XVII A.P.
DÜSSELDORF
21.5-1.6 1990
CCIR

XVIIth PLENARY ASSEMBLY
DÜSSELDORF, 1990

INTERNATIONAL TELECOMMUNICATION UNION

RECOMMENDATIONS OF THE CCIR, 1990

(ALSO RESOLUTIONS AND OPINIONS)

VOLUME X – PART 1

BROADCASTING SERVICE (SOUND)

CCIR INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

Geneva, 1990

CCIR

1. The International Radio Consultative Committee (CCIR) is the permanent organ of the International Telecommunication Union responsible under the International Telecommunication Convention "... to study technical and operating questions relating specifically to radiocommunications without limit of frequency range, and to issue recommendations on them..." (International Telecommunication Convention, Nairobi 1982, First Part, Chapter I, Art. 11, No. 83).*

2. The objectives of the CCIR are in particular:

a) to provide the technical bases for use by administrative radio conferences and radiocommunication services for efficient utilization of the radio-frequency spectrum and the geostationary-satellite orbit, bearing in mind the needs of the various radio services;

b) to recommend performance standards for radio systems and technical arrangements which assure their effective and compatible interworking in international telecommunications;

c) to collect, exchange, analyze and disseminate technical information resulting from studies by the CCIR, and other information available, for the development, planning and operation of radio systems, including any necessary special measures required to facilitate the use of such information in developing countries.

* *See also the Constitution of the ITU, Nice, 1989, Chapter 1, Art. 11, No. 84.*

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92-61-04261-9

Geneva, 1990

PLAN OF VOLUMES I TO XV
XVIIth PLENARY ASSEMBLY OF THE CCIR

(Düsseldorf, 1990)

VOLUME I (Recommendations) *Annex to Vol. I* (Reports)	Spectrum utilization and monitoring
VOLUME II (Recommendations) *Annex to Vol. II* (Reports)	Space research and radioastronomy services
VOLUME III (Recommendations) *Annex to Vol. III* (Reports)	Fixed service at frequencies below about 30 MHz
VOLUME IV-1 (Recommendations) *Annex to Vol. IV-1* (Reports)	Fixed-satellite service
VOLUMES IV/IX-2 (Recommendations) *Annex to Vols. IV/IX-2* (Reports)	Frequency sharing and coordination between systems in the fixed-satellite service and radio-relay system
VOLUME V (Recommendations) *Annex to Vol. V* (Reports)	Propagation in non-ionized media
VOLUME VI (Recommendations) *Annex to Vol. VI* (Reports)	Propagation in ionized media
VOLUME VII (Recommendations) *Annex to Vol. VII* (Reports)	Standard frequencies and time signals
VOLUME VIII (Recommendations)	Mobile, radiodetermination, amateur and related satellite services
Annex 1 to Vol. VIII (Reports)	Land mobile service – Amateur service – Amateur satellite service
Annex 2 to Vol. VIII (Reports)	Maritime mobile service
Annex 3 to Vol. VIII (Reports)	Mobile satelllite services (aeronautical, land, maritime, mobile and radiodetermination) – Aeronautical mobile service
VOLUME IX-1 (Recommendations) *Annex to Vol. IX-1* (Reports)	Fixed service using radio-relay systems
VOLUME X-1 (Recommendations) *Annex to Vol. X-1* (Reports)	Broadcasting service (sound)
VOLUMES X/XI-2 (Recommendations) *Annex to Vols. X/XI-2* (Reports)	Broadcasting-satellite service (sound and television)
VOLUMES X/XI-3 (Recommendations) *Annex to Vols. X/XI-3* (Reports)	Sound and television recording
VOLUME XI-1 (Recommendations) *Annex to Vol. XI-1* (Reports)	Broadcasting service (television)
VOLUME XII (Recommendations) *Annex to Vol. XII* (Reports)	Television and sound transmission (CMTT)
VOLUME XIII (Recommendations)	Vocabulary (CCV)
VOLUME XIV	Administrative texts of the CCIR
VOLUME XV-1 (Questions)	Study Groups 1, 12, 5, 6, 7
VOLUME XV-2 (Questions)	Study Group 8
VOLUME XV-3 (Questions)	Study Groups 10, 11, CMTT
VOLUME XV-4 (Questions)	Study Groups 4, 9

All references within the texts to CCIR Recommendations, Reports, Resolutions, Opinions, Decisions and Questions refer to the 1990 edition, unless otherwise noted; i.e., only the basic number is shown.

DISTRIBUTION OF TEXTS OF THE XVIIth PLENARY ASSEMBLY OF THE CCIR IN VOLUMES I TO XV

Volumes and Annexes I to XV, XVIIth Plenary Assembly, contain all the valid texts of the CCIR and succeed those of the XVIth Plenary Assembly, Dubrovnik, 1986.

1. Recommendations, Resolutions, Opinions are given in Volumes I-XIV and Reports, Decisions in the Annexes to Volumes I-XII.

1.1 *Numbering of texts*

When a Recommendation, Report, Resolution or Opinion is modified, it retains its number to which is added a dash and a figure indicating how many revisions have been made. 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.

1.2 *Recommendations*

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48	X-1	368-370	V	479	II
80	X-1	371-373	VI	480	III
106	III	374-376	VII	481-484	IV-1
139	X-1	377, 378	I	485, 486	VII
162	III	380-393	IX-1	487-493	VIII-2
182	I	395-405	IX-1	494	VIII-1
215, 216	X-1	406	IV/IX-2	496	VIII-2
218, 219	VIII-2	407, 408	X/XI-3	497	IX-1
239	I	411, 412	X-1	498	X-1
240	III	415	X-1	500	XI-1
246	III	417	XI-1	501	X/XI-3
257	VIII-2	419	XI-1	502, 503	XII
265	X/XI-3	428	VIII-2	505	XII
266	XI-1	430, 431	XIII	508	I
268	IX-1	433	I	509, 510	II
270	IX-1	434, 435	VI	513-517	II
275, 276	IX-1	436	III	518-520	III
283	IX-1	439	VIII-2	521-524	IV-1
290	IX-1	441	VIII-3	525-530	V
302	IX-1	443	I	531-534	VI
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313	VI	450	X-1	540-542	VIII-2
314	II	452, 453	V	546-550	VIII-3
326	I	454-456	III	552, 553	VIII-3
328, 329	I	457, 458	VII	555-557	IX-1
331, 332	I	460	VII	558	IV/IX-2
335, 336	III	461	XIII	559-562	X-1
337	I	463	IX-1	565	XI-1
338, 339	III	464-466	IV-1	566	X/XI-2
341	V	467, 468	X-1	567-572	XII
342-349	III	469	X/XI-3	573, 574	XIII
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1.2 *Recommendations (cont.)*

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584	VIII-1	632, 633	VIII-3	683, 684	VI
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591	VIII-3	638-641	X-1	687	VIII-1
592-596	IX-1	642	X-1	688-693	VIII-2
597-599	X-1	643, 644	X-1	694	VIII-3
600	X/XI-2	645	X-1 + XII	695-701	IX-1
601	XI-1	646, 647	X-1	702-704	X-1
602	X/XI-3	648, 649	X/XI-3	705	X-1 (1)
603-606	XII	650-652	X/XI-2	706-708	X-1
607, 608	XIII	653-656	XI-1	709-711	XI-1
609-611	II	657	X/XI-3	712	X/XI-2
612, 613	III	658-661	XII	713-716	X/XI-3
614	IV-1	662-666	XIII	717-721	XII
615	IV/IX-2	667-669	I	722	XII
616-620	V	670-673	IV-1	723, 724	XII
622-624	VIII-1	674, 675	IV/IX-2		

1.3 *Reports*

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19	III	319	VIII-1	472	X-1
122	XI-1	322	VI (1)	473	X/XI-2
137	IX-1	324	I	476	XI-1
181	I	327	III	478	XI-1
183	III	336*	V	481-485	XI-1
195	III	338	V	488	XII
197	III	340	VI (1)	491	XII
203	III	342	VI	493	XII
208	IV-1	345	III	496, 497	XII
209	IV/IX-2	347	III	499	VIII-1
212	IV-1	349	III	500, 501	VIII-2
214	IV-1	354-357	III	509	VIII-3
215	X/XI-2	358	VIII-1	516	X-1
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224	II	371, 372	I	521, 522	I
226	II	375, 376	IX-1	525, 526	I
227*	V	378-380	IX-1	528	I
228, 229	V	382	IV/IX-2	533	I
238, 239	V	384	IV-1	535, 536	II
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279	I	439	VII	569	V
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* Not reprinted, see Dubrovnik, 1986.

(1) Published separately.

1.3 *Reports (cont.)*

Number	Volume	Number	Volume	Number	Volume
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628, 629	XI-1	795	X-1	980-985	II
630	X/XI-3	798, 799	X-1	987, 988	II
631-634	X/XI-2	801, 802	XI-1	989-996	III
635-637	XII	803	X/XI-3	997-1004	IV-1
639	XII	804, 805	XI-1	1005, 1006	IV/IX-2
642, 643	XII	807-812	X/XI-2	1007-1010	V
646-648	XII	814	X/XI-2	1011, 1012	VI
651	I	815, 816	XII	1016, 1017	VII
654-656	I	818-823	XII	1018-1025	VIII-1
659	I	826-842	I	1026-1033	VIII-2
662-668	I	843-854	II	1035-1039	VIII-2
670, 671	I	857	III	1041-1044	VIII-2
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738	VII	930-932	IX-1	1149-1151	VI
739-742	VIII-1	934	IX-1	1152	VII
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760-764	VIII-3	950	X/XI-3	1187-1197	IX-1
766	VIII-3	951-955	X/XI-2	1198	X-1 (1)
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778	VIII-1	961, 962	XI-1	1227, 1228	X/XI-2
780*	IX-1	963, 964	X/XI-3	1229-1233	X/XI-3
781-789	IX-1	965-970	XII	1234-1241	XII

* Not reprinted, see Dubrovnik, 1986.

(1) Published separately.

1.3.1 *Note concerning Reports*

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

1.4 *Resolutions*

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15	I	64	X-1	89	XIII
20	VIII-1	71	I	95	XIV
23	XIII	72, 73	V	97-109	XIV
24	XIV	74	VI	110	I
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61	XIV	79-83	XIV		

1.5 *Opinions*

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2	I	45	VI	73	VIII-1
11	I	49	VIII-1	74	X-1 + X/XI-3
14	IX-1	50	IX-1	75	XI-1 + X/XI-3
15	X-1	51	X-1	77	XIV
16	X/XI-3	56	IV-1	79-81	XIV
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1.6 *Decisions*

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2. **Questions** (Vols. XV-1, XV-2, XV-3, XV-4)

2.1 *Numbering of texts*

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.

Note – The numbers of the Questions of Study Groups 7, 9 and 12 start from 101. In the case of Study Groups 7 and 9, this was caused by the need to merge the Questions of former Study Groups 2 and 7 and Study Groups 3 and 9, respectively. In the case of Study Group 12, the renumbering was due to the requirement to transfer Questions from other Study Groups.

2.2 *Assignment of Questions*

In the plan shown on page II, the relevant Volume XV in which Questions of each Study Group can be found is indicated. A summary table of all Questions, with their titles, former and new numbers is to be found in Volume XIV.

2.3 *References to Questions*

As detailed in Resolution 109, the Plenary Assembly approved the Questions and assigned them to the Study Groups for consideration. The Plenary Assembly also decided to discontinue Study Programmes. Resolution 109 therefore identifies those Study Programmes which were approved for conversion into new Questions or for amalgamation with existing Questions. It should be noted that references to Questions and Study Programmes contained in the texts of Recommendations and Reports of Volumes I to XIII are still those which were in force during the study period 1986-1990.

Where appropriate, the Questions give references to the former Study Programmes or Questions from which they have been derived. New numbers have been given to those Questions which have been derived from Study Programmes or transferred to a different Study Group.

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VOLUME X

BROADCASTING SERVICE (SOUND)

(Study Group 10)

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STUDY GROUP 10

BROADCASTING SERVICE (SOUND)

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.

1986-1990	*Chairman:*	C. TERZANI (Italy)
	Vice-Chairmen:	A. KELLER (France)
		O. P. KHUSHU (India)
		H. KUSSMANN (Germany (Federal Republic of))

As from the next study period, in conformity with Resolution 61 adopted at the XVIIth Plenary Assembly, Düsseldorf (May-June 1990), the scope of the work which will be undertaken and the names of the Chairman and Vice-Chairmen are as follows.

STUDY GROUP 10

BROADCASTING SERVICE (SOUND)

Scope:

International exchange of programmes and the technical and operating aspects of the broadcasting and broadcasting-satellite services, including audio frequency and recording equipment, as well as the overall performance of the means of delivering signals to the general public, where they are used for sound, data and ancillary services accompanying sound.

1990-1994	*Chairman:*	C. TERZANI (Italy)
	Vice-Chairmen:	H. KUSSMANN (Germany (Federal Republic of))
		A. KELLER (France)
		K. P. RAMASWAMY (India)
		M. YUNUS KHAN (Pakistan)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP 10

1. Organization of work

During the study period 1986-1990, Study Group 10 held its Interim Meeting in Geneva from 3 to 17 November 1987 and its Final Meeting in Geneva from 9 to 23 October 1989, under the chairmanship of Mr. C. Terzani (Italy), assisted by the three Vice-Chairmen, Mr. A. Keller (France), Mr. O. P. Khushu (India) and Mr. H. Kussmann (Germany (Federal Republic of)).

Mr. Khushu having resigned, he was replaced by Mr. Ramaswamy (India). The XVIIth Plenary Assembly also appointed a fourth Vice-Chairman, Mr. Yunus Khan (Pakistan).

The Interim and Final Meetings were attended, respectively, by 198/223 delegates from the administrations of 28/33 countries, 15/12 recognized private operating agencies, 3/4 scientific or industrial organizations and 2/8 international organizations.

The Study Group set up the following Working Groups:

- *Working Group 10A:* Amplitude-modulation sound broadcasting, chaired by Mr. G. Petke (Germany (Federal Republic of));
- *Working Group 10B:* Frequency-modulation sound broadcasting, chaired by Mr. A. Keller (France);
- *Working Group 10C:* Audio-frequency characteristics of sound-broadcasting signals, chaired by Mr. G. Steinke (German Democratic Republic);
- *Editorial Group:* Liaison with CMV and review of texts, chaired by Mr. A. Gourbeille (France) at the Interim Meeting and Mr. A. Komly (France) at the Final Meeting.

Study Group 10 also set up the following Joint Working Groups with Study Group 11:

- *Joint Working Group 10-11D:* Sound-data broadcasting, chaired by Prof. F. Cappuccini (Italy), at the Final Meeting;
- *Joint Working Group 10-11R:* Recording of sound broadcasting and television programmes, chaired by Mr. P. Zaccarian (CBS);
- *Joint Working Group 10-11S:* Broadcasting-satellite service, chaired by Mr. R. F. Zeitoun (Canada).

2. Texts produced by the Study Group

Following the order in which the texts appear in Volume X, the Recommendations and Reports are listed first, grouped according to subject matter, followed by the Questions, Study Programmes, Resolutions, Opinions and Decisions.

Following the decisions of the XVIIth Plenary Assembly, Questions have generally been abolished and the Study Programmes have become Questions.

In accordance with the decisions taken at the XVIth Plenary Assembly (Dubrovnik, 1986), the texts relating to satellite broadcasting and to sound and television recording will appear in Parts 2 and 3 of Volumes X and XI, respectively.

The new Recommendation 705 and the Annex thereto on HF transmitting antenna characteristics and patterns will be published separately.

2.1 *Recommendations and Reports*

2.1.1 *Amplitude-modulation sound broadcasting*

This subject was dealt with in Working Group 10A, chaired by Mr. G. Petke (Germany (Federal Republic of)), which at the Interim and Final Meetings of Study Group 10 considered 26/34 contributions, drafted 18/28 documents and set up 4/6 Drafting Groups, respectively.

Recommendation 559 on objective measurement of RF protection ratios in broadcasting was radically revised, in particular by deleting the section on the graphical method and adding a short text on the subject in the new section on the numerical method, while Recommendation 560 on RF protection ratios was amended at the Interim Meeting by the addition of information on fading prediction as well as an annex relating to planning parameters in band 7.

Recommendation 598 on the factors influencing coverage in Band 6 (MF) was amended by the addition of four annexes, derived from Report 616 and the annexes thereto.

The note at the end of Recommendation 411 (fading allowances in HF broadcasting) was updated, and the results of experiments carried out in the People's Republic of China were added in Recommendation 498 on ionospheric cross-modulation.

The Interim Meeting drafted new Recommendation 702 on synchronization and multiple frequency use per programme in HF broadcasting, to replace Recommendations 205-2 and 410, which were cancelled.

Recommendation 80 (transmitting antennas in HF broadcasting) was condensed and revised, and Reports 32 and 1062 were annexed to it; Recommendation 414 (presentation of antenna diagrams) was cancelled and replaced by a new Recommendation 705 with an Annex containing all necessary details for the calculation of HF antenna characteristics and patterns, which will be published separately, along with the associated computer programs, thereby constituting a new edition of the CCIR Book of Antenna Diagrams.

New Recommendation 703 on the characteristics of AM sound broadcasting reference receivers marks the completion of IWP 10/7's work; it will be brought to the attention of the IEC.

Slight amendments were made to Recommendation 640 on the SSB system in HF broadcasting, and the Study Group approved Recommendation 706 on a data system in monophonic AM sound broadcasting, setting out the specifications for such a system, which will be brought to the attention of the IEC.

With regard to broadcasting in the Tropical Zone, Recommendation 139 on transmitting antennas was slightly amended at the Interim Meeting.

Study Group 10 approved a new Report 1201 on HF transmitters using a single channel, as well as amending a number of other Reports. In Report 516 (field-strength resulting from several electromagnetic fields), the results of research conducted in the USSR were added to supplement the studies carried out in Italy and Hungary. Report 401 (transmitting antennas in LF and MF broadcasting) was updated and condensed in the light of comments received from Study Group 6. Amendments were also made to Report 458 (broadcasting system characteristics), Report 1059 (characteristics of SSB systems in HF broadcasting) and Report 1061 (transmission of supplementary information in AM sound broadcasting), which will be brought to the attention of the IEC, as well as to Report 1060 on energy saving methods and their influence on reception quality.

On the subject of sound broadcasting in the Tropical Zone, minor amendments were made to Report 304 on fading characteristics and Report 472 on SSB reception.

Report 32-5, 461, 616-3, 617-2, 619 and 1062 were cancelled.

In all, Study Group 10 approved 4 new Recommendations and 1 new Report, amended 8 Recommendations and 8 Reports and cancelled 3 Recommendations and 6 Reports, for a total of 20 Recommendations and 14 Reports concerning amplitude-modulation sound broadcasting.

It was also noted that it would be useful if an IEC Working Group could investigate the problem of measurements on transmitting antennas.

2.1.2 *Frequency-modulation sound broadcasting*

This subject was dealt with in Working Group 10B, chaired by Mr. A. Keller (France), which at the Interim and Final Meetings of Study Group 10 considered 44/53 contributions, drafted 14/18 documents and set up 6/9 Drafting Groups, respectively.

Recommendation 642 on limiters for high-quality sound-programme signals was slightly amended at the Interim Meeting. On the basis of the work of IWP 10/7, the Working Group proposed a new Recommendation 704 on the characteristics of FM receivers for monophonic and stereophonic reception using pilot-tone and polar modulation systems.

Amendments were made to Recommendation 412 on planning standards and to Recommendation 643 on the system for automatic tuning of receivers, while a new Recommendation 707 was approved on the emission of multisound in terrestrial television systems. The two latter Recommendations will be brought to the attention of the IEC.

Amendments were made to Report 1066 on control of modulation level and Report 1064 on particular cases of interference. Report 1202 was approved on the protection ratios in the case of the same programme and synchronized signals, based on contributions by France and Italy.

Report 464 (polarization of emissions), Report 945 (methods for the assessment of multiple interference), Report 946 (planning constraints), Report 300 (stereophonic or multi-dimensional sound) and Report 463 (transmission of several sound programmes with a single transmitter) were amended.

A new Report 1203 was produced on digital sound broadcasting to mobile, portable and fixed receivers using terrestrial transmitters, as well as a new Report 1198 on compatibility between the broadcasting service in the band 87.5-108 MHz and the aeronautical services in the band 108-137 MHz. This text, which is of considerable value, particularly as regards methods of predicting potential incompatibilities, needs to be studied in depth by JIWP 8-10/1 with a view to merging it with Study Group 8's Report 929 to provide a text, along with a Recommendation, which will now be dealt with by the new Study Group 12.

Finally, Report 795 on the transmission of two or more sound programmes or information channels in terrestrial television was completely revised, with, in annex, a draft new Recommendation for television system M.

In the field of frequency-modulation sound broadcasting, therefore Study Group 10 approved 2 new Recommendations and 3 new Reports and amended 3 Recommendations and 8 Reports, for a total of 9 Recommendations and 15 Reports.

2.1.3 *Audio-frequency characteristics of sound-broadcasting signals*

This subject was dealt with in Working Group 10C, chaired by Mr. G. Steinke (German Democratic Republic), which at the Interim and Final Meetings of Study Group 10 considered 32/40 contributions, produced 15/30 documents and set up 3/5 Drafting Groups, respectively.

Recommendation 562 on subjective assessment of sound quality was amended by the addition in Annex I of a paragraph on the subjective assessment of multi-dimensional sound systems. Recommendation 644 on audio quality parameters was amended, in particular by the addition of a new Annex on special methods of measurement of audio quality parameters.

Study Group 10 is submitting for approval by the Plenary Assembly a new Recommendation 708 on determination of the electro-acoustical properties of studio monitor headphones, which will be brought to the attention of AES, the IEC and ISO. The tolerances for such headphones are extremely low, in order to guarantee high quality.

Recommendation 647 on the digital audio interface for studios was amended so as to define the method for including the status of signals, and was supplemented by a new annex on development of the digital audio interface, for further consideration. AES is invited to send representatives to the meetings at which this subject will be discussed.

Report 1072 on sound systems for high-definition and enhanced television and Report 798 on simulated programme signals were both amended. Several new Reports were approved, namely Report 1199 (low bit-rate digital audio coding systems), Report 1200 (effect of propagation delay on sound broadcasting operations), Report 1204 (automatic synchronization of video and audio after transmission) and Report 1237 on satellite news gathering (to be published in Volume XII).

The Study Group also cancelled Report 465-3 on loudness, Report 797-2 on listening rooms, Report AE/10 on the measurement of non-linear distortion and Report AF/10 on studio monitor headphones.

Close cooperation with the IEC on the technical aspects of audio frequency signals is highly desirable.

In summary, in the field of audio-frequency characteristics of sound-broadcasting signals, Study Group 10 approved 1 new Recommendation and 4 new Reports, amended 4 Recommendations and 2 Reports and cancelled 4 Reports, for a total of 7 Recommendations and 13 Reports.

2.1.4 *Sound-data broadcasting*

This subject was dealt at the service level with in Joint Working Group 10-11D, which was set up at the Final Meetings, under the chairmanship of Professor F. Cappuccini (Italy).

The Joint Working Group examined 14 contributions on matters within the scope of Study Group 10, in 5 Sub-Working Groups.

The texts produced, which were drafted in collaboration with Working Groups 10A and 10B, include Recommendation 706 on data system in monophonic AM sound broadcasting (AMDS), Report 795 on the transmission of two or more sound programmes in terrestrial television and Report 463 on the simultaneous transmission of several sound programmes with a single transmitter in FM sound broadcasting.

The Group also requested the CCIR Secretariat to include additional information in the booklet describing teletext systems, incorporating the latest information on the recommended systems.

Finally, Joint Working Group 10-11D proposed that the necessary arrangements be made for all work on data broadcasting to be assigned to the Group and for all the CCIR texts relating to data broadcasting to be grouped together in a single separate Volume. That action will be studied by JIWP 10-11/5, which will submit proposals for consideration by Study Groups 10 and 11 during the next study period.

Following the decisions of the Plenary Assembly, JIWP 10-11/5 has been disbanded and the study of data broadcasting has been split up between Study Groups 10 and 11.

2.1.5 *Recording of sound-broadcasting programmes*

This subject was dealt with in Joint Working Group 10-11R, chaired by Mr. P. Zaccarian (CBS), which at the Interim and Final Meetings of Study Group 10 considered 22/27 contributions on sound and television broadcasting, respectively, drafting 21 documents with the assistance of two Sub-Working Groups.

In the field of sound broadcasting, amendments were made to Recommendation 407 (international exchange of sound programmes recorded in analogue form) to delete references to recording on disk records, and to Recommendation 408 (standards of sound recording on magnetic tape) to include the definitions of the reference recording-duplicating chains following the deletion of Report 800.

The Group also deleted Recommendation 564 on the use of magnetic tape cartridges and cassettes for sound-broadcasting.

In the area also concerning television, the Group drafted Recommendation 715 on the international exchange of recordings of electronic news broadcasts, which will be brought to the attention of the IEC, SMPTE and the broadcasting unions.

Study Groups 10 and 11 amended Report 468 on synchronizing methods and Report 950 on digital recording of audio signals, as well as deleting Report 800 on the recording-duplicating chain.

In all, on the recording of sound programmes, Study Group 10 drafted 1 new Recommendation, amended 2 Recommendations and 2 Reports and deleted 1 Recommendation and 1 Report, giving a total of 5 Recommendations and 3 Reports.

2.1.6 *Broadcasting service (sound) using satellites*

This subject was dealt with in Joint Working Group 10-11S, chaired by Mr. R. Zeitoun (Canada), which at the Interim and Final Meetings of Study Groups 10 and 11 received 62/83 contributions concerning sound and television broadcasting and produced 27/38 documents, respectively, setting up 3 Sub-Working Groups.

As regards sound broadcasting via satellite, Recommendation 566 on terminology was updated to take account of the definitions established by WARC ORB-88 and Recommendation 712 was adopted on high-quality sound and data standards in the 12 GHz band.

The corresponding systems are described in Report 1228, while another new Report 1227 was drawn up to cover satellite broadcasting systems for ISDB.

Report 215 (systems for the broadcasting-satellite service), Report 632 (technically suitable methods of modulation), Report 955 (satellite sound broadcasting with portable receivers and receivers in automobiles), Report 953 (digital coding for the emission of high-quality sound signals), Report 954 (multiplexing methods for the emission of several digital audio signals and also data signals), Report 810 (antennas) and Report 473 (ground receiving equipment) were amended and updated, as well as Report 631 on frequency sharing with terrestrial services and Report 807 on unwanted emissions.

Accordingly, in the field of satellite sound-broadcasting, Study Groups 10 and 11 are submitting to the Plenary Assembly 1 new Recommendation, 2 new Reports, 1 amended Recommendation and 9 amended Reports, for a total of 3 Recommendations and 11 Reports.

2.2 *Questions, Study Programmes, Resolutions and Opinions*

Question 44/10 on LF, MF and HF sound broadcasting was amended to include study of the factors affecting satisfactory coverage, along with 7 of the 12 Study Programmes relating to it. Furthermore, a new Study Programme was added on the design of systems for HF broadcasting.

The XVIIth Plenary Assembly abolished this Question, as well as Study Programmes 44D/10 and 44E/10.

Amendments were also made to Study Programme 45F/10 in order to provide more specific details on the studies to be carried out on transmitting antennas for short-distance sound broadcasting in the Tropical Zone and the Plenary Assembly proposed the transfer of Study Programme 45B/10 to Study Group 6 and the cancellation of Study Programmes 45C/10 and 45D/10.

Question 46/10 on FM sound broadcasting in the VHF band was modified to accommodate data broadcasting, and amendments were made to Study Programmes 46H/10 (transmission of supplementary information), 46J/10 on compatibility with the aeronautical services, which will be dealt with by the new Study Group 12 with the exception of the part concerning compatibility with television, and 46N/10 on immunity of FM receivers against interference. Two new Study Programmes were also drawn up, namely 46P/10 on the transmission of data information as an alternative to the main programme, now abolished by the Plenary Assembly, and 46Q/10 on transmitting and receiving antenna characteristics for planning in VHF broadcasting.

The Plenary Assembly also abolished Study Programmes 46A/10, 46D/10, 46E/10, 46F/10 and 46H/10, as well as Questions 47-1/10 and 48-1/10.

Question 50/10 on the audio-frequency characteristics of broadcasting signals was deleted by the Plenary Assembly, as well as Study Programmes 50A/10 and 50B/10. Study Programmes 50C/10 on the subjective assessment of sound quality and 50D/10 on the acoustic properties of control rooms were amended. Two new Study Programmes were drafted, namely 50F/10 on determination of the electro-acoustical properties of headphones and 50G/10 on sound systems for the hearing impaired. These Study Programmes have now all become Questions.

Question 51/10 on standards for digital techniques for sound in broadcasting was also amended to take account of signal path delay, as was Study Programme 51B/10 on digital coding standards, to include study of that phenomenon.

Study Group 10 also amended Question 52/10 on the recording of sound-broadcasting programmes for international exchange, together with Study Programme 52A/10 on sound recording standards, both subsequently abolished by the Plenary Assembly. Study Programme 52B/10 on sound recording using digital modulation was amended. A new Study Programme 52D/10 on optical recording was drafted and Study Programme 52C/10 on the automatic programming of sound broadcasting stations was deleted.

The Plenary Assembly decided to discontinue Question 54/10 on broadcasting systems using non-conventional energy sources.

A new Question was drawn up on interconnection specifications for audio-visual equipment related to broadcasting.

As regards satellite sound-broadcasting, amendments were made to Study Programmes 1A/10-11 on use of the 12 GHz band by the broadcasting-satellite service and 2K/10-11 on satellite sound-broadcasting.

Study Group 10 had proposed to the Plenary Assembly that Resolution 61 be amended so as to add a fourth item to its terms of reference concerning the overall performance of the means of delivering television signals to the general public. However, the Plenary Assembly, acting on Study Group 10's proposal, changed terms of reference to sphere of competence.

An amendment to Resolution 76 on the presentation of antenna diagrams is also proposed to accommodate the studies requested by WARC HFBC(2).

The Study Group is proposing amendments to Opinion 74 (facilities for the interconnection of sound-broadcasting receivers and associated equipment) to identify more clearly the studies to be carried out by the CCIR and indicate that the Opinion is to be transmitted to Study Group 11, the CCITT and the IEC. Similarly, a new Opinion was drafted on equipment interconnection in professional programme production installations, which will be brought to the attention of the IEC.

2.3 *Decisions and Interim Working Parties*

Study Group 10 amended Decision 79, thereby maintaining IWP 10/1, under the chairmanship of Mr. G. Groeschel (Germany (Federal Republic of)), to enable it to complete its work on HF broadcasting antennas and move on to LF and MF antennas, as well as receiving antennas. This has now become Working Party 10D.

Interim Working Party 10/7 on reference receivers had completed its work, under the chairmanship of Mr. M. Schneider (Switzerland), and was thus disbanded by Study Group 10. Decision 52 was deleted accordingly.

Decision 78 establishing IWP 10/9 to standardize the basic requirements for control and listening rooms, under the chairmanship of Mr. T. Magchielse (Netherlands), was retained without change, with a view to the preparation of a draft Recommendation replacing Report 797, for submission to the next Interim Meeting of Study Group 10. This IWP has been disbanded and replaced by a Special Rapporteur in Working Party 10C.

The Study Group approved new Decision 96 setting up IWP 10/10, under the chairmanship of Mr. W. Richards (United States of America), to carry out CCIR studies for the WARC-93 dealing with matters connected with the HF broadcasting service. IWP 10/10 will prepare the CCIR's consolidated report to WARC HFBC-93, incorporating the reports by IWP 10/1, with the collaboration of Study Groups 1 and 6. The consolidated report will be forwarded to the Conference at least ten months before it opens, once approved by the Chairmen of Study Groups 10, 1 and 6.

In accordance with new Decision 99, IWP 10/11 is to be established, under the chairmanship of Mr. K. Hunt (EBU), in order to prepare a report on HF broadcasting system design for submission to the next Final Meeting of Study Group 10. This IWP has been disbanded and replaced by a Special Rapporteur in Working Party 10A.

New Decision 94 provides for the establishment of IWP 10/12, under the chairmanship of Mr. G. Theile (Germany (Federal Republic of)), to study multi-channel sound systems (for high-definition and enhanced television). After establishing the necessary contacts with the other groups concerned by this subject, the IWP will submit draft Recommendations to the Interim Meeting of Study Group 10 in 1991. In the new CCIR structure, this IWP has become Task Group 10/1.

Decision 71, establishing JIWP 8-10/1 on compatibility between the aeronautical services and MF sound broadcasting stations in the band 87-108 MHz, under the chairmanship of Mr. J. Karjalainen (Finland), was amended to enable the JIWP to continue its work, in particular with a view to drafting a consolidated text which, once approved by Study Groups 8 and 10, will be published in a separate Volume. The Decision will be brought to the attention of the ICAO. This JIWP comes under the new Study Group 12.

The Study Groups concerned approved new Decision 97 establishing JIWP 10-3-6-8/1, under the chairmanship of Mr. J.S. Finnie (United Kingdom), to identify more precise criteria and parameters for sharing between broadcasting and fixed and mobile services in the band 2-30 MHz and to draw up a report on the subject by the end of 1990.

Study Group 10 agreed to disband JIWP 10-3-8/1, chaired by Mr. A. Romero Sanjinés (Peru), to which thanks were extended for its work in preparing the technical bases for the RARC for the planning of broadcasting in the band 1605-1705 kHz in Region 2.

Decision 43 concerning the establishment of JIWP 10-11/1, under the chairmanship of Mr. D. Sauvet-Goichon (France), responsible for studying satellite sound broadcasting and sharing and spectrum aspects of broad RF band HDTV was amended to include the sharing and spectrum aspects of HDTV.

Decision 51, concerning the establishment of JIWP 10-11/3 under the chairmanship of Mr. Ö. Mäkitalo (Sweden) to deal with satellite broadcasting of HDTV signals and the accommodation of several audio or data channels in terrestrial or satellite broadcasting channels was amended to cover transmission aspects relating to terrestrial HDTV and the coding and multiplexing of sound channels in HDTV signals.

The Decision contains a draft Resolution instructing JIWP 10-11/3 to revise, by 31 December 1990, the CCIR special publication "Specifications of transmission systems for the broadcasting-satellite services".

A new Decision was drawn up specifying the work to be accomplished by JIWPs 10-11/1 and 10-11/3 in preparation for WARC-92, so that the relevant report may be submitted directly to the JIWP for preparation of the Conference, to be established by the CCIR Plenary Assembly, no more than two months before the JIWP meets.

Decision 59 establishing JIWP 10-11/4, under the chairmanship of Mr. P. Zaccarian (CBS), to study problems relating to television programmes recorded on digital tape and film was amended, in particular so as to ensure more effective liaison with the IWPs studying similar subjects and to indicate that the JIWP shall complete its work in the 1990-1994 study period. The Decision will be brought to the attention of the IEC, ISO and SMPTE.

Decision 72 establishing JIWP 10-11/5, under the chairmanship of Prof. F. Cappuccini (Italy), to study services using data broadcasting was updated, in particular to incorporate data broadcasting in HDTV. This WP has been disbanded so far as Study Group 10 is concerned.

JIWP 10-11/6 is set up by new Decision 95 to study subjective assessment of television sound and picture quality, thereby extending the scope of the old IWP 11/4 to include subjective assessment of sound quality. The JIWP will be chaired by Mr. D. Wood (EBU). This WP has been disbanded and replaced by a Special Rapporteur in Working Party 10C.

Under Decision 75, JIWP AFBC(2) of Study Groups 1, 5, 8, 9, 10 and 11 had been set up, under the chairmanship of Mr. H. Kussmann (Germany (Federal Republic of)), to study sharing criteria between the services using the bands 790-862 MHz in the African Broadcasting Area and the use of circular polarization, in preparation for the Second Session of the Regional Administrative Conference for the Planning of Television Broadcasting in the African Broadcasting Area and Neighbouring Countries. Study Groups 10 and 11 having taken cognizance of the reports to the Conference, the JIWP, which had fulfilled its task, was disbanded with congratulations and thanks.

New Decision 98 provides for the establishment of JIWP 10-CMTT/1, under the chairmanship of Mr. A. Komly (France), to consider low bit-rate digital audio coding systems. The JIWP will work in liaison with the IWPs studying similar subjects and will submit a draft Recommendation to the Interim Meetings in 1991. Decision 98 will be brought to the attention of the IEC and ISO. This WP has become Task Group 10/2.

Decision 76 establishing JIWP CMTT 4-10-11/1 on satellite news gathering, under the chairmanship of Mr. J. A. Colson (NANBA), was revised to enable the JIWP to pursue its work and prepare an overall strategy for SNG. This WP now comes under the CMTT as Task Group 5.

Decision 18 on digital systems for the transmission of sound-programme and television signals was amended so as to convert IWP CMTT/1 into a JIWP CMTT-10-11/1, which will cooperate with CCITT Study Groups I, XV and XVIII in order to make the CCIR and CCITT Recommendations on the digital transmission of sound and television broadcasting signals as compatible as possible. JIWP CMTT-10 11/1 has been placed under the chairmanship of Mr. G. Simpson (United Kingdom). This IWP has been disbanded and the subject will be dealt with by a CMTT Working Party.

The JIWP of Study Groups 1, 2, 4, 5, 8, 9, 10 and 11 to prepare for WARC ORB-88, set up under the chairmanship of Mr. E. Hauck (Switzerland) by Resolution 90, which replaced Decision 73, had completed its work and was disbanded with thanks. It was also proposed that Resolution 90 and Decision 73 be deleted.

The JIWP of Study Groups 1, 5, 6, 8, 9, 10 and 11 on sharing criteria between the broadcasting service and the fixed and mobile services in the VHF and UHF bands, set up under the chairmanship of Mr. J. N. McKendry (Australia) in accordance with Resolution 94, is continuing its work in preparation for the conference responsible for developing the above criteria in Region 3 and the countries concerned in Region 1. The JIWP has drawn up a report for Study Group 1. The subject will be dealt with by the new Study Group 12.

The Director of the CCIR submitted to the Study Groups concerned a draft Decision on the studies to be carried out by the CCIR with a view to WARC-92 dealing with frequency allocation in certain parts of the spectrum. The new Decision foresees that the CCIR Plenary Assembly should create a JIWP of Study Groups 1, 2, 3, 4, 5, 6, 8, 9, 10 and 11 on the basis of proposals formulated by the meeting of Study Group Chairmen in January 1990. The JIWP will study, in particular, the problem of frequency sharing between services, and will draw up a consolidated report to the conference on the basis of the reports prepared by the different Study Groups (the reports within the scope of Study Group 10 will be drafted by JIWPs 10-11/1 and 10-11/3, as indicated in the new Decision). The Plenary Assembly in Düsseldorf set up JIWP WARC-92.

3. Cooperation with other Study Groups

Cooperation between Study Group 10 and the other Study Groups is effected primarily through the Interim Working Parties described in the previous section. Study Group 10 also considered documents received from Study Groups 1, 2, 3, 5, 6, 8, 9, 11, CMTT and CMV and gave its opinion on their content.

Study Groups 10 and 11 also drafted a note to Study Group 4 requesting it to communicate the results of studies concerning transportable transmitting earth stations for feeder-links to broadcasting satellites.

They also approved a note addressed to Study Groups 5 and 9 concerning the protection of line-of-sight terrestrial radio-relay systems against possible interference which may be caused by the BSS in the 20 GHz band. This note will be published in Part 2 of Volumes X and XI.

Study Group 10 confirmed that, in order to ensure the necessary coordination, it will be represented in CMTT by the Chairman of Working Group 10C.

Finally, Study Groups 10 and 11 addressed a note to CCV drawing attention to the amendments made to Recommendation 566 on space radiocommunications terminology and to its comments concerning the terms defined in Chapters 723 and 725 of the International Electrotechnical Vocabulary.

Study Group 10 will have to appoint a new Rapporteur for Spanish on CCV. The Spanish Administration has proposed Mr. L. Del Amo Ruiz. Its Rapporteurs for French and English are Mr. A. Keller (France) and Mr. A. H. Jones (United Kingdom), respectively.

4. Problems concerning the developing countries

Resolution 33 on technical cooperation invites the developing countries to take an active part in the work of the CCIR Study Groups, states that the CCIR should take up actively the study of Questions posed by developing countries and asks Chairmen to include in the Volumes of the CCIR published after each Plenary Assembly a section, to be as comprehensive as possible, especially devoted to problems of interest to 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 especially interested in the texts relating to broadcasting in the Tropical Zone, in which several of them are situated.

With regard to the recording of sound-broadcasting programmes, Recommendation 408 (standards of sound recording on magnetic tape for the international exchange of programmes) concerns the developing countries, and their attention is particularly drawn to the CCIR special publications on transmission systems for satellite broadcasting and on recording, prepared in accordance with Resolution 81.

In the field of satellite broadcasting, 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 Report 955.

The attention of the developing countries is also drawn to the importance of the Interim Working Parties for the preparation of forthcoming ITU conferences, in particular IWP 10/10, which will be preparing the HF broadcasting conference, and the JIWP for the preparation of the 1992 World Administrative Radio Conference to study frequency allocations in certain parts of the spectrum.

Resolution 108 on information meetings also concerns the developing countries in particular, in enabling them to familiarize themselves with relevant CCIR texts.

