angle radiation to a minimum;
- 3. the development of suitable computer programme for the design of a suitable antenna for sound broadcasting in the Tropical Zone.

Note. — See Report 301 and Recommendation 139.

* This Study Programme replaces Question 29-1/10.

QUESTION 46/10

**FREQUENCY-MODULATION SOUND BROADCASTING
IN BAND 8 (VHF)**

(1982)

The CCIR,

CONSIDERING

the following Resolutions and Recommendations of the WARC-79:

- *Resolution No. 510*: Regional Administrative Radio Conference (sound broadcasting in the band 87.5 to 108 MHz for Region 1 and certain countries concerned in Region 3;
- *Resolution No. 509*: Convening of a Regional Administrative Broadcasting Conference to review and revise the provisions of the Final Acts of the African VHF/UHF Broadcasting Conference, 1963;
- *Resolution No. 702*: Regional Administrative Radio Conference to establish criteria for the shared use of the VHF and UHF bands allocated to fixed, broadcasting and mobile services in Region 3;
- *Recommendation No. 69*: Frequency tolerances of transmitters;
- *Recommendation No. 70*: Studies of the technical characteristics of equipment;
- *Recommendation 704*: Compatibility between the broadcasting service (100-108 MHz) and the aeronautical radionavigation service (108-117.975 MHz),

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the technical characteristics to be recommended for sound-broadcasting systems, using frequency modulation, operating in band 8 (VHF);
2. what systems should be recommended for the transmission of compatible stereophonic or multi-dimensional sound signals;
3. what are the possibilities for, and the relative merits of, the simultaneous transmission of several sound programmes by the same transmitter, and what systems should be recommended;
4. what are the possibilities for the transmission, by the same transmitter, of supplementary information, compatible with the main monophonic or stereophonic sound programme;
5. what are the technical bases for planning which lead to efficient spectrum utilization;
6. what are the technical criteria for compatibility between VHF sound broadcasting and other services using the same band or adjacent bands?

Note. — See Reports 122, 300, 463, 464, 620, 796, 945, 946, 947 and Recommendations 412, 467, 599.

STUDY PROGRAMME 46A/10

**THE USE OF COMPANDOR SYSTEMS IN FREQUENCY-MODULATION
SOUND BROADCASTING**

(1982)

The CCIR,

CONSIDERING

- (a) that it is desirable to preserve the possibility of taking advantage of the full dynamic range of the programme signal;
- (b) that the use of compandors leads to improved signal-to-noise characteristics and reduces susceptibility to interference;
- (c) that application of compression at the transmitter without subsequent expansion at the receiver may lead, depending on the programme material used, to impaired signal-to-noise characteristics and cause increased interference;

- (d) that the use of expanders at the receiver makes it possible to restore fully or partly the dynamic range of the programme signal;
- (e) that the degree of compression determines whether it is necessary to use expanders at the receiver,

UNANIMOUSLY DECIDES that the following studies should be carried out:

the determination, as a function of the compressor characteristics, such as degree of compression, frequency dependency, etc. of:

1. the compatibility of compressed signals when received with conventional receivers without dynamic expansion;
2. the advantage in signal-to-noise ratio to be obtained with compressed signals;
3. the influence of the compandor system on the radio-frequency protection ratio.

STUDY PROGRAMME 46B/10

MODULATION LEVEL CONTROL IN FREQUENCY-MODULATION SOUND BROADCASTING

(1982)

The CCIR,

CONSIDERING

- (a) that maximum peak programme level and test signal level to be used for a programme distribution network are specified by the CCITT in its Recommendations J.14, J.15 and N.13;
- (b) that peak programme meters for programme level monitoring are specified in Report 292;
- (c) that exceeding the maximum frequency deviation of the FM system can increase adjacent channel interference and cause distortion in the receivers;
- (d) that the use of both pre-emphasis networks (50 μ s or 75 μ s) and compressors in FM transmitters causes a risk of excessive modulation if higher audio-frequency components are present, even if the programme level is correctly monitored;
- (e) that the high-frequency content of programme material appears to have increased over the years;
- (f) that it is desirable to take advantage of the total dynamic range of the transmitter,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the relationship between the test level used and the frequency deviation of the transmitter, giving sufficient margin for programme peaks and pre-emphasis;
 2. the maximum permissible peak programme level readings to be allowed during a programme to minimize the risk of excessive modulation, taking the effect of pre-emphasis into account;
 3. the limiting techniques to be used to prevent excessive modulation in extreme cases without significantly affecting the programme quality, taking the effect of pre-emphasis into account;
 4. the techniques to avoid overmodulation that may be caused, in the polar-modulation system, by a change in the levels of signals ($A + B$) and ($A - B$);
 5. the effect of excessive modulation on protection ratio requirements and on non-linear distortion in receivers.
-

STUDY PROGRAMME 46C/10 *

POLARIZATION OF EMISSIONS IN FM SOUND BROADCASTING

(1982)

The CCIR,

CONSIDERING

that emissions from frequency modulation sound-broadcasting stations are usually transmitted with horizontal polarization,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the comparison of advantages and disadvantages in coverage and interference, in using for monophonic and stereophonic sound broadcasting in band 8 (VHF) for an emission from the same location on the same frequency:
 - 1.1 horizontal polarization;
 - 1.2 vertical polarization;
 - 1.3 a polarization having both horizontal and vertical components;
 2. the types of antennas to be used for transmission and reception.
- Note.* – See Reports 122, 464.

STUDY PROGRAMME 46D/10 **

**STEREOPHONIC OR MULTI-DIMENSIONAL SOUND IN
FREQUENCY-MODULATION SOUND BROADCASTING**

(1982)

The CCIR,

CONSIDERING

- (a) that compatible stereophonic sound transmissions in sound broadcasting have become general in numerous countries;
- (b) that transmissions of multi-dimensional sound signals may gain increasing interest;
- (c) that standardization of stereophonic or multi-dimensional sound transmission systems is desirable as it would assist in:
 - avoiding interference problems,
 - reducing spectrum occupancy,
 - reducing receiver costs by enabling standardization of larger parts of receivers,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the methods by which compatible stereophonic or multi-dimensional sound signals can be transmitted in sound broadcasting with a view to ensure maximum economy in frequency usage;
2. the systems that can ensure compatibility together with the least practicable loss of coverage or increase in mutual interference with existing services. The study should include:
 - 2.1 with respect to compatibility:
 - the general principles of each system,
 - the detailed specification of each system,
 - the overall theoretical evaluation of the performance of each system;

* Formerly Question 19/10.

** This Study Programme replaces Question 15/10 and Study Programme 15A-1/10.

- 2.2 with respect to coverage and frequency usage:
- coverage with stereophonic or multi-dimensional sound,
 - interference effects,
 - the bandwidth involved and other matters concerned with channel utilization;
3. the feasibility and applicability of the systems to existing broadcast transmitters;
4. the suitability of the systems with respect to the performance of:
- monophonic receivers when tuned to the stereophonic or multi-dimensional sound transmission;
 - stereophonic receivers when tuned to a monophonic or multi-dimensional sound transmission;
5. the parameters to be standardized.
- Note.* — See Reports 300, 463.

STUDY PROGRAMME 46E/10 *

**COMPATIBILITY OF A MONOPHONIC SIGNAL OBTAINED
FROM A STEREOPHONIC SOURCE**

(1982)

The CCIR,

CONSIDERING

- (a) that the compatibility of stereophonic programmes is determined, among other considerations, by the difference in phase and transmission time between the two local channels of a stereophonic system;
- (b) that the difference in phase between the two stereophonic channels can be cumulative over successive components in the system;
- (c) that the differences in phase depend on the source of the programme and the programme link;
- (d) that the tolerance limits for phase differences between channels as shown in Fig. 3 of Report 293 for stereophonic reproduction may not be adequate for listening to the compatible monophonic signal,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the limits of perceptibility of the phase differences between channels for compatibility in the frequency range 40 Hz to 15 kHz;
2. determination of the feasibility of controlling the phase differences between channels of a system (amplifying, recording, reproducing, broadcasting or receiving);
3. determination of the permissible phase-shift distribution between the various parts of the system;
4. determination of the electrical and mechanical characteristics of the equipment to satisfy the phase-shift distribution limits;
5. definition of applicable methods of measurement.

Note. — See Reports 463, 620.

* Formerly Study Programme 15C/10.

STUDY PROGRAMME 46F/10 *

**TECHNIQUES FOR CHECKING THE ESSENTIAL CHARACTERISTICS OF
FREQUENCY-MODULATION STEREOPHONIC BROADCASTING**

(1982)

The CCIR,

CONSIDERING

- (a) that incorrect modulation in frequency-modulation stereophonic broadcasting can result in objectionable crosstalk between channels *A* and *B*, and possibly between the stereophonic and supplementary communication multiplex channels. It can also produce objectionable distortion in stereophonic or in compatible monophonic reception;
- (b) that ensuring correct stereophonic modulation involves the measurement of quantities which are not encountered in monophonic broadcasting (e.g. the relative polarity of the *A* and *B* audio-frequency signals and, in the case of the pilot-tone system, the phase of the pilot-tone);
- (c) that it is also important to extend these studies to include studio and transmitter links;
- (d) that the problem of checking stereophonic transmissions requires thorough study, especially with regard to the parameters to be checked at the transmitter output,

UNANIMOUSLY DECIDES that the following studies should be carried out:

the techniques that can be used for checking that the transmitted signal conforms to the system specifications and in particular with a view to,

1. Checking of stereophonic transmissions

- 1.1 the parameters that it is essential or desirable to check during transmission, to ensure that the transmitter output signal conforms to the specifications for the stereophonic system used;
- 1.2 the parameters it would be useful to adjust during routine maintenance;
- 1.3 the most appropriate methods for these checks.