Although it may be thought that the developing countries 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 those countries if they took a more active part in its work, so as to focus attention on problems of particular interest to them, in line with the provisions of Resolution 95 of the XVIIth Plenary Assembly.

5. Conclusions and future activities

The 1986-1990 study period saw the drafting of new Recommendations on HF transmitting antenna diagrams, on the characteristics of AM and FM reference receivers, on AM data broadcasting systems, on the international exchange of electronic news reports and on high-quality sound and data standards in satellite broadcasting. Study Group 10 also made an active contribution to the preparation of ITU conferences, in particular with respect to MF sound broadcasting in Region 2, television in the African Broadcasting Area and use of the geostationary-satellite orbit for the transmission of sound signals.

More preparatory work for ITU conferences will be required during the forthcoming study period, particularly with a view to the 1992 Conference responsible for studying frequency allocations to HF broadcasting and to satellite sound broadcasting in the band 0.5-3 GHz and the 1993 Conference responsible for studying problems relating to the HF broadcasting service.

In the forthcoming study period, Report 292 on the measurement of programme level in sound broadcasting may be cancelled and annexed to Recommendation 645.

A considerable amount of work will be required on sound recording, in particular with respect to standards and operating practices for the digital recording of audio signals on magnetic tape, recording using new methods, measurement methods and methods of synchronizing separate media bearing components of a single programme.

Closer collaboration between the IEC, ISO and CCITT and the CCIR is considered necessary, as foreseen by the Plenary Assembly.

Above all, however, while remaining competent for the study of the sound broadcasting service, Study Group 10, following the decision of the XVIIth Plenary Assembly, will have to develop an organizational structure and working methods which are more flexible and faster to enable it to keep abreast of the unrelenting progress being made in sound broadcasting and provide up-to-date technical bases for sound broadcasting applications and for the decisions to be taken by forthcoming conferences concerning the sound broadcasting service.

The XVIIth Plenary Assembly in Düsseldorf modified the organization, structure and working methods of the CCIR. Hence this Volume is published in two parts: Part A, containing the Recommendations, Resolutions, Opinions and Questions, and Part B, a more economical presentation, containing the Reports and Decisions. There will also be Handbooks approved by the Study Groups, while the Study Programmes have either been turned into Questions or discontinued. Each Study Group sets up Working Parties to deal with the Questions assigned to it and Task Groups to consider urgent Questions. The Working Parties and Task Groups meet separately from the Study Groups.

Resolution 97 sets out the procedure to be followed for the approval of Recommendations between Plenary Assemblies.

A plan showing the structure of Study Group 10 during the period 1990-1994 is attached.

Study Group 10

Structure

Working Parties (WP)

WP 10A: Amplitude modulation sound broadcasting and sound broadcasting in the Tropical Zone

Q. (urgent):	S.P. 44K-1/10, S.P. 44L-1/10
Q. (important):	S.P. 44M/10, S.P. 46K/10, S.P. 44N/10, S.P. 44A-2/10, S.P. 44B-1/10, S.P. 44C-1/10, S.P. 44F-1/10, Q. 45/10, S.P. 45A/10, S.P. 45E/10, S.P. 44J/10, Q. 49/10

WP 10B: Frequency modulation sound broadcasting (except in the Tropical Zone)

Q. (urgent):	S.P. 46B/10, S.P. 46J-2/10, S.P. 47A/10
Q. (important):	Q. 46/10, S.P. 46C/10, S.P. 46G/10, S.P. 46H-1/10, S.P. 46L/10, S.P. 46N-2/10, S.P. 47B/10, Q. 49/10 (except the antennas)

WP 10C:	Audio-frequency characteristics and digital sound broadcasting	
	Q. (urgent):	New Question derived from S.P. 50C-2/10, S.P. 51A/10, S.P. 51B-1/10, S.P. 51C/10, S.P. 51D/10, S.P. 51E/10
	Q. (important):	S.P. 50C-2/10, S.P. 50D-1/10, S.P. 50E/10, S.P. 50F/10, S.P. 50G-1/10, Q.51-1/10
WP 10D:	Transmitting and receiving antennas for sound broadcasting	
	Q. (important):	New Question derived from S.P. 44G-1/10, S.P. 44H/10, S.P. 45F-1/10, S.P. 46Q/10

Task Groups (TG)

TG 10/1:	Sound systems for HDTV and EDTV	
	Q. (urgent):	S.P. 47C/10
TG 10/2*:	Low bit-rate digital audio coding systems	
	Q. (urgent):	S.P. 51B-1/10, S.P. 51C/10, S.P. 18G/CMTT

Drafting Groups (DG)
(convened by a Special Rapporteur)

DG 10/A-1:	System design for HF broadcasting	
	Q. (important):	S.P. 44N/10
DG 10/A-2:	Sound broadcasting in the Tropical Zone	
	Q. (urgent):	Q. 45/10, S.P. 45A/10, S.P. 45E/10, S.P. 46K/10
	Q. (important):	S.P. 45B/10 to Study Group 6
DG 10/C-1:	Acoustical properties of control rooms	
	Q. (important):	S.P. 50D-1/10
DG 10/C-2:	Digital sound broadcasting	
	Q. (urgent):	S.P. 51B-1/10, S.P. 51C/10, S.P. 51D/10, S.P. 51E/10
	Q. (important):	Q. 51-1/10
DG 10/C-3:	Quality assessment	
	Q. (urgent):	New Question derived from S.P. 50C-2/10, S.P. 51A/10
	Q. (important):	S.P. 50C-2/10, S.P. 50E/10

Joint Working Parties (JWP)

JWP 10-11S:	Satellite broadcasting	
	Q. (important):	S.P. 2K/10 and 11
JWP 10-11R:	Recording of programmes	
	Q. (important):	S.P. 52B-3/10, S.P. 52D/10

Interim (Joint) Working Parties
(for preparation of WARCs)

IWP 10/10:	Studies for the WARC-93	
	Q. (urgent):	New Question derived from S.P. 44A-2/10, S.P. 44B-1/10, S.P. 44C-1/10, S.P. 44F-1/10
JIWP 10-3-6-8/1:	Compatibility in the band 2-30 MHz in preparation of the WARC-92	
	Q. (important):	S.P. 44M/10
JIWP 10-11/1:	Satellite sound broadcasting and some aspects of HDTV	
	Decisions 43-5 and 93	
JIWP 10-11/3:	Satellite HDTV and several sound signals	
	Decision 51-4 and 93	

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* This Task Group is also of interest to the CMTT.

SECTION 10A-1: AMPLITUDE-MODULATION SOUND BROADCASTING IN BANDS 5 (LF), 6 (MF) and 7 (HF)

RECOMMENDATION 638 *

TERMS AND DEFINITIONS USED IN FREQUENCY PLANNING FOR SOUND BROADCASTING **

(Questions 44/10, 46/10)

(1986)

The CCIR

UNANIMOUSLY RECOMMENDS

that for the purpose of frequency planning for sound and television broadcasting, the following terms and definitions should be used:

1. Signal-to-interference ratios

1.1 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.

1.2 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.

1.3 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.

1.4 *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, carrier offset, carrier-frequency tolerance, modulation characteristics (type of modulation, modulation depth, pre-emphasis characteristics, frequency deviation, etc.), characteristics of the AF signal (bandwidth, dynamic compression), receiver input level as well as the receiver characteristics (selectivity and susceptibility to cross-modulation, etc.).

2. Specific field strengths

2.1 *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.

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

** This Recommendation merges Recommendations 447 and 499 which are hereby cancelled.

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.

2.2 *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.

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 Report 945 for information.

2.3 *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.

3. 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 (bands 5, 6 and 7) 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.

RECOMMENDATION 561-2*

DEFINITIONS OF RADIATION IN LF, MF AND HF BROADCASTING BANDS

(1978–1982–1986)

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.

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 G_v 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.

Note 1 – Definitions 1 and 2 are mainly used in LF and MF broadcasting.

3. Equivalent isotropically radiated power (e.i.r.p.)

The product of the power supplied to the antenna and the antenna gain G_i in a given direction relative to an isotropic antenna (absolute or isotropic gain) (Radio Regulations, No. 155).

The idealized reference antenna, when fed with a power of 1 kW, is considered to provide an e.i.r.p. of 1 kW in all directions and to produce a field strength of 173 mV/m at 1 km distance.

4. Effective radiated power (e.r.p.) (in a given direction)

The product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction (Radio Regulations, No. 156).

Radio Regulations No. 154 (b) defines the gain of an antenna in a given direction relative to a half-wave dipole G_d, as the gain relative to a loss-free reference antenna isolated in space whose equatorial plane contains the given direction.

The reference antenna, when fed with a power of 1 kW, is considered to radiate an e.r.p. of 1 kW in any direction in the equatorial plane and produces a field strength of 222 mV/m at 1 km distance.

Note 1 – Definitions 3 and 4 are mainly used in HF broadcasting.

Note 2 – The relationship between the radiated power expressed in the different units is given in Annex I.

Note 3 – For information, some guidance on the determination of the radiated power is given in Annex II.

Note 4 – For information, radiated power standards for propagation curves are discussed in Annex III.

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

ANNEX I

RELATIONSHIP BETWEEN RADIATED POWERS EXPRESSED IN DIFFERENT UNITS

1. 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	short vertical	0	95	– 10	0.1
1	short vertical	0	300	0	1
10	short vertical	0	950	+ 10	10
100	λ/2 vertical	2	3 800	+ 22	160
300	λ/2 vertical	2	6 600	+ 27	475
1000	λ/2 vertical	2	12 000	+ 32	1600

2. Relationship between e.r.p. and e.i.r.p.

The value of the e.r.p. is related to the e.i.r.p. by the expression:

$$\text{e.r.p.} = 0.61 \text{ e.i.r.p. (linear scale)}$$

$$\text{e.r.p.} = \text{e.i.r.p.} - 2.2 \text{ dB (logarithmic scale)}$$

ANNEX II

DETERMINATION OF THE RADIATED POWER

1. Vertical antennas

For vertical antenna systems which are actually in operation, the radiation 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 $(E_0 d_0)$ gives the c.m.f. A method of extrapolation has been proposed by [Surutka and Gavrilov, 1983].

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 radiated power 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 radiated power may be estimated from a calculation of the system performance over a perfectly conducting surface, and from the estimated efficiency of the antenna system.

2. Horizontal antennas

In this case, the most practical method is a computation in which the gain of the antenna, assumed to be situated above perfectly conducting ground, and the total transmitter power (less the feeder loss) determine the radiated power. If applicable, the radiated power should be the combination of two orthogonal components, perpendicular to the direction of propagation, made on a root mean square basis.

3. Transmitter carrier power as a function of c.m.f.

For a single vertical mast radiator, neglecting losses:

$$p = (F_c/300)^2 \cdot (1/G_v) \tag{1}$$

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:

$$W = \frac{1}{120\pi} \iint_{sphere} F_c^2\ (\varphi, \theta)\ \cos\theta \cdot d\theta\, d\varphi \tag{2}$$

where F_c (φ, θ) 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).

REFERENCES

SURUTKA, J. V. and GAVRILOV, T. S. [1983] Experimental determination of the cymomotive force of ground-based vertically polarized antennas. *Telecomm. J.*, Vol. 50, **IX**, 482-486.

ANNEX III

RADIATED POWER STANDARDS FOR 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 at LF and MF to apply for an e.m.r.p. 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.

An e.i.r.p. of 1 kW at all angles of elevation is generally used in HF propagation prediction methods.

RECOMMENDATION 559-2*

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

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

(1978-1982-1990)

The CCIR,

CONSIDERING

(a) that the radio-frequency protection ratio is directly related to the audio-frequency protection ratio (see Recommendation 638);

(b) that this relationship depends on a number of technical parameters, such as:

- 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 single channel measurement circuit using a standardized instrument or an instrument based on a two-channel measurement circuit (see § 1.2).

1.2 *Output measurement*

For measuring the wanted and interfering signals at the output of the receiver, use should be made of:

- a standardized instrument which should include a network for weighting the subjective interference effect of different interfering frequencies in accordance with Recommendation 468 and a voltmeter suitable for r.m.s. measurements**;
- or a special instrument based on the circuit shown in Fig. 1 and having weighting filters with an amplitude-frequency characteristic as shown in Fig. 2. This instrument has circuits for the separation of narrow-band and wideband interference by means of retunable band and rejection filters respectively, circuits for weighting each of these types of interference with maxima in the region of 4 kHz, and 0.5 kHz and 3.0 kHz respectively, an adder and an r.m.s. voltmeter.

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* Further information is given in Recommendation 560.

** 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.

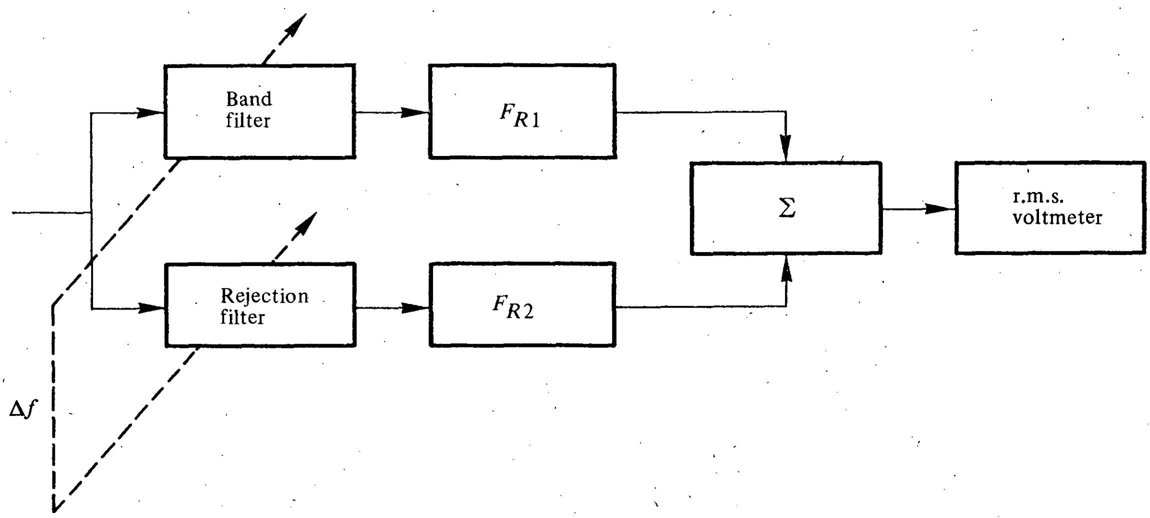


FIGURE 1 – *Schematic of the measuring apparatus*

F_{R1}, F_{R2}: weighting networks

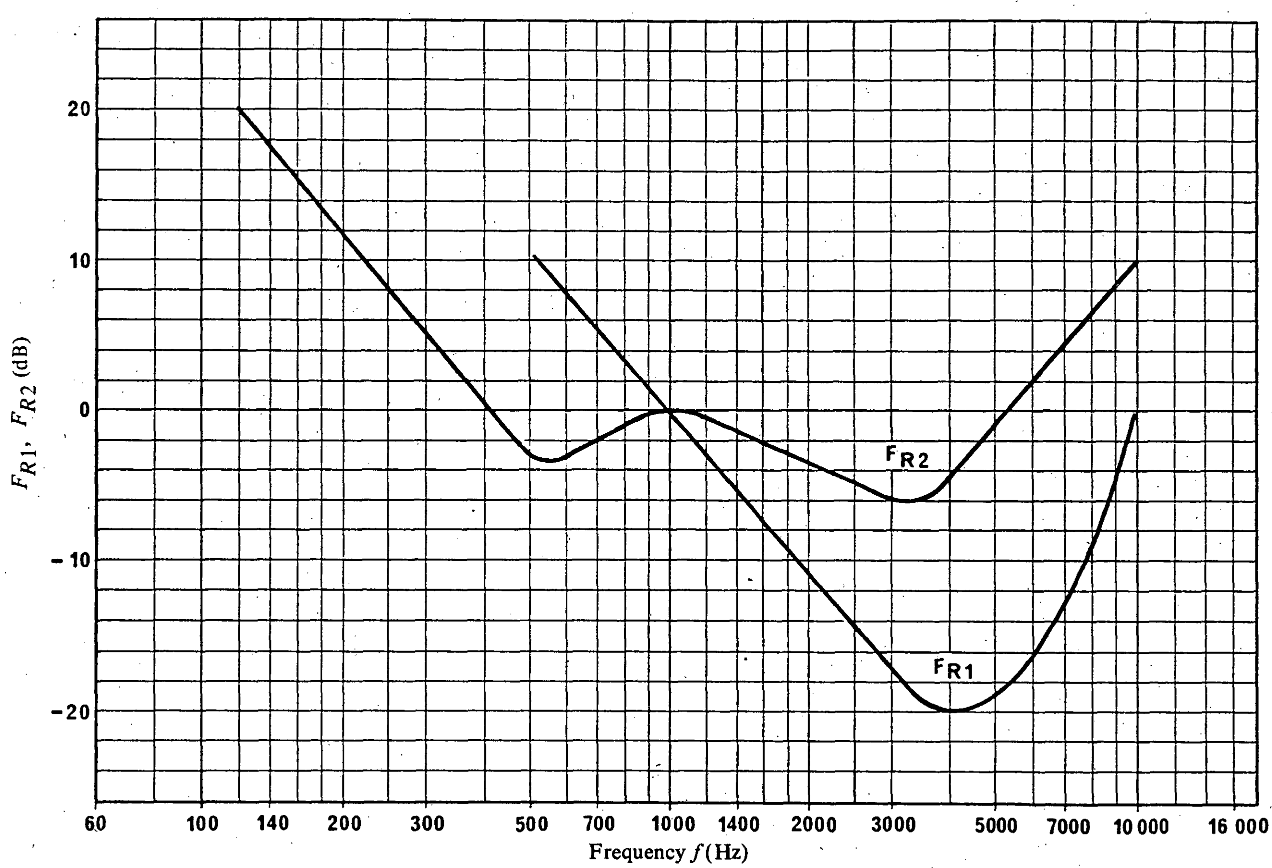


FIGURE 2 – *Frequency responses of the weighting networks*

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. 3, 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. 4. The frequency-response characteristic of this filter is reproduced as curve B of Fig. 3. (It should be noted that the difference between curves A and B of Fig. 3 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.

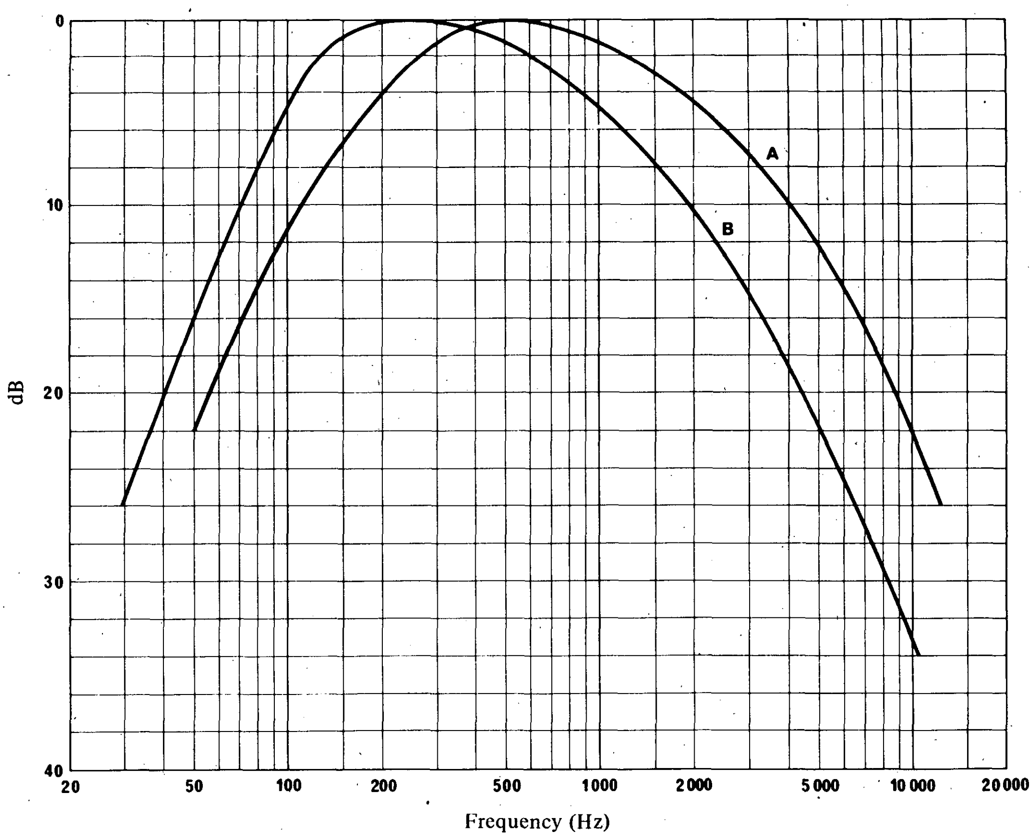


FIGURE 3

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

* 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.)

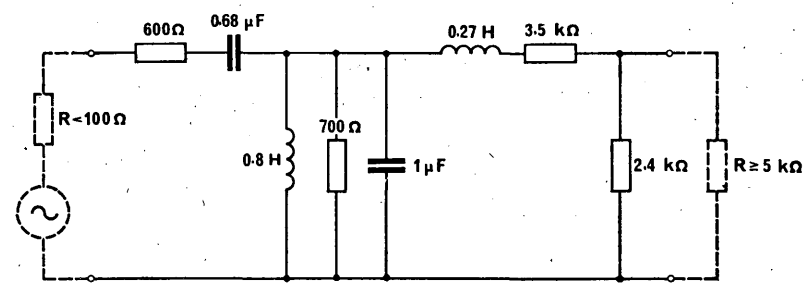


FIGURE 4 – *Filter-circuit*

1.4 *Measuring arrangements*

Figure 5 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.

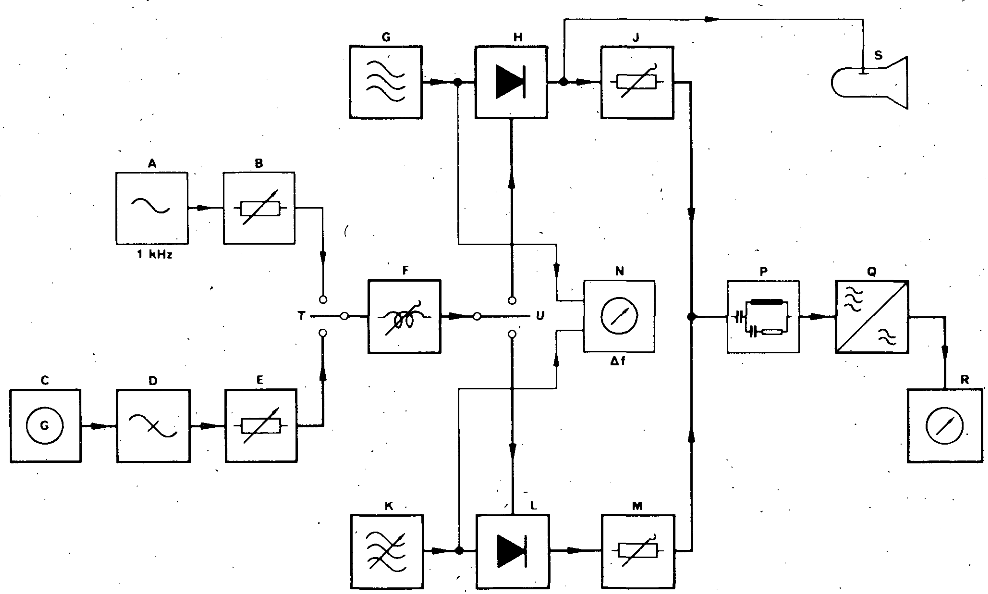


FIGURE 5 – *Schematic of the measuring apparatus*

A: 1 kHz audio-frequency generator (for calibration of the depth of modulation)
B: calibrated attenuator
C: noise generator
D: noise-shaping filter (see Fig. 4)
E: calibrated attenuator
F: low-pass filter
G: signal generator (wanted signal)
H: modulator
J: calibrated attenuator
K: signal generator (interfering signal)
L: modulator
M: calibrated attenuator
N: frequency meter for measuring the frequency difference between signal generators G and K
P: artificial antenna (according to Recommendation 331)
Q: receiver under test
R: instrument for measuring r.m.s. values in accordance with § 1.2
S: oscilloscope (for monitoring purposes)
T: selector switch for the modulation (1 kHz tone or standardized noise signal)
U: change-over switch for the modulation (signal generator G or K)

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).

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].

The results of protection ratio measurements depend to a considerable extent on the receiver passband. For measurements or calculations by the single-channel method, the error in protection ratio measurements ΔA versus frequency difference Δf for two receiver passband values on the intermediate frequency $2\Delta f = 9$ kHz and $2\Delta f = 5$ kHz (at -6 dB) is shown in Fig. 6 [CCIR, 1986-90].

2. **Numerical method**

2.1 *Principle*

To determine the relative radio-frequency protection ratio, the physical processes underlying the objective methods, viz., the determination of the weighted noise power by single- or two-channel methods (see § 1.2), are simulated by means of a mathematical model.

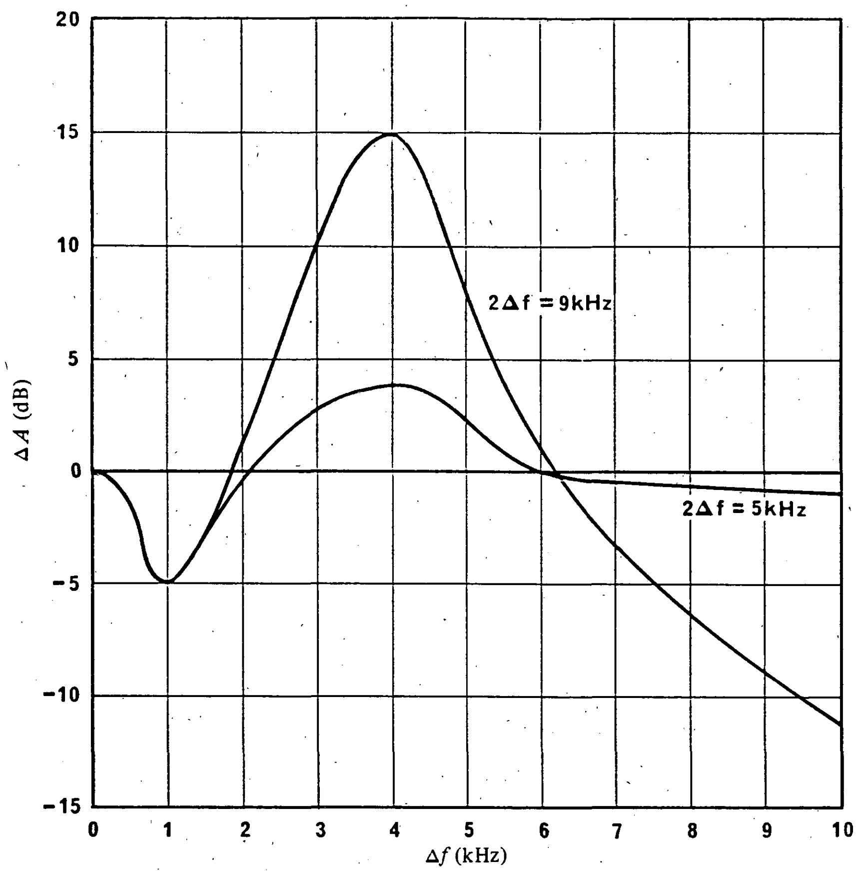


FIGURE 6 – *Error in protection ratio measurements* ΔA *versus frequency difference* Δf

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 single-channel or two-channel methods, was represented by means of the function F_R or F_{R1} and F_{R2}, respectively, 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 7 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:

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

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.

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

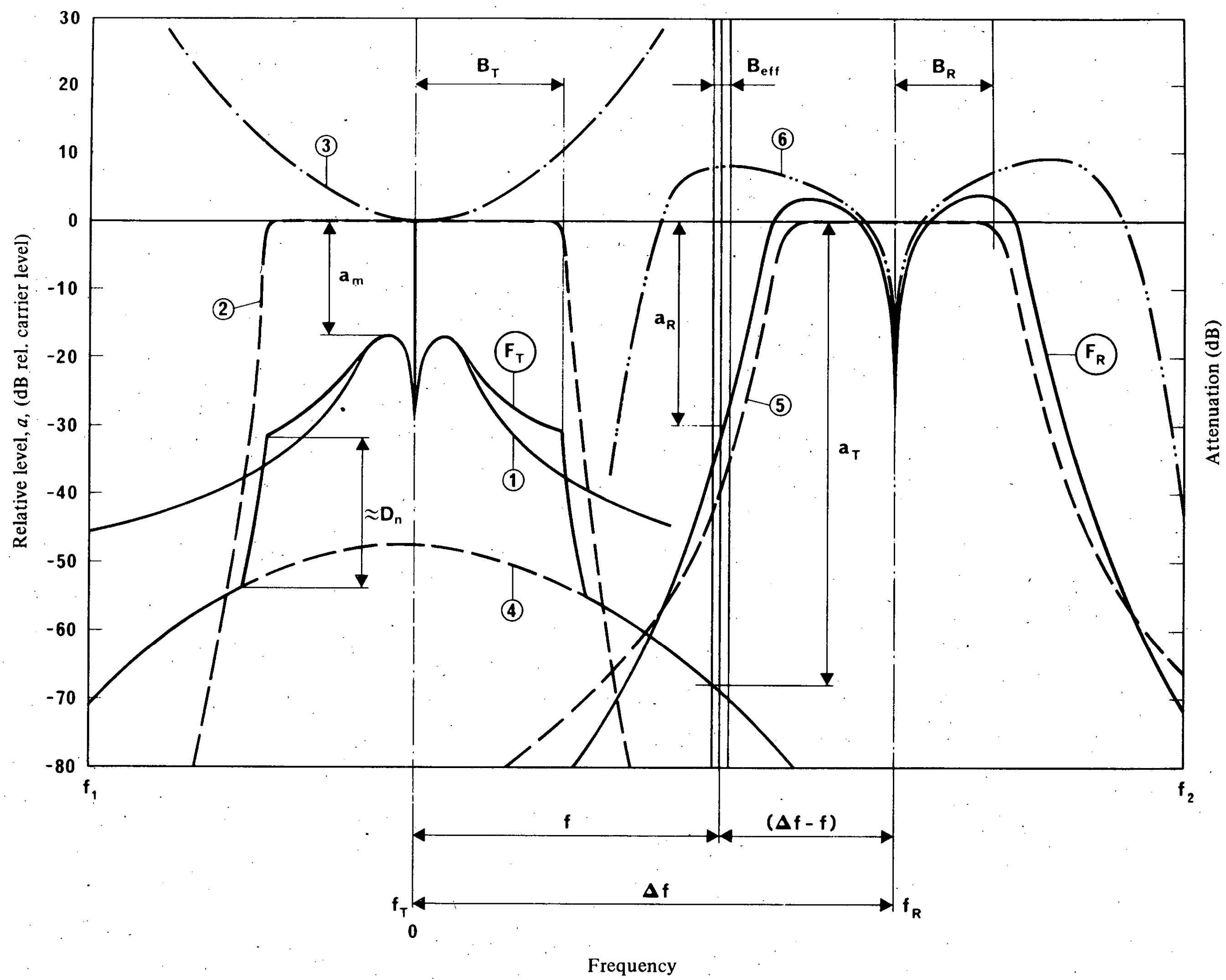


FIGURE 7 – *Fundamental relationships*

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

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.

A simplified version of this method was developed in France [Parreaux, 1972]. In principle, the method only takes account of the frequency f which mainly contributes to the integral of equation (1). Thus the protection ratio can be determined in a graphic way using representative curves of the functions F_T and F_R. The method is entitled "the graphical method".

2.2 *Accuracy and limits of the method*

The results obtained for a double-sideband system are shown in Fig. 8 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 can no longer be neglected. These factors are not taken into account in the calculation.

The graphical method is, in general, appropriate for estimating protection ratio values, provided the interference is mainly determined by a rather limited part of the interfering signal sepctrum. The differences in such values, when compared with those derived from objective measurements do not exceed 3 dB.

Note – The measuring method is more accurate than the graphical or numerical methods, since all technical parameters are more 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.

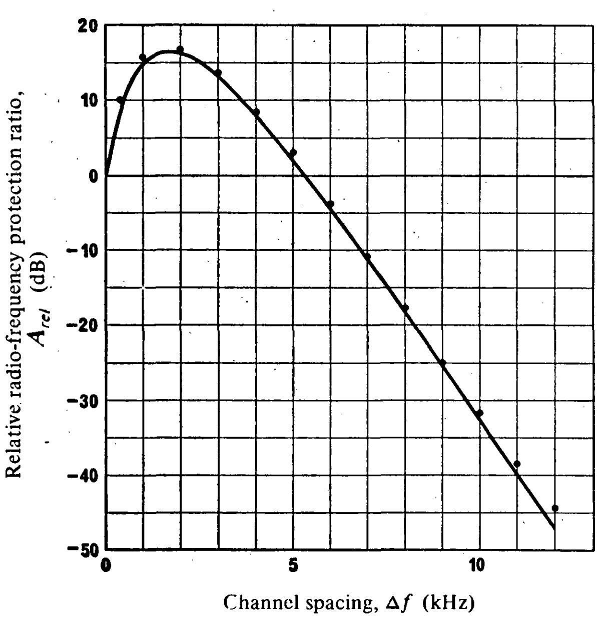


FIGURE 8 – *Comparison between the calculated and measured values of the relative radio-frequency protection ratio for a double-sideband system*

——— : calculated values • : measured values

REFERENCES

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.

CCIR Documents

[1974-78]: 10/324 (USSR).

[1986-90]: 10/60 (USSR).

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.

KOKOREV, A.V. and MUSSEL, K.M. [1980] Sposob izmereniya otnosheniya signal/pomekha (Method for measuring signal-to-interference ratio). Inventor's certificate No. 907827.

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

TSVIKER, E. and FELDKELLER, P. [1971] Ukho kak priemnik informatsii (The ear as a receiver of information). *Sviaz*, Moscow, USSR.

TÜXEN, O. [1941] Die Trennschärfe des Empfangsgleichrichters (Selectivity of the receiving detector). *Z. für Techn. Physik*, 22, **1**, 1-9.

CCIR Documents

[1986-90]: 10/252 (USSR).

RECOMMENDATION 560-3 *

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

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

(1978–1982–1986–1990)

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 638), 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 Annex III).

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 – A co-channel protection ratio of 26 dB was used by the Regional Administrative MF Broadcasting Conference (Region 2) (Rio de Janeiro, 1981) for both ground-wave and sky-wave services. Region 2 has two noise zones, 1 and 2, the former for most of the Region, the latter for a defined tropical area. In noise zone 1, the nominal usable field strength is 100 μV/m day-time and 500 μV/m night-time for Class A stations which have secondary service areas. It is 500 μV/m day-time for Classes B and C, and 2500 and 4000 μV/m respectively, night-time.

In noise zone 2, these values are generally 2.5 times more than the above figures.

Night-time protection, computed for two hours after sunset, is afforded for 50% of the nights of the year, except that the countries of North America agreed to protection from each other for 90% of the nights.

Note 3 – Co-channel protection ratios of 30 dB and 27 dB were used by the Regional Administrative LF/MF Broadcasting Conference for Regions 1 and 3, Geneva, 1975, for ground-wave and sky-wave services, respectively.

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.

* Annex III to this Recommendation replaces Report 794, which is hereby cancelled.

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.

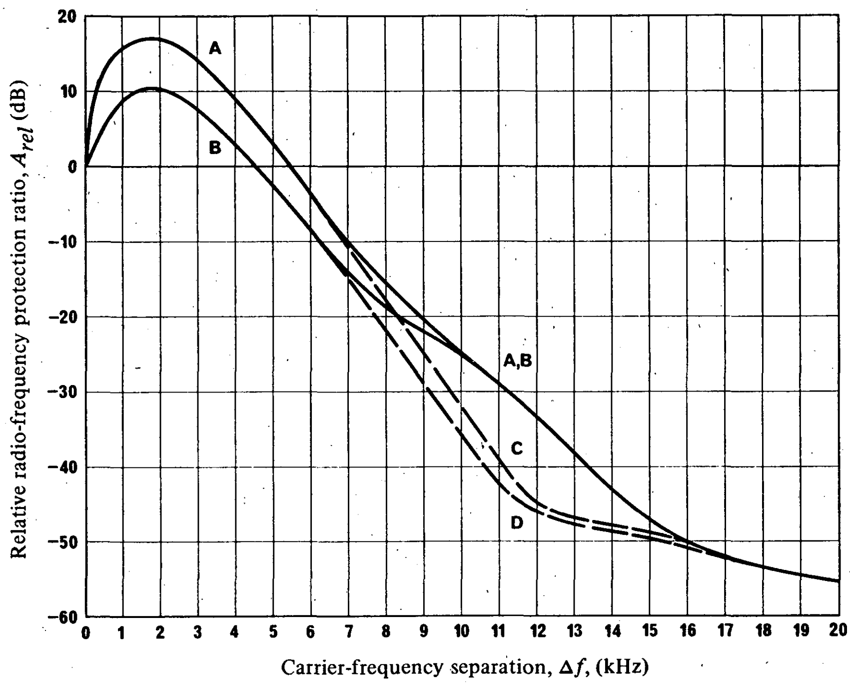


FIGURE 1 – *Relative value of the radio-frequency protection ratio as a function of the carrier-frequency separation*

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].

REFERENCES

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

* The WARC HFBC(2) decided, that the upper limit of the audio-frequency band (at −3 dB) of the transmitter shall not exceed 4.5 kHz and the lower limit shall be 150 Hz, with lower frequencies attenuated at a slope of 6 dB per octave.

If audio-frequency signal processing is used, the dynamic range of the modulating signal shall be not less than 20 dB.

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).

ANNEX III

PROTECTION RATIOS IN LF, MF AND HF BROADCASTING

1. Introduction

This Annex is a summary of the information available on the subject of protection ratios for amplitude-modulation sound-broadcasting services. It is confined, however, to results obtained since 1948.

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.

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.

Protection ratios depend on a multiplicity 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 (see Recommendation 559).

It is well known that the radio-frequency protection ratios for transmitters working in the same channel and transmitting the same programme can be improved considerably by synchronizing techniques, thereby increasing the coverage areas of these transmitters (see also Report 616). Actual values for these protection ratios depend on various factors, including the synchronization method (see § 10). 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 638).

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 frequency 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.

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.

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. Radio-frequency protection ratios for ground-wave services

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

In § 1 of this Recommendation, 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 by the Regional Administrative LF/MF Conference for Regions 1 and 3, whereas 26 dB was used by the Regional Administrative MF Broadcasting Conference (Region 2).

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 this Recommendation. 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.

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

5.2.1 *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 § 1 of this Recommendation, the value for short-term fading has been incorporated in the radio-frequency protection ratio.

5.3 *Long-term field-strength variations*

Detailed information is contained in Report 266 and Recommendation 435.

6. 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.

No value is recommended for use when the service is provided by the sky wave.

6.1 *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.

6.2 *Band 7 (HF)*

In band 7, following the studies carried out in India [CCIR, 1978-82a], the USA, and USSR and in the EBU, the radio-frequency protection ratio to be used for co-channel transmission ($\pm$ 10 Hz, see Note) should be in the range of 27-40 dB for steady state conditions. According to the subjective assessments of reception quality carried out in Japan [CCIR, 1982-86a] and the People's Republic of China [CCIR, 1982-86b], a co-channel protection ratio of 27 dB for steady-state conditions corresponds to grade 4 of the five-grade impairment scale (see Recommendation 562) with a carrier-frequency difference of 100 Hz or less.

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 $\leqslant$ 100 Hz between the carriers is proposed.

For the determination of appropriate fading allowances, some information can be found in Reports 266 and 894. It should be noted, however, that other factors, such as the correlation between the fading of the wanted and the unwanted signal, need also to be taken into account.

We may conveniently distinguish between two types of within-the-hour fade: short-term fades due to interference between individual signal components with a correlation period of up to a few seconds, and long-term phenomena in which the signals averaged over a few minutes fade in periods of up to tens of minutes.

Interference-type within-the-hour wanted signal fades affect only the subjective signal quality, which is significantly improved by receiver AGC. A suitable duration for purposes of quality evaluation is 1 min.

For the evaluation of fading margins or channel reliability, we may conveniently apply the statistical data for within-the-hour fades, characterized by periods of a few minutes or longer. The standard deviation of this type of fade may vary within wide limits depending on the ionospheric conditions and the location of the path, the path length and its direction. This applies to the wanted and interfering signals alike.

7. Data available on protection ratios

Annex I to Recommendation 639 deals with the effect of a limitation of the bandwidth of emission on radio-frequency protection ratios. 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.

8. Measurement results

Measurement of protection ratios for stable signals were carried out in the USSR [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 assessments using these criteria were made in the USSR by a number of experts subjectively assessing an agreement between a given fragment of the programme and a predetermined criterion.

The results of measurement are given in Figs. 2, 3 and 4.

Figure 2 shows the results of the co-channel protection ratio measurements. The value of K denotes the proportion of the experts who found the interference tolerable. The interfering programme was modern dance music. The shaded parts correspond to a change of passband from wide to narrow.

Figure 3 shows the values of protection ratio as a function of the wanted and interfering carrier-frequency spacing for $K = 0.9$. Shaded parts of the curves correspond to the scatter determined by the receiver passband.

Figure 4 gives the receiver selectivity curves, where the shaded parts indicate the dispersion of curves for receivers of different classes. Also shown in Fig. 4 is the selectivity curve of the EBU MBF receiver.

In addition, the effect of the modulating signal bandwidth on protection ratios was studied for the highest-class receiver. 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. The results of measurements showed that a change of modulating signal bandwidths has no pronounced effect on protection ratios.

9. Subjective assessment of the quality of reception

9.1 *Investigations carried out in the USSR*

Statistical and subjective tests were carried out in the USSR 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].

9.2 *Investigations carried out in Japan*

Results of a subjective assessment carried out in Japan [CCIR, 1982-86a] concerning the relationship between reception quality and radio-frequency wanted-to-interfering signal ratio is shown in Fig. 5(a) for co-channel interference and Fig. 5(b) for adjacent-channel interference. Listening tests were made using three receivers (A, F, H) by ten experts.

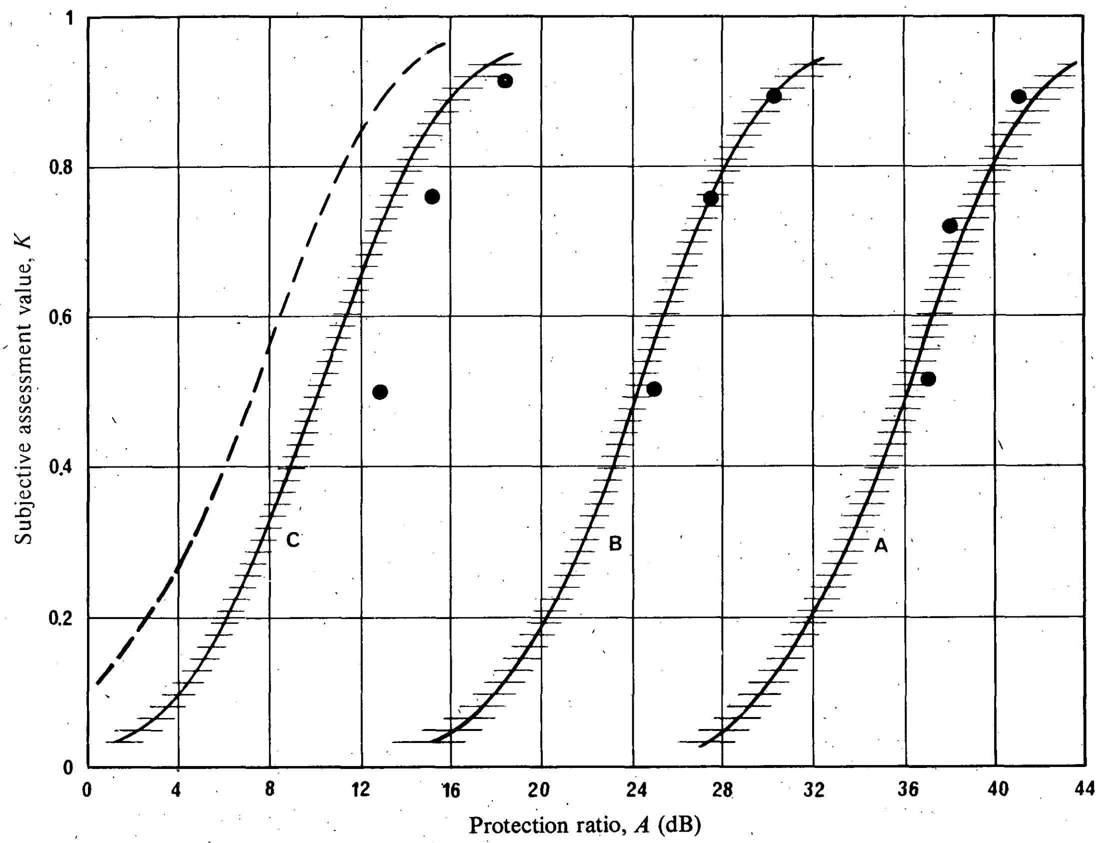


FIGURE 2 – *Co-channel protection ratio measurements*

● : 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

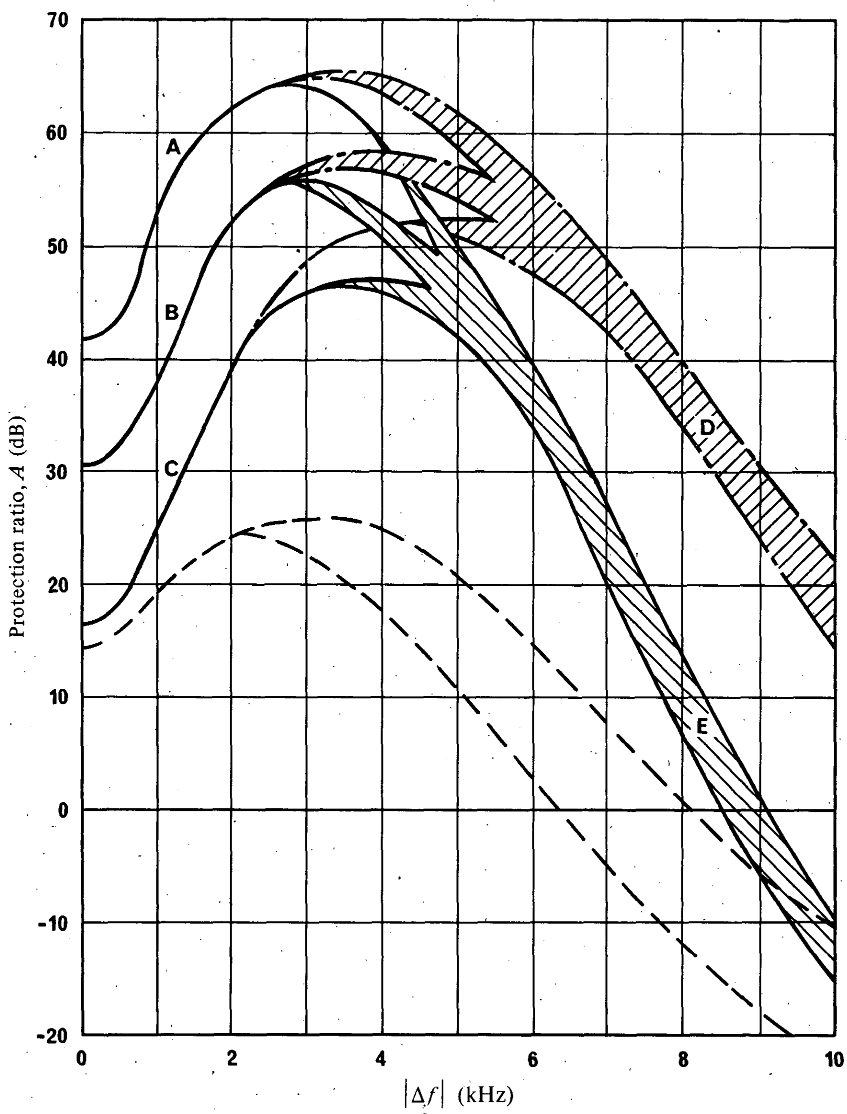


FIGURE 3 – *Protection ratio as a function of carrier spacing*

- - - - : worst case, wanted and interfering programmes broadcast in one language with wide dynamic range, no band constraints and 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
D: wideband
E: narrowband

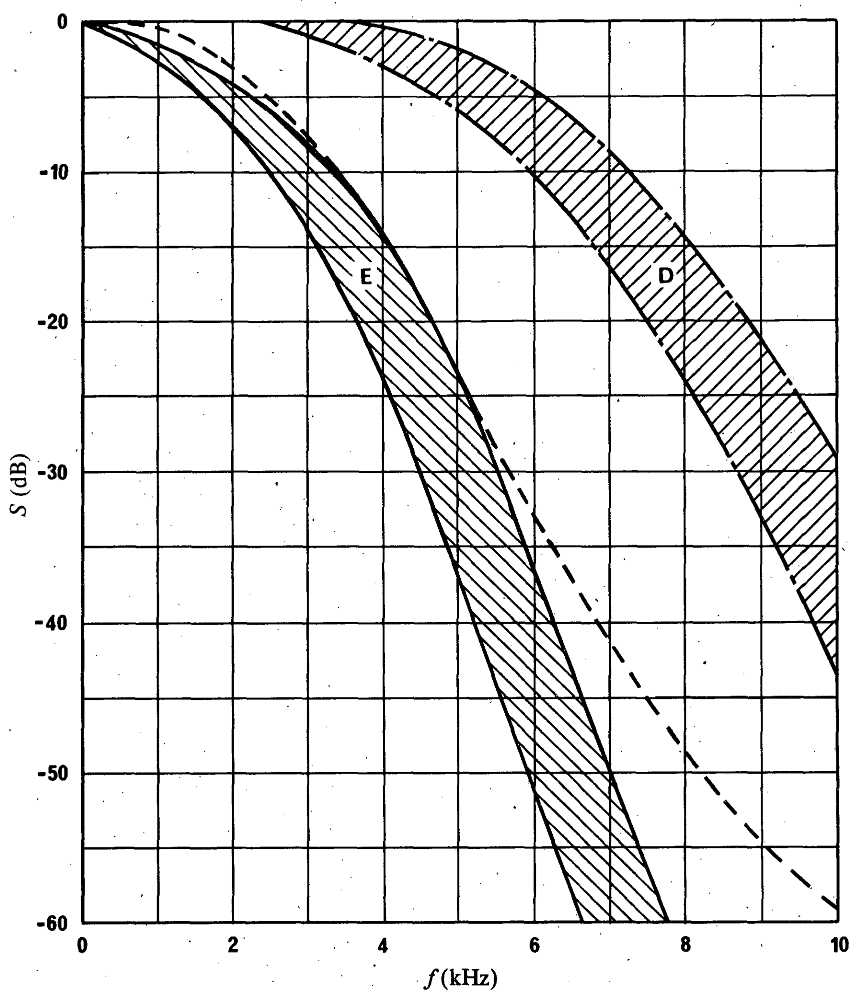
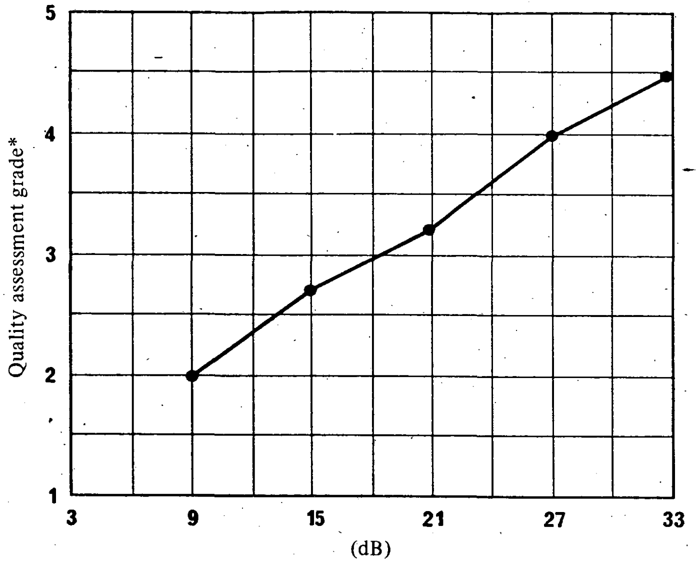


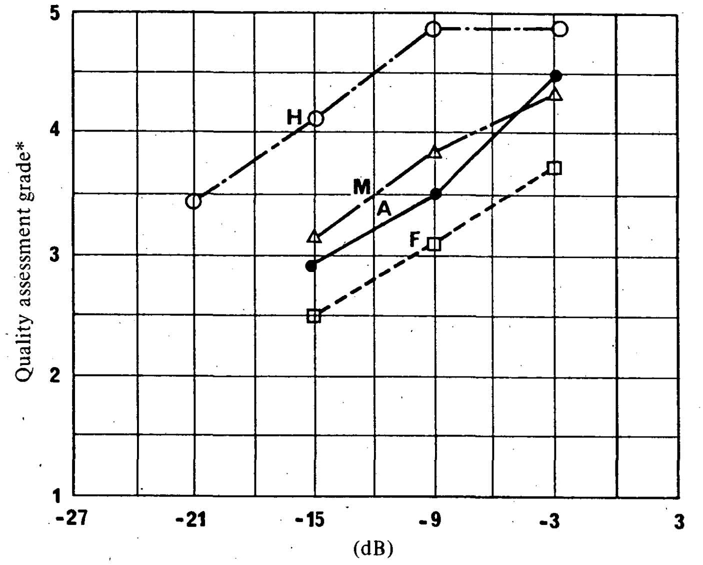
FIGURE 4 – *Receiver selectivity curves*

– – – : EBU MBF receiver

Curves D: wideband
E: narrowband



(a) In case of co-channel interference



(b) In case of adjacent-channel (10 kHz spacing) interference

M: results for average of three receivers

FIGURE 5 – *Relationship between reception quality and radio-frequency wanted-to-interfering signal ratio*

* See Recommendation 562.

10. Radio-frequency protection ratios for synchronized broadcasting transmitters

10.1 *Investigations carried out in the USSR*

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.

10.1.1 *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.

10.1.2 *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%.

Figure 6 shows the variations in protection ratio as a function of the phase difference 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.

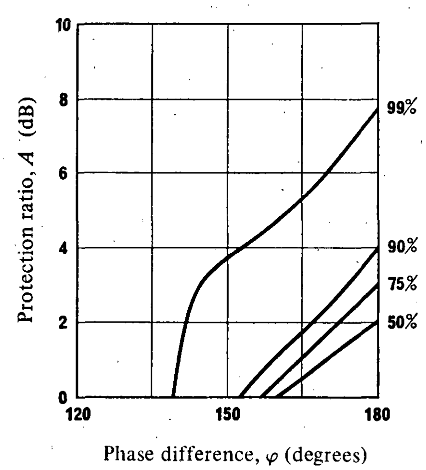


FIGURE 6 – *Quality of speech and music transmissions as a function of the phase difference between the carriers of two transmitters (non-fading conditions)*

Figure 7 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.

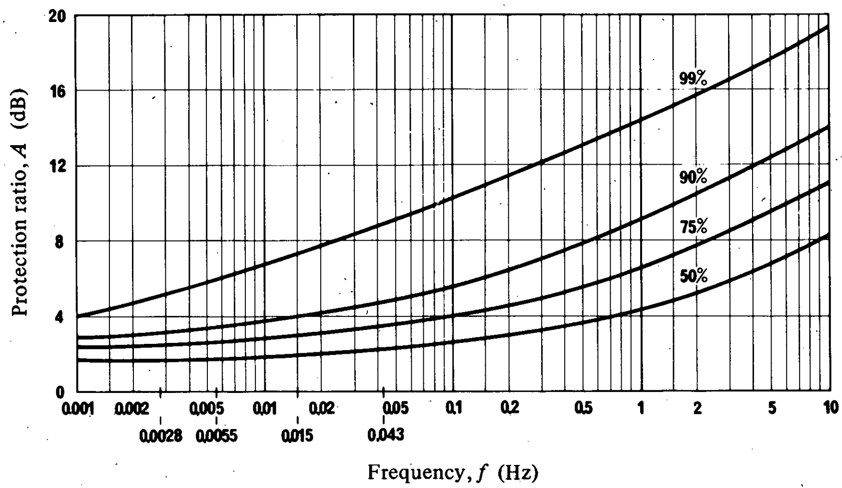


FIGURE 7 – *Quality of speech and music transmissions as a function of difference in frequency of two transmitters (non-fading conditions)*

Figure 8 contains similar results 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.

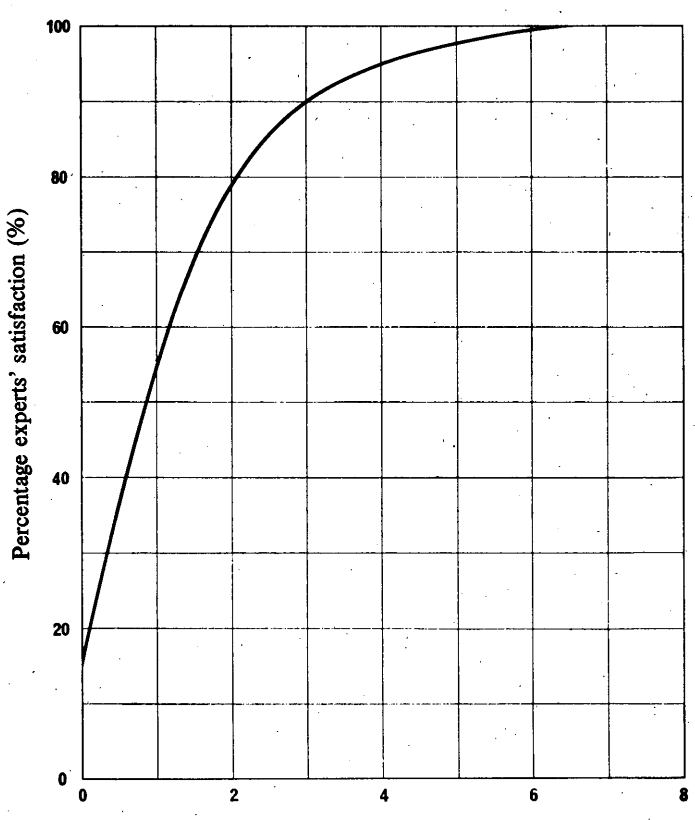


FIGURE 8 – *Quality of speech reception and of music transmissions as a function of the field-strength ratios of three transmitters synchronized in phase*

10.2 *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.

10.3 *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 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.

With the use of 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 advantageous [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 will 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.

10.4 *Investigations carried out in the United Kingdom*

10.4.1 *Equalization of modulation delay*

Laboratory tests conducted by the BBC [Whythe, 1976] to study the effect of modulation delay in a common-channel, same-programme system gave the results shown in Table I 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 I 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 I

Carrier-amplitude ratio (dB)	Subjective grade of impairment exceeded for 10% of the time for modulation-delay inequality of: (1)					
	0	30 μs	50 μs	84 μs	250 μs	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 I 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 ± 30° 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.

10.4.2 *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 § 10.4.1) 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.

10.5 *Investigations carried out in India*

Subjective tests were carried out in India with a view to determining the protection ratio applicable to synchronized transmitter groups in band 7 (HF). These tests indicated that a large majority of the listeners did not observe any degradation in the quality of programme even in a zone where the field strength of the synchronized transmitters differed only by 2-3 dB at a distance of approximately 2000 km from the transmitters. It has therefore been concluded that in the case of synchronized transmitters in band 7, the appropriate co-channel protection ratio would be as low as 3 dB if the transmitters are driven by a common oscillator and operate with antennas of similar vertical radiation characteristics [CCIR, 1978-82c; CCIR, 1982-86c].

10.6 *Investigations carried out in Japan*

A synchronized network composed of seven MF transmitters has been operated in Okayama, Japan, since January 1984, using an identical carrier frequency in the MF broadcasting band [CCIR, 1982-86d]. It is necessary that the following conditions are met, in order to improve the quality of signals received in the interference zones:

- transmitters comprising the network have an identical carrier frequency and are phase-locked to each other, using a synchronizing signal transmitted via radio-relay links between the broadcasting transmitters. In addition, the phase of the two carrier signals is maintained in phase in the area where both carrier signals propagate in the same direction;
- the field strength of each transmitter is set at not less than 1 mV/m in the interference zones where the number of listeners is large;
- the phase difference of modulation signals is maintained within 5° over the frequency band from 80 Hz to 4 kHz in the interference zone.

Seven transmitters of an identical carrier frequency (1494 kHz) having a total power of 9.2 kW offer a coverage area of about 80 km by 90 km which corresponds approximately to the area (for the Okayama district) which a single high-power transmitter of 150 kW at the main station would provide. When the above three conditions are satisfied, a good enough quality of received signals is obtained in the interference zones, as long as the S/I ratio is not less than 1 dB (Fig. 9).

Due to its size, no interference due to short-range fading or multipath propagation was experienced in the coverage area. However, in large coverage areas this type of interference may lead to some difficulty in achieving the same results.

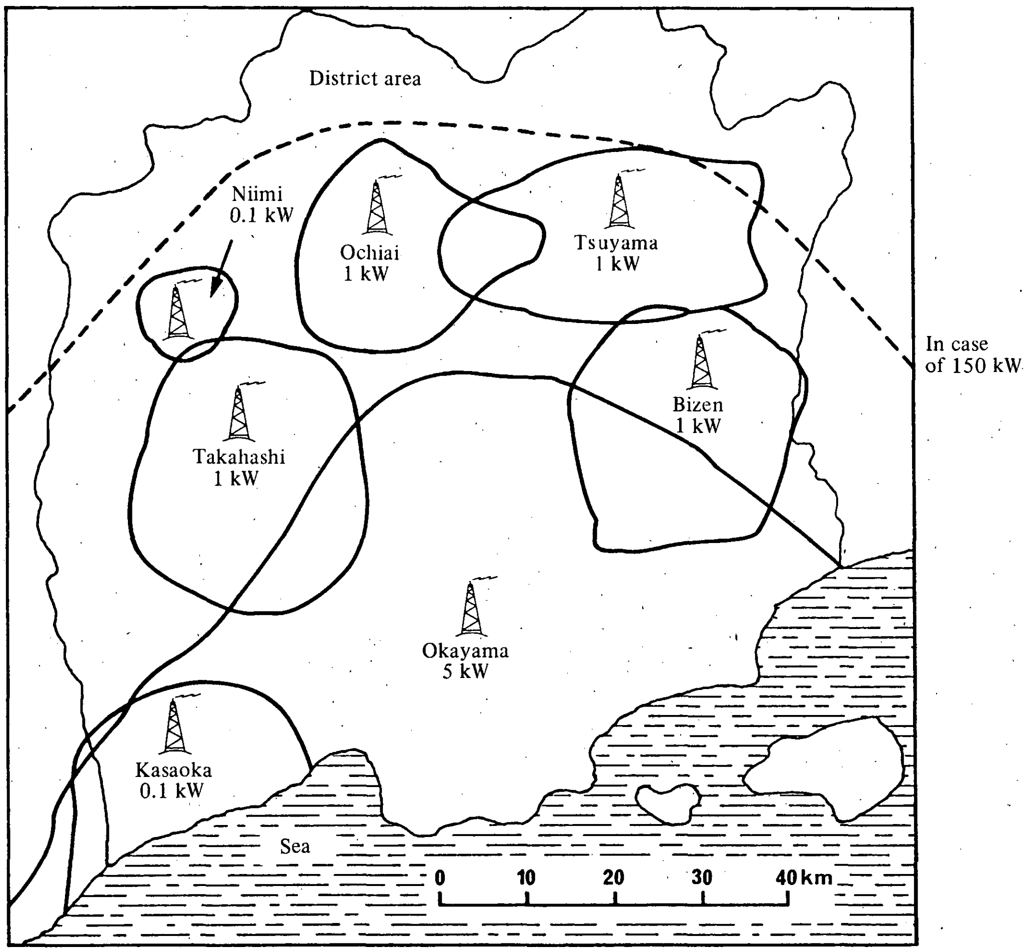


FIGURE 9 – *Synchronization of the MF transmitter chain on 1494 kHz*

All subsidiary stations: audio phase equalized to principal station
Contour: 1 mV/m
Population in the district area: 1 871 000

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.*, Part A – Technical, **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.

WHYTHE, 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 (USSR).

[1978-82]: **a.** 10/245 (India); **b.** 10/209 (Rev. 1) (USSR); **c.** 10/82 (India).

[1982-86]: **a.** 10/6 (Japan); **b.** 10/112 (China (People's Republic of)); **c.** 10/69 (India); **d.** 10/209 (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, Moscow, USSR.

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, Moscow, USSR.

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)).

[1986-90]: 10/59 (USSR).

ANNEX IV

PLANNING PARAMETERS IN BAND 7 (HF) CONSIDERED BY THE WARC HFBC(2)

The WARC HFBC(2) considered that RF protection ratios, minimum usable field strengths and signal fading allowances are basic planning parameters which may be improved as a result of further studies and recommended that the IFRB should use the following parameters in its Technical Standards.

1. Radio-frequency protection ratios

1.1 *Protection ratio for unsynchronized transmissions*

The HFBC Planning System shall endeavour to satisfy the requirements with a minimal co-channel RF protection ratio of 17 dB without taking account of the fading allowances and multiple interference entries. In cases of congestion this ratio may be lowered until the congestion is resolved.

1.2 *Protection ratio for synchronized transmissions*

The co-channel protection ratio between synchronized transmissions in the same network should be:

Distance L between synchronized transmitters (km)	Protection ratio (dB)
$L \leqslant 700$	0
$700 < L \leqslant 2500$	4
$2500 < L$	8

1.3 *Relative radio-frequency protection ratios*

The relative RF protection ratios (α) for carrier frequency separations* (Δf), with reference to the co-channel protection ratio, should be:

Δf (kHz)	α (dB)
0	0
± 5	−3
± 10	−35
± 15	−49
± 20	−54

2. Minimum usable field strength

The minimum usable field strength should be determined by adding 34 dB to the greater of:

– the field strength due to atmospheric radio noise as contained in Report 322,
– 3.5 dB(μV/m), which is the intrinsic receiver noise level.

3. Signal fading allowance

3.1 *Short-term (within the hour) fading*

The upper-decile amplitude deviation from the median of a single signal is to be taken as 5 dB and the lower-decile is to be taken as −8 dB.

3.2 *Long-term (day-to-day) fading*

The magnitude of the long-term fading, as determined by the ratio of the operating frequency to the basic MUF, is given in Table III of CCIR Report 266.

For synchronized transmissions, the fading allowance associated with the predominant signal should be used. In cases where the contributing wanted field strengths are equal and Note 1 of Table III of CCIR Report 266 applies to at least one of the paths, the values for geomagnetic latitudes ⩾ 60° should be used.

* Frequency separations $\Delta f < -20$ kHz, as well as $\Delta f > +20$ kHz, need not be considered.

3.3 *Combined distribution of fading applicable to wanted and unwanted signals*

The fading allowances for 10% and 90% of the time are each to be taken as 10 dB, except where the provisions of the following notes apply. In the latter case, 14 dB is to be used.

Note 1 – If any point on that part of the great circle which passes through the transmitter and the receiver, and which lies between control points located 1000 km from each end of the path reaches a corrected geomagnetic latitude of 60° or more, the values for ⩾ 60° must be used.

Note 2 – These values relate to the path of the wanted signal only.

Note 3 – For synchronized emissions, the fading allowance associated with the predominant wanted signal is to be used. For those conditions where the constituent wanted field strengths are equal and Note 1 above applies to at least one of the paths, the value of 14 dB is to be used for the decile values.

RECOMMENDATION 598-1 *

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

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

(1982-1990)

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;

(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.

Practical aspects of MF coverage are given in Annexes II, III, IV and V.

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* This Recommendation incorporates, in Annexes II to V, the contents of Reports 616-3 (Dubrovnik, 1986) and 461 (Dubrovnik, 1986) which are hereby deleted.

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:

$$E_u = E_w = \sqrt{E_{min}^2 + \sum_{i=1}^{n} (E_i \times a_i)^2} \qquad \text{(see Report 945)}$$

Note – Where field strengths or protection ratios are expressed in dB(μV/m) or dB, respectively, the conversion can be made by means of the following formulae:

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

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):

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

– 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.

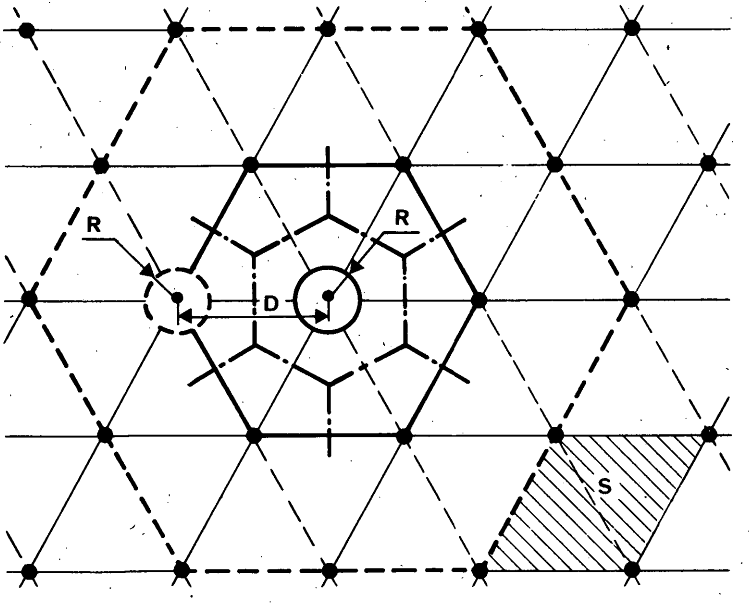


FIGURE 1 – *Regular lattice of transmitter sites*

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 (μV/m);
- the radio-frequency protection ratio values are $A = 40$, 30 or 27 dB;
- the ground conductivity values are $\sigma = 10^{-3}$, 3×10^{-3} or 10^{-2} S/m.

As a matter of fact, the rigorous and systematic use of directional antennas was also studied for aproach 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 Annex II).

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 μV/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 $\geqslant 20$ 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.

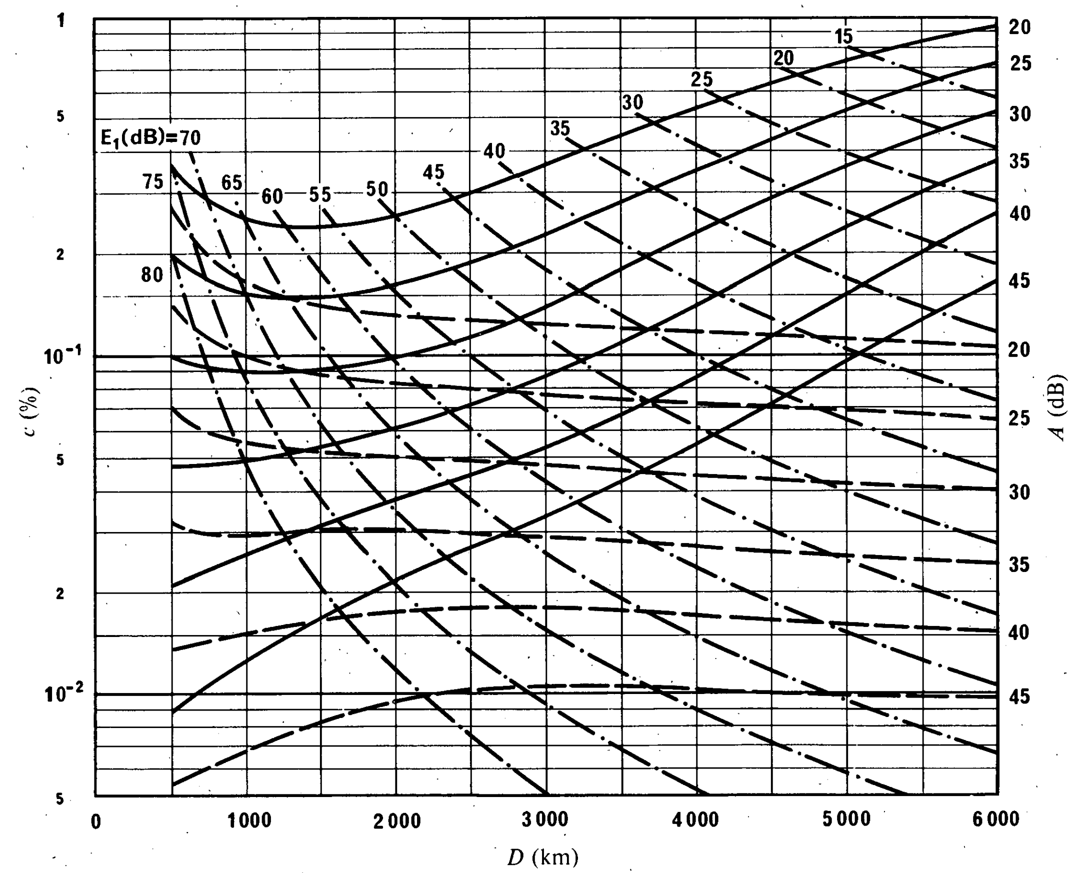


FIGURE 2 – *Coverage factor per channel (c) as a function of distance between co-channel transmitters (D) for various propagation conditions*

Parameters: – radio-frequency protection ratio A
– field of the wanted transmitter at the limit of the coverage area E_1; (p = 1 kW)

Propagation conditions:
– wanted signal: ground wave ($\sigma = 3 \times 10^{-3}$ S/m), Recommendation 368
– unwanted signals: sky wave: type 1 (Recommendation 435)
type 2 (Report 575)

No coverage limitation by noise

The curves of Figs. 2, 3 and 4 presenting the results obtained with approach B show the influence of the power p (which is the parameter indicated on the curves) in the presence of noise for the three protection-ratio values mentioned above. The coverage factor c is represented on a logarithmic scale to facilitate, in each of the Figures, a comparison between the five examples shown:

- ground-wave service interfered with by ground-wave signals (day-time conditions): group A of curves;
- ground-wave service interfered with by sky-wave signals (night-time conditions) for the two types of sky-wave propagation curves under study: groups B_1 and B_2 of curves;
- sky-wave service interfered with by sky-wave signals (night-time conditions) for the two types of sky-wave propagation curves under study: groups C_1 and C_2 of curves.

Figures 3 and 4 show that in the presence of noise:

- the optimum separation between transmitters using the same channel varies considerably with transmitter power;
- the optimum separation is completely different under day-time and night-time conditions;
- the lowest coverage will result when a ground-wave service is interfered with by the sky-wave signals of the unwanted transmitters.

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 ($p \geqslant 30$ 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.

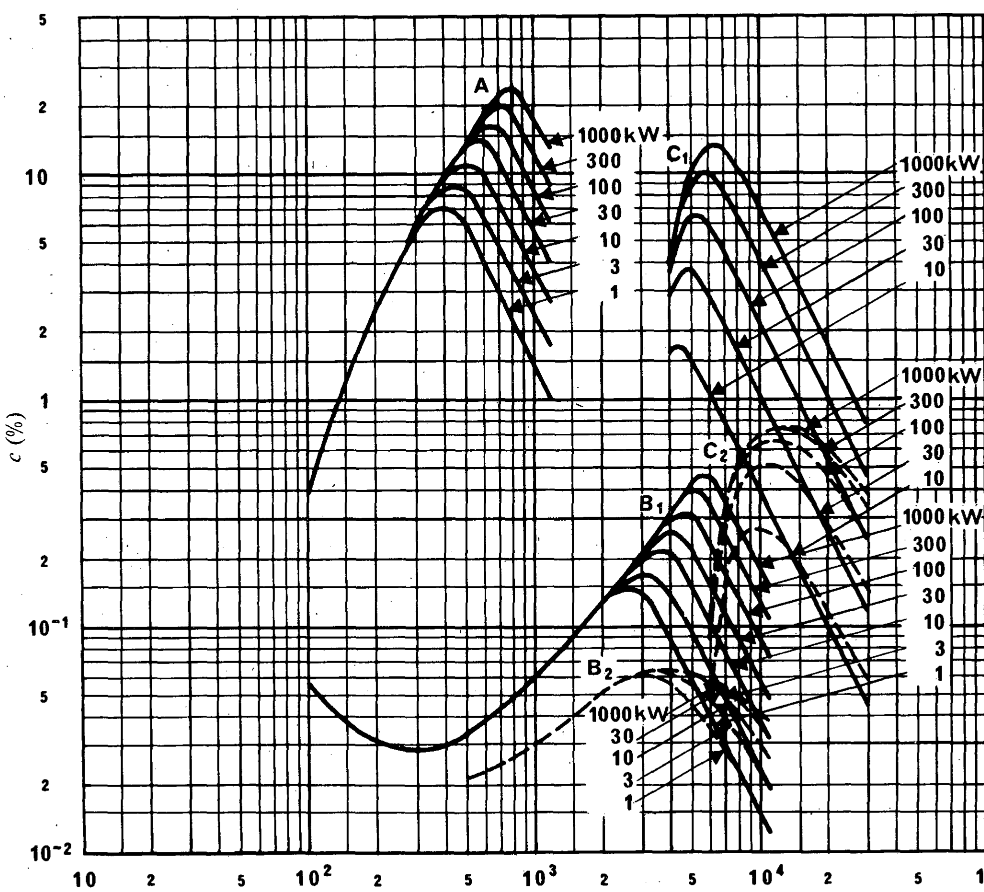


FIGURE 3a – *Coverage factor per channel (c) as a function of distance between co-channel transmitters (D) for various propagation conditions*

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(μV/m)
Ground conductivity: $\sigma = 10^{-2}$ S/m
Protection ratio: A = 40 dB

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.

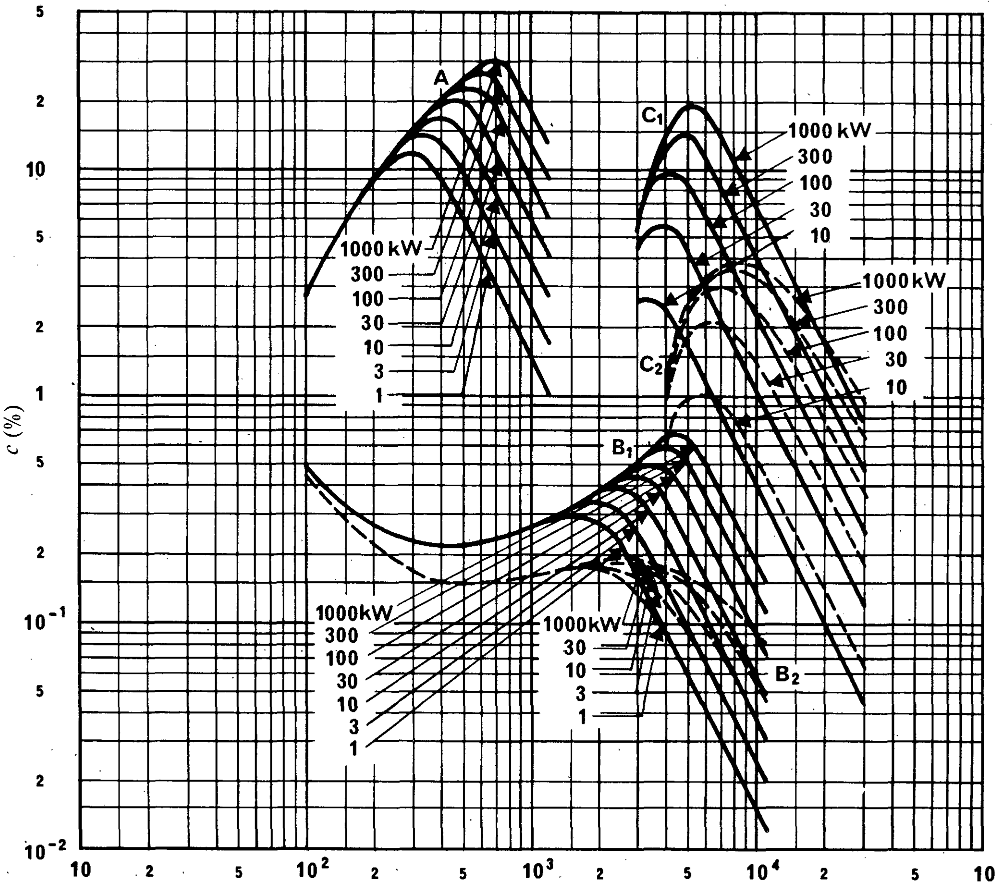


FIGURE 3b – *Coverage factor per channel (c) as a function of distance between co-channel transmitters (D) for various propagation conditions*

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(μV/m)
Ground conductivity: $\sigma = 10^{-2}$ S/m
Protection ratio: A = 30 dB

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.