2. Checking of stereophonic links

- 2.1 the parameters it is essential or desirable to check during operation, to preserve stereophonic quality;
- 2.2 the parameters it would be useful to check during routine link maintenance;
- 2.3 the most appropriate methods for these checks.

Note. — See Recommendation 467.

STUDY PROGRAMME 46G/10 **

**TRANSMISSION OF SEVERAL PROGRAMMES WITH A SINGLE
TRANSMITTER IN FM SOUND BROADCASTING**

(1982)

The CCIR,

CONSIDERING

- (a) that, for certain applications, in frequency-modulation broadcasting, it might be desirable to transmit two or more sound programmes with the same transmitter;
- (b) that such transmissions might be particularly useful in areas where several languages are spoken;
- (c) that two or more programmes might be transmitted with a specially designed system;

* Formerly Question 16/10 and Study Programme 16A/10.

** This Study Programme replaces Question 17-2/10, Study Programme 17A-2/10 and Question 26-1/10.

- (d) that use of existing receivers (adapted or modified) for reception of the supplementary programmes is not to be considered a primary requirement;
- (e) that individual automatic receiver control including programme selection, volume balancing, and regulation of dynamic range, etc., might be required by listeners,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the systems that can be used with a single transmitter for the transmission of several programmes in frequency-modulation broadcasting and the technical parameters to be standardized, such as:
 - 1.1 the frequency of each sub-carrier;
 - 1.2 the type of modulation of sub-carriers;
 - 1.3 the degree of modulation of the main carrier by each sub-channel signal;
 - 1.4 the degree of modulation of each sub-carrier if frequency modulation is chosen;
 - 1.5 the maximum audio modulating frequency;
 - 1.6 the pre-emphasis characteristics of supplementary channels;
 - 1.7 the time constants and input/output characteristic of any compressor/expander used in the system;
 - 1.8 the dynamic range;
 - 1.9 any other parameters which need to be considered;
2. the influence of such standardized parameters upon:
 - 2.1 the intermodulation between the different channels;
 - 2.2 the signal-to-noise ratio of each channel;
 - 2.3 the frequency response of each channel;
 - 2.4 the harmonic distortion in each channel;
 - 2.5 the radio-frequency protection ratios;
 - 2.6 any other characteristics which need to be considered;
 - 2.7 stereophonic broadcasting;
3. the types of receiver which should be used to allow the listener to select each programme;
4. the system to be used for the transmission of control signals while still maintaining the possibility of simultaneous transmission of two or more sound programmes;
5. the frequency economy that can be obtained by the system when comparing, on an equal audio-quality basis, the coverage areas (limited by noise and/or interference) of each programme with those that could be obtained if the various programmes were broadcast by separate transmitters of adequate power;
6. the extent to which it is possible to increase the coverage area of the additional programme transmissions by using either a compressed signal at the input to the transmitter only or a complete compandor system, without increasing the level of interference to reception of other emissions and without decreasing the quality of reception.

STUDY PROGRAMME 46H/10 *

TRANSMISSION OF SUPPLEMENTARY INFORMATION WITH A SINGLE TRANSMITTER IN FREQUENCY-MODULATION SOUND BROADCASTING

(1982)

The CCIR,

CONSIDERING

- (a) that the broadcasting with a single transmitter of information supplementary to the sound programmes is technically feasible, particularly through the use of digital signals modulating a sub-carrier;
- (b) that the use of many types of supplementary information for various applications can be foreseen;
- (c) that the transmission of such information with no direct relationship to the main programme can be accomplished by such techniques;
- (d) that it is desirable to encourage development of compatible or possibly common systems,

* Formerly Study Programme 17B/10.

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the applications that can be envisaged;
2. the minimum demands on the transmission channel for these applications, e.g. information rate, access time, coverage compared with that of the monophonic service, acceptable loss- and error-rates;
3. the possibilities of using the same transmission channel for future applications;
4. the transmission systems satisfying the preceding minimum demands, in particular, frequency of sub-carrier, type of modulation, information rate, digital frame structure, error-detecting and/or correcting systems, sensitivity to the content of the main programme and to the reception conditions;
5. the compatibility with existing broadcasting services.

STUDY PROGRAMME 46J/10 *

COMPATIBILITY BETWEEN VHF SOUND BROADCASTING, TELEVISION AND OTHER SERVICES USING THE SAME BAND OR ADJACENT BANDS

(1982)

The CCIR,

CONSIDERING

that knowledge of the conditions of sharing frequency bands between different services can lead to improved radio spectrum utilization,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the criteria for compatibility between VHF sound broadcasting and:
 - 1.1 television broadcasting in the same band or in adjacent bands;
 - 1.2 the fixed and mobile services, except the aeronautical mobile (R) service, operating in the same band or in adjacent bands;
 - 1.3 the aeronautical radionavigation service, operating in the band 108 to 117.975 MHz;
2. the additional technical methods which could be developed to improve compatibility between these services with special reference to the reduction of interference caused by intermodulation products.

Note. — See Report 947.

STUDY PROGRAMME 46K/10 **

SOUND BROADCASTING IN BAND 8 (VHF) IN THE TROPICAL ZONE

(1982)

The CCIR,

CONSIDERING

- (a) that sound broadcasting in band 8 (VHF) is providing a high-quality service in many parts of the world;
- (b) that the rate of failure of transmission systems in band 8 is extremely low;
- (c) that domestic receivers with adequate sensitivity are readily available for operation in band 8;

* This Study Programme should be brought to the attention of Study Groups 8, 9 and 11.

** This Study Programme replaces Question 32-1/10.

- (d) that band 6 (MF), used for good quality broadcast service is heavily congested in tropical countries and that further expansion of broadcast service in this band is limited, especially during night-time;
- (e) that band 7 (HF), suffers from adverse effects of interference and fading and cannot provide reliably a broadcasting service of good quality in tropical countries,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the advantages and disadvantages of using band 8 for sound-broadcasting applications in the Tropical Zone;
2. the minimum usable field strength and protection ratios for co-channel operation for satisfactory frequency-modulation reception at VHF and for the planning of frequency-modulation services at VHF in tropical countries;
3. the design factors for systems and equipment to be studied to off-set the adverse effect of propagation and noise in the Tropical Zone.

STUDY PROGRAMME 46L/10

TECHNICAL BASES FOR PLANNING OF FREQUENCY-MODULATION SOUND BROADCASTING IN BAND 8 (VHF)

(1982)

The CCIR,

CONSIDERING

that the most important aim in planning is to improve utilization of the radio-frequency spectrum,

UNANIMOUSLY DECIDES that the following studies should be carried out:

the technical bases for planning which lead to the most efficient utilization of the band between 87.5 and 108 MHz for the broadcasting service (sound).

Note. — See Report 946 and Recommendations 412, 599.

STUDY PROGRAMME 46M/10

MINIMUM USABLE FIELD STRENGTH FOR SOUND BROADCASTING IN BAND 8 (VHF)

(1982)

The CCIR,

CONSIDERING

- (a) that Recommendation 412, which contains the planning standards of FM broadcasting systems, gives the values of minimum usable field strength (at 10 m above ground level) to overcome the prevalent atmospheric and man-made noise and for different environments;
- (b) that the minimum usable field strength for satisfactory reception at low antenna heights (below 10 m) depends, in part, on the type of polarization used for transmission;
- (c) that considerable improvements have occurred in receiver design (particularly noise figure) since the values for minimum usable field strength given in Recommendation 412 were established;
- (d) that, at present, portable and mobile receivers using essentially vertically polarized aerials often receive horizontally polarized emissions;
- (e) that portable and mobile FM sound receivers are often used in an environment with a high audio noise level and quality is not therefore the dominant constraint,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the minimum usable field strength requirements for satisfactory service for various types of polarization of emissions in the presence of radio noise and interference from industrial domestic and field equipment in different environments for the case of portable FM receivers with in-built antennas;
2. the percentage of location probability which should be considered in defining the minimum value of usable field strength for satisfactory reception;
3. the definition of satisfactory reception criteria as applied to portable and mobile FM sound receivers.

QUESTION 47/10

TRANSMISSION OF SOUND AND INFORMATION SIGNALS * ACCOMPANYING THE VIDEO SIGNAL IN A TELEVISION CHANNEL

(1982)

The CCIR,

CONSIDERING

- (a) that a need has been expressed for the possibility of transmitting, in a television channel, two or more sound signals accompanying the video signal; these sound signals being either monophonic, compatible stereophonic or even multi-dimensional;
- (b) that it would be desirable that these sound transmissions be compatible with the transmission of digital data carrying information relating to the programme (programme or sound identification signals, ...) or other non-related signals (teletext, ...).

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the technical characteristics to be recommended for the transmission, in television broadcasting in bands 8 (VHF) and 9 (UHF), within one and the same channel, of:
 - two or more sound-programme signals,
 - compatible stereophonic or multi-dimensional sound signals accompanying the video signal in a television programme;
 2. what are the possibilities for the transmission, together with the sound, of supplementary information?
- Note.* — See Report 795.

STUDY PROGRAMME 47A/10 **

TRANSMISSION OF TWO OR MORE SOUND PROGRAMMES AND/OR INFORMATION CHANNELS *** IN TELEVISION

(1982)

The CCIR,

CONSIDERING

- (a) that it is often desirable, for the purpose of international television programme exchange, to transmit two or more sound programmes and/or information signals *** in the same television channel;
- (b) that such a transmission may also be useful in areas where several languages are spoken;

* This Question is restricted to the transmission of information signals together with the sound signals.

** This Study Programme replaces Question 18-2/10 and Study Programmes 18A/10 and 18B-1/10. (See also Study Programme 47B/10.)

*** This study is restricted to the transmission of information signals together with the sound signals.

- (c) that for the transmission of two sound programmes in one television channel on the normal sound carrier, a sub-carrier FM-FM system appears to meet the requirements more satisfactorily than other sub-carrier systems;
- (d) that a sub-carrier frequency which is a multiple of the line frequency appears to be the best choice;
- (e) that the use of compressors and associated expanders improves the signal-to-noise ratio;
- (f) that in many cases a second carrier can be added to the sound transmitter for the transmission of a second sound programme, without causing additional adjacent channel interference;
- (g) that sound transmission in time-division multiplex with the picture signal also seems possible,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the systems to be used, preferably with a single transmitter, for the transmission of two or more sound-programmes and/or information signals * in television. These systems should not involve any significant increase in bandwidth of the television channel. Moreover, existing types of receiver should be able to receive, without modification, one of the sound programmes while maintaining picture and sound quality;
2. the characteristics which should be standardized, e.g. for:
 - the FM-FM sub-carrier system;
 - the supplementary sound-carrier system;
 - any sound transmission system using time-division multiplex with the video signal;
 - a combination of any of the above systems;
3. the modifications to be made to existing types of receiver, to allow the viewer to select individually any of the transmitted sound-programmes and/or information signals;
4. the extent to which these systems could be used for stereophonic sound transmissions in television;
5. the change in coverage area (determined by either random noise, impulsive noise or interference) arising from the introduction of such systems, as compared with the coverage areas for the existing video programme and/or single sound-programme signal transmission;
6. the crosstalk attenuation between the transmitted sound-programme and/or information signals that would be obtained with such a system;
7. the best objective method for measuring crosstalk, giving results comparable with subjective assessments.

Note. — See Reports 468 and 795.

STUDY PROGRAMME 47B/10

STANDARDS FOR THE TRANSMISSION OF SEVERAL SOUND SIGNALS IN ONE TELEVISION CHANNEL IN TERRESTRIAL OR SATELLITE BROADCASTING

(1982)

The CCIR,

CONSIDERING

- (a) that there is a requirement to transmit more than one sound signal including stereophony with a television picture;
- (b) that within a television channel as used in present systems several sound channels could be accommodated;
- (c) that the use of some of these additional possibilities could necessitate changes to the present television standards;
- (d) that changes affecting existing transmissions can only be introduced if compatibility with existing receivers, at least during a sufficiently long transition period, is retained;

* This study is restricted to the transmission of information signals together with the sound signals.

- (e) that a prerequisite of a new system is that the sound signals should serve at least the same coverage area as the vision signal;
- (f) that a new system could also provide for the transmission of sound programmes, independent from the picture, or in place of a television picture;
- (g) that the technical quality of the sound transmission can be improved,

UNANIMOUSLY DECIDES that the following studies * should be carried out:

definition of unified ** standards for the transmission of several sound signals to be incorporated in one television channel in terrestrial or satellite broadcasting including the use of digital modulation and the case where some of those sound signals are to be integrated into the video waveform.

QUESTION 48/10 ***

PROTECTION OF SOUND-BROADCASTING STATIONS AGAINST LIGHTNING

(1982)

The CCIR,

CONSIDERING

- (a) that there are vast areas in the world where, despite the installation of protective devices against lightning, equipments are often damaged, sometimes severely, by atmospheric voltage surges;
- (b) that considerable economic and social harm is often caused by the loss of service;
- (c) that in certain countries, protection criteria have already been established, but have not yet been disseminated or standardized internationally;
- (d) that the IEC is studying the standardization of levels of insulation for all the electrical, electronic and telecommunications equipment present in a station and that such standardization may also be applied to broadcasting stations;
- (e) that the CCITT is studying the classification of levels of (immunity) of telecommunications equipment to atmospheric voltage surges;
- (f) that WARC-79 Resolution No. 64 invites the CCIR, in consultation with the CCITT, to study this phenomenon and to formulate a Recommendation in this matter,

UNANIMOUSLY DECIDES that the following question should be studied:

what are the most suitable precautions for protection against local atmospheric discharges at sound-broadcasting stations, taking into account the studies in progress in the CCITT, in the IEC and in the CCIR Study Groups with a view, in particular, to defining:

- limit values of lightning characteristics in relation to accepted risk and the probability of the station being struck by lightning;
- criteria for evaluating the effects of lightning on stations; and
- criteria and procedures for the design of station protective equipment?

Note. – See Report 943 and Question 62/1.

* In these studies Questions 2/10 and 2/11 should also be taken into account.

** In this context the term “unified” implies that the standards to be defined should as far as practicable apply both to terrestrial and to satellite broadcasting.

*** This Question should be brought to the attention of Study Groups 1 and 11. Results of studies should be brought to the notice of Study Group 1.

QUESTION 49/10 *

RECEIVERS AND RECEIVING ANTENNAS FOR SOUND BROADCASTING

(1982)

The CCIR

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the main characteristics of receiving installations (receiver and associated antenna) which may be useful for the planning work of Administrative Conferences, the IFRB and other organizations concerned;
2. what are the minimum performance specifications for receiving installations permitting a sound quality compatible with CCIR specifications, for the various types of sound-broadcasting systems:
 - double-sideband amplitude modulation;
 - single-sideband amplitude modulation (including the technical and economic problems concerning receivers that would arise with the introduction of this type of modulation in the HF broadcasting bands);
 - frequency modulation?

These technical characteristics should be defined for the three cases of:

- individual reception;
- community reception;
- community listening.

Note 1. – The minimum performance specifications should take account of the latest IEC work.*Note 2.* – It is desirable that texts concerning the conclusions of these studies be assembled in a single section of Volume X of the CCIR.*Note 3.* – Taking into account that the reception conditions for satellite sound broadcasting are not specified, this Question deals only with terrestrial sound broadcasting until such time when the system characteristics for satellite sound broadcasting are determined.*Note 4.* – In the case where the antenna is incorporated in the receiver the possibility of adapting a separate antenna should be studied and the antenna characteristics together with the input impedance at the “antenna” socket should be specified.*Note 5.* – See Report 617.

QUESTION 50/10

AUDIO-FREQUENCY CHARACTERISTICS OF BROADCASTING SIGNALS

(1982)

The CCIR

UNANIMOUSLY DECIDES that the following question should be studied:

1. which audio-frequency signal characteristics, including tolerable values and measurement methods, should be recommended for the monophonic and stereophonic production, transmission and reproduction of sound in broadcasting;
2. how should the subjective loudness of a programme be assessed and measured;
3. how should the subjective quality of the sound, including the effects of interference, be assessed;
4. which acoustical properties of listening rooms and control rooms should be determined?

Note. – See Reports 292, 465, 797 and Recommendations 468, 562.

* This Question replaces Study Programme 36A/10.

STUDY PROGRAMME 50A/10 *

**DETERMINATION OF THE SUBJECTIVE LOUDNESS
OF A BROADCASTING PROGRAMME**

(1982)

The CCIR,

CONSIDERING

- (a) that existing specifications and techniques for the determination of sound modulation levels in broadcasting are generally based on peak or quasi-peak programme levels;
- (b) that neither true peak nor quasi-peak programme levels are necessarily indicative of subjective loudness;
- (c) that it may be advantageous to take subjective loudness into account in the determination of programme levels;
- (d) that the dynamic range of sound programmes and its measurement and control are of importance,

UNANIMOUSLY DECIDES that the following studies should be carried out:

determination of the effects of amplitude, frequency range, signal duration, strident delivery and the psychological and physiological reaction of a representative cross-section of listeners to these and other factors in subjective loudness; and in particular:

- the parameters which it is essential or desirable to check upon during transmission to establish the subjective loudness of different types of programmes;
- the methods to be used to determine the effect of these parameters on subjective loudness;
- the results to be obtained from the use of these methods, and how they are expressed;
- in television transmission, the effect of the associated picture.

Note. — See Report 465.

STUDY PROGRAMME 50B/10 **

**MEASUREMENT AND CONTROL
OF SUBJECTIVE LOUDNESS IN BROADCASTING**

(1982)

The CCIR,

CONSIDERING

- (a) that the problems of measurement, indication and control of the subjective loudness of a broadcasting programme require thorough investigation and study, especially with regard to the parameters to be found in the relationship between music and voice announcements;
- (b) that existing specifications and techniques for the determination of programme levels in broadcasting are generally based on peak or quasi-peak readings;
- (c) that neither true peak nor quasi-peak programme levels are necessarily indicative of subjective loudness;
- (d) that it is considered advantageous to take subjective loudness into account in the determination of modulation levels,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the indication of subjective loudness on an instantaneous and continuous basis:
 - 1.1 the techniques or instrumentation which may be used to measure the subjective loudness of programme material in broadcasting;

* Formerly Question 4/10 and § 1 of Study Programme 4A-1/10.