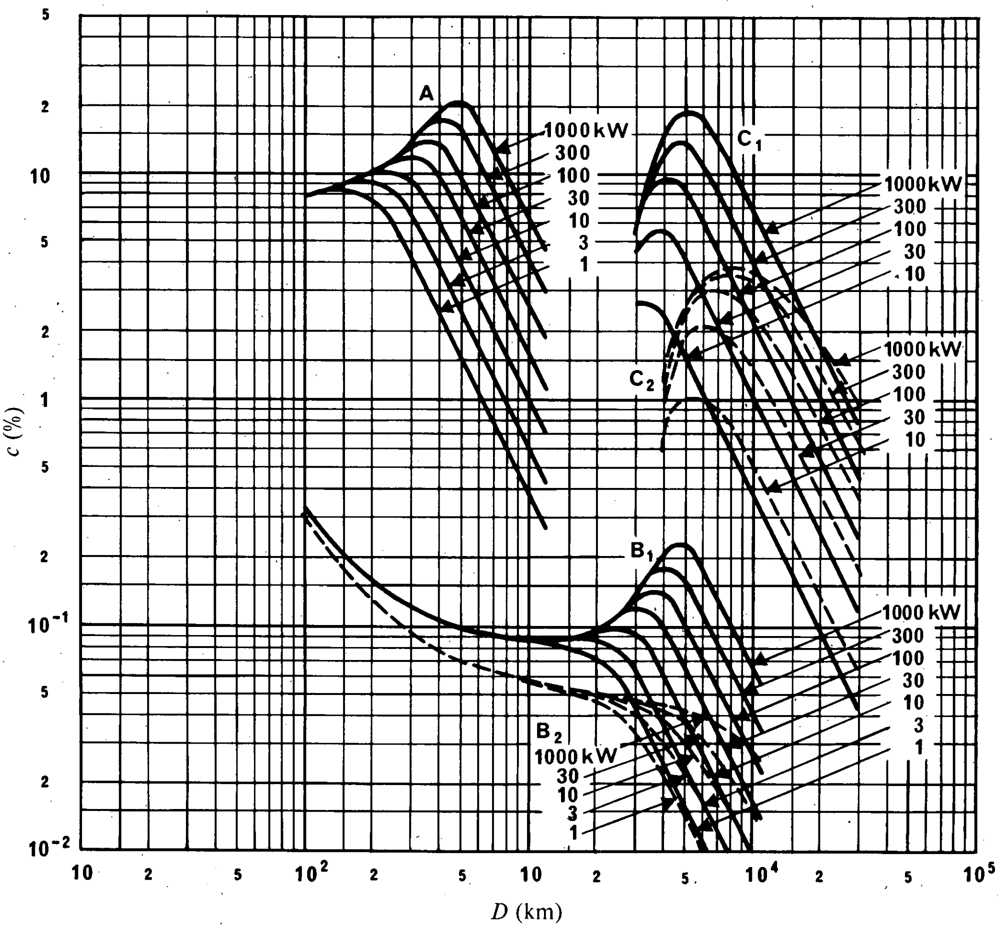


FIGURE 4a – *Coverage factor per channel (c) as a function of distance between co-channel transmitters (D) for various propagation conditions*

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(μV/m)
Ground conductivity: $\sigma = 3 \times 10^{-3}$ S/m
Protection ratio: A = 30 dB

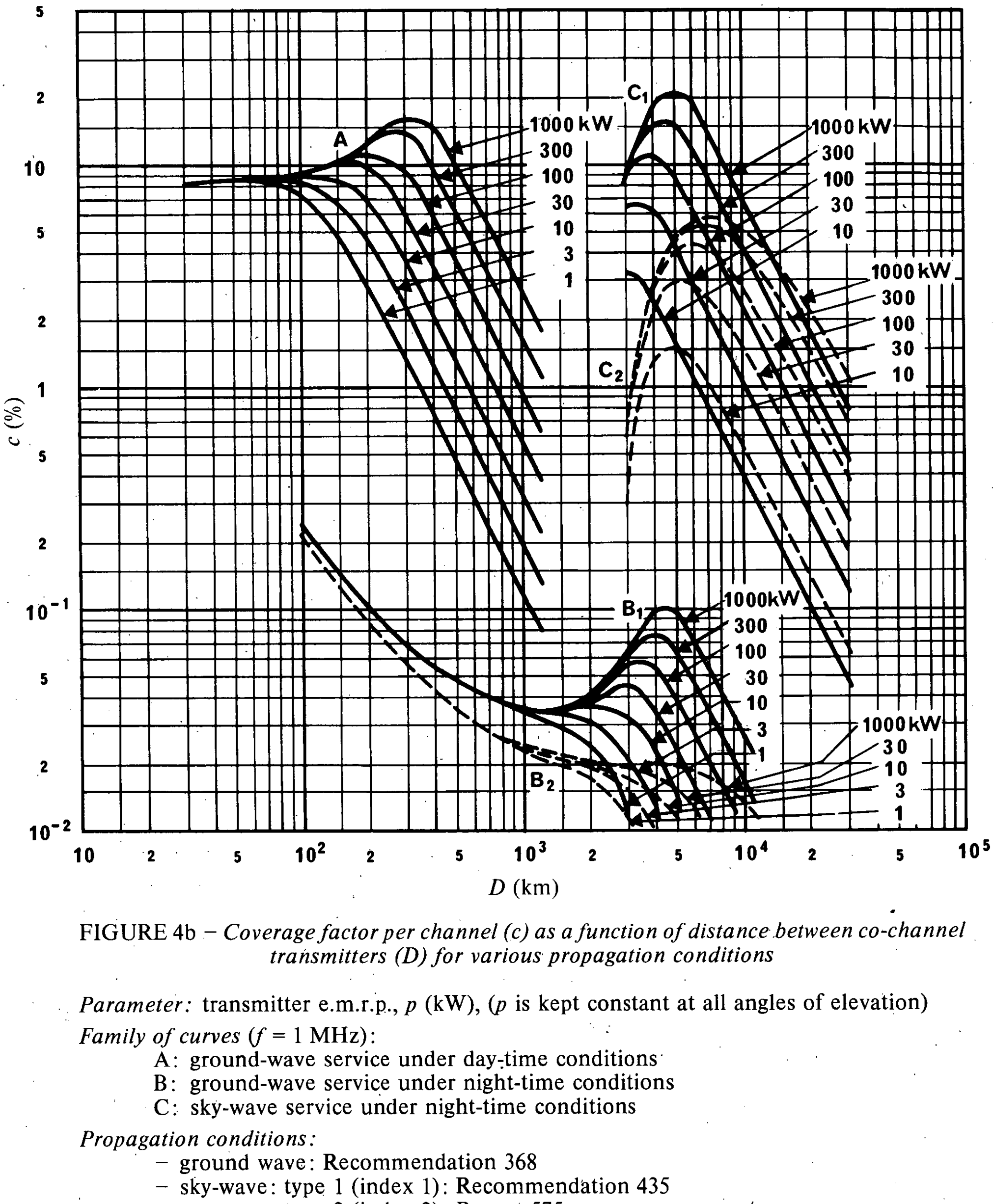


FIGURE 4b – *Coverage factor per channel (c) as a function of distance between co-channel transmitters (D) for various propagation conditions*

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

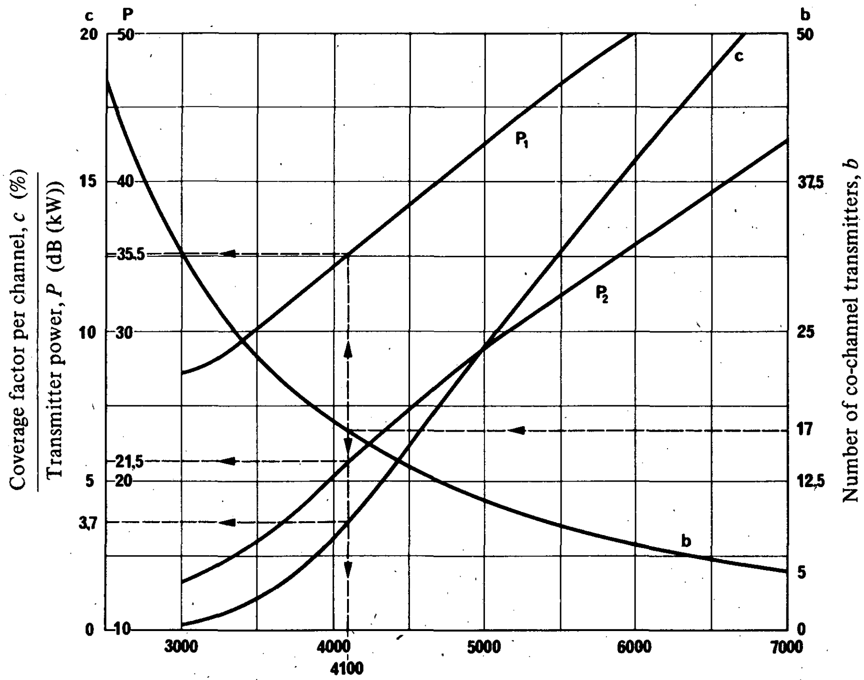
Family of curves (f = 1 MHz):
- A: ground-wave service under day-time conditions
- B: ground-wave service under night-time conditions
- C: sky-wave service under night-time conditions

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(μV/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.



Separation between co-channel transmitters, D (km)

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(μV/m)
P_3: transmitter power (dB (1 kW)) for E_{min} = 60 dB(μV/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(μV/m)
or
P = 35.5 (dB (1 kW)) for E_{min} = 74 dB(μV/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 km^2). Similar studies were carried out in the U.S.S.R. [Shlüger, 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.

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).

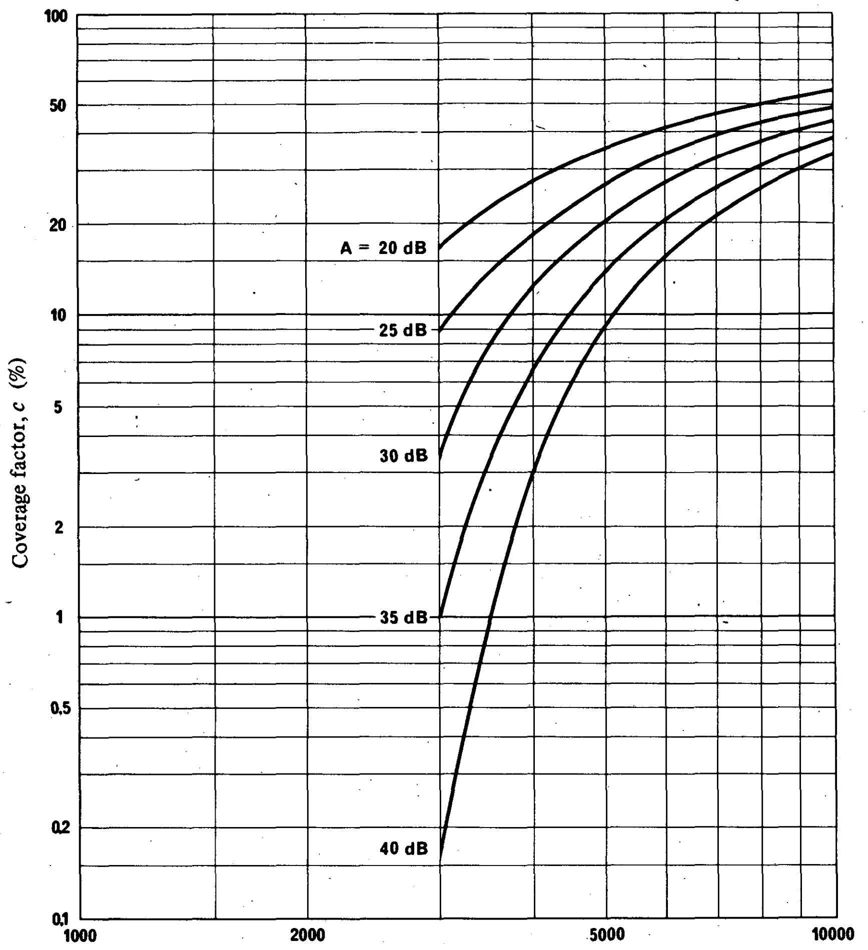


FIGURE 6 – *Coverage factor, c, for a spherical Earth, as a function of separation between transmitters, D, with protection ratio, A, as a parameter.*

Frequency: 1 MHz

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.

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.

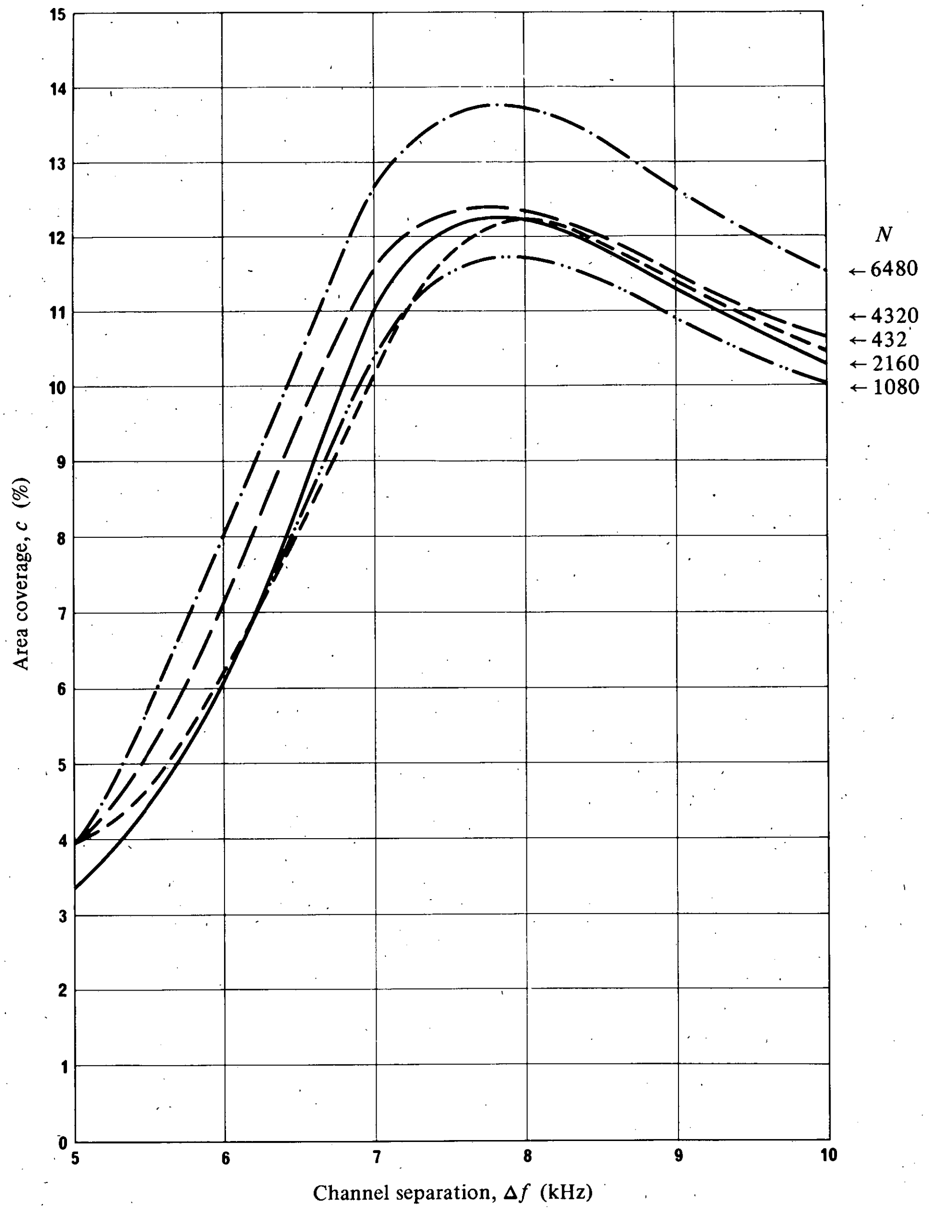


FIGURE 7 – *Coverage, c, obtainable using a 1080 kHz band with N stations in an area of 42×10^6 km² by a ground-wave service under night-time conditions*

Propagation curve used:

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

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.

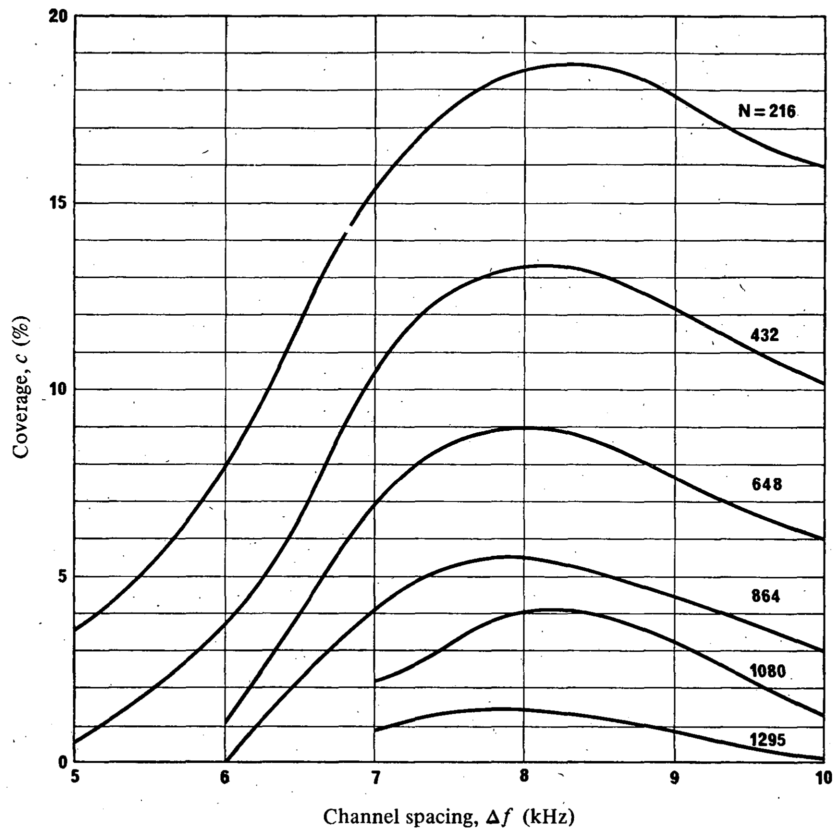


FIGURE 8 – *Coverage, c, obtainable by the sky-wave with all channels in band 6 (MF)*

Parameter: number of frequency assignments, N

Basic assumptions:
- total area: 42×10^6 km^2
- co-channel protection ratio for the median field: 27 dB
- relative protection ratios: curves 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]

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 Annex II):

- 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.

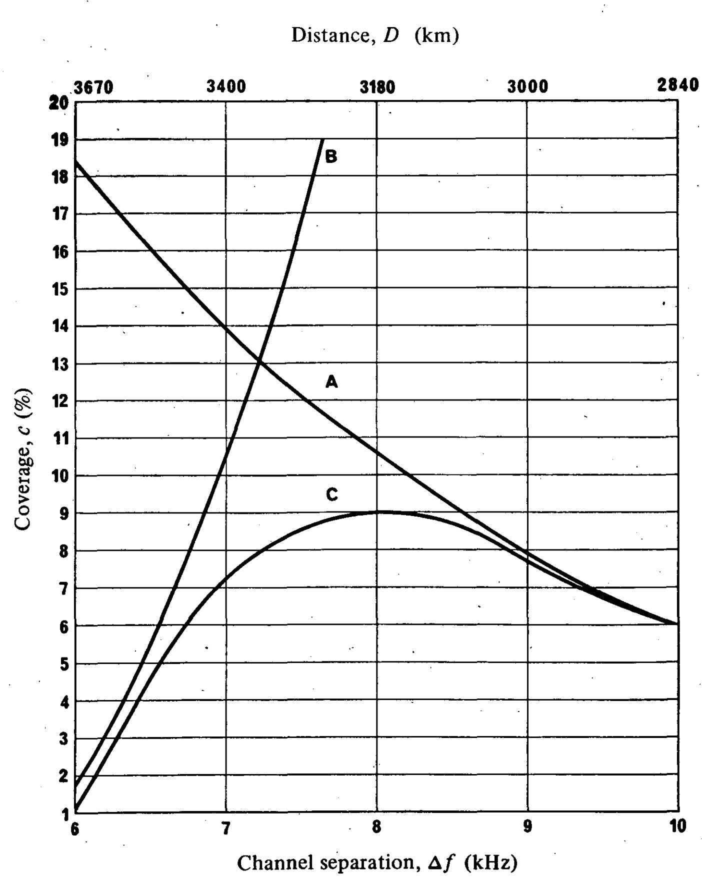


FIGURE 9 – *Limits for area coverage (radio-frequency protection ratio: 27 dB)*

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

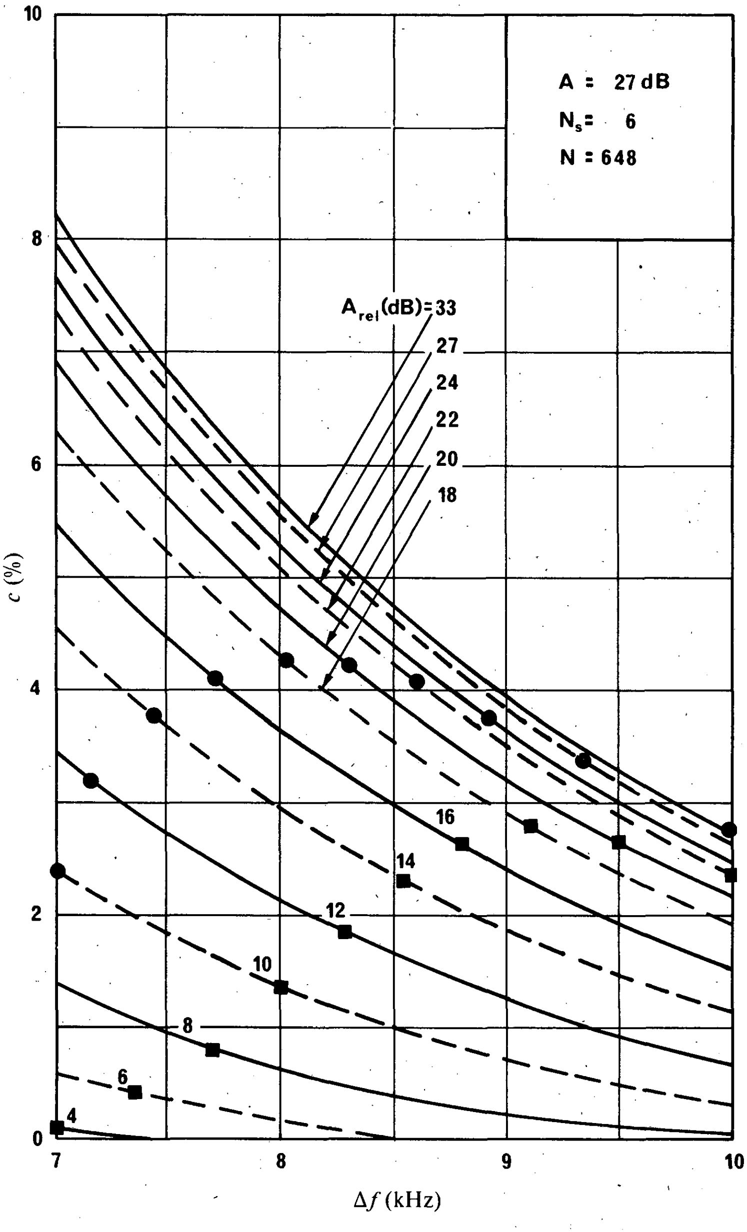


FIGURE 10 – *Coverage factor (c) as a function of channel spacing*

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.

ANNEX II

PRACTICAL ASPECTS OF MF BROADCASTING COVERAGE

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 III) 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 638) 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. 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 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 IV.

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 IV. 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 sufficently 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 assignment standards used by the Regional Administrative MF Broadcasting Conference (Region 2) (Rio de Janeiro, 1981) may serve as an example for combined day-time and night-time coverage.

Three classes of stations are provided, A, B and C. Class A are generally permitted 100 kW maximum power day-time and 50 kW night-time, Class B, 50 kW for either operation, and Class C 1 kW, except that in the tropical noise zone 2, Class C are permitted a maximum 5 kW day-time power. Class A are intended to provide extensive secondary (sky-wave) service areas, Class B relatively large primary (ground-wave) service areas, and Class C small local primary service areas.

The night-time coverage, based upon *26 dB co-channel* protection of ground-wave service areas from multiple sky-wave interfering sources, is afforded on the basis of an RSS addition of interfering signals. However, only the major contributors enter the determination of usable field strength (E_u). With the interfering signals listed in order of magnitude, any contributor whose signal is less than half the arithmetic value of the *RSS total of interfering fields* calculated using all greater contributions is not deemed to cause interference. The process applies only where the E_u is greater than the nominal usable field strength (E_{nom}). Typically, only two or three interfering stations contribute to the E_u despite the presence of numerous co-channel stations in the Region. New stations must contribute less than half the value of existing E_us, and must contribute less than the smallest contributor considered to interfere so as not to displace that contributor.

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 V 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;
- 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 less than 2000 km).

By concentrating the power away from the horizontal plane, the sky-wave coverage is 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 a non-directional antenna. 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 Stasierski, 1976].

With regard to the reduction of sky-wave in broadcasting in band 6 (MF), 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.

[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).

This method using mainly extraordinary modes cannot be recommended for all classes of power because of ionospheric cross-modulation effects especially caused by the extraordinary wave (see above).

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 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 aerials.

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] Porownanie skutecznosci 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

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

[1974-78]: 10/35 (USA).

BIBLIOGRAPHY

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

DIXON, J. M. [December, 1968] Experimental tests with orthogonal transmission. *Proc. IEE*, Vol. 155, **12**, 1755-1761.

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 III

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)		
	$\sigma = 1 \times 10^{-3}$ (S/m)	$\sigma = 3 \times 10^{-3}$ (S/m)	$\sigma = 10 \times 10^{-3}$ (S/m)
Lower third of band 6			
525		180	310
900	80	130	
Upper third of band 6			
1 250		105	180
1 605	60	90	

ANNEX IV

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.

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

TABLE IV

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

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

ANNEX V

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 411-4

FADING ALLOWANCES IN HF BROADCASTING

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

(1963–1966–1978–1986–1990)

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). For HF, Study Group 6 has proposed appropriate fading allowances for a range of percentages of time and has concluded in particular that the long-term fading of wanted or interfering signal depends upon the ratio of the wave frequency to the basic MUF and also upon the great-circle path geomagnetic latitude. These allowances are contained in Table III of Report 266.

RECOMMENDATION 498-2

IONOSPHERIC CROSS-MODULATION IN THE LF AND MF BROADCASTING BANDS

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

(1974-1978-1990)

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, in the Federal Republic of Germany [Haberkant and Vogt, 1966; Haberkant *et al.*, 1971] and in the People's Republic of China [CCIR, 1986-90]. 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].

1.3 The percentage of cross-modulation decreases as the modulating frequency of the interfering transmitter increases. Laboratory experiments [Whythe 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%.

* This Annex is given for information.

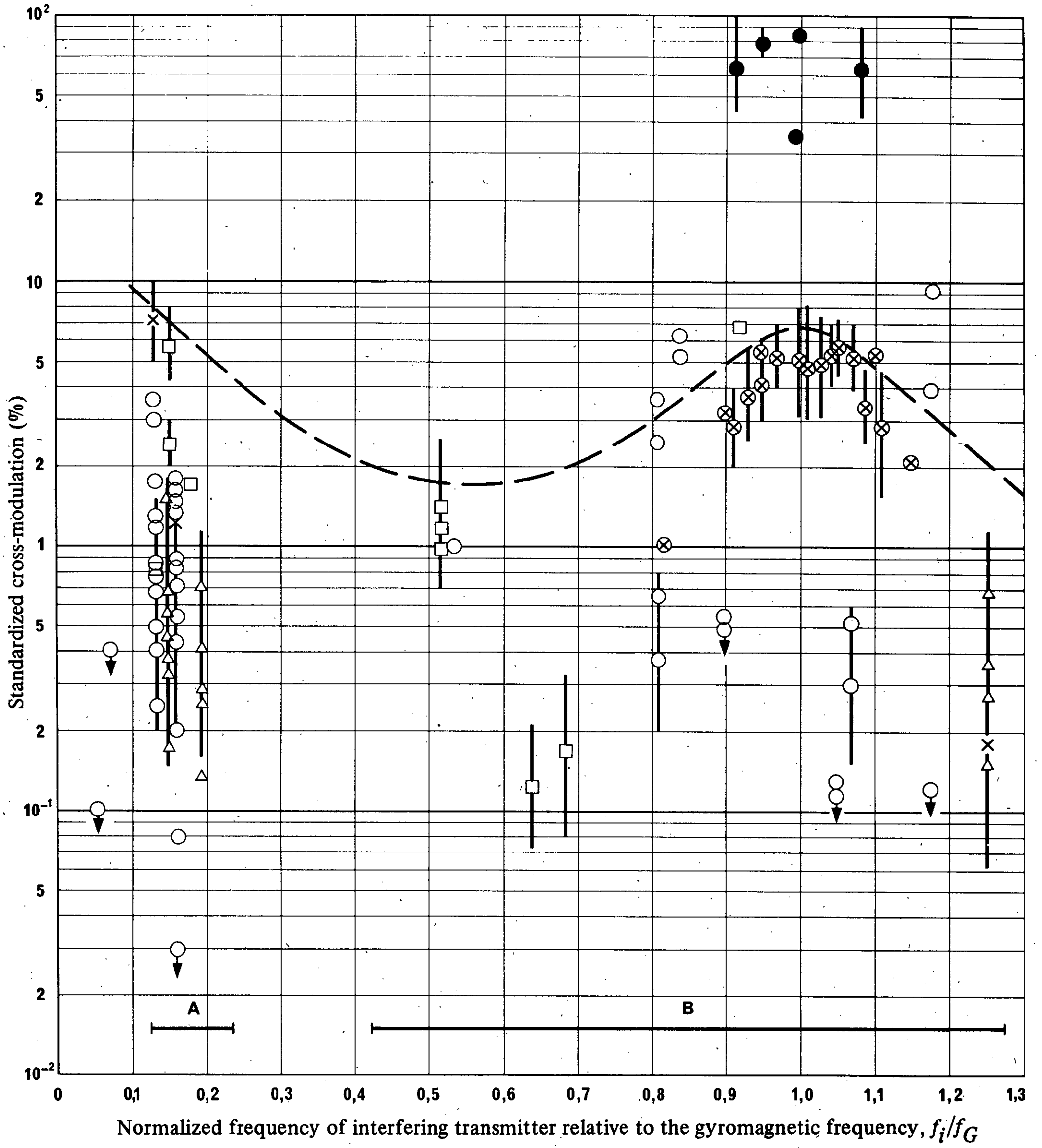


FIGURE 1 – *Measurements of ionospheric cross-modulation at medium latitudes*

□ :	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 *et al.*, 1947; Ratcliffe and Shaw, 1948; Huxley *et al.*, 1948; Huxley, 1950; Shaw, 1951; Bell, 1951]
● :	measurements in Italy	[Cutolo and Ferrero, 1948 and 1949; Cutolo *et al.*, 1950; Cutolo, 1952]
⊗ :	measurements in Australia	[Bailey *et al.*, 1952; Hibberd, 1964]
△ :	measurements in Western Europe after 1945	[Haberkant and Vogt, 1966; Haberkant *et al.*, 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.

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 gyromagnetic frequency. Figure 5 shows a map giving the value of the gyromagnetic 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 and Report 575, 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 $\mu W/m^2$ (-57 dB(W/m^2)), which corresponds to a maximum field strength of 27 mV/m (89 dB($\mu V/m$)).

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	$< 0.25\ \lambda$	$0.25\ \lambda$	$0.5\ \lambda$	$0.55\ \lambda$	$0.64\ \lambda$	$0.64\ \lambda$ (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.

Tables I and II 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.

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; c.m.f. : cymomotive force. } See also Recommendation 561

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 setting limits for the maximum effective monopole-radiated power as a function of the angle of elevation and type of antenna if a certain amount of interference caused by ionospheric cross-modulation is not to be exceeded. The conclusions drawn so far from these studies are set out hereafter.

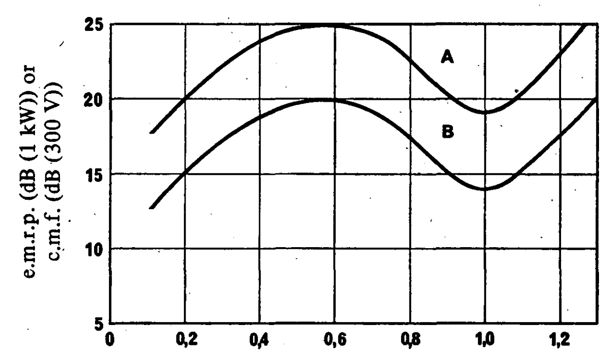
It is recommended that the annoyance due to cross-modulation should not exceed that resulting from co-channel interference with a protection ratio of 30 dB. However, cross-modulation, unlike co-channel interference, decreases with increasing modulation frequency, so that subjective experiments are necessary 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.

The results of subjective assessment of the degree of annoyance by cross-modulation carried out in China under normal transmission of sound broadcasting programmes and a co-channel protection ratio of 27 dB for sky-wave service show that the quality grade of 4 is achieved and the interference is perceptible but not annoying, when the percentage of cross-modulation is 8.9%.

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_i 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.

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 $\chi \approx l/\lambda$ 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.

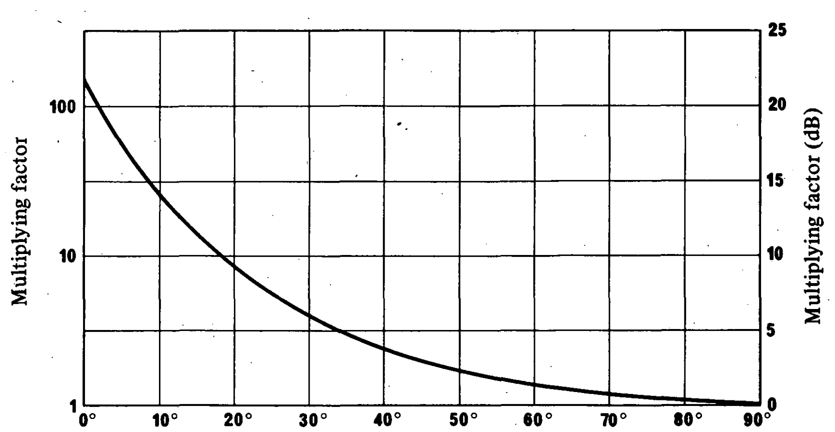
In a ground-wave service which is to be protected against cross-modulation at night, it may be assumed that the sky-wave field strength of the wanted transmitter is 10 dB below the ground-wave field strength at the service limit. Since only the sky-wave component is subject to cross-modulation, an increase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



Frequency of interfering emission relative to the gyromagnetic frequency f_i/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



Angle of elevation, θ (degrees)

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)

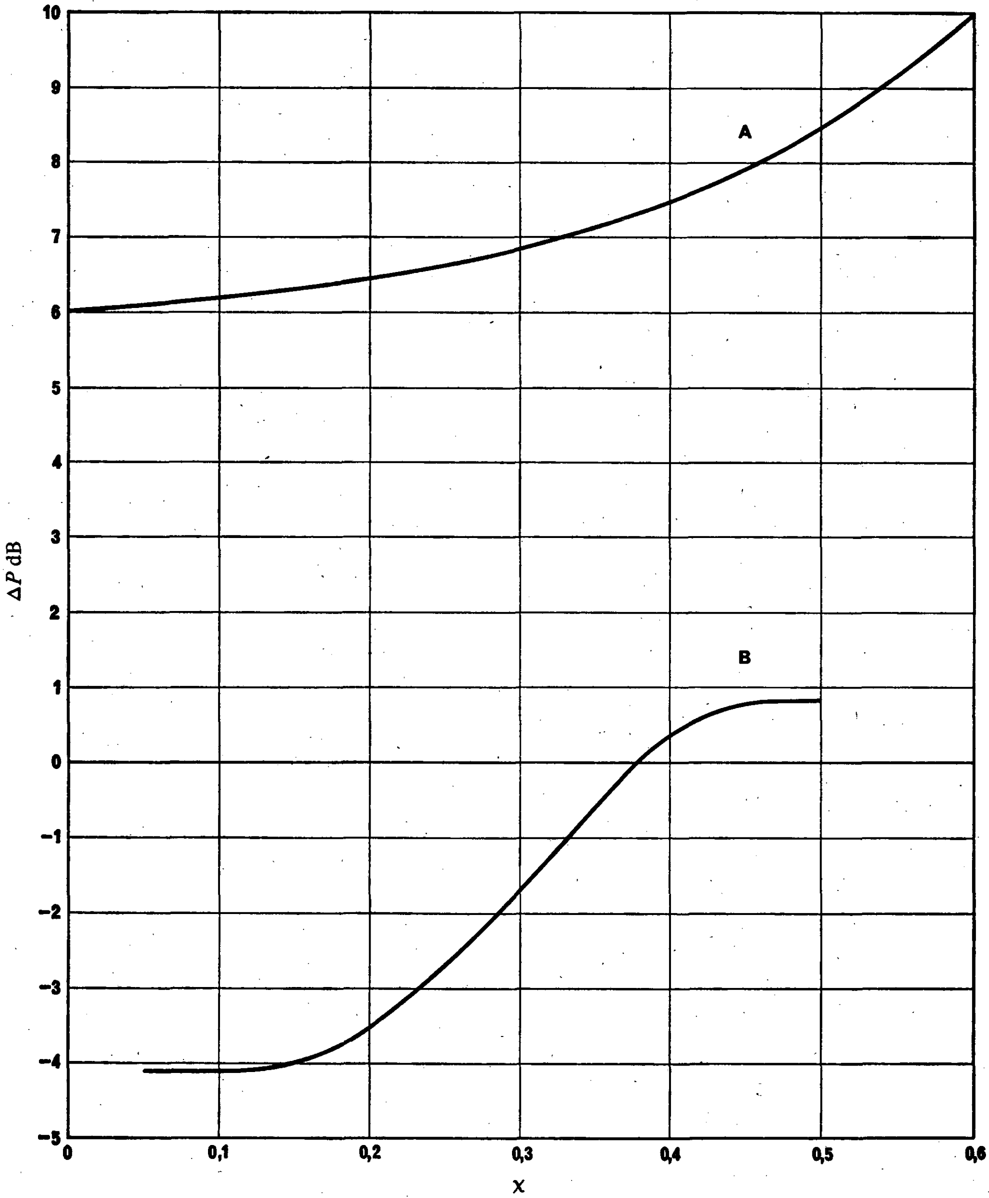


FIGURE 4 – *Correction factor, ΔP, for different types of antenna*

Curve A: vertical antenna
x: relative length of antenna, l/λ

Curve B: horizontal dipole ($l = 0.5\lambda$)
x: relative height above ground, h/λ

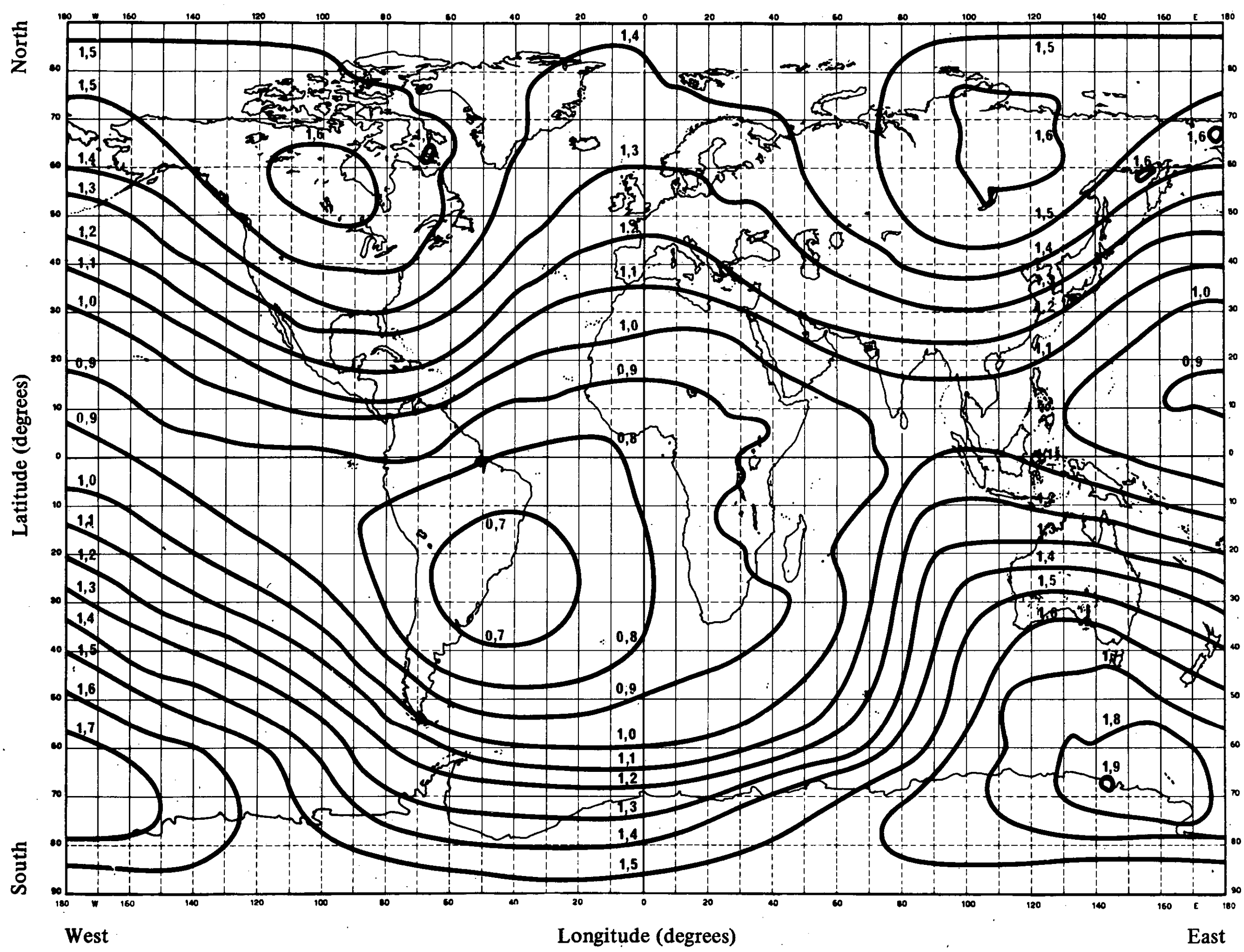


FIGURE 5 – *World-wide distribution of gyro-frequency (MHz)*

As a practical example, consider a short vertical antenna in band 5 (LF) (f_i/f_G = 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. $\approx$ 400 kW.

Curves showing the relationship between the depth of cross-modulation at the point of reception and the field strength at the point of reflection in the ionosphere are given in Fig. 6. They have been obtained following investigations carried out in China. These curves may be used to evaluate the percentage of cross-modulation at a given reception point for different values of interfering field strength at the point of reflection in the ionosphere and to calculate approximately the zone of influence of cross-modulation.