** Formerly Study Programme 4A-1/10 §§ 2 to 4.

- 1.2 the degree of accuracy obtainable with each;
- 1.3 if a meter is used, the characteristics it should possess to measure subjective loudness;
- 1.4 the point in the transmission chain where the measuring instrument should be connected;
2. the non-automated control of loudness for optimum balance of subjective characteristics of different types of programmes:
 - 2.1 the elements in the transmission chain which may affect the control of subjective loudness;
 - 2.2 the point in the transmission chain where the loudness control should be connected;
 - 2.3 the element(s) which should be varied to balance the subjective loudness of different programmes;
 - 2.4 the control method(s);
 - 2.5 the level of listening loudness in programme control rooms;
3. the automatic control of loudness for optimum balance of subjective characteristics of different types of programmes:
 - 3.1 the use of a speech-music switch controlled by the actual sound signal and the point where it should be fitted;
 - 3.2 the static and dynamic characteristics of speech compressors (e.g., degree of compression, actuation time, recovery time, etc.);
 - 3.3 the characteristics of the recorded programme signal which should be measured before broadcasting, and coded so that they can be applied in automated programme suites (e.g., dynamics, quasi-peak-level, mean loudness, etc.);
 - 3.4 the methods and equipment which could be used in sound and television receivers to influence the speech-music dynamics and balance for better satisfaction of audience requirements.

Note. — As an aid in comparing the results of studies it is suggested that administrations should state programme levels in terms of peak values measured with one of the peak meters described in Report 292. The type used should be specified.

STUDY PROGRAMME 50C/10 *

SUBJECTIVE ASSESSMENT OF SOUND QUALITY IN BROADCASTING

(1982)

The CCIR,

CONSIDERING

- (a) that subjective methods of testing are frequently necessary to assess the relative quality of programme sound and the effect of interference and other impairments upon it;
- (b) that many different methods of subjective testing are possible;
- (c) that the results of subjective tests depend on the conditions under which they are carried out;
- (d) that the results of subjective tests can be interpreted in many ways;
- (e) that it is highly desirable to standardize the methods of subjective testing and the interpretation of the results, so that true comparisons may be made between results obtained at different times,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the methods of subjective testing best suited to the assessment of the relative quality of sound in broadcasting and of the effects of interference and other impairments upon it, taking particular account of:
 - the use of full-range opinion rating methods and the scales to be used and, alternatively, the use of comparison methods of assessment;
 - the selection of test sound programme sequences;

* Formerly Study Programme 4B/10.

- the listening conditions;
 - the selection and number of listeners;
 - the instructions to listeners before tests;
2. the analysis and presentation of the results obtained;
3. the use of the methods described in §§ 1 and 2 during international transmissions (Note 1).
- Note 1.* – Study under § 3 is to be carried out in cooperation with the CMTT.
- Note 2.* – See Recommendation 562.

STUDY PROGRAMME 50D/10 *

**DETERMINATION OF THE ACOUSTICAL PROPERTIES OF
CONTROL ROOMS AND HIGH QUALITY LISTENING ROOMS
IN BROADCASTING**

(1982)

The CCIR,

CONSIDERING

- (a) that the geometric and acoustical properties of control rooms and listening rooms can have a considerable influence on audition, especially in stereophony;
- (b) that this influence may cause studio operators to impair the response curve by means of the filters with which the rooms are equipped;
- (c) that the acoustics of these rooms can cause a stereophonic recording from another broadcasting organization to be judged unfavourably;
- (d) that it is desirable to prepare a recommendation on the properties of listening rooms with a view to unifying acoustical impressions in the case of programme exchanges, particularly with multiple channels,

UNANIMOUSLY DECIDES that the following studies should be carried out:

- 1. the influence of the acoustics of control rooms and listening rooms on auditive quality and the subjective methods which should be used to evaluate the parameters of the rooms;
 - 2. the parameters which should be studied in detail (volume and proportions of the room, reverberation time) for:
 - monophony,
 - stereophony,
 - quadraphony and other similar multi-channel techniques;
 - 3. the placing of listeners and loudspeakers, taking into account all acoustical conditions for monophony, stereophony and quadraphony.
- Note.* – See Report 797.

STUDY PROGRAMME 50E/10

**PARAMETERS AND TOLERANCE LIMITS FOR THE TECHNICAL QUALITY
OF PROGRAMMES INTENDED FOR INTERNATIONAL EXCHANGE**

(1982)

The CCIR,

CONSIDERING

- (a) that in Report 293 basic material for the whole transmission chain was collected which should be supplemented and processed by further studies so that in the next step(s) a Recommendation for programme exchange can be derived;
- (b) that further work is necessary to determine the subjective limits and the attainable and/or desirable objective global values at the end of the transmission chain;

* Formerly Question 38/10.

- (c) that by means of addition laws, the limits for the different transmission links can be derived from such global values;
- (d) that it is necessary to standardize measuring methods for special parameters,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of parameters and tolerances to characterize high quality sound-programmes for international exchange, for both analogue and digital techniques (see Study Programme 51A/10);
2. determination of attainable and/or desirable values for the whole transmission chain, especially with regard to the relationship between objective and subjective values;
3. determination of measuring methods, additional to those given by IEC, ISO, etc., that are especially appropriate to broadcasting use.

Note. — See Recommendation 468, and Report 292.

QUESTION 51/10 *

STANDARDS FOR DIGITAL TECHNIQUES FOR SOUND IN BROADCASTING

(1982)

The CCIR,

CONSIDERING

- (a) that the use of digital signals in production, transmission ** and emission may lead to an improvement in quality and reliability;
- (b) that digital transmission and emission open up the possibility of enhanced use of the frequency spectrum by permitting new methods of multiplexing the different signals;
- (c) that the signals used for different applications should be identified in their characteristics;
- (d) that the methods of coding, insertion in the digital channel and modulation should be standardized to facilitate international exchanges of programmes and to rationalize the receiving equipment;
- (e) that satellite *** and terrestrial broadcasting services will co-exist and that methods compatible with both modes of broadcasting should be found,

UNANIMOUSLY DECIDES that the following question should be studied:

1. what digital coding methods should be used for sound signals and what advantages would be derived from them:
 - in studio plant, including recording; ****
 - for direct emission from terrestrial transmitters or satellites; ***
2. what is the most practicable method for multiplexing several digital sound signals;
3. what type of carrier modulation by digital signals can be recommended for optimum use of the frequency bands;
4. what are the simplest and most efficient techniques for monitoring the quality of digitally-coded sound signals?

Note. — See report 948.

* Formerly Question 39/10. This Question should be brought to the attention of the CMTT.

** See Question 18/CMTT, Study Programme 18C/CMTT.

*** Since this Question 51/10 relates in part to matters which are also under consideration by Study Group 11, it should be brought to the attention of Study Group 11.

**** For digital sound recording see also Study Programme 52B/10.

STUDY PROGRAMME 51A/10 *

**SUBJECTIVE ASSESSMENT OF SOUND QUALITY
IN BROADCASTING USING DIGITAL TECHNIQUES**

(1982)

The CCIR,

CONSIDERING

- (a) that the introduction of digital techniques in the studio (including tape recording), in transmission circuits and at the transmitter should allow an improvement in quality and simplified operational use;
- (b) that these techniques entail their own specific signal impairments;
- (c) that it is desirable to ensure high quality performance throughout the broadcasting chain without unnecessary expense,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the relation between subjective assessment and objective measurements on digital systems;
2. determination of the tolerable values of subjective impairment in the whole broadcasting chain;
3. determination of the subjective influence of the conversion processes in the transmission chains;
4. determination of the subjective effect of the various studio processes on the digital signal (level changes, frequency response corrections, etc.);
5. determination of the maximum number of times that processing of any kind may be applied to the signal in the studio and on the transmission circuits and the associated subjective effect;
6. determination of the subjectively acceptable values of impairment (expressed in objective terms):
 - in transmission circuits;
 - in recording equipment;
 - in other studio equipment;
 - in broadcasting emissions.

Note 1. – Digital signals used in the studio may differ from those used for transmission.*Note 2.* – See in particular, Decision 18 and Reports 647 and 799.*Note 3.* – The studies should also include a comparison with the best analogue techniques.

STUDY PROGRAMME 51B/10 **

DIGITAL AUDIO CODING STANDARDS

(1982)

The CCIR,

CONSIDERING

- (a) that although the use of digital sound signals in studios should lead to an improvement in quality, digital techniques entail their own specific impairments;
- (b) that impairments to broadcast sound signals will be minimized, and the cost of transcoding equipment may be reduced, if there is a simple relationship between the coding standards used for production, transmission links and broadcasting;

* These studies, formerly designated Study Programme 39A/10, should be carried out in conjunction with Study Programme 50C/10.

** These studies should be conducted in conjunction with Study Programme 2C/10 and 11. See also Study Programme 52B/10.

- (c) that sound studio equipment may need coding parameters different from those required for the emission of high quality broadcast signals. For example, they may need higher numbers of bits/sample to allow processing "headroom";
- (d) that there may be other factors affecting the choice of coding parameters in certain equipment used in broadcasting studios. For example, there might be constraints due to video-recording on the same recorder;
- (e) that Study Group 11 is currently studying the coding parameters needed to meet different production requirements for video signals in television studios;
- (f) that a number of different sets of coding parameters are currently being proposed for digital audio equipment,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. identification of the nature of signal impairments due to digital processing in studios and definition of the appropriate methods of measurement;
2. definition of objective limits for signal impairments in the different links in the studio chain;
3. investigation of the minimum number of coding standards (each relating to a particular process-capability), needed for production including recording, for transmission links * and for the various broadcasting applications;
4. investigation of the best coding parameters for each of these standards, ** taking account of the need for simple transcoding;
5. investigation of the methods of transcoding;
6. problems arising from the need in studios to make use of asynchronous signals and appropriate methods of synchronization.

Note. — See Reports 948, 949.

STUDY PROGRAMME 51C/10 ***

DIGITAL CODING IN BROADCASTING FOR EMISSION OF SOUND SIGNALS

(1982)

The CCIR,

CONSIDERING

- (a) that the introduction of digital techniques for emission should allow an improvement in the quality of the signals transmitted;
- (b) that signals may be of a widely varying nature and coding methods have not yet been clearly defined;
- (c) that digital techniques entail their own specific signal impairments,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. identification of the characteristics of the sound signals for the different applications to be emitted in digital form;
2. evaluation of the various digital coding methods usable for sound in broadcasting and advisability of recommending a single method suited to all the applications referred to in § 1 above;
3. possible methods of converting these various digital signals into a form suitable for broadcasting emission;

* Based on studies by the CMTT.

** For transmission links, based on studies by the CMTT.

*** These studies should be conducted in conjunction with Study Programme 2C/10 and 11.

4. evaluation of protective methods against errors, having regard to possible differences arising from the frequency bands used.

Note. — See Report 953.

STUDY PROGRAMME 51D/10 *

**MULTIPLEXING METHODS FOR THE EMISSION OF DIGITAL
SOUND SIGNALS IN BROADCASTING**

(1982)

The CCIR,

CONSIDERING

- (a) that the introduction of digital techniques for emission of sound signals may permit the time sharing of signals which may be of different types;
- (b) that the nature of the services transmitted may evolve in time without, however, requiring a particularly complex receiver;
- (c) that access to the service may be subject to special authorization procedures (such as tariffs),

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. advantages and disadvantages of the various methods for multiplexing digital signals;
2. study of service allocation and procedures for programming the receiver in the light of access requirements and restrictions.

STUDY PROGRAMME 51E/10 *

**METHODS OF MODULATION FOR THE EMISSION OF
DIGITAL SOUND SIGNALS IN BROADCASTING**

(1982)

The CCIR,

CONSIDERING

- (a) that the World Administrative Radio Conference (Geneva, 1979) allocated certain frequency bands on a shared basis with equality of rights between the broadcasting service and other terrestrial services;
- (b) that such sharing might give rise to interference between services;
- (c) that in planning the services intended for operation in shared bands, both the (field strength) level of the wanted signal for satisfactory reception and the level which the interfering signal should not exceed if the interference is to be regarded as acceptable should be specified for each of the services concerned,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. study of types of carrier modulation for the digital sound signals, and the necessary bandwidths;
2. determination of protection ratios between two carriers in the same radio-frequency channel, one of which is modulated by digital sound signals and the other by either analogue or digital sound signals, particularly for the various sound signals likely to be transmitted on a television channel.

* These studies should be conducted in conjunction with Study Programme 2C/10 and 11.

QUESTION 52/10

**RECORDING OF SOUND BROADCASTING PROGRAMMES
FOR INTERNATIONAL EXCHANGE**

(1982)

The CCIR

UNANIMOUSLY DECIDES that the following question should be studied:

what standards should be recommended for the recording of sound broadcasting programmes for international exchange, with specific reference to:

- standards for recordings on magnetic tapes;
- automatic programming of sound broadcasting stations?

Note. — See Recommendations 407, 408.

STUDY PROGRAMME 52A/10 *

**STANDARDS OF SOUND RECORDING
FOR THE INTERNATIONAL EXCHANGE OF PROGRAMMES**

(1982)

The CCIR

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. an investigation of the possibility of adopting, for the international exchange of sound programmes on magnetic tape, a speed of 9.525 cm/s (3.75 in./s), and the determination of the standards to be used, especially the reproducing characteristics;
2. investigation of methods for measuring slow speed fluctuation (< 0.2 Hz) and rapid speed fluctuation (> 200 Hz) and of permissible values of these; investigation of permissible limits for wow and flutter measured in accordance with Recommendation 409;
3. further investigation of the technique of sound recording to extend and improve the recommendations already made and to reduce the tolerances.

Note. — See Reports 622, 800 and Recommendations 407, 408, 409, 563 and 564.

STUDY PROGRAMME 52B/10 **

SOUND RECORDING USING DIGITAL MODULATION

(1982)

The CCIR,

CONSIDERING

- (a) that digital recording techniques are suitable for high quality programme recording;
- (b) that present magnetic recording devices and materials have adequate characteristics for high-density recording on magnetic tape;
- (c) that there is no internationally agreed format for recording digital sound programme signals on magnetic tape,

* Formerly Study Programme 1A-1/10.

** See also Study Programme 50B/10.

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. form and number of signal tracks for programme channels;
2. permissible drop-out error and its correction method;
3. preferred coded signal allocation on a magnetic tape;
4. suitable method for the channel coding in a digital magnetic tape recorder.

Note. — See Report 950.

STUDY PROGRAMME 52C/10 *

STANDARDS FOR AUTOMATIC PROGRAMMING
OF SOUND BROADCASTING STATIONS

Cue signals and track formats

(1982)

The CCIR,

CONSIDERING

- (a) that automatic programming of sound broadcasting stations is in widespread use in several countries and gaining interest in others;
- (b) that automatic programming has improved the quality of operation in several sound broadcasting stations;
- (c) that automatic programming offers an economic advantage by reduction of and better utilization of the station operating personnel;
- (d) that the cue signals, track format and other features of pre-recorded programme magnetic tapes should be standardized in the event of international exchange,

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the track formats suitable for the cue track(s) and programme track(s) for different types of magnetic tape recordings; reel-to-reel, endless loop cartridge, cassette;
2. the standardization of the cue information required for international exchange of programme tapes for the various types of machines.

QUESTION 53/10 **

METHODS OF SYNCHRONIZING VARIOUS RECORDING
AND REPRODUCING SYSTEMS

(1982)

The CCIR,

CONSIDERING

- (a) that there is an increase in use by broadcasting organizations of video-tape or filmed programmes having a synchronous stereo audio recording for transmission by the same or different transmitters;
- (b) that there is a growing interest in the international exchange of these programmes between broadcasting organizations;

* Formerly Question 37/10.

** This Question is identical to Question 40/11 and replaces Question 22-1/11. It should be brought to the attention of the CMTT.

- (c) that, for the purpose outlined in §§ (a) and (b), an international system or systems should be adopted;
- (d) that in other cases, it may also be necessary to synchronize a number of audio and/or picture components of a programme;
- (e) that no single method or system is in general use which will meet all the different possible requirements for synchronization,

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the required capabilities of such methods of synchronizing;
2. what methods are applicable to the synchronization of the various types of recording and reproducing devices;
3. insofar as it may be necessary, in what form should the signals, including coding and frequency of repetition of the timing information, be recorded;
4. what use should be made of any audio signal processing techniques;
5. what format and media should be preferred for the international exchange of such programmes?

RESOLUTION 64

DETERMINATION OF THE NOISE LEVEL FOR SOUND BROADCASTING IN THE TROPICAL ZONE

(1978)

The CCIR,

CONSIDERING

that studies on the characteristics of atmospheric radio noise and collection of noise data come within the purview of Study Group 6,

UNANIMOUSLY DECIDES

1. that the results of studies contained in Report 303 (Geneva, 1974), which no longer appear in current CCIR texts, should be brought to the notice of Study Group 6;
2. that this information should be considered by Study Group 6 whenever revision of world-wide noise grade data, as given in Report 322, is attempted.

RESOLUTION 76

PRESENTATION OF ANTENNA DIAGRAMMS

(1982)

The CCIR,

CONSIDERING

- (a) that the WARC-79 in Recommendation No. 500 (§ 4) requests the CCIR to publish a new edition of the Book of Antenna Diagramms;
- (b) that the form of presentation of these diagrams adopted in the present edition published in 1978 by the CCIR has given every satisfaction, is very familiar to its users and they will not find it easy to use if changes are made;
- (c) Recommendation 414 of the CCIR concerning the method of labelling the curves of equal field strength and the work already carried out by the CCIR regarding the new diagrams,

UNANIMOUSLY DECIDES

that the new diagrams should be presented in as nearly as possible the same style as that adopted for the edition of 1978, and in particular that:

1. the sinusoidal projection shall be used;
2. for antennas having symmetrical diagrams, the right-hand side of the diagram will show half of the forward radiation pattern over a brown grid and the left-hand side will show half of the backward radiation pattern over a blue grid. For asymmetrical antenna radiation patterns (e.g. slewed curtain arrays) the presentation adopted in the 1978 edition is to be retained;
3. a small sketch on the right-hand side of the pages will show the structure and the dimensions of the antennas;
4. for vertical antennas, a small sketch on the left-hand side of the pages will show a horizontal radiation pattern;
5. the curves of equal field strength be labelled with relative gain values, the direction of maximum radiation is to be marked 0 dB in accordance with Recommendation 414; in addition, a small table is to show the relationship between relative and absolute values;
6. the curves of equal field strength (in dB relative to the maximum) shall be determined by the following values:
 - *vertical antennas* (ground of perfect conductivity):
0, 1, 2, 3, 4, 6, 8, 10, 13, 16, 20, 25, 30 and ∞ ;
 - *dipole antennas and arrays of horizontal dipoles* (average ground, $\sigma = 10^{-2}$ S/m, $\epsilon = 4$):
0, 1, 2, 3, 4, 6, 8, 10, 13, 16, 20, 25, 30 and 40;
 - *rhombic antennas* (average ground, $\sigma = 10^{-2}$ S/m, $\epsilon = 4$):
0, 3, 6, 10, 20 and 40.
7. each diagram is to show:
 - the value of electromotive force E_{cs} (in volts) in the direction of maximum radiation;
 - the gain values (in dB): for vertical antennas (LF and MF) to be expressed relative to a short vertical antenna, G_v ; for antennas used at HF, principally horizontally polarized antennas, the gain value is to be expressed relative to a half wave dipole G_d and the isotropic gain G_i included.