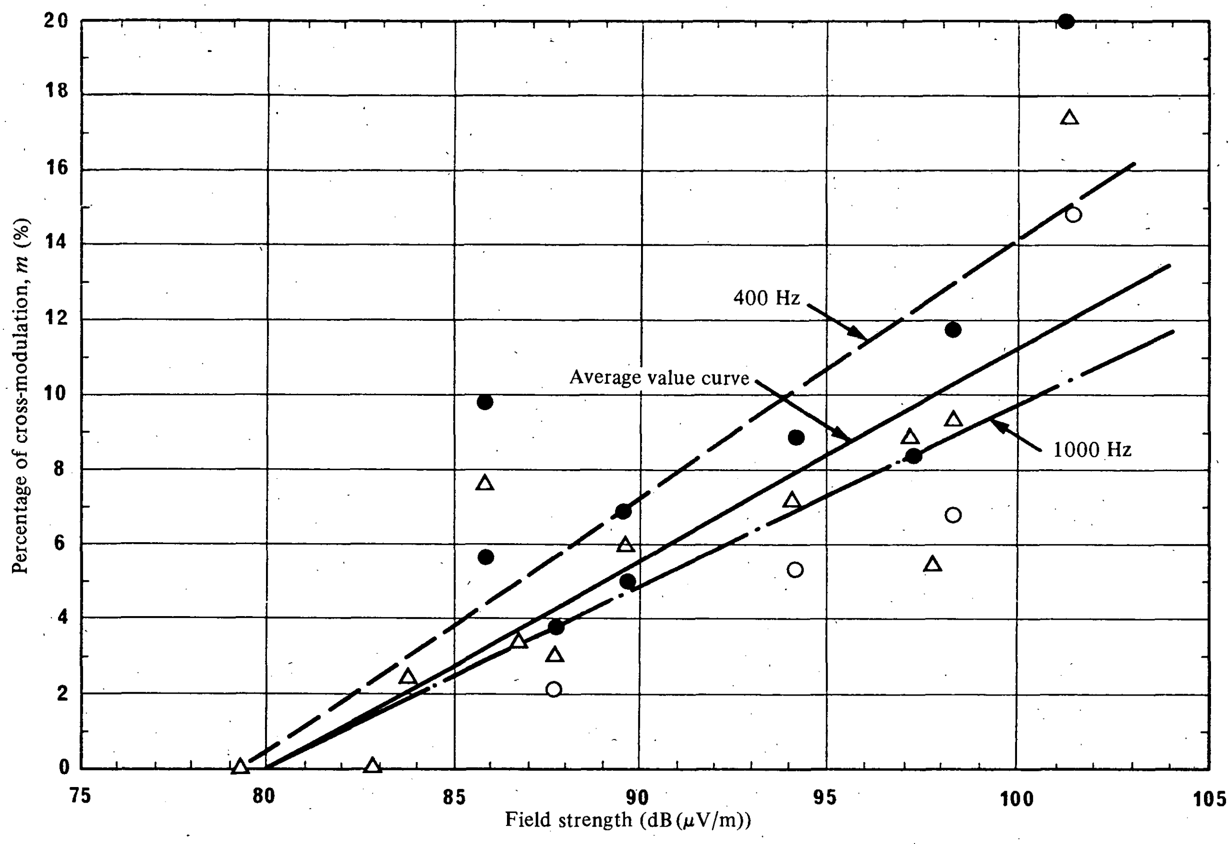


FIGURE 6 – *Relationship between the depth of cross-modulation and the field strength at the point of reflection in the ionosphere*

(correlation coefficient r = 0.84 for the curves)

● 400 Hz measured value
○ 1000 Hz measured value
△ average of measured value

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 Elektroakustic*, 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 Luzemburg (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., 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. *Tijdsc. 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.

CCIR Documents

[1986-90]: 10/318 (China (People's Republic of)).

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.

HUXLEY, L. G. H. [1952] A synopsis of ionospheric cross-modulation. *Nuovo Cimento*, Supplement to Vol. IX, Series IX, 59-89.

RECOMMENDATION 639*

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

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

(1986)

The CCIR,

CONSIDERING

(a) that in amplitude modulated double-sideband (AM-DSB) sound broadcasting, the bandwidth of emission is twice the audio-frequency (AF) bandwidth;

(b) that for quality reasons, the AF bandwidth should be as high as possible;

(c) that adjacent-channel interference is determined by, among other factors, the bandwidth of the modulating signal, and that some sound processing of the audio programme may significantly increase the higher frequency audio components;

(d) that the bandwidth of the complete AM-DSB transmission system (system bandwidth) is determined by the combined effect of the bandwidth of emission and the receiver bandwidth;

(e) that in most practical cases the bandwidth of emission considerably exceeds the receiver bandwidth, although receivers with wider or double bandwidths are becoming more prevalent in some parts of the world;

(f) that, among other factors, efficiency of spectrum utilization is affected by the carrier spacing and also by the necessary bandwidth of emission;

(g) that adjacent-channel interference decreases in areas relatively close to the wanted transmitter, where, for a transmitter of medium to low power, a larger concentration of audience can usually be presumed;

(h) that where adjacent-channel interference is minimized by appropriate geographical spacing of stations, some advantage can be taken of bandwidths of emission significantly greater than the channel spacing, thus increasing system bandwidth, particularly where receivers of wider bandwidth are employed,

UNANIMOUSLY RECOMMENDS

that where required, either for optimizing spectrum utilization or for providing an improved overall system AF response, the overall system can be optimized and planning problems can be reduced by taking advantage of the existing knowledge of the interrelation between system bandwidth, channel spacing and adjacent-channel protection ratio, as given in Annex I.

ANNEX I

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

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].

* This Recommendation should be brought to the attention of Study Group 1.

** The essential contents of Report 457 having been transferred into Annex I of this Recommendation, Report 457 is hereby cancelled.

2. Necessary bandwidth of emission

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

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 areas where adjacent-channel interference is expected not to be negligible, the use of equal values for channel spacing, bandwidth of emission and receiver passband would be a good solution. In areas where less adjacent-channel interference is to be expected, different values may be suitable, e.g., the bandwidth of emission and the receiver passband may be equal and considerably exceed the channel spacing. This is especially true if the same transmitter network is operated during day and night. In such circumstances receivers, equipped with filters of switchable bandwidths, may be used successfully to improve the reception quality under different propagation conditions.

2.2 *Band 7 (HF)*

In short-wave broadcasting, the necessary bandwidth of emission for AM-DSB should in no case exceed the value of 9 kHz. Recommendation 640 specifies a maximum of 4.5 kHz necessary bandwidth for AM-SSB broadcasting.

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 Recommendations 559 and 560. 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.

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.

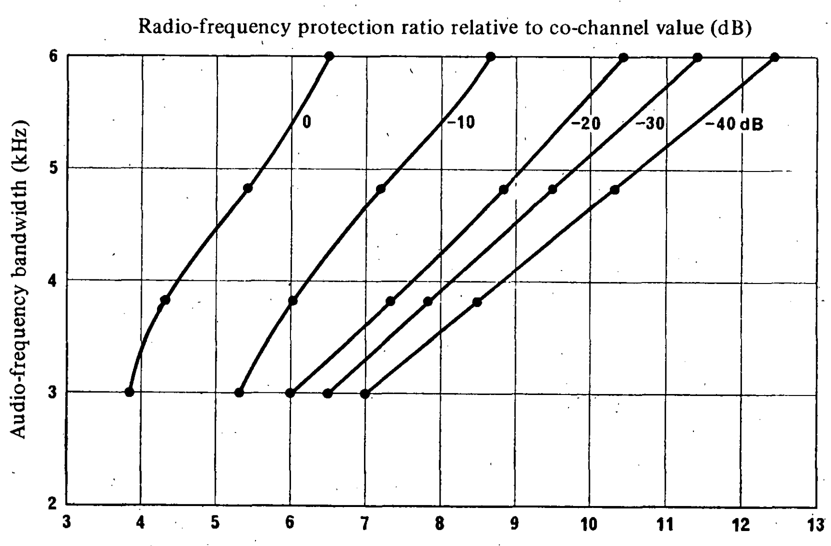


FIGURE 1 – *Use of the frequency spectrum*

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 40 dB/octave less with curve B than with curve A.

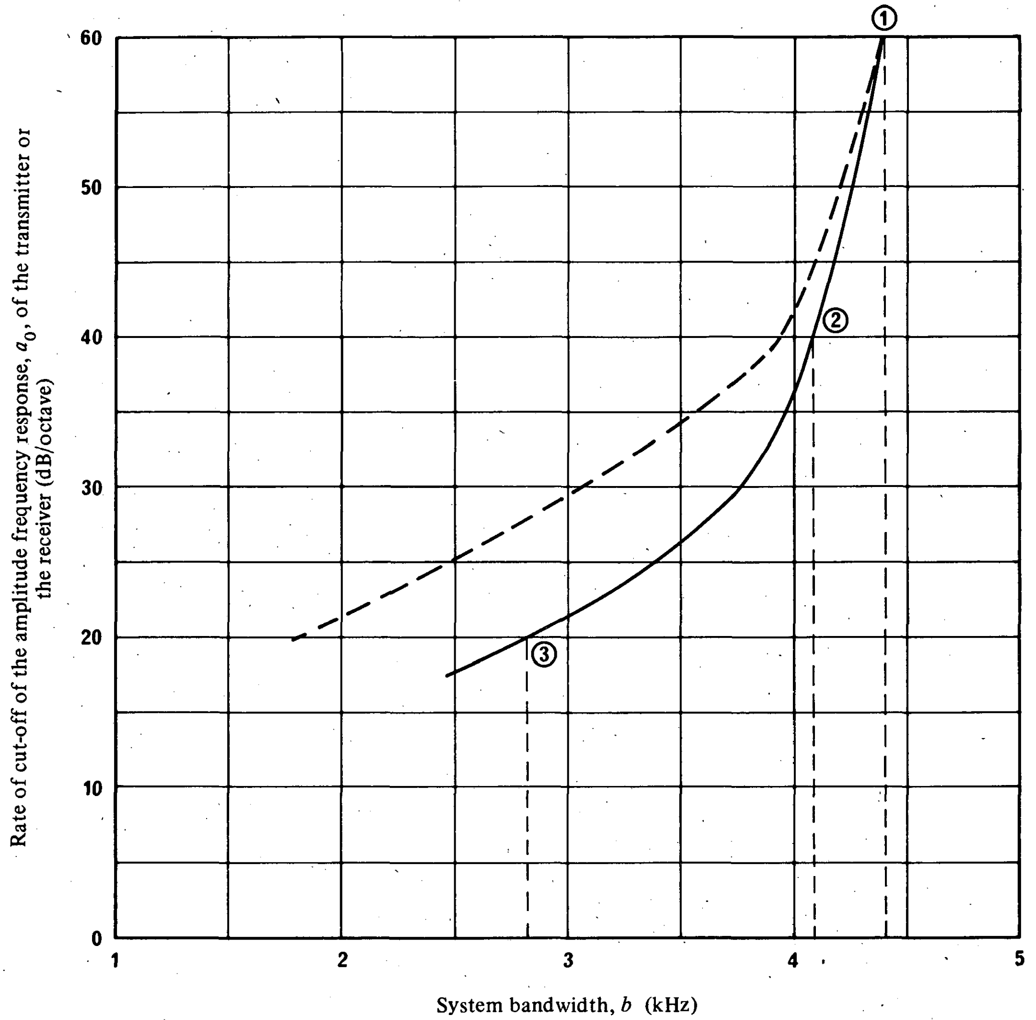


FIGURE 2 – *Characteristics of an amplitude-modulation sound-broadcasting system for optimum quality of reproduction*

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

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 USSR [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.

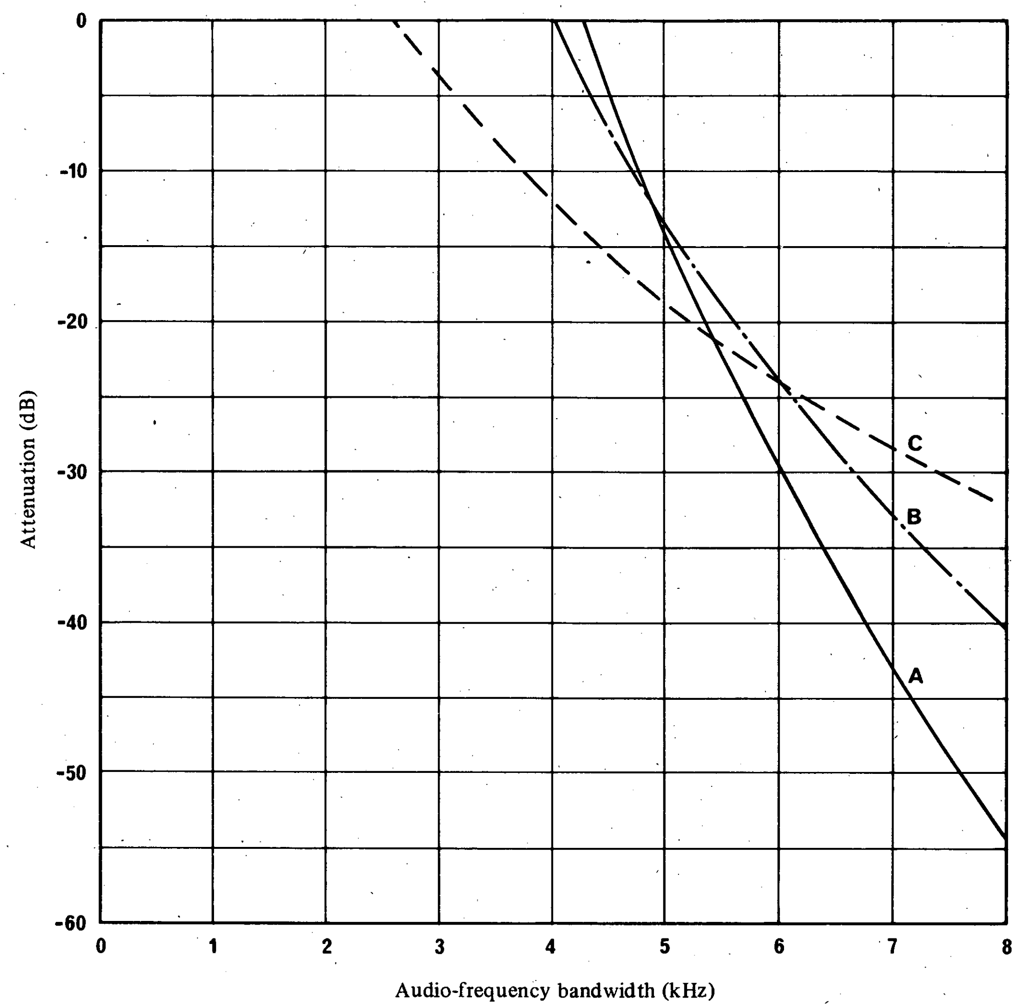


FIGURE 3 – *Overall amplitude/frequency response for an amplitude-modulation sound-broadcasting system for optimum quality of reproduction*

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

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. The effect of audio signal processing on bandwidth

Some transmitters operating in band 7 (HF) employ an audio shaping filter and limiter to achieve higher average modulation. The use of the filter is commonly referred to as the trapezoidal modulation technique. Measurements in India [CCIR, 1982-86a] have indicated that in the case of trapezoidal modulation, the occupied bandwidth of emission is greater than in the case of conventional modulation. Table I summarizes the results of the measurements.

TABLE I – *Occupied bandwidth for trapezoidal and conventional modulation*

Percentage modulation (%)	Occupied bandwidth (kHz)			
	Trapezoidal modulation		Conventional modulation	
	Upper limit of modulating frequency (kHz)		Upper limit of modulating frequency (kHz)	
	4.5	5.0	4.5	5.0
30	11.0	12.0	10.3	11.5
50	11.7	12.9	11.1	12.0
70	13.7	14.6	12.1	13.0

However, when the highest frequency of a coloured-noise modulating signal (see Recommendation 559) is not restricted to a value of 10 kHz by a low-pass filter, the occupied bandwidth in the case of trapezoidal modulation becomes less than in the case of conventional modulation. This result is attributed to the sound-shaping filter used for trapezoidal modulation which actually reduces the frequency components beyond about 8 kHz in the modulating signal.

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 (USSR).

[1982-86]: **a.** 10/286 (India).

RECOMMENDATION 597-1

CHANNEL SPACING FOR SOUND BROADCASTING IN BAND 7 (HF)

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

(1982-1986)

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 a uniform value of 10 kHz should be used world-wide for channel spacing in band 7 (HF);

2. that the nominal carrier frequencies should be an integral multiple of the channel spacing;

3. that interleaving channels with carrier frequencies separated by 5 kHz from those of the main channels may be used for coverage of geographically separated areas;

4. that, wherever possible, the intermediate frequency (or frequencies) in receivers should be an integral multiple of the channel spacing;

5. that a value of 5 kHz should be used world-wide for channel spacing for any SSB system that may be selected for future use in band 7 (HF).

RECOMMENDATION 702*

SYNCHRONIZATION AND MULTIPLE FREQUENCY USE PER PROGRAMME IN HF BROADCASTING

(Question 44/10 and Study Programme 44L/10)

(1990)

The CCIR,

CONSIDERING

(a) that the overloading of the HF bands is well known;

(b) 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...";

(c) that the WARC HFBC-87 recognized that the synchronization of transmitters is an accepted technique for improving the efficient use of the spectrum,

UNANIMOUSLY RECOMMENDS

1. that, wherever possible, only one frequency should be used to radiate a particular programme to a given reception area;

2. that over certain paths, e.g. very long paths, those passing through the auroral zone, or paths over which the propagation conditions are changing rapidly, it may be found necessary to use more than one frequency per programme;

3. that in certain special circumstances, namely:

- where the depth of the required service area extending outwards from the transmitter is too great for it 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,
- where the required service area subtends an azimuth angle greater than can be served by a single directional antenna,

more than one frequency per programme or synchronization could be used as appropriate;

4. 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.

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* This Recommendation replaces Recommendation 205-2 (Dubrovnik, 1986) and 410 (Dubrovnik, 1986) which are hereby deleted.

RECOMMENDATION 80-3 *

TRANSMITTING ANTENNAS IN HF BROADCASTING

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

(1951-1978-1986-1990)

The CCIR,

CONSIDERING

(a) that a directional transmitting antenna should be used whenever appropriate, both to obtain adequate coverage of an intended service area and to minimize unwanted radiation, and potential interference, elsewhere;

(b) that the design and installation of a wide variety of directional HF antenna types of improved performance are feasible using current technology;

(c) that directional transmitting antennas can radiate significant power in unwanted directions;

(d) that comprehensive and detailed information on the theoretical radiation characteristics of HF antennas is given in Part 1 of Annex I to Recommendation 705;

(e) that information regarding the differences between the theoretical and practical performance of HF antennas is given in Part 2 of Annex I to Recommendation 705,

UNANIMOUSLY RECOMMENDS

1. that Annex I and Annex II should be used to give guidance on the choice of a suitable HF transmitting antenna;

2. that side-lobe radiation should be maintained at the lowest practical value;

3. that in practical operating conditions, for purposes of calculating interference, the field strength in other azimuths at angles of elevation corresponding to those of the main lobe, cannot be assumed to be less than 222 mV/m at a distance of 1 km for 1 kW of power supplied to the antenna, in the case of high gain antennas. A lower value of interfering field strength may need to be considered in the case of low gain antennas.

4. that Annex I to Recommendation 705 should be used as a source for more detailed information.

Note – The World Administrative Radio Conference for the Planning of HF Bands Allocated to the Broadcasting Service (WARC HFBC(1)), Geneva, 1987 has adopted for use, calculated values of minimum radiation which in some cases are lower than that given above (see Annex II).

ANNEX I **

1. The use of non-directional and directional antennas

In HF broadcasting the antenna is the means by which the radio-frequency energy is directed towards the required service area. The selection of the right type of antenna will enhance the signal in this area, while reducing radiation in unwanted directions. This will protect other users of the radio-frequency spectrum operating on the same channel or adjacent channels in another service area. The use of directional antennas with well defined radiation patterns is thus recommended as far as possible.

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* Since the content of Reports 32-5 and 1062 have been modified and annexed to this Recommendation as Annexes I and II, respectively, Reports 32-5 (Dubrovnik, 1986) and 1062 (Dubrovnik, 1986) are hereby deleted.

** Nomenclature is explained in Annex I to Recommendation 705 and in Annex II to the present Recommendation.

Non-directional antennas can be used when the transmitter is located within the required service area. In this case the required service area as seen by the transmitter extends over an azimuthal angle greater than 180°.

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 satisfactory reception by means of their power gains.

A chart in Fig. 1 gives some general guidelines for the choice of optimum antennas for a given type of service according to the required distance range. Two different categories are considered: short distance and medium/long-distance services.

A short distance service is understood here to have a range of up to about 2000 km. The corresponding area can be covered with either a non-directional or a directional antenna whose beamwidth can be selected according to the sector to be served. In the case of directional antennas, both horizontal dipole curtain and logarithmic-periodic antennas can be employed.

Medium and long distance services can be considered to reach distances greater than approximately 2000 km. Such coverage can be provided by antennas whose main lobe elevation angle is small (6°-13°) and whose horizontal beamwidth – depending on the area to be served – is either wide between 65° and 95° (generally 70°) or narrow between 30° and 45° (generally 35°).

The value of the field strength in the reception area is influenced by the radiation characteristics of the antenna, which depends upon the type of array. 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

For the purpose of avoiding interference in frequency sharing, the reduction of subsidiary lobes in high-frequency broadcasting directional antenna systems is of utmost importance. 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.

HF curtain antennas constructed of horizontal dipole elements are made unidirectional by the addition of a reflector screen. This screen can be comprised of either:

- an identical array of dipoles tuned to provide an optimum front-to-back ratio over the range of operating frequencies. In general no power is applied to this type of reflector, which is known as either a "tuned dipole" or a "parasitic" reflector; or
- a screen consisting of horizontal wires which act as an untuned reflector. This type of reflector is known as an "aperiodic screen".

The maximum slew values obtained in practice for different antenna types are given in Table I of Annex II.

While 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. In slewing, the gain of main lobe decreases with the increase of the slewing angle and side lobe radiation increases. As a consequence the field strength created by the side lobes will substantially increase.

Practical experience in the People's Republic of China has confirmed the possibility of obtaining satisfactory slewing by using the value of current phase differences determined by a successive approximation method of calculation [CCIR, 1986-90a].

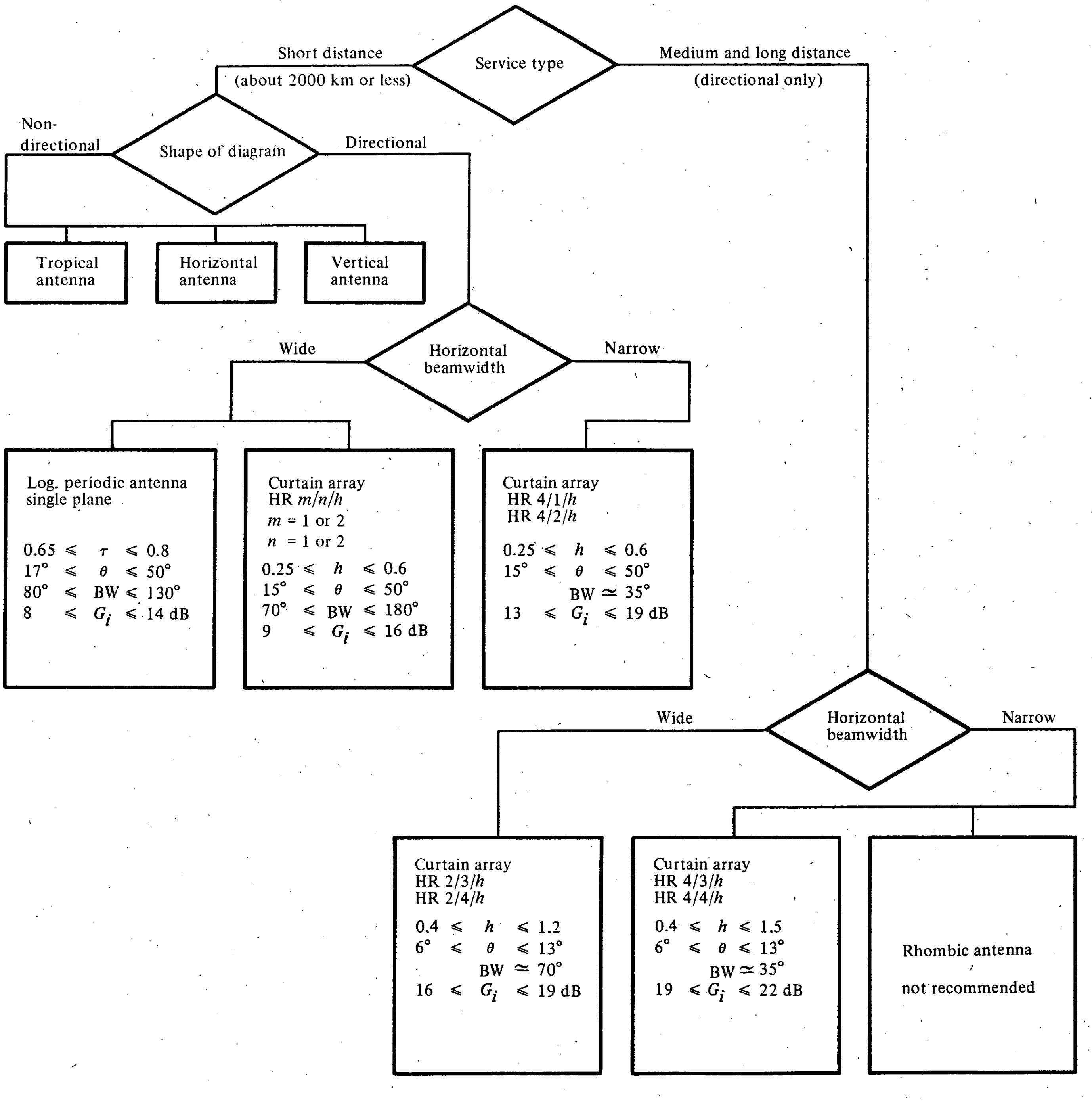


FIGURE 1 – *Antenna selection chart*

- θ: elevation angle
- G_i: gain (dB) relative to an isotropic antenna isolated in space } of maximum radiation of the main beam
- G_d: gain (dB) relative to a half-wave dipole isolated in space ($G_i = G_d + 2.2$ dB) } of maximum radiation of the main beam
- BW: total horizontal beamwidth (−6 dB relative to maximum)
- HR: horizontal dipole curtain antenna with reflector curtain
- m: number of half-wave elements in each row
- n: number of half-wave elements in each stack (one above the other)
- h: height above ground in full wavelengths of the bottom row of elements
- τ: taper ratio of log. periodic antenna

Tests in Italy [CCIR, 1963-66a] have shown that with an antenna of the type HRS 5/4/1.5 it is possible to reduce the amplitude of subsidiary lobes significantly when feeding the five stacks of dipoles separately. This property is maintained when the main beam is slewed.

A special feature of some type HR 4/4 antennas manufactured in France is that the reflector is fed, an arrangement which makes it possible to adjust accurately the current amplitudes and phases in the back and front of the arrays. Measurements of the pattern, using 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.

Calculations in France have also shown that, for multiband antennas of the type HR $2/n/h$ extension of the frequency ratio to a value of f_{max}/f_{min} close to 3 would result in satisfactory theoretical radiation patterns without significant development of subsidiary lobes.

Although it is possible to achieve a substantial degree of suppression of side lobes for curtain arrays, the methods so far employed introduce mechanical difficulties and increase the cost.

3. Verification of radiation patterns

The RAI in Italy and the Vatican City State [CCIR, 1982-86a, 1986-90b] have made a series of field-strength measurements to investigate and verify the effective radiation pattern of a variety of types of HF antennas. The measurements have been performed by using airborne equipment. The results of these measurements on non-obstructed antennas confirm that the radiation patterns of the main beam are in good agreement with the theoretical values given by the CCIR special publication on Antenna Diagrams, 1984. Detailed studies by several administrations confirm the validity of these theoretical values. Details on these studies may be found in for example [CCIR, 1986-90c]. Furthermore it is shown that in the case of a practical horizontal dipole antenna with an aperiodic screen reflector the back radiation and that in the principal minimum in the forward direction is about 20 dB below the maximum of the main lobe. It can be concluded that the methodology of measuring antenna patterns by helicopter described in Part 2 of Annex I to Recommendation 705 is a reliable and valuable means of evaluating the performance of transmitting antennas.

4. Discrimination obtained in practice by directional antennas

Extensive measurement campaigns have been carried out in different countries, to evaluate the field strength of co-located transmitters and of transmitters on different transmitting sites using directional antennas directed to geographically separated service areas. These results were used to derive antenna discrimination values, that is, the reduction in field strength, relative to the main beam value, at angles of azimuth and elevation other than those of the main beam. The discrimination obtained in practice was consistent with the limiting value given in this Recommendation. The discrimination deduced from theoretical antenna considerations (see Part 1 of Annex I to Recommendation 705 would in most cases have been much higher than that actually measured. These measurement campaigns are reported by the United Kingdom in [CCIR, 1962, 1963, 1963-66b, 1970-74] and India [CCIR, 1974-78].

REFERENCES

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).

[1982-86]: **a.** 10/254 (Italy and Vatican City State).

[1986-90]: **a.** 10/92 (China (People's Republic of)); **b.** 10/47 (Italy and Vatican City State); **c.** IWP 10/1-7 (Italy).

BIBLIOGRAPHY

CCIR [1978] Antenna Diagrams.

CCIR [1984] Antenna Diagrams.

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**.

LACHARNAY S. [1983] *Antennes pour la radiodiffusion*, 1st edition. Information Promotion Française, Paris, France.

MAGENTA, A. and GIUDICI, P. V. [September-October, 1985] Diagrammi di Antenne. *Poste e Telecomunicazioni*, anno LIII, **5**.

MAGENTA, A. and GIUDICI, P. V. [July-August, 1987] Diagrammi di irradiazione di antenna per onde medie verifica e misura con elicottero. (MF antenna radiation patterns: control and measurement by helicopter). *Poste e Telecomunicazioni*, anno LV, **4**.

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**.

ANNEX II

HF ANTENNA PATTERNS FOR SYSTEM DESIGN AND PLANNING

1. A set of reference antenna characteristics

The formulae and the associated software for the calculation of antenna patterns and values of maximum gain are given in Recommendation 705 for a wide range of HF antenna types. A limited set of reference HF antenna characteristics using the patterns of horizontal dipole antennas was adopted by WARC HFBC-87. Patterns of horizontal dipoles were used because it was found that these were the most commonly used antenna type. An examination of the variation in performance of this set of antennas forms a useful introduction to the range of antenna characteristics found in practice.

The principal characteristics of this reference set of patterns are summarized in Table I, containing 24 types of directional antenna together with a simplified pattern of a non-directional antenna (type 25). This set of antennas was selected so that a relatively wide range of characteristics is represented with only small changes between types. It also includes multiband operation and slewing.

The characteristics given in Table I apply to a design frequency of 10 MHz and ground of average conductivity. The characteristics for dual band and multiband antennas are frequency dependent. Information regarding typical expected changes in performance with frequency is given in § 3.

Information is given regarding:

– the maximum directivity gain of the main lobe of radiation in dB relative to an isotropic antenna;

– the elevation angle at which maximum radiation occurs;

– the azimuthal beamwidth to the –6 dB points;

– information regarding the practical slewing capabilities for the cases where the radiator/reflectors are one of the following:

  – (A): aperiodic screen reflector with centre-fed elements;

  – (T): tuned dipole reflector with centre-fed elements;

  – (TE): tuned dipole reflector with end-fed elements.

Types 1-6 are arrays having four collinear dipoles in each row, with from two to four parallel rows of dipoles stacked one above the other, and using one of the types of reflectors listed above, and have been extended to include multiband operation and slewing.

As the number of elements stacked above one another is decreased or the height of the lowest row of dipoles is decreased, it can be seen that:

- the maximum gain decreases;
- the elevation angle of the maximum of the main lobe increases;
- the azimuthal beamwidth does not change.

The main beam of multiband and dual band antennas with centre-fed elements can be slewed to a maximum of ± 30° before the secondary lobes have maximum gain values approaching −6 dB relative to the main beam maximum.

Note – The elevation and the azimuthal characteristics will change with operating frequency for multiband and dual band antennas (see § 3).

TABLE I – *Set of reference HF antenna types*

Principal characteristics at design frequency

Antenna reference No.	Antenna type HR(S) $m/n/h$	Max. gain G_i (dBi)	Elevation angle of maximum radiation (degrees)	Azimuthal beamwidth (−6 dB) (degrees)	Maximum slew (degrees)
01	HR (S) 4/4/1.0	22.3	7	36	
02	HR (S) 4/4/0.8	22.1	8	36	(A) Multiband 30
03	HR (S) 4/4/0.5	21.5	9	36	(T) Multiband 30
04	HR (S) 4/3/0.5	20.5	12	36	(T) Dual band 30
05	HR (S) 4/2/0.5	19.1	17	36	(TE) Single band 15
06	HR (S) 4/2/0.3	18.1	20	36	
07	HR (S) 2/4/1.0	19.7	7	66	
08	HR (S) 2/4/0.8	19.4	8	68	
09	HR (S) 2/4/0.5	18.8	9	68	(A) Multiband 15
10	HR (S) 2/3/0.5	17.9	12	68	(T) Multiband 15
11	HR (S) 2/2/0.5	16.5	17	68	(T) Dual band 15
12	HR (S) 2/2/0.3	15.5	20	70	
13	HR (S) 2/1/0.5	14.5	27	72	
14	HR (S) 2/1/0.3	13.4	40	80	
15	HR 1/2/0.5	14.1	17	108	
16	HR 1/2/0.3	13.1	20	110	
17	HR 1/1/0.5	11.8	27	116	
18	HR 1/1/0.3	9.6	44	148	
19	H 2/1/0.5	10.8	28	78	
20	H 2/1/0.3	8.5	47	106	
21	H 1/2/0.5	11.2	17	114	
22	H 1/2/0.3	10.2	21	116	
23	H 1/1/0.5	8.9	28	124	
24	H 1/1/0.3	6.9	47	180	
25	ND	3.9	47	360	

H: horizontal dipole curtain antenna
R with reflector
S: slewable antenna
m: number of collinear elements in each horizontal row
n: number of parallel elements in each vertical stack
h: height above ground of lowest row of element(s) in wavelengths at the design frequency
(A): aperiodic screen reflector centre-fed elements
(T): tuned dipole reflector centre-fed elements
(TE): tuned dipole reflector end-fed elements
ND: non-directional antenna

Types 7-14 have two collinear dipoles in each row with from one to four rows of dipoles stacked one above the other. The same trends are observed, as for the previous group, except that the azimuthal beamwidth widens significantly for the antennas with very few elements.

Slewing of the main beam should normally be restricted to a maximum of ± 15° to avoid secondary lobes having maximum gain values approaching −6 dB relative to the main beam maximum.

Types 15-18 are arrays with a single dipole in each row, and using a reflector. These unidirectional antennas have the maxima of their elevation patterns at higher angles and have a comparatively wide azimuthal beamwidth between the −6 dB points.

Types 19-24 include arrays with one or two elements stacked above one another, all without reflectors. The characteristics are generally similar to those in the previous group except that the radiation patterns are bi-directional because no reflector is used. The non-directional antenna, type 25, has an elevation pattern similar to that of type 24.

2. Comparisons of CCIR data with practical performance

Comparisons between the data produced by the CCIR computer program, the values obtained from the reference data and that according to this Recommendation are illustrated in Fig. 2, for azimuthal patterns (HR 2 and HR 4) and Fig. 3 for vertical patterns (HR $m/2/0.5$) and (HR $m/4/0.5$).

Annex I refers to measurements which show that radiation to the rear of the antenna and in the minima may be no more than 20 dB below the maximum for a typical HR $4/4/h$ antenna.

Further studies are needed to verify the practical performance of low gain antennas particularly regarding the attenuation achieved, in practice, in directions other than those of the main lobe.

3. Multiband and dual band antennas

Multiband antennas may be operated over a frequency range of approximately 2 : 1, i.e. from about 0.6 to 1.4 times the ratio of the operating frequency to the design frequency (Fr). Dual band antennas can only be operated over a frequency range of 0.9 to 1.1 times Fr.

Table II gives details of the maximum gain, the elevation angle at which this occurs and the vertical attenuation at intervals of 3° of elevation angle for ratios of Fr from 0.6 to 1.4 for multiband antenna types HR(S) 4/4/0.5 ($m = 4$) and HR(S) 2/4/0.5 ($m = 2$). The vertical characteristics given show that the elevation angle of maximum radiation decreases and the main beam of the antenna becomes narrower as Fr is increased.

Table III gives the values of azimuthal attenuation at intervals of 5° in azimuth for these two types of antenna for values of Fr from 0.6 to 1.4.

Table IV gives the values of azimuthal attenuation for a HR(S) 4/4/0.5 multiband antenna fitted with an aperiodic screen reflector operating at the design frequency, in the unslewed condition and for slew angles in 5° steps up to a maximum of 30°.

4. Equivalent antenna elevation patterns

The elevation pattern characteristics of HF antennas are dependent upon the height of the lowest row of elements, h, the number of parallel elements stacked above one another, n, and the conductivity of the ground. Elevation patterns are calculated using a ground reflection function which depends upon the spacing between the radiating elements and their images in the ground. This function can be simplified by using half this distance i.e. the mean height, h_m, of the radiating elements, illustrated for 2-stack and 4-stack antennas in Fig. 4a.

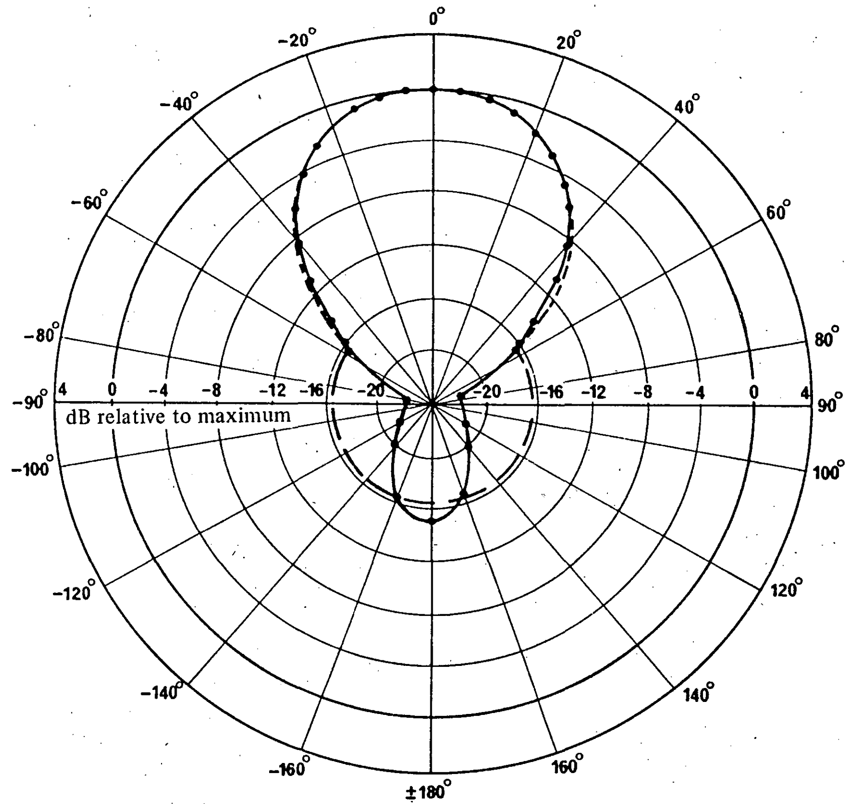
The elevation angle at which the maximum of the first main lobe occurs is then given approximately by:

$$\theta_{max} = \arc\sin\,(1/4.5 \times h_m)$$

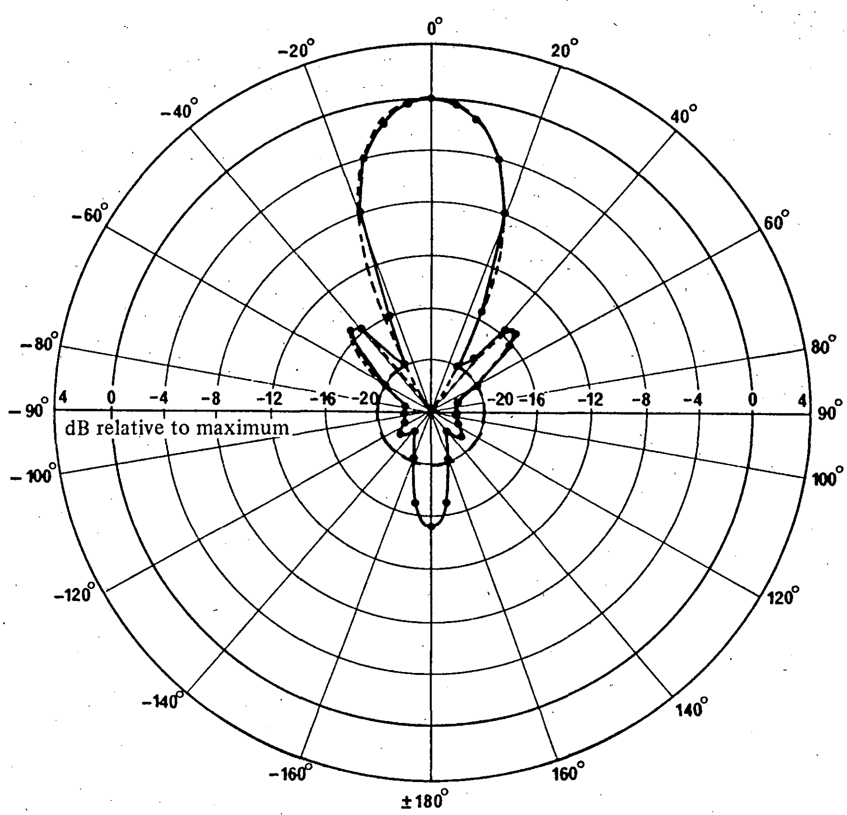
where:

$$h_m = h + 0.25\,(n - 1),$$

h and n are defined in Table I.