 OPINION 15-3

BROADCASTING IN THE 26 MHz BAND

(1953–1966–1970–1974)

The CCIR,

CONSIDERING

- (a) that it is important that long-distance broadcasting should use all frequency bands available to it;
- (b) that when the smoothed relative sunspot number reaches 70, long-distance broadcast transmissions can be carried out efficiently during daylight hours, over many routes, at frequencies within the 26 MHz broadcasting band;
- (c) that these frequencies are seldom used;
- (d) that such transmissions on these frequencies, whenever they are possible, are particularly advantageous, because of the very low atmospheric-noise intensity and the low absorption,

IS UNANIMOUSLY OF THE OPINION

1. that administrations should bring to the notice of broadcasting organizations the advantages of the 26 MHz band for long-distance terrestrial broadcasting when ionospheric conditions are favourable;
 2. that receiver manufacturers be informed of these possibilities and encouraged to extend the tuning range of their products to permit reception in the 26 MHz band.
-

OPINION 16-2 *

**ORGANIZATIONS QUALIFIED TO TAKE ACTION ON SOUND
AND TELEVISION RECORDING**

(1956–1970–1978)

The CCIR,

CONSIDERING

- (a) that differences of opinion may exist as to which of the organizations, the International Electrotechnical Commission (IEC), the International Organization for Standardization (ISO) or CCIR, is in the best position to take action on questions concerning recording;
- (b) that unnecessary duplication of work and a multiplicity of standards may result, if the present situation is allowed to continue,

IS UNANIMOUSLY OF THE OPINION

1. that the CCIR should determine the acceptability of existing standards and should collaborate with other international organizations in formulating new standards, when the existing ones are unsuitable for the international exchange of programmes;
2. that CCIR texts should make reference to existing standards that are judged to be acceptable; references should refer directly to the relevant information without involving successive cross-references; these texts may also include brief descriptive excerpts from these standards when this may help the reader to grasp quickly the full technical content of a specification;
3. that the Director, CCIR, should keep in close touch with the IEC and the ISO, with a view to avoiding unnecessary duplication of work;
4. that to inform the IEC and the ISO of CCIR studies and decisions, the Director, CCIR, should transmit all relevant documents to these organizations inviting them to take CCIR views into account.

OPINION 51 **

**STUDY OF DIGITAL TECHNIQUES BY CCIR STUDY GROUPS
AND THE CMTT**

(1974)

The CCIR,

CONSIDERING

- (a) that the study of digital techniques will be an important part of the future work of CCIR Study Groups 4, 9, 10, 11 and the CMTT;
- (b) that CCITT Study Group XVIII has been assigned all questions relating to pulse-code modulation under study by CCITT;
- (c) that CCITT Study Group XVIII will establish performance requirements for transmission systems and, for this work, will need to know the likely digit rates for the various services to be carried by digital networks and performance capabilities of various transmission media, including terrestrial radio and satellite systems,

IS UNANIMOUSLY OF THE OPINION

1. that the work of CCIR Study Groups 4 and 9 on digital transmission systems should be closely coordinated with the work of CCITT Study Group XVIII. The Director, CCIR, should transmit the relevant documents of Study Groups 4 and 9 directly to CCITT Study Group XVIII;

* This Opinion also concerns Study Group 11.

** Also concerns Study Group 11 and the CMTT.

2. that Study Groups 10 and 11 should study the methods of digital encoding and error protection appropriate to the broadcasting, recording and studio processing of sound programme and television signals respectively, and to study methods for the reduction of redundancy in these signals;
3. that the CMTT should study the methods of digital encoding, transcoding and error protection appropriate to the long distance transmission of sound programme and television signals. The CMTT should also provide the necessary coordination to ensure that the work of Study Groups 10, 11 and the CMTT is transmitted to CCITT Study Group XVIII in a unified manner through the Director, CCIR;
4. that the results of the work of CCITT Study Group XVIII should be transmitted to the CCIR Study Groups concerned through the Director, CCIR.

OPINION 59 *

SIMULATED PROGRAMME SIGNALS

(1978)

The CCIR,

CONSIDERING

- (a) that simulated programme signals in the form of coloured noise, serving different purposes, are included in Recommendations 559 and 571, and are under consideration by the IEC;
- (b) that the number of these signals should be kept to a minimum,

IS UNANIMOUSLY OF THE OPINION,

1. that the work of CCIR, Study Group 10 on simulated programme signals should be closely co-ordinated with the work of CMTT and SC 29 B of the IEC. The Director, CCIR, should transmit the relevant documents of Study Group 10 directly to the IEC, and the Chairman, Study Group 10 should do likewise to the Chairman, CMTT;
2. that the IEC should be invited to transmit any further results of its work to CCIR Study Group 10 through the Director, CCIR.

OPINION 74 **

**FACILITIES FOR THE INTERCONNECTION OF SOUND-BROADCASTING
RECEIVERS AND ASSOCIATED EQUIPMENT**

(1982)

The CCIR,

CONSIDERING

- (a) that it is possible to transmit additional signals accompanying the normal programmes in sound broadcasting;
- (b) that existing receivers do not, in most cases, enable such signals to be used;
- (c) that, for this purpose, it would be preferable to use ancillary units which could be interconnected with new receivers,

IS UNANIMOUSLY OF THE OPINION

that the IEC should be requested to study this matter and to standardize the interconnection facilities so as to permit the use of such equipment associated with sound-broadcasting receivers.

* See Report 798.

** The Director, CCIR, is requested to bring this Opinion to the attention of the IEC and the CCITT.

DECISION 39-1

SOUND BROADCASTING IN BAND 7 (HF)

(1980-1981-1982)

CCIR Study Group 10,

CONSIDERING

- (a) that the Administrative Council has scheduled a World Administrative Radio Conference to plan for sound broadcasting in Band 7 (HF) with a first session to commence in January, 1984;
- (b) that the WARC (Geneva 1979) in Resolution No. 508 has requested the CCIR to accelerate the studies described in Recommendations Nos. 500 and 501 of that Conference;
- (c) that in addition it would be desirable to specify values for other essential technical parameters used in planning;
- (d) that spectrum utilization efficiency needs to be improved;
- (e) that the XVth Plenary Assembly will be the latest occasion on which the CCIR could approve the relevant texts,

DECIDES

1. that an Interim Working Party 10/5 be established to prepare, within the general terms of reference of Study Group 10, the technical bases for planning the HF bands allocated exclusively or on a shared basis to the broadcasting service (except the bands reserved for broadcasting in the Tropical Zone), and in particular:
 - to recommend the most suitable values of protection ratios, channel spacing and minimum signal-to-noise ratios required for a satisfactory service, taking into account the performance of typical receivers and receiving antennas;
 - to identify the principal types of transmitting antenna in common use and, if appropriate, recommend additional antenna types to be included in the CCIR Book of Antenna Diagrams;
 - to prepare and present data on the practical performance of directional antennas in a form suitable for planning purposes;
 - to study the utilization of single-sideband (SSB) techniques for broadcasting in the HF bands and develop technical specifications for suitable SSB systems paying particular attention to the manner in which such systems could be progressively introduced as well as attention to the economic problems associated with transmitters and receivers;
 - to study other technical parameters required for use in the planning process including the relationship between coverage and the parameters listed in Study Programme 44F/10 as well as the minimum number of frequencies necessary to provide satisfactory reception of the particular programme in each of the areas for which it is intended (Recommendation 410).
2. that as far as possible the work should be completed four months prior to the date of the next meeting of Study Group 10;
3. that the IWP should present a report to the next meeting of Study Group 10;
4. that the IWP may propose amendments to relevant Study Group 10 texts or prepare new ones as appropriate;
5. that as far as possible the work should be conducted by correspondence but in view of the urgency of the work a meeting or meetings would be desirable and these may be arranged upon the proposal of the Chairman, following consultations with the Director of the CCIR;
6. that the IWP will consist of representatives of Germany (Federal Republic of), Saudi Arabia, Australia, Belgium, Brazil, Canada, China (People's Republic of), Spain, United States of America, Finland, France, India, Iran, Italy, Japan, Norway, Netherlands, German Democratic Republic, United Kingdom, Sweden, Switzerland, Turkey, U.S.S.R., Deutsche Welle, the International Radio and Television Organization (OIRT) and the European Broadcasting Union (EBU);

7. that the Chairman of this IWP will be a representative of the Administration of the Netherlands;
8. that Study Group 6 be invited to appoint experts in HF propagation to join in the work of Interim Working Party 10/5.

Note. — The Director, CCIR is requested to bring this Decision to the attention of all administrations, inviting them to participate in the work of the CCIR and to designate their representative(s) and offer contributions to the work of IWP 10/5.