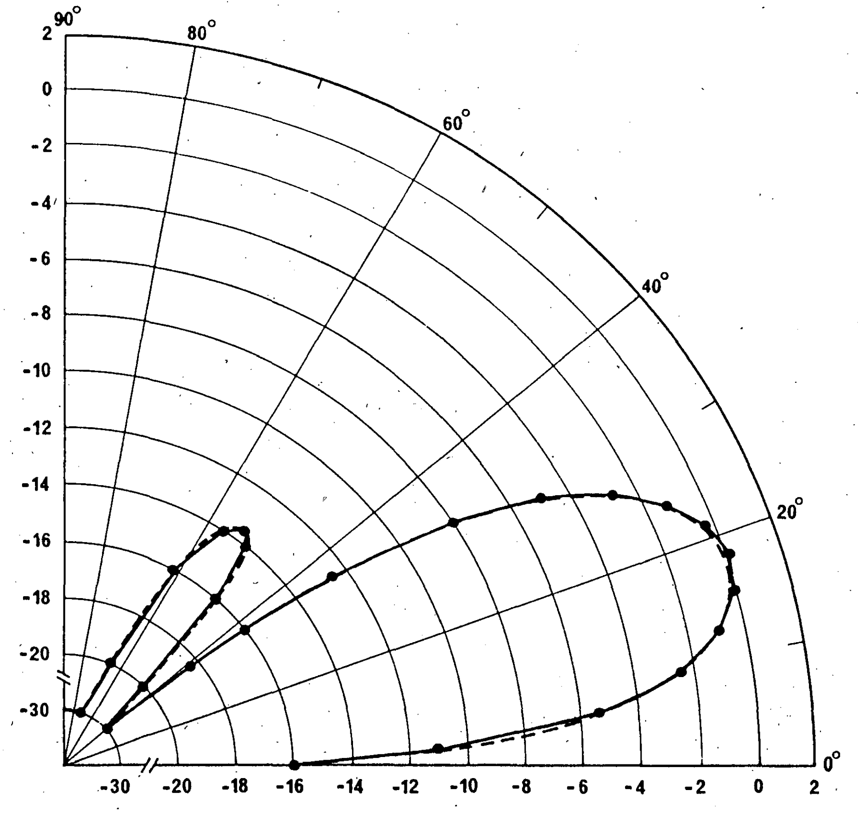
a) Azimuthal pattern HR 2/4/0.5, maximum gain 19 dBi



b) Azimuthal pattern HR 4/4/1, maximum gain 22 dBi

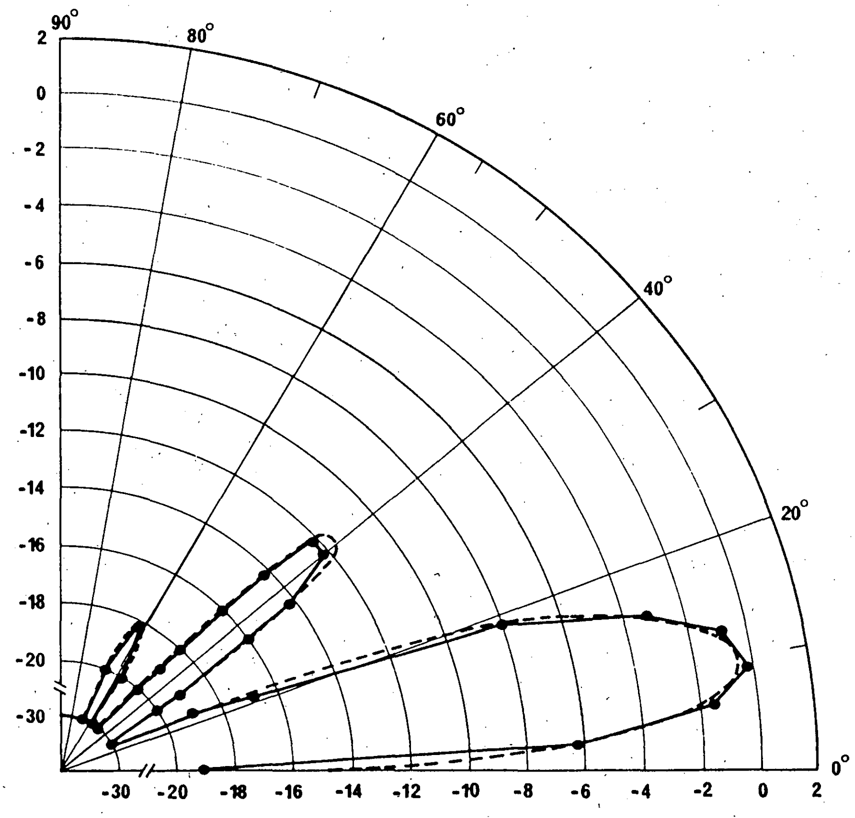
FIGURE 2 – *Azimuthal patterns*

Representative data
CCIR data
Recommendation 80



dB relative to maximum

a) Vertical pattern HR *m*/2/0.5



dB relative to maximum

b) Vertical pattern HR *m*/4/0.5

FIGURE 3 – *Vertical patterns*

Representative data

TABLE II – *Vertical characteristics of antenna types HR(S) 4/4/0.5 and HR(S) 2/4/0.5*

Frequency ratio		0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
G_i max (dB)	$m = 4$	17.8	18.9	19.9	20.7	21.5	22.2	22.8	23.3	23.5
	$m = 2$	16.1	16.9	17.5	18.2	18.8	19.4	20.0	20.4	20.7
Elevation angle of maximum (degrees)		15	13	11	10	9	8	8	7	7
Elevation angle (degrees)		Vertical attenuation (dB)								
0		30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
3		9.9	8.7	7.7	6.8	6.0	5.3	4.7	4.1	3.6
6		4.4	3.4	2.5	1.9	1.3	0.8	0.5	0.3	0.1
8		2.4	1.6	0.9	0.5	0.2	0.0	0.0	0.1	0.3
9		1.7	1.0	0.4	0.1	0.0	0.0	0.2	0.6	1.1
12		0.4	0.1	0.0	0.3	0.8	1.6	2.7	4.2	6.1
15		0.0	0.2	0.8	1.9	3.5	5.6	8.6	12.7	19.0
18		0.3	1.2	2.8	5.2	8.6	13.6	22.4	30.0	23.9
21		1.3	3.2	6.2	10.8	18.4	30.0	24.2	25.3	30.0
24		2.9	6.2	11.4	21.3	28.7	23.8	30.0	23.5	15.2
27		5.2	10.5	20.5	28.0	24.3	30.0	19.6	13.5	11.2
30		8.3	17.0	30.0	24.3	30.0	18.8	13.1	11.5	12.7
33		12.5	28.9	24.4	30.0	20.2	13.5	11.9	13.8	21.5
36		18.4	27.4	27.2	24.6	14.8	12.3	14.1	22.6	20.3
39		27.8	24.8	30.0	17.4	13.0	13.7	21.0	21.6	15.7
42		30.0	27.5	23.4	14.5	13.3	18.2	25.3	16.6	18.0
45		26.2	30.0	18.3	13.7	15.7	27.5	18.4	17.4	30.0
48		25.9	29.5	15.9	14.3	20.4	22.9	17.3	23.7	22.1
51		28.4	22.8	15.1	16.2	28.3	19.0	19.5	30.0	18.1
54		30.0	19.8	15.3	19.5	25.5	18.5	26.3	21.8	19.6
57		30.0	18.3	16.2	24.5	21.6	20.2	30.0	19.7	25.0
60		30.0	17.7	17.9	30.0	20.4	24.0	25.4	21.0	20.4
63		27.8	17.9	20.2	28.9	20.8	30.0	22.5	25.1	15.6
66		25.7	18.5	23.1	26.0	22.3	30.0	22.4	27.1	13.6
69		24.8	19.6	26.7	24.9	24.7	30.0	23.9	23.1	13.1
72		24.7	21.0	30.0	25.0	28.0	28.6	26.7	20.6	13.7
75		25.3	22.8	30.0	25.9	30.0	28.1	30.0	19.8	15.2
78		26.5	25.1	30.0	27.5	30.0	29.0	30.0	20.2	17.3
81		28.6	27.9	30.0	29.9	30.0	30.0	30.0	21.7	20.2
84		30.0	30.0	30.0	30.0	30.0	30.0	30.0	24.7	24.1
87		30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
90		30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

TABLE IIIa – *Azimuthal attenuation of unslewed antenna type HR(S) 4/4/0,5*

Frequency ratio	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
Azimuthal angle	Azimuthal attenuation (dB)								
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8
10	0.8	1.0	1.2	1.5	1.8	2.2	2.6	3.0	3.5
15	1.8	2.3	2.9	3.5	4.3	5.3	6.3	7.6	9.1
20	3.2	4.1	5.3	6.6	8.3	10.5	13.3	17.6	25.3
25	5.1	6.6	8.7	11.3	15.2	21.8	30.0	21.5	16.4
30	7.5	9.9	13.5	19.4	30.0	22.6	16.9	14.1	12.7
35	10.4	14.4	21.6	30.0	20.4	16.0	14.1	13.4	13.7
40	14.0	20.7	30.0	21.3	16.8	15.0	14.8	15.8	18.6
45	18.5	30.0	24.4	18.6	16.5	16.3	17.7	21.7	30.0
50	24.5	30.0	21.6	18.5	17.9	19.2	23.3	30.0	25.1
55	30.0	27.5	21.4	19.8	20.5	24.0	30.0	28.3	20.9
60	30.0	26.5	22.7	22.2	24.4	30.0	30.0	24.7	20.9
65	30.0	27.5	25.0	25.6	29.4	30.0	30.0	25.0	22.9
70	30.0	29.8	28.3	29.8	30.0	30.0	30.0	27.4	26.6
75	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
80	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
85	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
90	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
95	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
100	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
105	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
110	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
115	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
120	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
125	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
130	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
135	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
140	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
145	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
150	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	29.4
155	28.3	29.4	30.0	30.0	30.0	30.0	30.0	30.0	30.0
160	26.7	27.1	27.7	28.4	29.3	30.0	30.0	30.0	30.0
165	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.5	25.7
170	24.6	24.2	23.9	23.4	22.9	22.3	21.6	20.8	19.9
175	24.0	23.5	22.9	22.3	21.5	20.6	19.6	18.4	17.1
180	23.9	23.3	22.7	21.9	21.0	20.1	19.0	17.7	16.2

TABLE IIIb – *Azimuthal attenuation of unslewed antenna type HR(S) 2/4/0,5*

Frequency ratio	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
Azimuthal angle	Azimuthal attenuation (dB)								
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
10	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7
15	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.7
20	1.4	1.6	1.7	1.9	2.1	2.3	2.6	2.8	3.1
25	2.2	2.4	2.7	3.0	3.3	3.7	4.1	4.6	5.1
30	3.2	3.5	3.9	4.4	4.9	5.5	6.1	6.9	7.9
35	4.4	4.9	5.4	6.0	6.8	7.7	8.8	10.1	11.8
40	5.8	6.4	7.1	8.0	9.1	10.4	12.1	14.5	18.1
45	7.5	8.2	9.2	10.3	11.8	13.8	16.5	21.3	30.0
50	9.4	10.3	11.5	13.0	15.0	18.0	22.9	30.0	24.9
55	11.6	12.7	14.2	16.1	18.9	23.5	30.0	28.2	20.1
60	14.1	15.5	17.3	19.7	23.4	30.0	30.0	24.1	19.0
65	17.1	18.7	20.8	23.8	28.9	30.0	30.0	23.7	19.7
70	20.5	22.5	25.0	28.6	30.0	30.0	30.0	25.3	21.8
75	24.8	27.0	29.9	30.0	30.0	30.0	30.0	28.6	25.5
80	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
85	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
90	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
95	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
100	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
105	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
110	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
115	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
120	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
125	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
130	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
135	29.0	29.4	30.0	30.0	30.0	30.0	30.0	30.0	30.0
140	27.9	28.1	28.5	28.9	29.5	30.0	30.0	30.0	30.0
145	27.0	27.0	27.1	27.3	27.4	27.7	28.1	28.7	29.5
150	26.2	26.1	25.9	25.8	25.7	25.6	25.5	25.4	25.3
155	25.5	25.2	24.9	24.6	24.3	23.9	23.4	22.9	22.2
160	24.9	24.5	24.1	23.7	23.1	22.5	21.8	20.9	19.9
165	24.4	24.0	23.5	22.9	22.2	21.4	20.5	19.5	18.3
170	24.1	23.6	23.0	22.3	21.6	20.7	19.7	18.5	17.1
175	23.9	23.4	22.7	22.0	21.2	20.2	19.1	17.9	16.4
180	23.9	23.3	22.7	21.9	21.0	20.1	19.0	17.7	16.2

TABLE IV – *Azimuthal attenuation of slewed antenna type HR(S) 4/4/0,5*

Frequency ratio: 1.0							
Slew =	0	5	10	15	20	25	30
Az max =	0	4	9	13	17	22	26
−6 dB =	18	23	27	32	37	42	46
−6 dB =	−18	−13	−9	−4	0	5	9
Width =	36	36	36	36	37	37	37
s_{eff} =	0	5	9	14	18	23	27
Angle	Azimuthal attenuation (dB)						
0	0.0	0.4	1.5	3.5	6.8	12.7	30.0
5	0.5	0.0	0.3	1.3	3.1	6.1	11.2
10	1.8	0.5	0.0	0.2	1.0	2.6	5.3
15	4.3	2.0	0.7	0.1	0.1	0.8	2.1
20	8.3	4.5	2.2	0.8	0.1	0.0	0.5
25	15.2	8.4	4.7	2.4	0.9	0.2	0.0
30	30.0	14.7	8.5	4.9	2.6	1.1	0.3
35	20.4	29.7	14.2	8.5	5.1	2.9	1.4
40	16.8	23.8	24.9	13.6	8.5	5.4	3.2
45	16.5	19.0	29.7	21.8	13.2	8.7	5.7
50	17.9	18.4	22.2	30.0	19.7	12.9	9.0
55	20.5	19.5	21.0	27.2	30.0	18.4	13.0
60	24.4	22.0	22.0	24.9	30.0	25.9	17.8
65	29.4	25.4	24.3	25.7	30.0	30.0	23.7
70	30.0	29.9	27.9	28.2	30.0	30.0	30.0
75	30.0	30.0	30.0	30.0	30.0	30.0	30.0
80	30.0	30.0	30.0	30.0	30.0	30.0	30.0
85	30.0	30.0	30.0	30.0	30.0	30.0	30.0
90	30.0	30.0	30.0	30.0	30.0	30.0	30.0
95	30.0	30.0	30.0	30.0	30.0	30.0	30.0
100	30.0	30.0	30.0	30.0	30.0	30.0	30.0
105	30.0	30.0	30.0	30.0	30.0	30.0	30.0
110	30.0	30.0	30.0	30.0	30.0	30.0	30.0
115	30.0	30.0	30.0	30.0	30.0	30.0	30.0
120	30.0	30.0	30.0	30.0	30.0	30.0	30.0
125	30.0	30.0	30.0	30.0	30.0	30.0	30.0
130	30.0	30.0	30.0	30.0	30.0	30.0	28.5
135	30.0	30.0	30.0	30.0	30.0	28.7	25.8
140	30.0	30.0	30.0	30.0	28.9	25.8	23.7
145	30.0	30.0	30.0	29.1	25.7	23.5	22.1
150	30.0	30.0	29.3	25.7	23.4	22.0	21.2
155	30.0	29.4	25.6	23.3	21.9	21.1	20.9
160	29.3	25.5	23.2	21.8	21.1	21.0	21.5
165	25.4	23.0	21.7	21.1	21.1	21.9	23.2
170	22.9	21.6	21.1	21.2	22.1	23.7	26.3
175	21.5	21.1	21.3	22.3	24.1	27.1	30.0
180	21.0	21.4	22.5	24.5	27.9	30.0	30.0
185	21.5	22.7	24.9	28.4	30.0	30.0	30.0
190	22.9	25.1	28.9	30.0	30.0	30.0	30.0
195	25.4	29.1	30.0	30.0	30.0	30.0	30.0
200	29.3	30.0	30.0	30.0	30.0	30.0	30.0
205	30.0	30.0	30.0	30.0	30.0	30.0	30.0
210	30.0	30.0	30.0	30.0	30.0	30.0	30.0
215	30.0	30.0	30.0	30.0	30.0	30.0	30.0
220	30.0	30.0	30.0	30.0	30.0	30.0	30.0
225	30.0	30.0	30.0	30.0	30.0	30.0	30.0
230	30.0	30.0	30.0	30.0	30.0	30.0	30.0
235	30.0	30.0	30.0	30.0	30.0	30.0	30.0
240	30.0	30.0	30.0	30.0	30.0	30.0	30.0
245	30.0	30.0	30.0	30.0	30.0	30.0	30.0
250	30.0	30.0	30.0	30.0	30.0	30.0	30.0
255	30.0	30.0	30.0	30.0	30.0	30.0	30.0
260	30.0	30.0	30.0	30.0	30.0	30.0	30.0
265	30.0	30.0	30.0	30.0	30.0	30.0	30.0
270	30.0	30.0	30.0	30.0	30.0	30.0	30.0
275	30.0	30.0	30.0	30.0	30.0	30.0	30.0
280	30.0	30.0	30.0	30.0	30.0	30.0	30.0
285	30.0	30.0	30.0	30.0	30.0	30.0	30.0
290	30.0	30.0	30.0	28.7	27.2	27.9	30.0
295	29.4	30.0	30.0	26.4	24.0	23.7	25.7
300	24.4	30.0	30.0	25.8	22.0	20.7	21.3
305	20.5	24.4	30.0	27.9	21.3	18.7	18.1
310	17.9	19.8	25.5	30.0	22.7	18.1	16.2
315	16.5	16.7	19.4	27.5	29.2	19.3	15.6
320	16.8	15.0	15.8	19.2	30.0	24.5	16.8
325	20.4	15.1	13.9	15.0	18.9	30.0	21.8
330	30.0	18.3	13.9	12.9	14.2	18.3	30.0
335	15.2	30.0	16.7	12.8	12.0	13.2	17.2
340	8.3	15.4	30.0	15.7	12.0	11.1	12.1
345	4.3	8.2	15.3	30.0	15.0	11.2	10.2
350	1.8	4.1	7.8	14.8	30.0	14.7	10.6
355	0.5	1.7	3.8	7.4	13.9	30.0	14.8

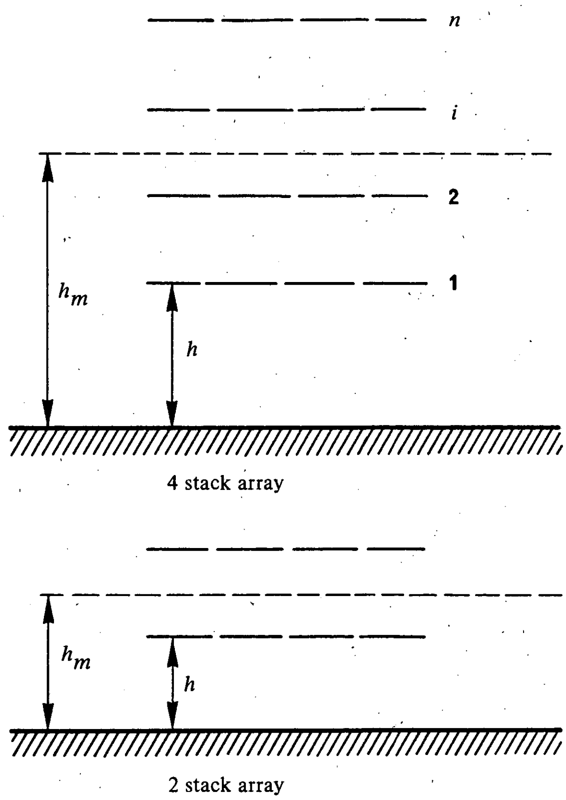


FIGURE 4a

Fig. 4b shows elevation angles of maximum radiation obtained from the CCIR antenna calculations plotted against mean height, h_m, and the curve obtained from the formula above. Figure 4c illustrates h_m at the design frequency and the variation in the value of h_m for the multiband antennas listed in Table I.

An HR 4/6/0.5 antenna has a mean height of 1.75 wavelengths at the design frequency, and will, as can be seen from Fig. 4c, have the same mean height and therefore a similar elevation angle of maximum radiation to that of an HR 4/4/1.0 antenna.

5. Horizontally slewed antennas

The angle of slew is the difference between the azimuth of the normal to the dipoles, i.e., the direction of the maximum of the unslewed beam, and the azimuth of the slewed radiation. The actual angle of slew of the maximum of the slewed beam may vary with operating frequency.

Slewing is usually effected by phase-shifting the feeds of the horizontally displaced radiating elements. As a result, if the slew is such that the azimuth of the main beam is increased, then the azimuths of the rearward directed side-lobes will decrease.

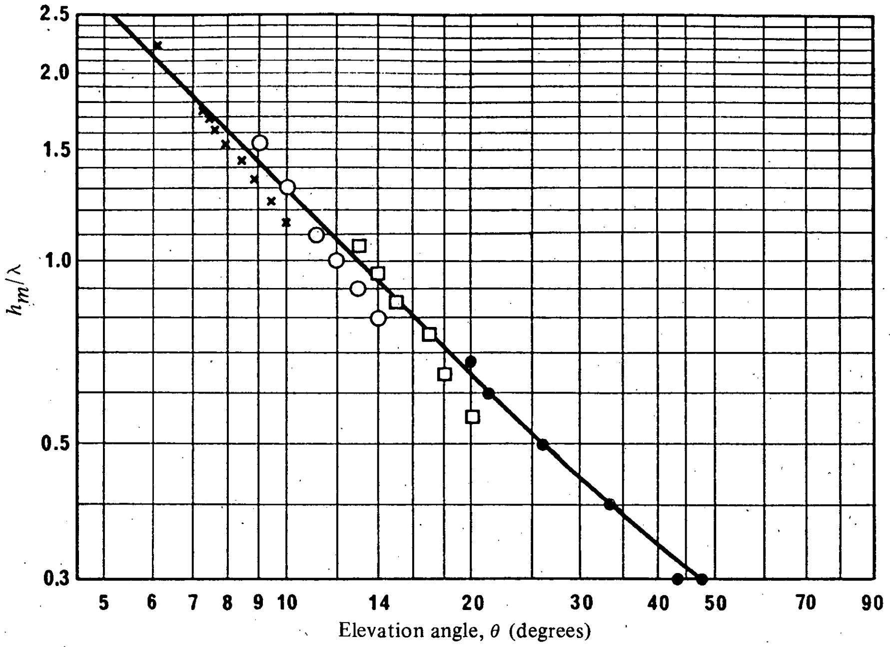


FIGURE 4b – *Angle of maximum radiation v. mean height (h_m)*

× Elements per stack 4
○ Elements per stack 3
□ Elements per stack 2
● Elements per stack 1

For example, if the maximum of the unslewed beam was 90° E of N and the beam was slewed to 110° E of N, the corresponding azimuths of a single lobe of rearward radiation would be 270° and 250° E of N respectively. This is illustrated in Fig. 5.

When an antenna is slewed horizontally, the horizontal radiation pattern is not symmetrical with respect to the azimuth of maximum radiation. The degree of the asymmetry increases as the magnitude of the slew increases.

It should also be noted that the slew angle, s, does not always precisely define the centre of the horizontal pattern given by the mean of the angles at which the maximum gain in the forward radiation pattern is reduced by 6 dB. The mean value is called the "effective slew", s_{eff}. This parameter more accurately reflects the reality of the performance of the slewed antennas, particularly multi-band antennas. The adoption of the term "effective slew", as defined above would help to reduce the ambiguities often found in descriptions of slewed antenna radiation patterns.

Because there is a strong possibility of confusion when dealing with slewed antennas, particularly when reference is made to a slew angle, it is recommended that the azimuths of maximum radiation for the unslewed and slewed antenna should be quoted in all documentation.

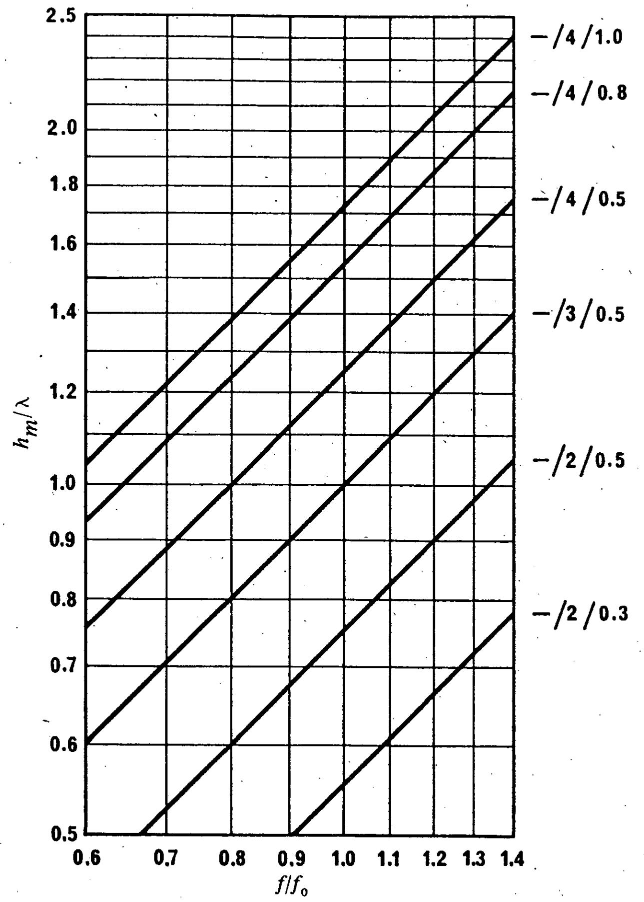


FIGURE 4c – *Variation in mean height* (h_m) *for typical multiband antennas*

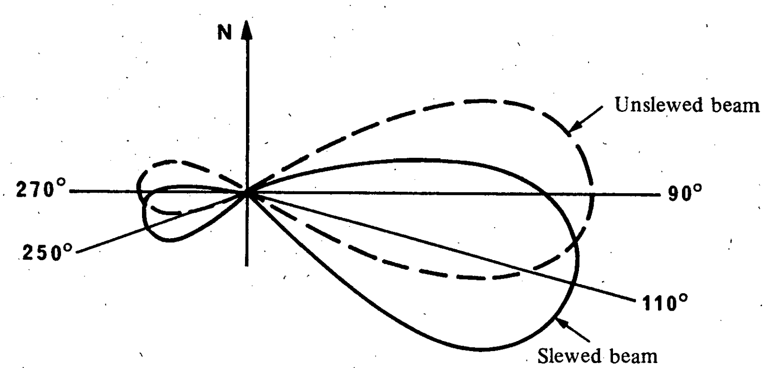


FIGURE 5 – *Pattern for slewed and unslewed antenna*

RECOMMENDATION 705

HF TRANSMITTING ANTENNAS CHARACTERISTICS AND DIAGRAMS

(Question 44/10, Study Programme 44G/10 and 44H/10)

(1990)

This Recommendation is published separately.

RECOMMENDATION 703*

CHARACTERISTICS OF AM SOUND BROADCASTING REFERENCE RECEIVERS FOR PLANNING PURPOSES

(1990)

The CCIR,

CONSIDERING

(a) that frequency assignment plans must of necessity take into account the characteristics of receivers;

(b) that the range of performance of receivers used by the public is very large;

(c) that a reference receiver with characteristics based on currently available receivers may be useful in a planning context;

(d) that standards for reference receivers should therefore be defined, which can be taken as a basis for frequency planning purposes;

(e) that these standards need to be taken into account by receiver manufacturers,

UNANIMOUSLY RECOMMENDS

that the receiver characteristics contained in Annex I should be used for AM sound broadcasting planning purposes.

ANNEX I

In deriving the recommended characteristics, the parameters contained in Annex II were also considered.

1. Sensitivity

For planning purposes, "sensitivity" is understood to mean "noise-limited sensitivity", given in terms of field strength, required to achieve a specified signal-to-noise ratio at the audio output.

Most commonly available AM receivers are now provided with built-in antennas. In the LF and MF bands, these are usually ferrite antennas (see Note 1). For the HF bands, when included, telescopic rod antennas are frequently used. Therefore, receivers using these types of antennas should be used as a reference, even though a variety of external antennas may occasionally be used to improve reception.

For those Administrations that employ wide-band systems (see Note 2) in the MF band, the use of monopole antennas is preferred as a reference.

Sensitivity should be presented as a single mean figure for each broadcasting band, from which the minimum usable field strength may be calculated taking into account other influences (e.g. man-made noise). The following values are suggested for the minimum sensitivity of an average receiver:

Band 5 (LF):	66 dB(μV/m)
Band 6 (MF):	60 dB(μV/m) (see Note 3)
Band 7 (HF):	40 dB(μV/m) (see Note 4)

These values are based upon an AF signal-to-unweighted noise (r.m.s.) ratio of 26 dB and are related to a modulation of 30%. For other AF signal-to-noise ratios the corresponding minimum sensitivity can be easily calculated (see Annex II, § 6). The AF signal-to-noise measurement is made according to IEC Publication 315-3; the field-strength values for the LF and MF band are measured according to IEC Publication 315-1.

* The Director of the CCIR is requested to bring this Recommendation to the attention of the IEC. This Recommendation supersedes Report 617-2 (Dubrovnik, 1986) which is hereby deleted.

Note 1 – A special arrangement of two ferrite rod antennas with their outputs separately received and processed up to the stage of detection has been reported to substantially reduce the effects of fading in the night-time interference zone in band 6 (MF) and 7 (HF) [CCIR, 1970-74].

Note 2 – According to present day planning arrangements in the various ITU Regions, in general a "narrow-band system" refers to one in which the system bandwidth is less than 5 kHz. A "wide-band system" refers to one with a system bandwidth greater than 5 kHz.

Note 3 – Values of 54 dB(μV/m) and 40 dB(μV/m) were also supported respectively by [CCIR, 1982-86a and b] and [CCIR, 1986-90a].

Note 4 – The WARC HFBC(2), Geneva 1987, adopted this value for DSB and SSB reception.

2. Selectivity

Selectivity of a receiver is a measure of its ability to discriminate between a wanted signal to which the receiver is tuned and unwanted signals entering through the antenna circuit.

The selectivity is understood as an effective selectivity comprising RF selectivity, IF selectivity, demodulator and AF frequency response.

The selectivity shall be sufficient, so that the relative RF protection ratios given in § 2.1, 2.2 and 2.3 are met. Relative RF protection ratios are defined in Recommendation 560 and should be measured according to Recommendation 559.

2.1 For LF, MF, HF bands in case of DSB reception in a narrow band system (see Note 2 of § 1), the relative RF protection ratios of Recommendation 560, curve D, should be met for a carrier frequency separation $\leqslant$ 20 kHz. For a carrier frequency separation $>$ 20 kHz a constant value of -55 dB should be met.

The use of curve D is suitable for a situation where a maximum number of channels is to be planned in a given area and where quality criteria are not considered as a priority factor.

The protection ratio curves of Recommendation 560 are based on a single receiver selectivity curve. It should, however, be noted that other combinations of 3 dB bandwidth and selectivity roll-off can also meet the relative protection ratio curves shown in Recommendation 560. (Examples see Annex II, § 2.)

2.2 For wide-band systems, in the MF band, where a wider bandwidth of the audio-frequency modulating signal is employed, the use of the relative protection ratios of Recommendation 560, curve A or B, may be more appropriate. However, these curves were based upon the EBU MBF reference receiver.

2.3 For HF bands, in the case of SSB reception (after the transition period) see Report 1059. The relative protection ratios of Fig. 1 should be met for a carrier frequency separation $\leqslant$ 10 kHz. For a carrier frequency separation $>$ 10 kHz a constant value of -57 dB should be met (see also Recommendation 640).

Relative RF-protection ratios A_{rel} for SSB are given with respect to the frequency difference Δf between the wanted carrier f_w and the interfering carrier f_i: $\Delta f = f_w - f_i$, thus, negative Δf describes interference from the upper adjacent channel.

3. Performance in the presence of strong signals

AM broadcasting receivers overloading by strong input signals may result in:

- desensitization;
- cross-modulation and intermodulation;
- AF signal distortion in the amplifier stages and/or in the demodulator.

Limiting values of maximum input voltage to the receiver to be taken into account in planning, cannot be recommended due to the unavoidable occurrence of the phenomenon in close proximity of AM transmitters.

These difficulties may be alleviated by a careful choice of the transmitter site at the planning stage and/or by implementing case by case solutions (ruggedized receivers) when receiving locations near the transmitting station cannot be avoided.

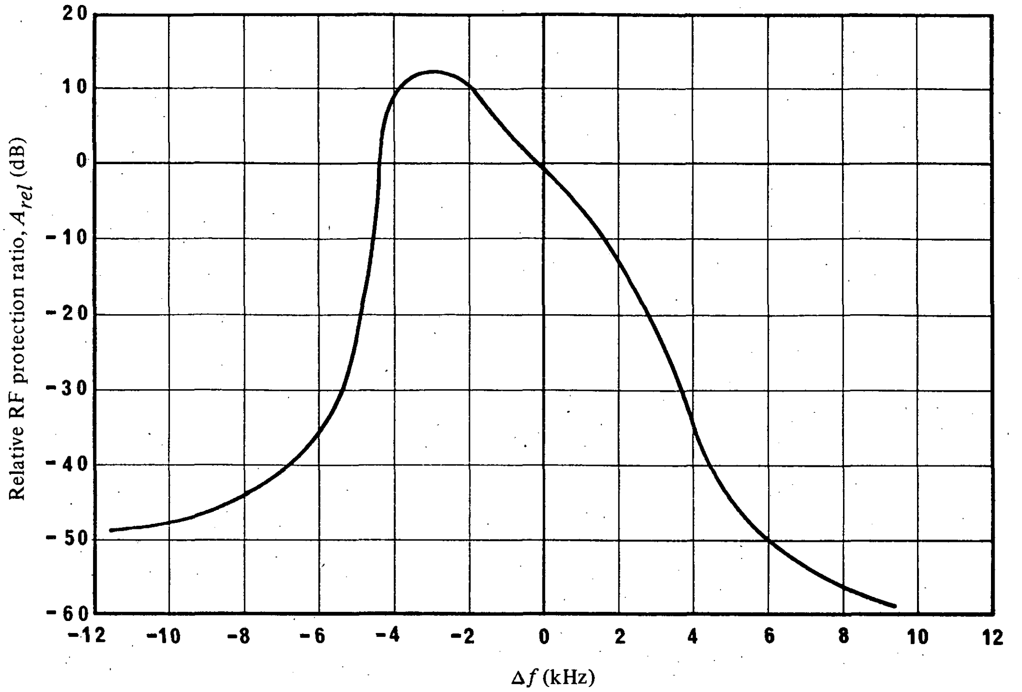


FIGURE 1* – *Relative RF-protection ratios A_{rel} for SSB*

* The WARC HFBC(1), Geneva, 1984, adopted this curve.

4. Intermediate frequency

The value of image and intermediate frequency rejection ratio and the production of harmonics of the intermediate frequency and/or of the oscillator frequency are factors influencing the choice of intermediate frequency.

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.

No specific intermediate frequency can be recommended, but the use of frequencies in the range 450-470 kHz is common. However, it should be noted that when such frequencies are used it is then not possible to achieve a sufficient image rejection ratio in the HF bands. For this case the use of much higher intermediate frequency in conjunction with double-conversion should be considered for HF.

4.1 *Image rejection ratio*

It is assumed that an image rejection ratio of 30 dB can be obtained when measured according to IEC Publication 315-3.

REFERENCES

CCIR Documents

[1970-74]: **a.** 10/119 (Australia).

[1982-86]: **a.** 10/8 + Add.1 (Japan); **b.** 10/334 (Working Group 10A).

[1986-90]: **a.** IWP 10/7-38 (United States of America).

ANNEX II

In defining the recommended characteristics given in Annex I the possible influence of the following receiver parameters was taken into account.

1. Overall audio-frequency response and system considerations

The overall audio-frequency response has a strong influence on the radio-frequency protection ratio curves.

1.1 *Narrow-band systems*

The curves defined in Recommendation 560 are based on the values shown in Table I.

TABLE I

Frequency (kHz)	Overall frequency response (dB)
2	−3
5	−24
10	−59

1.2 *Wide-band system*

In MF broadcasting, using 10 kHz channel spacing a standard preemphasis/deemphasis and 10 kHz bandwidth limitation has been implemented. This produces an emission/reception system with an overall audio frequency response that is essentially flat from 50 Hz to nearly 10 kHz, limited only by the receivers choice of bandwidth. The system reduces interference caused to stations operating ± 20 kHz removed in frequency and entirely eliminated undesired high-order dynamic intermodulation products that contribute to noise and interference on the MF band. This system is described in [CCIR, 1986-90a] and in Report 458. Its impact on relative RF protection ratios and, thus, selectivity of receivers is under study.

2. Relative RF protection ratios versus bandwidth and selectivity

The protection ratio curves shown in Recommendation 560 for DSB systems can be met with different combinations of bandwidth and roll-off of the selectivity curve of the receiver.

Some examples have been calculated using the numerical method as described in Recommendation 559 (§ 3).

In all cases the parameters of the transmitter for the narrow-band system corresponded to those of curve D of Recommendation 560. For the wide-band system a transmitter bandwidth of 10 kHz was assumed.

Five different combinations of receiver bandwidth $B_n(-3$ dB) and roll-off of the selectivity curve (in dB/kHz at the steepest slope of the overall selectivity curve) have been chosen such that at 9 kHz carrier difference for the narrow-band system, and at 20 kHz carrier difference respectively for the wide-band system a value of $A_{rel} = -29.5$ dB was reached in all cases. The value of −29.5 dB follows from curve D in Fig. 1 of Recommendation 560 and from the Rio Agreement, 1981.

The results for a narrow-band system with 9 kHz channel spacing are shown in Fig. 2.

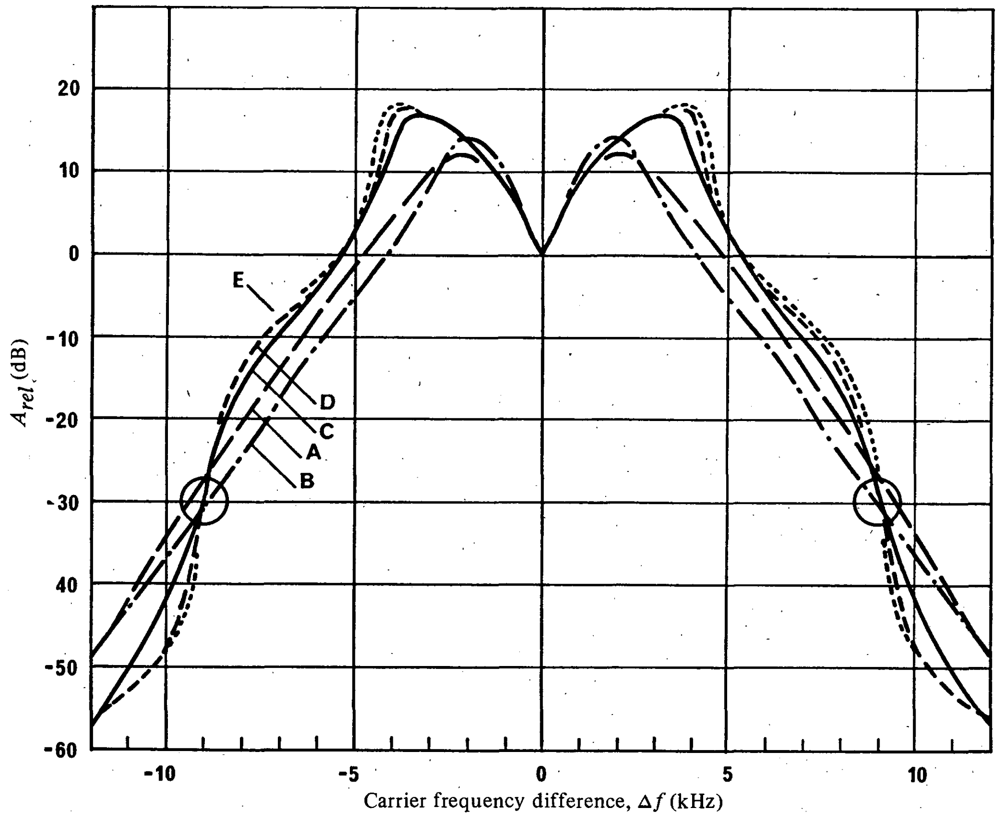


FIGURE 2 – *Relative RF protection ratios A_{rel} (dB) for a narrow-band system*

Combination	B_n (kHz)	Roll-off (dB/kHz)
A	2.0	8
B	2.2	12
C	3.7	16
D	4.0	25
E	4.2	40

B_n: overall bandwidth (−3 dB) of the receiver (kHz)

Roll-off: slope of attenuation of the overall selectivity characteristic of the receiver (dB/kHz at the steepest point of the slope)

3. Automatic gain control (AGC) performance

Using the sensitivity values given in Annex I, as a reference, it is assumed that the output level will not change by more than 6 dB for a reduction in signal level of 10 dB. Similarly, the output level will not change by more than 3 dB for an increase in signal level of 20 dB.