DECISION 40-1

PARAMETERS AND TOLERANCE LIMITS FOR THE TECHNICAL QUALITY OF PROGRAMMES INTENDED FOR INTERNATIONAL EXCHANGE

(1980-1981-1982)

CCIR Study Group 10,

CONSIDERING

- (a) that in Report 293 it has been possible so far to collect only basic material for the complete broadcasting chain which needs to be amended and processed in order to derive an appropriate Recommendation;
- (b) that not only terminological problems but also the different practical operating methods and the variable application of Recommendations and Reports of the CCIR and CMTT in the Member countries of CCIR have prevented a complete review of the processing and transmission methods of sound signals and their different level conditions and thus made it impossible to derive a proposal for a Recommendation;
- (c) that the introduction of digital techniques and new services makes it desirable to accelerate the work on the Report 293 to give fundamental values for the different transmission links in the chain for programme exchange and for the whole chain up to the listener desirable global values,

DECIDES

1. that an Interim Working Party 10/6 be established to prepare within the general terms of reference of Study Group 10 the technical bases for parameters and tolerance limits for the technical quality of programmes intended for international exchange, and in particular:
 - to determine the parameters needed to characterize high quality sound programmes for international exchange (see Study Programme 50E/10 for Report 293); and to define the corresponding measurement methods;
 - to determine attainable and/or desirable values for the whole transmission chain (see Study Programme 50E/10);
 - to compile, compare and standardize as far as possible, the conditions along the transmission chain (programme level, operating level, test tone level, adjusting level etc.), taking into account the increasing use of companders, limiters, and other control amplifiers with the consequent need for sufficient headroom (see also Study Programme 46B/10);
 - to recommend technical parameters and tolerance values required for the international exchange of programmes;
2. that the work of IWP 10/6 should continue on the basis of the timetable and work programme approved at the Final Meeting of Study Group 10, 1981, in order that a draft Recommendation, based on Report 293, may be produced for submission to the Interim Meeting of Study Group 10 in 1983;
3. that the IWP may propose amendments to relevant Study Group texts or prepare new ones as appropriate;
4. that as far as possible the work should be conducted by correspondence but in order to make significant progress in the work a meeting would be desirable and this may be arranged upon the proposal of the Chairman, following consultations with the Director of the CCIR;

5. that the IWP will consist of representatives of Germany, (Federal Republic of), Australia, Canada, United States of America, France, India, Iran, Italy, Japan, German Democratic Republic, United Kingdom, Sweden, Switzerland, Turkey, U.S.S.R. and the European Broadcasting Union (EBU);

6. that the Chairman of this IWP will be a representative of the Administration of the United Kingdom;

7. that CMTT be invited to appoint experts in those problems listed up in § 1 to join in the work of IWP 10/6.

Note. — The Director, CCIR is requested to bring this Decision to the attention of all administrations, inviting them to participate in the work of the CCIR and to designate their representative(s) and offer contributions to the work of IWP 10/6.

DECISION 52

REFERENCE SOUND-BROADCASTING RECEIVERS FOR PLANNING PURPOSES

(AM and FM modulation)

(1981–1982)

CCIR Study Group 10,

CONSIDERING

- (a) that frequency assignment plans must of necessity take into account the characteristics of receivers, regardless of the type of modulation or frequency band used;
 - (b) that the range of performance of receivers used by the public is very large;
 - (c) that standard reference receivers should therefore be defined, whose characteristics are to be taken as a basis for frequency planning purposes;
 - (d) that adequate information for this purpose is not available in current CCIR texts;
- and being aware of the activity of the IEC in defining suitable parameters and methods of measurement,

DECIDES

- 1. that an Interim Working Party 10/7 be established within the general terms of reference of Study Group 10:
 - 1.1 to identify and define the characteristics of sound-broadcasting receivers necessary for planning purposes;
 - 1.2 to prepare the performance specification of reference sound-broadcasting receivers (including the antennas whether built-in or external).

Both amplitude modulation (DSB and SSB) and frequency modulation systems are to be taken into account;
- 2. that the Interim Working Party should propose amendments to relevant Study Group 10 texts or prepare new ones as appropriate;
- 3. that the Interim Working Party should present a report to the next Interim Meeting of Study Group 10;
- 4. that as far as possible the work should be conducted by correspondence; however, it may meet, upon the proposal of its Chairman, following consultations with the Director of the CCIR;
- 5. that the Interim Working Party will consist of representatives of Germany (Federal Republic of), Canada, China (People's Republic of), Spain, the United States of America, France, India, Iran, Italy, Japan, United Kingdom, Switzerland, U.S.S.R., Deutsche Welle and the European Broadcasting Union (EBU);
- 6. that the Chairman of this Interim Working Party will be a representative of the Administration of Switzerland (see Annex I);

7. that Study Group 1 be invited to nominate a representative for participation in the work of Interim Working Party 10/7;

8. that the IEC be invited to participate in the work of Interim Working Party 10/7.

Note. — The Director, CCIR, is requested to bring this Decision to the attention of all administrations, inviting them to participate in the work of the CCIR and to designate representatives and offer contributions to the work of Interim Working Party 10/7.

ANNEX I

Chairman of Interim Working Party 10/7:

M. Markus Schneider
Direction générale des PTT
Division des recherches et du développement
Section de la technique de radiodiffusion
CH-3030 Berne, Switzerland.

ALPHABETICAL INDEX OF KEY WORDS AND TERMS OF VOLUME X

A

Acoustical properties, control and listening rooms (Rep.797)

Amplitude modulation

- double sideband systems (Rep.458)
- single-sideband, channel spacing (Rep.458)
- single-sideband, compatible systems (Rep.299, Rep.458)
- single-sideband system (Rep.299, Rep.458, Rep.472, Rep.620)
- single-sideband systems, carrier reduction (see Carrier reduction in amplitude modulation single-sideband system)
- single-sideband systems with synchronous detection (Rep.458)
- single-sideband transition period (Rep.458)
- systems in bands 5(LF), 6(MF), 7(HF) (Rec.205, Rec.410, Rep.411, Rec.499, Rep.299, Rep.457, Rep.458, Rep.461, Rep.619, Rep.794)

Antennas

- broadcasting receiving (Rec.140, Rec.599, Rep.617)
- broadcasting receiving in tropical zone (Rec.140)
- broadcasting transmitting HF (Rec.80, Rec.414, Rep.32)
- broadcasting transmitting in tropical zone (Rec.49, Rec.139, Rep.301)
- broadcasting transmitting LF-MF (Rec.414, Rec.561, Rep.401)
- directional (Rec.414, Rep.616) (see also Broadcasting transmitting)
- directivity of (Rec.414, Rec.559, Rep.616)
- presentation of antenna diagrams (Rec.414)

Atmospheric noise (see Noise, atmospheric)

Audio-frequency (AF) protection ratio (defn) (Rec.442, Rep.794)

Audio-frequency (AF) signal-to-interference ratio (defn) (Rec.448)

B

Bandwidth

- measurement in LF, MF and HF sound broadcasting (Rep.458)
- necessary in LF, MF and HF sound broadcasting (Rep.458)
- reduction and limitation in LF, MF and HF sound broadcasting (Rep.458)

C

Carrier-reduction in amplitude modulation single-sideband systems (Rep.458)

Cartridges

- magnetic tape (Rec.564)

Cassettes

- magnetic tape (Rec.564)

Channel distribution in regular networks (Rep.944)

Channel spacing

- for AM sound broadcasting in band 7(HF) (Rec.597)
- for FM sound broadcasting in band 8(VHF) (Rec.412, Rep.458)
- for AM sound broadcasting in bands 5(LF), 6(MF) and 7(HF) (Rec.597, Rep.457, Rep.458)
- in single-sideband broadcasting (Rep.458)

CCITT (Rep.292, Rep.622)

CISPR (see International Special Committee for Radio Interference)

Community listening

- low cost receivers, specifications of (Rec.416)

Compatibility of a monophonic signal obtained from a stereophonic source (Rep.620)

Compatible monophonic reception in stereophonic broadcasting (Rep.300)

Compatible SSB sound broadcasting (Rep.299)

Control and listening rooms, acoustical properties of (Rep.797)

Coverage (Rec.499, Rec.598, Rep.616)

Coverage area (defn) (Rec.499)

Coverage factor (Rec.598)

Coverage, MF (Rec.598)

- day-time (Rep.616)
- ground wave (Rep.616)
- night-time (Rep.616)
- population (Rep.616)
- skywave (Rep.616)

Cross-modulation

- ionospheric in LF and MF bands (Rec.498)

Cross-polarization, sound broadcasting FM (Rep.122, Rep.464) (see also Polarization, Orthogonal polarization)

Cross-talk into the stereophonic channels (Rep.300)

Cymomotive force

- measurement, (defn) (Rec.561)

D

Digital modulation, quality, subjective assessment of (Rep.799)

Digital technique

- coding of high quality sound signals in satellite broadcasting, (see also Vol.XI-2)
- for studios and quality measurements (Rep.948, Rep.949, Rep.799)
- recording of audio signals (Rep.950)
- sampling frequency for sound signals in studios (Rep.949), (see also Digital modulation)

Directivity of antennas (see Antennas, directivity of)

E

EBU (see European Broadcasting Union)

Effective monopole radiated power (e.m.r.p.) (defn) (Rec.561)

Equivalent sideband power (Rep.458)

European Broadcasting Union (EBU) (Rec.498, Rec.560, Rep.292, Rep.293, Rep.299, Rep.457, Rep.458, Rep.464, Rep.616, Rep.794)

F

Fading

- allowances in HF broadcasting (Rec.411)
- characteristics for broadcasting in tropical zone (Rep.304)
- reduction of effects (Rep.472, Rep.619)
- reduction of effects in tropical zone, by single-sideband reception (Rep.472)

Field strength

- minimum usable (Rec.412, Rec.499)
- nominal usable (Rec.499)
- reference usable (Rec.499)
- resulting from several electromagnetic fields (Rep.516)
- sky-wave reduction in band 6(MF) (Rep.461, Rep.619)
- specific (defn) (Rec.499)
- usable (Rec.499, Rep.944)