It is assumed that the output level of an SSB receiver will not change by more than 3 dB when changing from reception of DSB emissions to SSB emissions with 6 or 12 dB carrier reduction and appropriate "equivalent sideband power" (see Report 1059).

4. Automatic frequency control of SSB receivers

It is assumed that the SSB receiver is equipped with a synchronous demodulator, using for the carrier acquisition a device which generates a carrier by means of a suitable control loop which phase locks the receiver to the incoming carrier of the SSB emission of which the carrier can be reduced by up to 12 dB (see Report 1059).

5. Overall total harmonic distortion

It is assumed that the overall total harmonic distortion does not exceed 3% at 80% modulation depth, measured according to IEC Publication 315-3.

6. AF signal-to-noise ratio at higher input signal levels

It can be assumed that the AF signal-to-noise ratio will improve linearly to at least 40 dB, with increasing input signal level.

7. System effects on stereophonic AM broadcasting

(Under consideration.)

8. Compatibility between the main programme and additional information signals

When additional signals are added, account must be taken of certain interference effects. Receiver designers should consider these in order to avoid interference to the main programme channel.

REFERENCES

CCIR Documents

[1986-90]: **a.** 10/103 (United States of America).

RECOMMENDATION 640-1

SINGLE SIDEBAND (SSB) SYSTEM FOR HF BROADCASTING*

(Study Programme 44K/10)

(1986-1990)

The CCIR,

CONSIDERING

(a) that the use of single sideband (SSB) instead of double sideband (DSB) modulation techniques would lead to improved spectrum utilization;

(b) that, additionally, improved reproduction quality could be provided by receivers equipped with synchronous demodulators for both DSB and SSB modulation;

(c) that the vast majority of existing receivers is equipped with envelope detectors;

(d) that, with envelope detectors, the reproduction quality of SSB emissions decreases with increasing reduction of the carrier power relative to peak-envelope power;

(e) that a sufficiently long transition period is needed within which DSB modulation can still exist and SSB modulation is progressively introduced;

(f) that, with envelope detectors, acceptable reception quality can only be achieved if the degree of carrier reduction relative to peak-envelope power is low,

UNANIMOUSLY RECOMMENDS

that the following SSB system specifications should be applied whenever SSB modulation techniques are used in HF broadcasting:

1. SSB emission specifications

1.1 *Audio-frequency bandwidth*

The upper limit of the audio-frequency bandwidth (−3 dB) of the transmitter shall not exceed 4.5 kHz with a further slope of attenuation of 35 dB/kHz and the lower limit shall be 150 Hz with lower frequencies attenuated at a slope of 6 dB per octave.

1.2 *Necessary bandwidth*

The necessary bandwidth shall not exceed 4.5 kHz.

1.3 *Characteristics of modulation processing*

The audio-frequency signal shall be processed so that the modulating signal retains a dynamic range of not less than 20 dB. Excessive amplitude compression, together with improper peak limitation, leads to excessive out-of-band radiation and thus to adjacent-channel interference, and is therefore to be avoided.

1.4 *Channel spacing*

The channel spacing and carrier-frequency separation shall be 5 kHz (10 kHz until the end of the transition period).

* For further information, see Report 1059.

1.5 *Nominal carrier frequencies*

The carrier frequencies for SSB shall be integral multiples of 5 kHz.

1.6 *Sideband to be emitted*

The upper sideband shall be used.

1.7 *Suppression of the unwanted sideband*

The degree of suppression of the unwanted (lower) sideband and of intermodulation products in that part of the transmitter spectrum shall be at least 35 dB, and, whenever possible, exceed 40 dB, relative to the wanted sideband signal level.

1.8 *Degree of carrier reduction*

The carrier reduction relative to peak-envelope power shall be 12 dB (6 dB until the end of the transition period).

1.9 *Frequency tolerance*

The frequency tolerance of the SSB carriers shall be ± 5 Hz. This tolerance presumes receiver characteristics as specified in § 2.2.

2. SSB reception specifications

2.1 *Overall selectivity of the receiver*

The reference receiver shall have an overall bandwidth (−3 dB) of 4 kHz, with a slope of attenuation of 35 dB/kHz. This results in a relative RF protection ratio of about −27 dB at 5 kHz carrier difference, a value suitable for planning.

Receivers using other combinations of bandwidth and slope of attenuation shall provide the same relative RF protection ratio of about −27 dB at 5 kHz carrier difference. Two examples of possible combinations of bandwidth and slope of attenuation are given below:

Slope of attenuation	*SSB receiver audio-frequency bandwidth*
25 dB/kHz	3300 Hz
15 dB/kHz	2700 Hz

2.2 *Detection system of SSB receivers*

SSB receivers shall be equipped with a synchronous demodulator, using for the carrier acquisition a method whereby a carrier is regenerated by means of a suitable control loop which phase locks the receiver to the incoming carrier. Such receivers must work equally well with conventional DSB transmissions and with SSB transmissions, regardless of whether the carrier reduction is 6 dB or 12 dB relative to peak-envelope power.

RECOMMENDATION 706

DATA SYSTEM IN MONOPHONIC AM SOUND BROADCASTING (AMDS)

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

(1990)

The CCIR,

CONSIDERING

(a) the growing interest for a data transmission system for AM broadcasting and its applications;

(b) that it is desirable to have one system applicable to all AM broadcasting bands and that the future introduction of SSB in HF and of synchronous detection should be taken into account;

(c) that existing systems cannot be implemented on single-sideband (SSB) transmission in band 7 (HF);

(d) that certain applications of an AM data transmission system could correspond to similar features in the FM radio data system (RDS), as defined in Recommendation 643, taking account of the lower bit rate available;

(e) that the design of such a system should take into account the mass production of receivers;

(f) that data signals can be added to existing AM broadcast transmissions in such a way that they are inaudible, thus achieving good compatibility with reception of the normal monophonic sound programme signals;

(g) that a number of systems for data transmission in AM broadcasting in band 5 (LF) and band 6 (MF) have been described (see Report 1061),

UNANIMOUSLY RECOMMENDS

1. that a system for data transmission in AM broadcasting (AMDS) should fulfil the requirements listed in Annex I;

2. that since a system fulfilling all the requirements listed in Annex I including SSB in band 7 (HF) is not available, a system for data transmission in AM broadcasting in bands 5 (LF) and 6 (MF) shall comply with the minimum specification listed in Annex II.

ANNEX I

REQUIREMENTS FOR AN AM RADIO-DATA TRANSMISSION SYSTEM

1. Compatibility aspects

1.1 *Compatibility with the main programme*

The supplementary data system must be compatible with the main audio programme under all operational conditions including:

- transmitters operated with energy-saving carrier-control techniques;
- synchronized networks of transmitters;
- SSB transmissions (if the introduction of an AM data system in HF broadcasting is feasible);
- transmitters which are used as a high stability frequency reference;
- mobile reception and, where necessary, reception with a stereophonic AM receiver in band 6 (MF).

1.2 *Compatibility with other programmes in co- or adjacent channels*

The protection ratios used in planning should not be affected, i.e. no additional interference should be caused to the audio programme signal by the data signals.

2. Reliability of data reception

The area in which the data signal can be reliably received, should be at least as large as that where the main programme service for ground- and sky-wave propagation conditions is provided.

3. Applications

Because of the low data-rate which is expected to be available in an AM radio-data system, it may not be feasible to support simultaneously more than a few of the applications listed below.

It is expected that a large part of the data-transmission capacity will usually be used for features related to automatic or assisted tuning functions. These features are therefore labelled "primary". Other applications are labelled "secondary" and may be introduced to meet the needs of individual broadcasters. Note that although similar terms are used, these features may not correspond exactly with those used in RDS (see Recommendation 643).

Primary

- Programme Identification (PI) code including:
  - unique country code for each ITU country;
  - unique language code.
- List of Alternative Frequencies (AFs) (the necessary number of alternative frequencies is still under consideration)
- Programme Service (PS) name: this comprises at least 4 alpha-numeric characters and is intended for display
- Traffic Programme (TP) identification and Traffic Announcement (TA) identification.

Secondary (examples)

- Clock-Time (CT) and date (UTC and MJD)
- Programme Item Number (PIN)
- Decoder Identification code (DI) (e.g. stereo)
- Programme Type code (PTY)
- Transparent Data Channel (TDC)
- In-House (IH) applications
- Traffic Message Channel (TMC)
- Radio Paging (RP)

ANNEX II

SPECIFICATION OF A DATA SYSTEM FOR USE IN MONOPHONIC AM SOUND-BROADCASTING

Frequency bands:	LF, MF
Method of modulation:	phase modulation of the main carrier
Maximum phase deviation:	depending on bit rate according to Fig. 1
Maximum bit rate:	200 bit/s
Data format:	depending on application

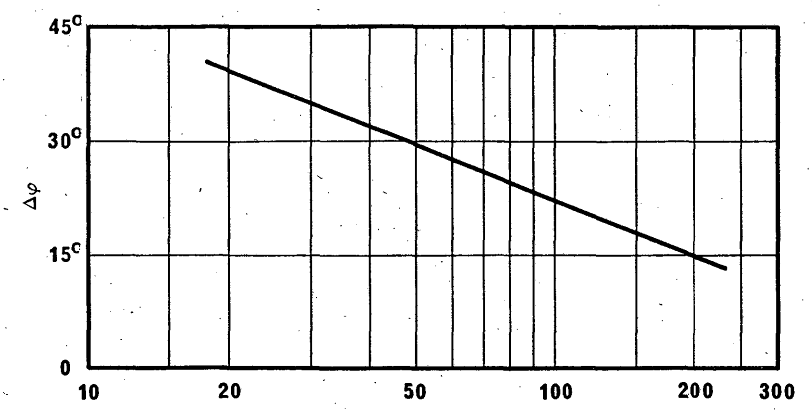


FIGURE 1 – *Dependence of the permitted phase deviation value Δφ on the transmission bit rate (B_r)*

Δφ: maximum peak phase deviation

$$\Delta\varphi^\circ = \frac{210}{\sqrt{B_r(\text{bit/s})}}$$

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SECTION 10A-2: SOUND BROADCASTING IN THE TROPICAL ZONE

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 μV/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.

RECOMMENDATION 48-2

CHOICE OF FREQUENCY FOR SOUND BROADCASTING IN THE TROPICAL ZONE

(Question 45/10, Study Programme 45E/10)

(1951-1978-1986)

The CCIR,

CONSIDERING

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

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 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;

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.

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* See Article 30 of the Radio Regulations.

RECOMMENDATION 139-3*

TRANSMITTING ANTENNAS FOR SOUND BROADCASTING IN THE TROPICAL ZONE

(Question 45/10, Study Programme 45F/10)

(1953-1978-1986-1990)

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 Annex I to this Recommendation gives the principles on which antennas for sound broadcasting in the Tropical Zone should be designed and constructed as well as a description of the antennas commonly used for sound broadcasting in the Tropical Zone,

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 is 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 provide to the CCIR practical operational data concerning these antennas.

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 the 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.

* This Recommendation incorporates in Annex I information contained in Report 301 which is hereby cancelled.

3. Antennas for vertical incidence

The arrays commonly used by different organizations for the purpose of sound broadcasting in the Tropical Zone include the Trinidad antenna, the Jamaica antenna, the 16-element array, and a high incidence array consisting of four full-wave dipoles arranged in the form of a square.

The schematic and the radiation pattern of the Trinidad antenna are described in Figs. 20 and 21 of the publication [CCIR, 1969].

The Jamaica antenna consists of four half-wave end-fed dipoles in the same horizontal plane. All the elements are 0.2 λ above ground. This parameter is not critical. The elements are fed with currents in the same phase and magnitude. The Jamaica antenna, sometimes also designated as type TRO/*n*/*h* antenna has an azimuthal radiation pattern which is approximately omnidirectional. The radiation pattern for the TRO/2/0.2 type is given in Fig. 16 of the publication [CCIR, 1969].

The schematic and the radiation pattern of the 16-element array are given in Fig. 17 of the publication [CCIR, 1969].

Some organizations use 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 0.15 λ but this does not seem to be critical. The radiating elements are built up of a four-wire cage, resulting in an impedance of 2200 Ω each, which, when paralleled at the centre, gives a good match to a 550 Ω 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 the publication [CCIR, 1969]. The gain of the array, relative to an isotropic radiator, is 8 dBi. At any angle of elevation below 30°, the radiation from the high incidence array is 16 dB below the maximum radiated by a dipole at that elevation. The high-angle radiation of the array is greater than that of a 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.

A simple two-tier dipole array, H 1/2, with a standard 0.5 λ spacing may also be used with a view to giving adequate coverage up to 800 km [CCIR, 1963-66]. An H 1/2/0.5 antenna fed out-of-phase, gives an angle of fire of 41°. Field trials on an antenna system H 1/2/0.4 fed out-of-phase have shown that at distances below 600 km the field strength laid down by the antenna is higher than that from a single dipole. At distances above 600 km, the field strength laid down by the antenna is low compared to the dipole [CCIR, 1963-66].

4. General consideration in design of antenna

While designing an 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 when designing such antenna systems (Fig. 1 of [CCIR, 1966-69]).

REFERENCES

CCIR [1969] Broadcasting in band 7 (HF) in the Tropical Zone.

CCIR Documents

[1963-66]: XII/4 (India).

[1966-69]: XII/6 (India).

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 0.2 λ above ground.

CCIR [1984] Atlas of antenna diagrams.

RECOMMENDATION 415-2*

MINIMUM PERFORMANCE SPECIFICATIONS FOR LOW-COST SOUND-BROADCASTING RECEIVERS

(1963–1982–1986)

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 solid state 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 difference.

1.6 In the case of community listening, higher output powers are necessary, whereas the other requirements remain unchanged.

* This Recommendation contains text from the former Recommendation 416 which is hereby cancelled.

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,	250-3150 Hz, within 18 dB limits
Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be	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 μV
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 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,	250-3150 Hz within 18 dB limits
Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be	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,	200-5000 Hz within 18 dB limits
Alternatively, it may be more convenient for some manufacturers to consider only the electrical characteristics which should be	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.

SECTION 10B: FREQUENCY-MODULATION SOUND BROADCASTING IN BANDS 8 (VHF) AND 9 (UHF)

RECOMMENDATION 642-1

LIMITERS FOR HIGH-QUALITY SOUND-PROGRAMME SIGNALS

(Questions 46/10, 19/CMTT and 20/CMTT, Study Programme 46B/10)

(1986–1990)

The CCIR,

CONSIDERING

(a) that over-modulation of FM transmitters can cause distorsion of the programme material and interference to other transmissions;

(b) that the level of some sound-signal components (most commonly those at the higher audio frequencies) may be raised by the application of pre-emphasis to the modulating signal;

(c) that techniques exist to design low-distortion limiters without overshoot (for example, by the use of delay lines);

(d) it is generally undesirable to subject sound signals to more than one limiting process,

UNANIMOUSLY RECOMMENDS

1. that low-distortion limiters should be employed to protect transmitters against over-modulation, and enable more efficient use to be made of the available dynamic range;

2. that if pre-emphasis is applied, the limiter should take account of this. An example of a limiter which does this is described in Annexes I and II.

3. that the limiter be situated at the interfaces between studios and sound-programme distribution circuits, so that each limiter may serve a relatively large number of transmitters and that in principle there may be no need to employ any subsequent limiting. Limiters so positioned may also provide a usefuld degree of protection against overload for the sound-programme circuits which follow.

ANNEX I

VARIABLE-EMPHASIS LIMITERS

Limiters are commonly employed at the programme inputs of frequency modulated sound-programme transmitters in order that the carrier deviation, and hence the signal-to-noise ratio at the receiver, may be kept as high as is practicable, whilst avoiding over-deviation and the consequent risk of audible distortion or of causing interference. Similarly, limiters may be used at the sending ends of point-to-point sound-programme transmission circuits, analogue or digital, so that the signal-to-noise ratios at the receiving ends are optimized, by permitting the signal levels on the circuits to be kept high without risk of distortion caused by over-loading.

In the above cases, the sound signals are commonly subjected to high-frequency pre-emphasis. However, programme levels are normally controlled using a meter (see Report 292) at a point in the circuit which is not subject to pre-emphasis. In consequence high-level, high-frequency, components are likely to cause overmodulation – even on properly controlled programmes – unless a limiter is employed to prevent this.

In a conventional limiter, gain variations affect all sound signals equally, and limiter action brought about by high-amplitude high-frequency components may cause obvious and objectionable level fluctuations of low- and medium-frequency components in the reproduced programme. This effect, commonly known as "gain ducking" or "limiter-cut-back", may be reduced by allowing a wide margin between the nominal maximum programme peaks and the limiting level. Such a practice is considered to be undesirable, as the listening signal-to-noise ratio would then be less than it otherwise could be. Tests have shown [Manson, 1973, 1975] that the need for this wide margin may be avoided by the employment of a frequency-selective form of limiter.

REFERENCES

MANSON, W. I. [1973] Frequency-dependent limiters for f.m. sound transmitters. BBC Research Department Report 1973/25.

MANSON, W. I. [1975] Frequency dependent limiters for f.m. sound broadcasting: optimisation of attack period and of delay-length in the variable de-emphasis stage. BBC Research Department Report 1975/22.

ANNEX II

DESCRIPTION OF A VARIABLE-EMPHASIS LIMITER FOR HIGH-QUALITY SOUND-PROGRAMME SIGNALS

A block diagram illustrating one form of a variable-emphasis limiter which has been found to be suitable for use on 50 μs pre-emphasized signals (a different value of pre-emphasis time constant may be used if appropriate) is shown in Fig. 1.

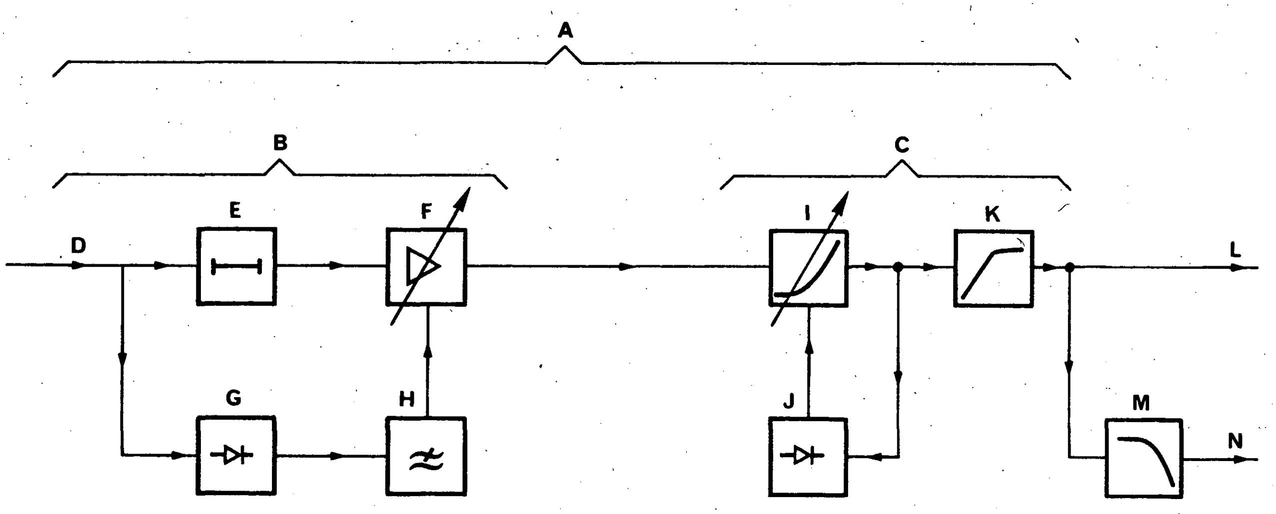

FIGURE 1 – *Block diagram illustrating one possible variable-emphasis limiter arrangement*

A: variable-emphasis limiter (complete)
B: 1st limiter stage (flat-spectrum, delay-line design)
C: 2nd limiter stage (variable-emphasis design)
D: audio input
E: delay line
F: variable-gain amplifier, with law appropriate for control provided by G
G: control signal rectifier, smoothing and time-constant circuits
H: shaping network (low-pass filter)
I: variable-pre-emphasis circuit, 50 μs quiescent
J: control-signal rectifier, smoothing and time constant circuits
K: peak clipper
L: audio output, 50 μs pre-emphasis protected
M: 50 μs de-emphasis network (optional)
N: audio output, 50 μs pre-emphasis protected signal with 50 μs de-emphasis applied, if required (i.e. for monitoring)

In the first stage, the incoming audio signal is limited by a "flat-spectrum" limiter using delay-line and gain change-rate control techniques [Shorter *et al.*, 1967] to prevent transient overshoot.

In the second stage it is limited by a variable pre-emphasis circuit. This imposes 50 μs pre-emphasis so long as the resulting output signal does not exceed the prescribed maximum value, but momentarily reduces the amount of pre-emphasis as necessary to ensure that the prescribed maximum output level is not exceeded when high-level high-frequency programme signal components are present.

Subjective tests [Manson, 1973] show a definite preference for a variable-emphasis limiter rather than a flat limiter. Further tests [Manson, 1975] have indicated that if a peak clipper, set about 0.75 dB above the limiting level, is employed at the output of the limiter as shown in Fig. 1, it is not necessary for the variable emphasis stage to include a delay line.

REFERENCES

MANSON, W. I. [1973] Frequency-dependent limiters for f.m. sound transmitters. BBC Research Department Report 1973/25.

MANSON, W. I. [1975] Frequency-dependent limiters for f.m. sound broadcasting; optimisation of attack period and of delay-length in the variable de-emphasis stage. BBC Research Department Report 1975/22.

SHORTER, D. E. L., MANSON, W. I. and STEBBINGS, D. W. [1967] The dynamic characteristics of limiters for sound-programme circuits. BBC Engineering Division Monograph No. 70.

RECOMMENDATION 641 *

DETERMINATION OF RADIO-FREQUENCY PROTECTION RATIOS FOR FREQUENCY-MODULATED SOUND BROADCASTING

(Question 46/10, Study Programme 46L/10)

(1986)

The CCIR,

CONSIDERING

(a) that the radio-frequency protection ratio is closely related to the audio-frequency protection ratio (see Recommendation 638);

(b) that this relationship depends on a number of technical parameters, including:

– the frequency separation between the wanted and unwanted carrier;
– the maximum peak deviation;
– the energy distribution both with spectrum and time of the modulation signal;
– the pre- and de-emphasis characteristics;
– the reception mode (monophonic or stereophonic);
– the audio characteristics of the human ear (appropriately taken account of by using the weighting network of Recommendation 468);
– the receiver input voltage;

(c) that the radio-frequency protection ratio further depends on the receiver characteristics, the most important of which are:

– the selectivity characteristics;
– the characteristics of the limiter and the stereo decoder;
– large signal performance and sensitivity;
– the audio-frequency response,

UNANIMOUSLY RECOMMENDS

1. that the objective two-signal method of measurement described in Annex I should be used for the determination of radio-frequency protection ratios in frequency-modulation sound broadcasting with transmission standards using a maximum frequency deviation of ± 75 kHz and a pre-emphasis of 50 μs;

2. that the results obtained by this method should be checked by subjective listening tests whenever possible.

ANNEX I

OBJECTIVE TWO-SIGNAL METHOD OF MEASUREMENT FOR TRANSMISSION STANDARDS USING A MAXIMUM FREQUENCY DEVIATION OF ± 75 kHz AND A PRE-EMPHASIS OF 50 μs

1. Measuring method

The objective method 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.

* This Recommendation replaces Report 796 which is hereby cancelled.

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.

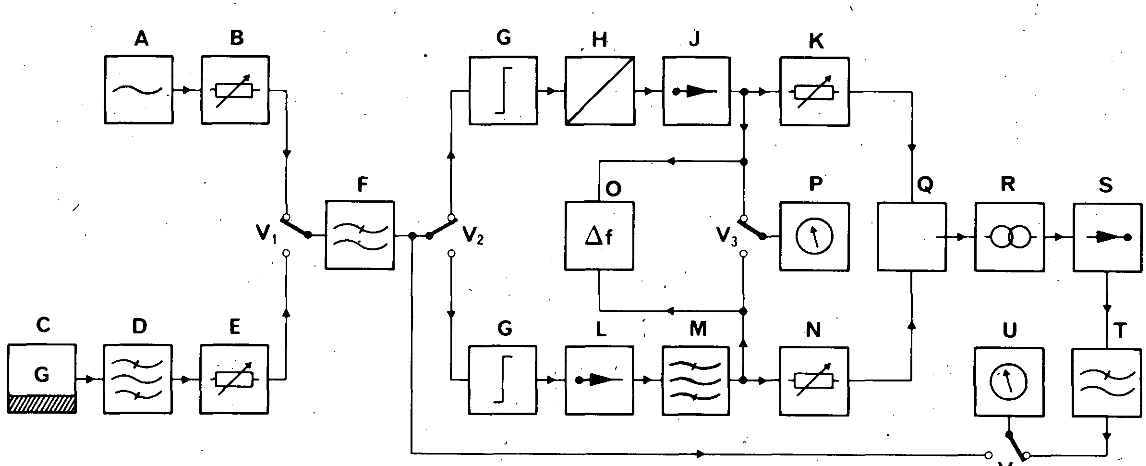

FIGURE 1 – *Diagram of the measuring apparatus*

- A: 500 Hz AF generator (for transmitter line-up procedure)
- B: calibrated AF attenuator
- C: noise generator
- D: noise shaping filter complying with Recommendation 559
- E: calibrated AF attenuator
- F: 15 kHz low-pass filter
- G: pre-emphasis network
- H: stereo coder
- J: signal generator (wanted signal)
- K: calibrated RF attenuator
- L: signal generator (unwanted signal)
- M: RF band-pass filter (tuneable)
- N: calibrated RF attenuator
- O: frequency-meter for measuring the frequency difference between signal generators J and L
- P: frequency-deviation meter
- Q: coupling device
- R: matching network
- S: receiver under test
- T: 15 kHz low-pass filter
- U: psophometer (switchable weighting network)
- V_1: selector switch for the modulation
- V_2: selector switch for modulating one or other of the signal generators
- V_3: selector switch for the frequency-deviation meter (J and L generators)
- V_4: selector switch for measuring the AF signal levels

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 (see Note).

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.

Note. – A normal sound-broadcasting programme without compression is simulated by modulating the unwanted transmitter with the standardized coloured noise signal using a frequency deviation of ± 32 kHz. Therefore, the results obtained with this method and this deviation are only valid for sound broadcasting programmes without compression.

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 betwen 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)).

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.

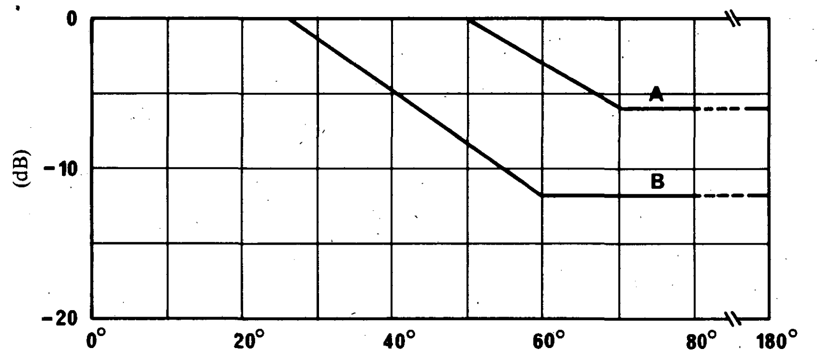

FIGURE 1 – *Discrimination obtained by the use of directional receiving antennas*

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.

RECOMMENDATION 704*

CHARACTERISTICS OF FM SOUND BROADCASTING REFERENCE RECEIVERS FOR PLANNING PURPOSES

(1990)

The CCIR,

CONSIDERING

a) that frequency assignment plans must of necessity take into account the characteristics of receivers;

b) that the range of performance of receivers used by the public is very large;

c) that a reference receiver with characteristics based on currently available receivers may be useful in a planning context;

d) that standards for reference receivers should therefore be defined, which can be taken as a basis for frequency planning purposes;

e) that these standards need to be taken into account by receiver manufacturers,

UNANIMOUSLY RECOMMENDS

that the receiver characteristics contained in Annex I should be used for FM sound broadcasting planning purposes.

ANNEX I

MONOPHONIC AND STEREOPHONIC RECEPTION USING THE PILOT-TONE SYSTEM (± 75 kHz FREQUENCY DEVIATION) OR THE POLAR-MODULATION SYSTEM (± 50 kHz FREQUENCY DEVIATION)

In deriving the recommended characteristics, the parameters contained in Annex II and Annex III were also considered.

1. Antenna

Recommendation 599 gives the directivity of an external antenna which is applicable for fixed installations only. Portable or car receivers normally have rod antennas; however, for portable or mobile reception of sound broadcasts, no directivity of the reception antenna should be applied in planning.

2. Sensitivity

For planning purposes, "sensitivity" is understood to mean "noise-limited sensitivity", given in terms of field strength or power level, required to achieve a specified signal-to-noise ratio at the audio output. Sensitivity should be presented as a single mean figure. The following values are suggested for the sensitivity of an average receiver:

- with an external antenna input (car receivers included):

  −5 dB(pW) for monophonic reception,

  15 dB(pW) for stereophonic reception;

- with a built-in antenna (oriented for optimum reception in the actual field in which the receiver is placed, for conditions of measurement see [CCIR, 1986-90a and b]:

  30 dB(μV/m) for monophonic reception,

  50 dB(μV/m) for stereophonic reception.

These values are based upon an AF signal-to-noise ratio of 40 dB. The AF signal-to-noise measurement is made according to IEC Publication 315-4 in conjunction with CCIR Recommendation 468; reference frequency deviation: ± 75 kHz for the pilot-tone system, and ± 50 kHz for the polar-modulation system. If higher AF signal-to-noise ratios are to be applied in a planning context, the corresponding sensitivity can be calculated by linear extrapolation up to at least 56 dB (see Annex II, § 5).

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

3. Selectivity

Selectivity of a receiver is a measure of its ability to discriminate between a wanted signal to which the receiver is tuned and unwanted signals entering through the antenna circuit.

The selectivity is understood as an effective selectivity comprising RF selectivity, IF selectivity, limiter, discriminator, stereophonic decoder characteristics and AF frequency response.

3.1 *Selectivity with carrier frequency separations ≤ 400 kHz*

The selectivity should be sufficient to meet the RF protection ratios given in Recommendation 412. Protection ratio measurements are made in accordance with Recommendation 641. It is assumed that test signals are fed via the built-in antenna for receivers without an external antenna input.

3.2 *Selectivity with carrier frequency separations > 400 kHz*

RF protection ratios substantially lower than −25 dB should be met. At the critical carrier frequency separation of 10.7 MHz (assumed nominal intermediate frequency), RF protection ratios lower than −20 dB should be met.

4. Performance in the presence of strong signals*

FM broadcasting receivers overloading by strong input signals may result in:

– desensitization or comparable effects,
– intermodulation.

Such overloading may e.g. occur in the following cases:

(a) a (very) strong wanted signal;
(b) the wanted signal and one strong unwanted signal;
(c) the wanted signal and two strong unwanted signals;
(d) the wanted signal and more than two strong unwanted signals.

With reference to (b), the RF protection ratios should not be seriously affected (≤ 3 dB) if the input power of the wanted signal is increased to 50 dB(pW). Further information may be found in [CCIR, 1986-90c].

5. Automatic frequency control (AFC)

The AFC should be switchable (see Annex II, § 4).

6. Stereo/mono operation

Stereo portable and car receivers should preferably be equipped with a manual stereo/mono switch that will make possible satisfactory monophonic reception in case of insufficient field strength or in the presence of strong interfering signals.

7. Intermediate frequency

10.7 MHz is assumed even though some receivers use higher frequencies for different reasons (e.g. frequency diversity reception).

7.1 *Image rejection ratio*

The single signal image rejection ratio, when measured according to IEC Publication 315-4, should be at least 50 dB.

For the assumed intermediate frequency of 10.7 MHz the image rejection ratio can be disregarded with respect to in-band interference. However, interference from other services has to be taken into account.

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* Administrations are requested to contribute on this subject to the CCIR under Study Programme 46N/10.

7.2 *Interference generated within the receiver related to the intermediate frequency* (see Report 946)

The AF signal-to-noise ratio should be at least 50 dB at the critical frequencies which are integer multiples of the intermediate frequency (e.g. 96.3 MHz, 107 MHz); RF input level 40 dB(pW), stereophonic reception. The signal-to-noise ratio is measured according to IEC Publication 315-4 in conjunction with CCIR Recommendation 468; reference frequency deviation: ± 75 kHz for the pilot-tone system, and ± 50 kHz for the polar-modulation system.

8. Local oscillator radiation

Amendment No. 1 to CISPR Publication 13 and Draft European Standard EN 55013 indicate a measurement method and specify the following values:

Local oscillator fundamental frequency:	≤ 60 dB(μV/m)
Harmonics below 300 MHz:	≤ 52 dB(μV/m)
Harmonics above 300 MHz:	≤ 56 dB(μV/m)

However, some administrations apply the International Standard of the Council for Mutual Economic Assistance (CMEA) 784-77; 3894-82 and the National Standards of the USSR (GOST) 16842-82; 2205-83. In these standards the following values are specified:

Local oscillator fundamental frequency:	≤ 43.5 dB(μV/m)
Harmonics below 300 MHz:	≤ 43.5 dB(μV/m)
Harmonics above 300 MHz:	≤ 43.5 dB(μV/m)

ANNEX II

In defining the recommended characteristics given in Annex I for receivers related to the pilot-tone system, the possible influence of the following receiver parameters was taken into account:

1. Overall audio-frequency response

An overall audio-frequency response with maximum 3 dB attenuation at 40 Hz and 15 kHz has been assumed.

2. Overall total harmonic distortion

It is assumed that the overall total harmonic distortion is less than 1%, measured in accordance with IEC Publication 315-4.

3. Linear and nonlinear crosstalk

In stereophonic reception the crosstalk has an influence on the protection ratio curves. It is assumed that the linear crosstalk between A and B is less than −35 dB at frequencies between 100 Hz to 3 kHz, and less than −20 dB between 50 Hz to 100 Hz and 3 kHz to 15 kHz. Nonlinear crosstalk is assumed to be less than −40 dB.

These values are measured according to IEC Publication 315-4 and should not depend on the receiver input signal level, provided it is high enough to maintain adequate stereophonic operation.

4. Tuning facilities

Various receiver tuning facilities may be considered in a planning context, including:

- adequate mechanical and/or electrical means for continuous or step tuning;
- switchable automatic frequency control which avoid detuning in the case of strong adjacent channel signals and also for testing purposes;
- the features offered by RDS (see Recommendation 643) or other supplementary information systems (see Report 463).

5. AF signal-to-noise ratio at higher input signal levels

Taking into account Recommendation 641, the AF signal-to-noise ratio for monophonic and stereophonic reception is assumed to be at least 56 dB for an input signal level of 40 dB(pW). The AF signal-to-noise ratio measurement is made according to IEC Publication 315-4 in conjunction with Recommendation 468; reference frequency deviation: ± 75 kHz (see also Annex I, § 7.2).

6. Compatibility between the main programme and additional information signals

When additional signals are added on supplementary sub-carrier frequencies (see Recommendation 643 and Report 463), account must be taken of certain interference effects. Receiver designers should consider these in order to avoid interference to the main programme channel.

6.1 *RDS* (see Recommendation 643)

Spurious components due to RDS may appear in the AF band. In the presence of an RDS test signal which causes a deviation of ± 2 kHz on the main carrier, the power sum of these spurious components should be at least 76 dB below an audio signal level corresponding to a deviation of ± 75 kHz using a sinusoidal tone of 500 Hz. For measurements, an RDS test signal with only two sideband components symmetrically located with respect to 57 kHz is used by modulating with an "all zeroes" data stream. In order to eliminate the effects of uncorrelated broadband noise, the spurious components in the AF band are measured selectively.

ANNEX III

The definition of the recommended characteristics given in Annex I for receivers related to the polar-modulation system is based on the following values:

- an irregularity of ± 3 dB in the frequency band from 30 Hz to 15 kHz for the overall AF amplitude-frequency response;
- a distortion factor less than 1%;
- linear crosstalk between channels A and B less than −30 dB at the frequency 1000 Hz and less than −24 dB at the frequencies 250 and 5000 Hz.

REFERENCES

CCIR Documents

[CCIR 1986-90]: **a.** IWP 10/7-14 (France); **b.** IWP 10/7-46 (Switzerland); **c.** 10/308 (Germany (Federal Republic of)).

RECOMMENDATION 412-5*

PLANNING STANDARDS FOR FM SOUND BROADCASTING AT VHF

(Question 46/10, Study Programme 46L/10)

(1956-1959-1963-1974-1978-1982-1986-1990)

The CCIR

UNANIMOUSLY RECOMMENDS

that the following planning standards should be used for frequency-modulation sound broadcasting in band 8 (VHF):

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(μV/m) in rural areas,

60 dB(μV/m) in urban areas,

70 dB(μV/m) in large cities;

1.2 *for the stereophonic service:*

54 dB(μV/m) in rural areas,

66 dB(μV/m) in urban areas,

74 dB(μV/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(μV/m) or 48 dB(μV/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 those given by the curves M2 and M1 in Fig. 2 (see Annex I). The protection ratios at important values of the frequency spacing are also given in Table II.

* 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 § 2.4 and 2.6 which sets out the problems which will arise if the required characteristics of such receivers are not met.