Frequency modulation systems in bands 8(VHF) and 9(UHF) (Rec.412, Rec.450, Rec.467, Rep.293, Rep.300, Rep.463, Rep.464, Rep.620, Rep.796)

Frequency planning constraints (see Planning, constraints in band 8(VHF))

FM broadcasting

Frequency sharing with fixed service in tropical zone (Rec.214)

Frequency stability

- broadcasting, sound (Rep.458)

G

Ground conductivity, influence of on characteristics of transmitting antennas (Rep.401)

Ground-wave coverage (see Coverage, ground wave)

I

IEC (see International Electrotechnical Commission)

Image rejection ratio of receivers (see Rejection ratio)

Interference

- adjacent-channel in regular networks (Rep.944)
- broadcasting, shared bands, in (Rec.214, Rec.216)
- co-channel in regular networks (Rep.944)
- from D/SECAM television transmission to FM sound broadcasting in band 8(VHF) (Rep.944)
- generated by receivers (Rep.617)
- in tropical zone, in shared bands (Rec.48, Rec.49, Rec.214, Rec.216, Rep.302)
- man-made (Rep.464)
- multiple, methods of assessment of (Rep.944, Rep.945) (see also Signal-to-interference ratio and Protection ratio)
- to sound broadcasting in the shared bands in tropical zone (Rec.214, Rep.302)

Intermediate frequency

- characteristics of receivers (Rep.458, Rep.617)
- characteristics, low cost broadcasting receivers (Rec.415, Rec.416)
- passband of receivers (Rep.457)
- rejection ratio of receivers (see Rejection ratio)
- values (Rep.617)

International Electrotechnical Commission (IEC) (Rec.408, Rec.409, Rec.415, Rec.563, Rec.564, Rep.292, Rep.617, Rep.798, Rep.800)

International exchange of recorded sound programmes (Rec.407, Rec.408, Rep.622, Rep.800, (see also Recording, magnetic tape)

International organizations (see proper names)

International Radio and Television Organization (OIRT) (Rec.562, Rep.292, Rep.293, Rep.300, Rep.458, Rep.465, Rep.622, Rep.797)

International Special Committee on Radio Interference (CISPR) (Rec.412, Rec.415, Rep.617)

Ionospheric cross modulation (see Cross modulation, ionospheric)

L

Lattice, regular of transmitter sites in band 6(MF) (Rec.598)

Lightning protection (Rep.943)

Listening panel, for assessment of the quality of sound (Rec.562)

Listening rooms (see Acoustical properties, control and listening rooms)

Loudness, subjective determination of (Rep.465)

Low cost receivers (see Receivers, low cost)

Low power stations (Rep.616)

M

Magnetic tape recording (see Recording, magnetic tape)

Measurements

- cymomotive force (Rec.651)
- noise level, audio-frequency in sound broadcasting (Rec.468)
- noise, programme circuits (Rec.562)
- programme level (Rep.292)
- protection ratio (Rec.559, Rep.796)
- wow and flutter (Rec.409)

Minimum usable field strength (see Field strength, minimum usable)

Modulation (see also Amplitude modulation systems, Frequency modulation systems, Digital modulation or technique)

- pilot-tone FM (Rep.300)
- polar, FM (Rep.300)

Multiple frequency use in HF broadcasting (Rec.410)

Multiple interference, methods of assessment of (see Interference, multiple)

N

Network planning (see Planning of the networks)

Networks, regular (Rep.944)

Noise, atmospheric, effects of in tropical zone (Rep.303)

Noise level, audio-frequency in sound broadcasting measurement of (Rec.468)

Noise, measurements, programme circuits (Rec.562)

O

OIRT (see International Radio and Television Organization)

Orthogonal wave polarization, advantages to be gained by use of (Rep.122) (see also Polarization)

Oscillator frequency of receivers (Rep.617)

Out-of-band spectrum in LF, MF and HF sound broadcasting (Rep.457)

Overtone system, bandwidth saving (Rep.457)

P

Passband of receivers, characteristics of (Rep.457), (see also Radio-frequency, Intermediate frequency)

Peak-programme meter (Rep.292)

Pilot tone, stereophonic broadcasting (see Stereophonic broadcasting)

Planning

- constraints in band 8(VHF) FM broadcasting (Rep.947)
- standards for band 8(VHF) FM sound broadcasting (Rec.412)

Planning of the networks (Rep.944)**Polar modulation, stereophonic broadcasting** (see Stereophonic broadcasting)**Polarization** (see also Orthogonal polarization and Cross-polarization)

- dual (Rep.464)
- elliptical (Rep.464)
- horizontal (Rep.464)
- in FM sound broadcasting (Rep.464)
- mixed (Rep.464)
- slant (Rep.464)
- vertical (Rep.464)

Power

- effective monopole radiated (see Effective monopole radiated power)
- equivalent, sideband (Rep.458)
- limitation in tropical zone (Rec.214, Rec.215)
- maximum transmitter in tropical zone (see Maximum transmitter power in tropical zone)

Power sum method of assessment of multiple interference (Rep.945)**Pre-emphasis characteristics in FM sound broadcasting** (Rec.450)**Programme circuits**

- level, measurements (Rep.292)
- noise measurements (Rec.562)

Programme exchange (Rec.407, Rec.408, Rec.564, Rep.622, Rep.800)**Programme level, measurements** (Rep.292)**Programme meter, peak** (see Peak-programme meter, Programme level measurements)**Protection ratio** (Rec.216, Rec.412, Rec.447, Rec.559, Rec.560, Rep.617, Rep.794, Rep.796, Rep.944, Rep.947) (see also Audio-frequency protection ratio, Radio-frequency protection ratio)

- in the tropical zone (Rec.216)
- measurements (Rec.559, Rep.796)

Q**Quality of sound**

- assessment of (Rec.562, Rep.799)
- in broadcasting using digital techniques, subjective assessment of (Rep.799)

Quality parameters, audio-frequency tolerances of in stereophonic transmission and reproduction of sound (Rep.293)**R****Radiation** (defn) (see Cymomotive force, Effective monopole, Radiated power)**Radiation diagram** (see Antennas)**Radio-frequency passband of receivers** (Rep.458)**Radio-frequency (RF) protection ratio, general** (Rec.447, Rec.559, Rec.560, Rep.794, Rep.947)**Radio-frequency wanted-to-interfering signal ratio** (defn) (Rec.447)

- determination of (and measurement) (Rec.412, Rep.796)

for FM sound broadcasting in band 8(VHF) against interference from D/SECAM television transmission (Rep.947)

in LF, MF and HF broadcasting (Rec.559, Rec.560, Rep.794)

measurement of (Rec.559, Rep.796)

Re-broadcasting in tropical zone (Rep.472)**Receivers**

- characteristics (Rep.457, Rep.617, Rep.796)
- low-cost, for community listening, specification of (Rec.416)
- low-cost specifications of (Rec.415, Rec.416)

Recording

- on magnetic tape (Rec.408, Rec.563, Rec.564, Rep.622, Rep.800, Rep.950)
- wow and flutter, measurement of (Rec.409)

Reference usable field strength (see Field strength, reference usable)**Rejection ratio**

- image, of receivers (Rep.617)
- intermediate frequency of receivers (Rep.617)

S**Sampling frequency**

- for digital sound signals in broadcasting studios (Rep.949)

Selectivity of receivers (Rec.415, Rep.617)**Sensitivity of receivers** (Rec.415, Rep.617)**Service area** (defn) (Rec.499)**Service range** (Rep.616)**Several sound programmes**

- transmission of in FM sound broadcasting (Rep.463)
- transmission of in television (Rep.738)

Signal-to-interference ratio, in sound broadcasting (defn) (Rec.447) (see also Protection ratio)**Simplified multiplication method**

- of assessment of multiple interference (Rep.945)

Simulated programme signals (Rep.798)**Simultaneous transmission of several sound or information signals**

- in television (Rep.738)

Single sideband modulation (see Modulation, single sideband)**Site selection for transmitter in tropical zone** (Rec.49)**Sky-wave coverage** (see Coverage, sky-wave)**Sky-wave reception**

- in band 5(LF), 6(MF) and 7(HF) (Rep.619)

Sky-wave, reduction of in MF broadcasting (Rep.461)**Sky-wave signal, reduction of** (Rep.461, Rep.619)**Sound quality, subjective assessment of** (see Quality of sound)**Specific field strengths** (see Field strengths, specific)**Stereophonic AM broadcasting** (Rep.300)**Stereophonic FM broadcasting** (Rec.450, Rep.293, Rep.300, Rep.620, Rep.622)

- multidimensional systems (Rep.300)

Stereophonic reception (Rep.300)

Stereophonic recording (Rep.622)

Synchronized networks, coverage in (Rep.616)

Synchronized transmitters (see Transmitters, synchronized)

T

Transmission of several sound programmes

in FM sound broadcasting (Rep.300)

in television (Rep.795)

Transmission standards for band 8(VHF) FM sound broadcasting (Rec.450)

Transmitters

synchronized in HF broadcasting, use of (Rec.205)

Tropical zone

broadcasting in (Rec.48, Rec.49, Rec.139, Rec.140, Rec.214, Rec.215, Rec.216, Rep.301, Rep.302, Rep.304, Rep.472)

broadcasting in, choice of frequency for (Rec.48)

broadcasting in, protection ratio (Rec.216)

broadcasting in, site selection for transmitters (Rec.49)

W

Wanted-to-interfering signal ratio (see also Protection ratio)

Wow and flutter, measurement of (see Measurement, wow and flutter)