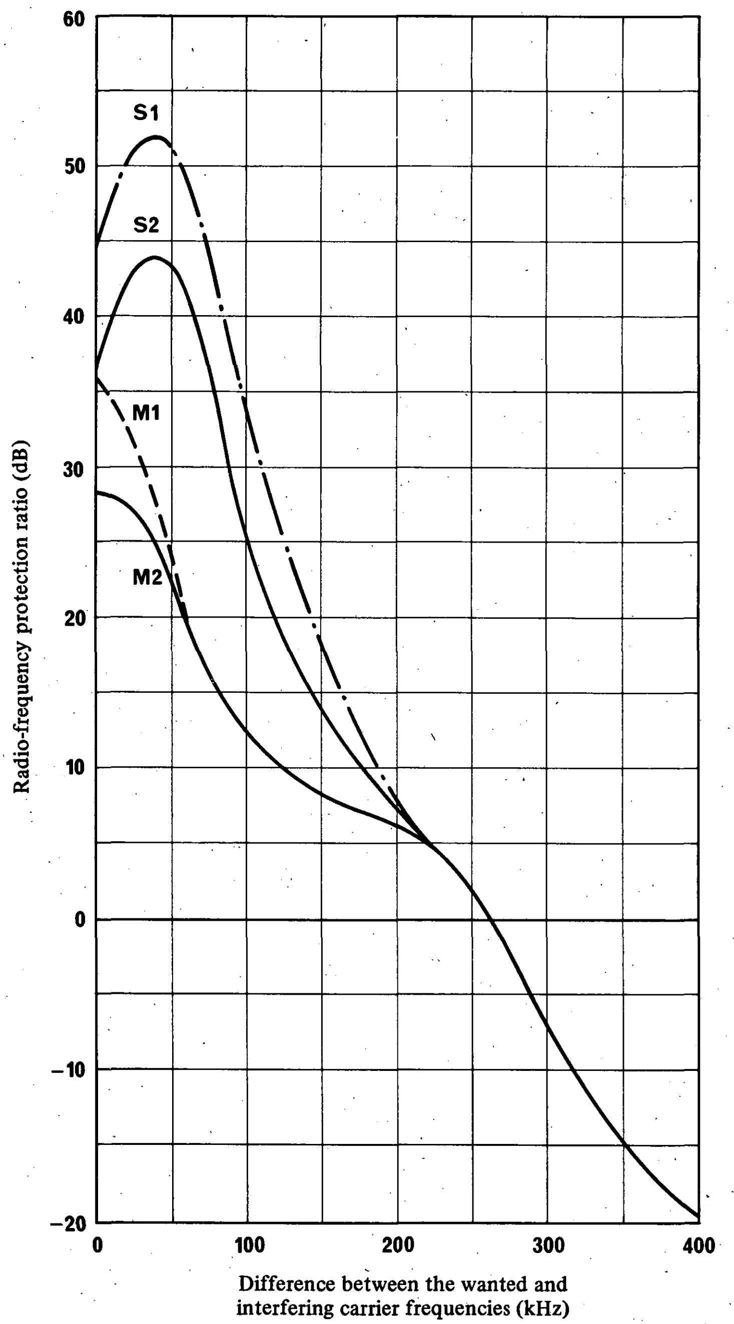


FIGURE 1 – *Radio-frequency protection ratio required by broadcasting services in band 8 (VHF) at frequencies between 87.5 MHz and 108 MHz using a maximum frequency deviation of ± 75 kHz*

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)

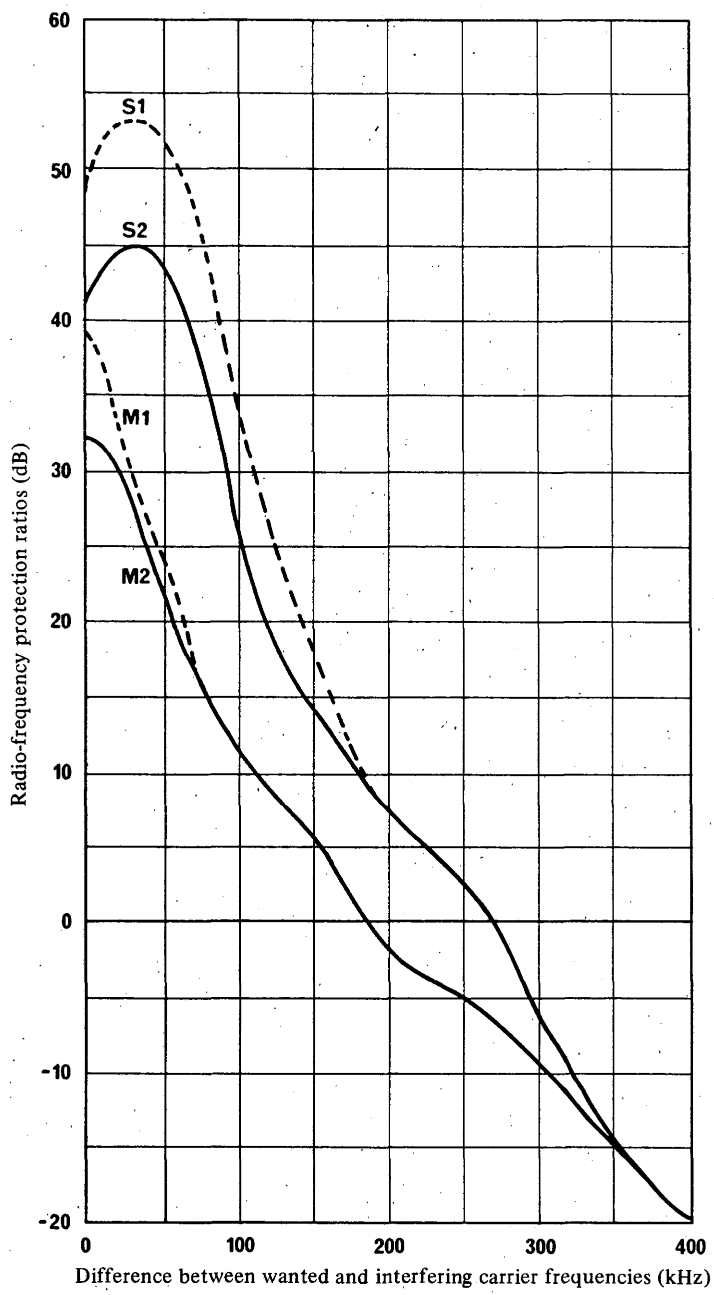


FIGURE 2 – *Radio-frequency protection ratios required by broadcasting services in band 8 (VHF) using a maximum frequency deviation of ±50 kHz*

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)

The values of curves S1 and S2 apply equally to the pilot-tone system and the polar-modulation system.

TABLE I

Frequency spacing (kHz)	Radio-frequency protection ratio (dB) using a maximum frequency deviation of ± 75 kHz			
	Monophonic		Stereophonic	
	Steady interference	Tropospheric interference	Steady interference	Tropospheric interference
0	36.0	28.0	45.0	37.0
25	31.0	27.0	51.0	43.0
50	24.0	22.0	51.0	43.0
75	16.0	16.0	45.0	37.0
100	12.0	12.0	33.0	25.0
125	9.5	9.5	24.5	18.0
150	8.0	8.0	18.0	14.0
175	7.0	7.0	11.0	10.0
200	6.0	6.0	7.0	7.0
225	4.5	4.5	4.5	4.5
250	2.0	2.0	2.0	2.0
275	−2.0	−2.0	−2.0	−2.0
300	−7.0	−7.0	−7.0	−7.0
325	−11.5	−11.5	−11.5	−11.5
350	−15.0	−15.0	−15.0	−15.0
375	−17.5	−17.5	−17.5	−17.5
400	−20.0	−20.0	−20.0	−20.0

TABLE II

Frequency spacing (kHz)	Radio-frequency protection ratio (dB) using a maximum frequency deviation of ± 50 kHz			
	Monophonic		Stereophonic	
	Steady interference	Tropospheric interference	Steady interference	Tropospheric interference
0	39	32	49	41
25	32	28	53	45
50	24	22	51	43
75	15	15	45	37
100	12	12	33	25
125	7.5	7.5	25	18
150	6	6	18	14
175	2	2	12	11
200	−2.5	−2.5	7	7
225	−3.5	−3.5	5	5
250	−6	−6	2	2
275	−7.5	−7.5	0	0
300	−10	−10	−7	−7
325	−12	−12	−10	−10
350	−15	−15	−15	−15
375	−17.5	−17.5	−17.5	−17.5
400	−20	−20	−20	−20

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. The corresponding values for stereophonic systems using a maximum frequency deviation of ± 50 kHz are those given by the curves S2 and S1 in Fig. 2. The protection ratios at important values of the frequency spacing are also given in Table II.

2.3 The radio-frequency protection ratios assume that the maximum peak deviation of ± 75 kHz is not exceeded. Moreover, it is assumed that the power of the complete multiplex signal (including pilot-tone and additional signals) integrated over any intervall of 60 s is not higher than the power of a multiplex signal containing a single sinusoidal tone which causes a peak deviation of ± 19 kHz (see Note 4).

It is important that the limits for modulation levels given above should not be exceeded as otherwise the radiated power of the transmitter has to be reduced in accordance with the increased figures for protection ratios given in Report 1064.

2.4 The radio-frequency protection ratio value for a frequency difference of 10.7 MHz should be below −20 dB.

For other differences which are greater than 400 kHz, the protection ratio value should be substantially lower than the one given above.

2.5 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.

2.6 In the case of AM-FM receivers, it is necessary to take measures so that the circuits at the AM intermediate frequency (generally 450-470 kHz) do not worsen the protection ratios when the receiver is operating in FM, particularly for differences between the frequencies of the wanted and interfering carrier greater than 300 kHz.

2.7 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 Annex I to Recommendation 641) 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 Annex III to Recommendation 644.

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 Annex I to Recommendation 641.

Note 4. – The power of a sinusoidal tone causing a peak deviation of ± 19 kHz is equal to the power of the coloured noise modulation signal according to Recommendation 641, i.e. a coloured noise signal causing a quasi-peak deviation of ± 32 kHz.

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 Figs. 1 and 2 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(μV/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. $E_s \geqslant E_t$

This means that A_s should be used in all cases when:

$$E(50{,}50) + A_s \geqslant E(50,T) + A_t.$$

REFERENCES

CCIR Documents

[1978-82]: 10/241 (Yugoslavia (Socialist Federal Republic of)).

BIBLIOGRAPHY

CCIR Documents

[1982-86]: 10/14 (EBU); 10/38 (USSR); 10/48 (Italy).

[1986-90]: 10/323 (Germany (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 USSR 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 μs or 75 μs.

Note 2. – In Europe, the pre-emphasis is 50 μs. In the United States, it is 75 μs.

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:

$$\overline{K}(f) = \frac{1 + \mathrm{j}\,6.4\,f}{5 + \mathrm{j}\,6.4\,f}$$

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 $\overline{K}(f)$;
- 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:

$\pm$ 75 kHz or $\pm$ 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 kHz $\pm$ 4 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 $\pm 3°$ 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 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 ± 75 kHz.

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.

RECOMMENDATION 643-1 *

SYSTEM FOR AUTOMATIC TUNING AND OTHER APPLICATIONS IN FM RADIO RECEIVERS FOR USE WITH THE PILOT-TONE SYSTEM

(Question 46/10, Study Programme 46H/10)

(1986-1990)

The CCIR,

CONSIDERING

(a) that, in VHF/FM broadcasting, the density of transmissions in many parts of the world is increasing to the extent that tuning to a given programme service is becoming more and more difficult, particularly for listeners using FM portable or car radios;

(b) that, on the other hand, new technologies offer the possibility of adding auxiliary data signals to the sound-programme signals which will offer a wide variety of methods for identifying the transmissions, thereby facilitating the implementation of assisted and automatic tuning in future radio receivers;

(c) that such radio-data signals can be added to existing VHF/FM broadcasts in such a way that they are inaudible, thus achieving good compatibility with reception of the normal stereophonic or monophonic sound-programme signals;

(d) that receiver technology is available to implement assisted or automatic tuning using radio-data signals, and that such technology can be inexpensive provided that it is mass-produced;

(e) that such a system offers the flexibility to implement a wide range of optional applications to suit the particular needs of individual broadcasting organizations;

(f) that most EBU Member countries have collaborated in the development of an internationally agreed standard for such a system;

(g) that many countries have implemented this system on their broadcasts;

(h) than an international standard is necessary to support mass-production of receivers using the system, thereby minimizing the cost of receivers to the consumer, and that an international standard is necessary also to permit receivers, especially FM portables and car radios, to be used abroad by travellers,

UNANIMOUSLY RECOMMENDS

that broadcasters wishing to introduce the transmission of supplementary information for station and programme identification in FM broadcasting and other applications, should use the radio-data system (RDS), as specified in Annex I.

Note – Information regarding the operational characteristics of RDS is given in Annex II.

ANNEX I

SPECIFICATIONS OF THE RADIO DATA SYSTEM **

1. Modulation of the data channel

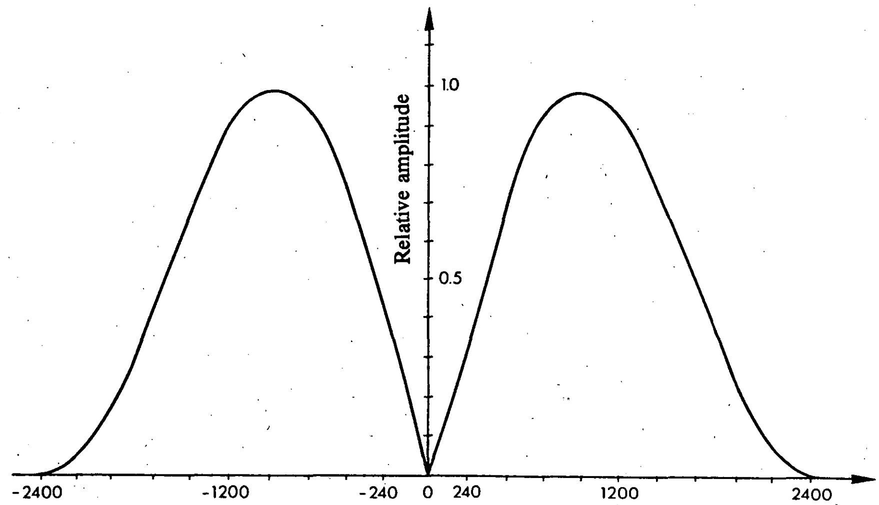
1.1 Sub-carrier frequency: 57 kHz, locked in phase or in quadrature to the third harmonic of the pilot tone 19 kHz (± 2 Hz) in the case of stereophony. (Frequency tolerance: ± 6 Hz.) If RDS is used simultaneously with the ARI traffic broadcast identification system (see Report 463), the RDS sub-carrier will have a phase difference of 90° ± 10°, and the recommended nominal deviation of the main carrier will be ± 1.2 kHz due to the RDS signal and ± 3.5 kHz due to the unmodulated ARI sub-carrier.

1.2 Sub-carrier level: the recommended nominal deviation of the main FM carrier due to the modulated sub-carrier is ± 2 kHz. The decoder should, however, be designed to work with sub-carrier levels corresponding to between ± 1 kHz and ± 7.5 kHz deviation.

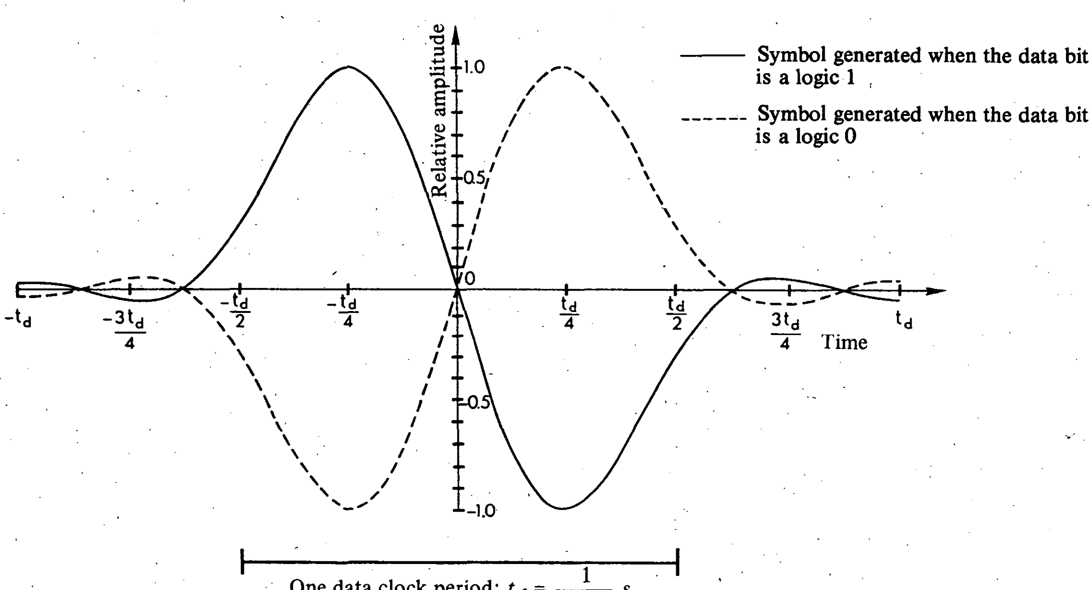
1.3 Method of modulation: the sub-carrier is amplitude-modulated by the shaped and biphase-coded data signal. The sub-carrier is suppressed (see Figs. *1a)* to *1c)*);

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

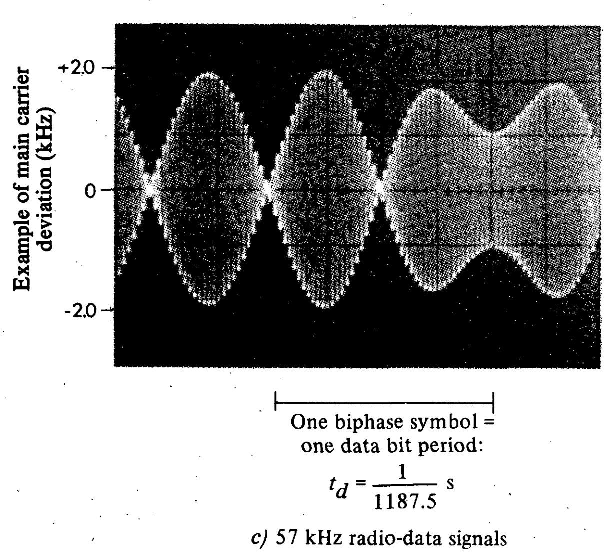
** The characteristics published here are only a summary drawn from a more detailed text which is published separately.



a) Spectrum of biphase coded radio-data signals



b) Time-function of a single biphase symbol



c) 57 kHz radio-data signals

FIGURE 1 – *Spectrum and time-functions of RDS signals*

1.4 Clock frequency and data rate: the basic clock frequency is obtained by dividing the transmitted sub-carrier frequency by 48. Consequently the basic data rate is 1187.5 bit/s ± 0.125 bit/s.

1.5 Differential coding: when the input data-level from the coder at the transmitter is 0, the output remains unchanged from the previous output bit, and when an input 1 occurs, the new output bit is the complement of the previous output bit.

2. Baseband coding

2.1 Coding structure: the largest element in the structure is called a "group" of 104 bits. Each group comprises 4 blocks of 26 bits. Each block comprises an information word and a checkword, of 16 and 10 bits respectively.

2.2 Order of bit transmission: all information words, checkwords and addresses have their most significant bit transmitted first.

2.3 Error protection: the 10-bit cyclic redundancy checkword, to which a 10-bit offset word is added for synchronization purposes, is intended to enable the receiver/decoder to detect and correct errors which occur in reception.

2.4 Synchronization of blocks and groups: the data transmission is fully synchronous and there are no gaps between the groups or blocks. The beginning and end of the data blocks may be recognized in the decoder by using the fact that the error-checking decoder will, with a high level of confidence, detect block synchronization slip. The blocks within each group are identified by different offset words added to the respective 10-bit checkwords.

2.5 Message format: the first five bits of the second block of every group are allocated to a five-bit code which specifies the application of the group and its version. The group types specified are given in Table I. There is also space left to add at a later stage applications yet to be defined.

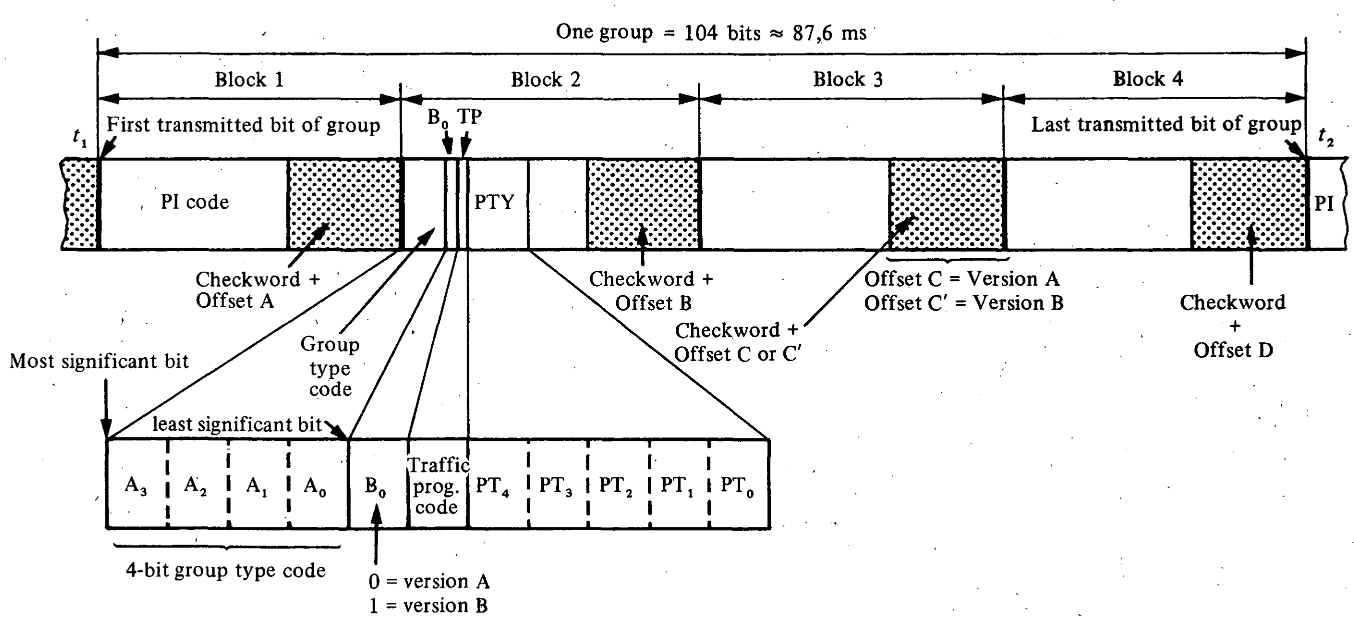


FIGURE 2 – *Message format and addressing*

Note 1. – Group type code = 4 bits.

Note 2. – B_0 = version code = 1 bit.

Note 3. – PI code = programme identification code = 16 bits.

Note 4. – TP = traffic programme identification code = 1 bit.

Note 5. – PTY = programme type code = 5 bits.

Note 6. – Checkword + offset "N" = 10 bits added to provide error protection and block and group synchronisation information.

Note 7. – $t_1 < t_2$: block 1 of any particular group is transmitted first and block 4 last.

TABLE I – *Group type codes*

Group type						Applications
Decimal value	Binary code A_3	A_2	A_1	A_0	B_0	
0	0	0	0	0	X (1)	Basic tuning and switching information
1	0	0	0	1	X	Programme item number
2	0	0	1	0	X	Radiotext
3	0	0	1	1	X	Application not yet defined
4	0	1	0	0	0	Clock-time and date
5	0	1	0	1	X	Transparent channels for text or other graphics (32 channels)
6	0	1	1	0	X	In-house applications
7	0	1	1	1	0	Radio paging
8-13						Applications not yet defined
14	1	1	1	0	X	Enhanced other networks information
15	1	1	1	1	1	Fast basic tuning and switching information

(1) X indicates that value may be "0" (version A) or "1" (version B).

A large part of the data-transmission capacity of the RDS system will be used for features relating to the automatic or assisted tuning functions of an FM receiver. Such messages are repeated frequently so that a short data-acquisition time for tuning or retuning may be achieved. Many of the relevant codes occupy fixed positions within every group. They can therefore be decoded without reference to any block outside the one which contains this information.

Table II explains the abbreviations used and the features to which they are relevant.

TABLE II – *List of abbreviations and features*

Tuning functions	Other functions
PI: Programme identification	TA: Traffic announcement identification
PS: Programme service name	DI: Decoder identification
AF: List of alternative frequencies	M/S: Music/speech switch
TP: Traffic programme identification	PIN: Programme item number
PTY: Programme type	RT: Radiotext
EON: Enhanced other networks information	TDC: Transparent data channel
	IH: In-house applications
	CT: Date and time
	RP: Radio paging

2.6 Repetition rates: Table III indicates the appropriate repetition rates for some of the main applications, when and if they are implemented by the broadcaster.

TABLE III – *Appropriate repetition rates*

Applications	Group types which contain this information	Appropriate repetition rate per second
Programme identification (PI) code	all	11.4 (1)
Programme type (PTY) code	all	11.4 (1)
Traffic programme (TP) identification code	all	11.4 (1)
Programme service (PS) name	0A, 0B	1 (2)
Alternative frequency (AF) code pairs	0A	4 (2)
Traffic announcement (TA) code	0A, 0B, 15B	4
Decoder identification (DI) code	0A, 0B, 15B	1
Music/speech (M/S) code	0A, 0B, 15B	4
Radiotext (RT) message	2A, 2B	0.2 (3)
Enhanced Other Networks information (EON)	14A, 14B	up to 2 (4)

(1) Valid codes for this item will normally be transmitted with at least this repetition rate whenever the transmitter carries a normal broadcast programme.

(2) A total of four 0A groups are required to transmit the entire PS name and therefore four 0A groups will be required per second. The repetition rate of group type 0A may be reduced if more capacity is needed for other applications. A minimum of two type 0A groups per second is necessary to ensure correct functioning of PS and AF features. It should be noted that in this case transmission of the complete PS will take 2 s. However, under typical reception conditions the introduction of errors will cause the receiver to take 4 s or more to acquire the PS name for display.

(3) A total of 16 type 2A groups are required to transmit a 64 character radiotext message and therefore 3.2 type 2A groups will be required per second.

(4) The maximum cycle time for the transmission of *all* data relating to *all* cross-referenced programme services shall be less than 2 min.

Note – Some administrations outside of Region 1 still have some of these issues under study and require more time before they can accept this Recommendation.

BIBLIOGRAPHY

CENELEC EN 50067 Specifications of the ratio data system (RDS).

EBU [March, 1984] Specifications of the radio data system RDS for VHF/FM sound broadcasting. EBU Tech. 3244, plus supplements.

EBU RDS Newsletter.

EDWARDSON, S.M. [1986] *Radio Receivers*, Chapter 14 Ed. W. Gosling. IEE Telecommunications Series 15, Peter Peregrinus, London, UK.

CCIR Documents

[1978-82]: 10/214 (Sweden).

[1982-86]: 10/15 + Add. (EBU); 10/32 (United Kingdom); 10/84 (Sweden); 10/234 (Sweden); 10/236 (Germany (Federal Republic of)); 10/271 (Japan).

ANNEX II

OPERATIONAL CHARACTERISTICS OF THE RADIO DATA SYSTEM "RDS"

1. Compatibility with existing VHF/FM broadcasts

1.1 *Compatibility with the pilot-tone stereophonic main programme*

The frequency, level and method of modulation of the sub-carrier used to convey the data signals have been carefully chosen so as to avoid interference to reception of the main stereo or mono programme signals. Because of the extreme importance of these compatibility considerations, extensive and prolonged field-trials have been conducted in several countries. It has been found that over a wide variety of propagation conditions, and with a wide variety of receivers, good compatibility is achieved. However, in some locations where the received signals are affected by severe multipath propagation, interference to the main programme signal may occur. In such circumstances, however, even in the absence of RDS signals, the quality of the received programme signal is usually poor due to distortion.

1.2 *Compatibility with existing auxiliary signals*

The radio data system, RDS, is designed so that its signals do not interfere with the existing auxiliary signals used in some countries to identify broadcast information for motorists (the ARI system (see Report 463)). This is achieved by shaping the transmitted spectrum of the RDS signals in such a way as to minimize overlap with the spectrum of the ARI signals. However, in those cases where the signals of both the RDS system and the ARI system are broadcast either simultaneously from the same transmitter or from different transmitters, the injection level of the RDS signal should be reduced so that the deviation of the main FM carrier due to the RDS signal is ± 1.2 kHz; this has been found necessary to ensure the required compatibility with some types of ARI receiver. Simultaneously, the deviation of the main FM carrier due to the unmodulated ARI sub-carrier should be reduced to ± 3.5 kHz. However, increases in deviation by the RDS signal may become possible in the future.

2. Reliability of reception of radio-data signals

When assessing the reliability of reception of radio-data signals it is important to devide the applications of the RDS system into two categories: those using short and frequently repeated messages, for example, automatic tuning functions; and those using longer messages which are repeated rarely, for example, radiotext (RT) messages.

In the case of field-strength limited reception conditions, as might be experienced in a fixed domestic installation, and with the recommended RDS injection level of ± 2 kHz, adequately reliable reception of short messages is possible for an input e.m.f. to the receiver down to about 15 dBμV (from a 50 Ω source) whilst adequately reliable reception of the longer messages required an input e.m.f. of about 20 dBμV. It should be stressed that the values given above depend on the noise figure of the receiver which is typically about 7 dB. These input voltages correspond to bit error-ratio in the received signal before error correction of 1×10^{-2} and 1×10^{-4}, respectively. Under these field-strength limited conditions, the bit error-ratio in the received signal decreases exponentially with increasing receiver antenna input level. Furthermore, for RDS injection levels at the transmitter in the specified range ± 1 kHz to ± 7.5 kHz, the receiver antenna input signal level needed to attain a given error-ratio increases almost proportionally with decreasing injection level and *vice versa.* For example, decreasing the injection level from ± 2 kHz to ± 1 kHz increases the antenna input e.m.f. needed by an RDS receiver to attain a given bit error-ratio by 6 dB.

In determining the best level for the injected RDS signals, it was found that a compromise had to be found between compatibility with the main programme signals on the one hand and reliability of RDS signal reception on the other. Overall, the recommended RDS injection level corresponding to ± 2 kHz deviation of the main FM carrier was found to give the best compromise over a wide range of reception conditions.

In the case of mobile reception in vehicles, multipath propagation is often found to be the dominant impairment to RDS signal reception. In order to obtain information about the performance of the RDS system under multipath limited reception conditions, extensive field trials were carried out in several countries.

In these field trials, which were conducted on roads where reception of signals from the local broadcast transmitter was severely impaired by multipath propagation, it was found that the frequently repeated messages needed for the automatic tuning functions of RDS receivers could be reliably received even though the received programme signal was often severely impaired by distortion and noise. As in the case of field-strength limited reception conditions, reception reliability was found to improve with increasing RDS injection level at the transmitter. However, it was found that adequate performance was maintained down to the minimum injection level of ± 1 kHz allowed by the specifications of the RDS system.

The RF protection ratio needed by the RDS system against interference from unwanted broadcast signals in the same or adjacent channels was determined by laboratory measurements using a procedure similar to that used to derive the protection ratios given in Recommendation 412. The results of these measurements for steady interference are given in Fig. 3. It may be noted that for transmissions using the recommended channel spacing of 100 kHz, the protection ratio needed by the RDS system is much less than that needed for the stereo programme signal. Figure 3 shows that RDS protection ratios are close to those for monophonic programme signals; these can be improved, if desired, by using an increased level of RDS sub-carrier.

The existing protection ratios needed for the monophonic and stereophonic broadcasting services were found to be unaffected by the inclusion of an RDS sub-carrier in the interfering signal. This was found to be true for deviation of the main carrier, by the sub-carrier, of up to ± 7.5 kHz.

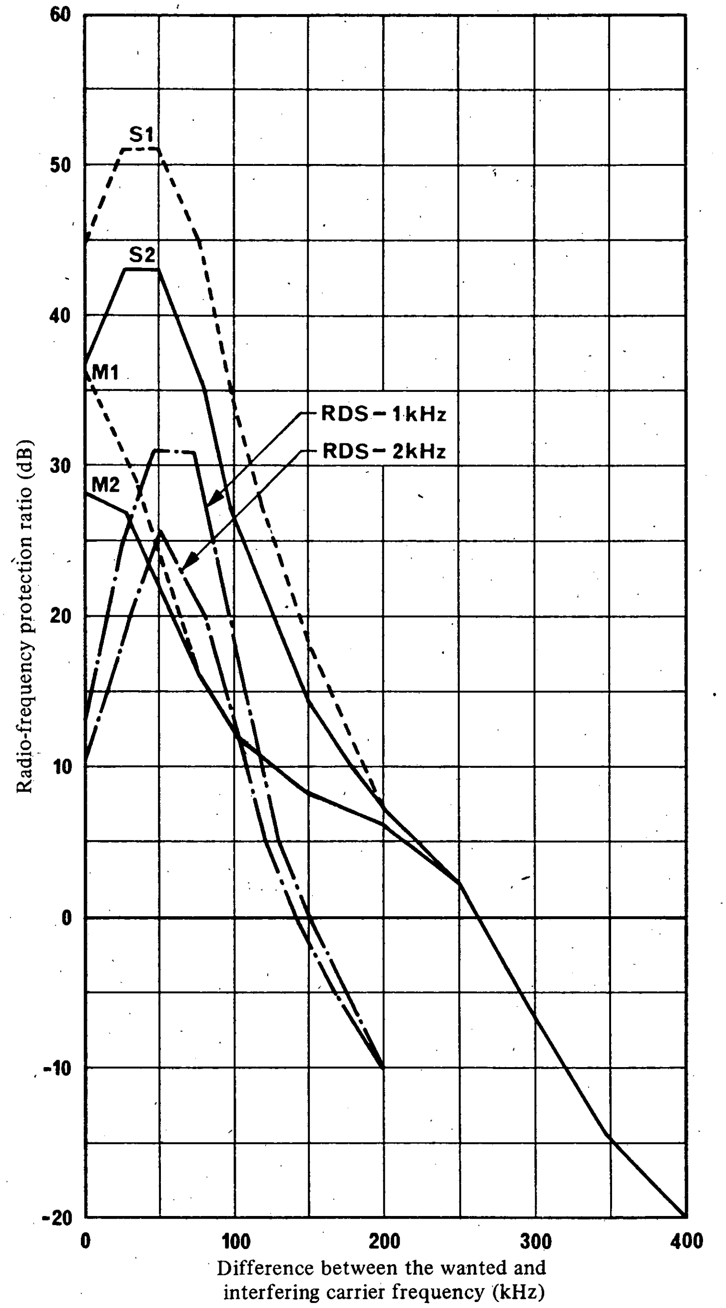


FIGURE 3 – *Comparison of protection ratios for monophony and stereophony given in Recommendation 412 with those measured for the radio-data system RDS*

Curve M1:	monophonic broadcasting, steady interference
Curve M2:	monophonic broadcasting, tropospheric interference
Curve S1:	stereophonic broadcasting, steady interference
Curve S2:	stereophonic broadcasting, tropospheric interference
Curve RDS-1 kHz:	radio-data transmission at ±1 kHz deviation, steady interference, bit-error rate 1 x 10^{-3}
Curve RDS-2 kHz:	radio-data transmission at ±2 kHz deviation, steady interference, bit-error rate 1 x 10^{-3}

RECOMMENDATION 707

TRANSMISSION OF MULTISOUND IN TERRESTRIAL PAL TELEVISION SYSTEMS B, G, H AND I*

(Question 47/10, Study Programmes 47A/10 and 47B/10)

(1990)

The CCIR,

CONSIDERING

(a) the increasing requirement worldwide for suitable means of broadcasting stereophonic and/or multichannel sound and/or data from terrestrial television transmitters;

(b) the technical developments in this area and in particular the relative merits of various possible analogue and digital methods, as described in Report 795;

(c) the improvements in television sound quality achieved with recent developments of equipment used for the transmission and reception of the two-sound carrier FM system;

(d) the improvments in television sound quality achieved with the NICAM-728 system using digital coding;

(e) Recommendation 651 concerning "Digital PCM coding for the emission of high quality sound signals in satellite broadcasting (15 kHz nominal bandwidth)";

(f) Recommendation 650 concerning the adoption of MAC/packet systems for satellite broadcasting in channels defined by WARC BS-77 and the desirability of a close measure of commonality between digital systems for satellite and terrestrial broadcasting;

(g) the advantage of low cost analogue circuitry for multisound television receivers for the two-sound carrier FM system;

(h) the development of digital audio circuitry for other applications in the home;

(j) the ruggedness of the two-sound carrier FM system in difficult reception areas – especially under multipath reception conditions – and its excellent compatibility with existing receivers, transmitters, networks and services, including the case of 7 MHz channel spacing;

(k) the need to use a digital sound system in television that satisfies simultaneously and with a generous margin, the contradictory constraints of:

- ruggedness in difficult reception areas, including the requirement for failure of sound after vision, and
- compatibility between the new and existing services, including the case of 7 MHz channel spacing;

(l) the fact that the two-sound carrier FM system was introduced to the CCIR in 1974, became operational in 1981, and is now in extensive use in the Federal Republic of Germany and in various other countries;

(m) the fact that the NICAM-728 system was introduced to the CCIR in 1987, became operational in 1988, is now in extensive use in Finland, Sweden and Denmark, is now in operation in the United Kingdom and is planned for introduction in various other countries:

(n) the urgency of establishing unified standards in order to provide for the introduction of stereophonic and/or multichannel sound for the television broadcast services,

UNANIMOUSLY RECOMMENDS

1. that if analogue multisound is introduced in terrestrial television emissions in countries using PAL television systems B, G and H, the two-sound carrier FM system, as defined in Annex I should be used;

2. that if digital multisound is introduced in terrestrial television emissions in countries using PAL television systems B, G, H and I, the system specified in Annex II should be used.

Note 1 – Studies are continuing to define multisound system parameters to be recommended for other television systems.

Note 2 – The transmission systems described, can in some cases, be used for data services. Where applicable, reference to these data services will be found in the Annexes containing the system specifications.

Note 3 – Interference caused by multisound emission to other television systems is dealt with in Report 1214.

* This Recommendation should be brought to the attention of Study Group 11 and IEC.

ANNEX I

SYSTEM SPECIFICATIONS FOR THE TWO-SOUND CARRIER FM SYSTEM

TABLE I – *Emission characteristics of the two-sound carrier FM system*

(Television systems B, G and H)

Characteristics		Sound carrier 1	Sound carrier 2
RF-sound carriers			
Frequency referred to vision carrier	(MHz)	5.5 ([1])	5.5 + 0.2421875 ([1])
Power referred to peak vision	(dB)	−13	−20
Modulation		FM	FM
Frequency deviation	(kHz)	± 50	± 50
Audio-bandwidth	(Hz)	40 to 15 000	40 to 15 000
Pre-emphasis	(μs)	50	50
AF-signals			
Monophonic		Monophonic 1	Monophonic 1
Stereophonic		$(A + B)/2$	B
Double sound		Monophonic 1	Monophonic 2
Identification signals ([2])			
Sub-carrier frequency	(kHz)		54.6875 ([3]) (3.5 × line frequency)
Modulation			AM
Modulation depth	(%)		50 ([4])
Modulation frequency: ([3])	(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
Audio-frequency companding ([5])		Not yet defined	

([1]) The frequency difference between both sound carriers is 15.5 × line frequency = 242.1875 kHz. Phaselocking of both sound carriers with the line frequency gives improvements, but is not absolutely necessary.

([2]) Additional identification signals of the three sound modes may also be transmitted in the digital data line in the vertical blanking interval.

([3]) The sub-carrier and identification frequencies are phaselocked with the line frequency.

([4]) The residual 50% AM modulation depth is reserved for future identification of audio-frequency companding.

([5]) The use of a compatible audio companding system would improve the audio signal-to-noise ratio.

Complete specifications for the system will be found in [ARD/ZDF, 1982].

REFERENCES

ARD/ZDF [1982] Technische Pflichtenhefte 5/2.3.1. Coder für das Zweitonträgerverfahren. ARD/ZDF.

ANNEX II

SUMMARY OF THE SYSTEM SPECIFICATION FOR DIGITAL MULTISOUND WITH TERRESTRIAL TELEVISION SYSTEMS B, G, H AND I

1. Introduction

The following is a summary of the specification of the system for transmission of digital multisound with terrestrial television systems B, G, H, and I. Complete specifications for the system will be found in [CCIR, 1986-90] and for system I as used in the United Kingdom in [IBA/BREMA/BBC, 1988].

2. Frame format

Frame length	: 728 bits
Frame transmission rate	: 1 frame/ms

2.1 *Frame structure*

Frame alignment word	: 8 bits
Control information	: 5 bits
Additional data	: 11 bits
Sound/data coding block	: 704 bits
Total	: 728 bits

The 720 bits which follow the frame alignment word form a structure identical with that of the first-level protected, companded sound-signal blocks in the systems of the MAC/packet family [CCIR, 1988], so that decoding of the sound signals may be performed by the same type of decoder which is used in the above MAC systems. The first 16 bits of the block, which have not yet been allocated in the systems of the MAC/packet family, are used to signal control information (see § 3.2) and as additional data bits (see § 3.3).

Frame structures for data services use the same frame alignment word (FAW), flag bit and additional data, with control bits as described in § 3.2.2, but the audio samples are replaced by other data.

2.2 *Bit interleaving*

Interleaving is applied to the sound/data coding block in order to minimise the effect of multiple-bit errors. The bits of each frame are transmitted in the following order:

FAW	5 control bits $C_0 \rightarrow C_4$	11 additional data bits $AD_0 \rightarrow AD_{10}$	704 bits of interleaved sound data 16 bits
1,2,3,4,5,6,7,8	9,10,11,12,13	14,15,16,17,18,19,20,21,22,23,24	25,69,113,157 .... 685 26,70,114 .... 686 27,71,115 .... 687 28,72,116 .... 688 — — — .... — — — — .... — — — — .... — — — — .... — 68,112,156 728
		44 bits 4 × 11 bit companded samples	

2.3 *Energy dispersal scrambling*

After bit interleaving, the transmitted bit-stream is scrambled for spectrum-shaping purposes by modulo-two addition of a pseudo-random binary sequence (PRBS). The framing code is not scrambled.

The PRBS generator is re-initialised after the frame alignment word of each frame such that the first bit of the sequence is added to the bit that immediately follows the frame alignment word. The generator polynomial of the PRBS is $x^9 + x^4 + 1$ and the initialisation word is 111111111.

3. Coding of information

3.1 *Frame-alignment word*

The frame-alignment word is 01001110, the left-most bit being transmitted first.

3.2 *Control information*

The control information is conveyed by a frame bit C_0, three application control bits, C_1, C_2 and C_3 and a reserve sound switching flag C_4.

3.2.1 *Frame flag bit*

The frame flag bit, C_0, is set to "1" for 8 successive frames and to "0" for the next 8 frames; thus it defines a 16-frame sequence. This frame sequence is used to synchronise changes in the type of information being carried in the channel.

$C_0 = 1$	Frames 1 - 8
$C_0 = 0$	Frames 9 - 16

3.2.2 *Application control bits*

The application control bit define the application of the 704-bit sound/data coding block, as shown below.

When a change to a new application is required, these control bits change to define the new application on frame 1 of the last 16-frame sequence of the current application. The 704-bit sound/data blocks change to the new application on frame 1 of the following 16-frame sequence.

Application control information			Contents of 704-bit sound/data block
C_1	C_2	C_3 (1)	
0	0	0	Stereo signal comprising alternate A-channel and B-channel samples.
0	1	0	Two independent mono sound signals transmitted in alternate frames (designated M1 and M2).
1	0	0	One mono signal and one 352 kbit/s transparent data channel transmitted in alternate frames.
1	1	0	One 704 kbit/s transparent data channel.

(1) $C_3 = 1$ provides for signalling additional sound or data coding options which have not yet been specified. When $C_3 = 1$, decoders not equipped for such additional options should provide no sound output.

3.2.3 *Reserve sound switching flag*

$C_4 = 0$ Analogue sound signal is not carrying same programme as digital signal.
$C_4 = 1$ Analogue sound signal is carrying same programme as digital stereo signal (or mono signal in M1 frames).

3.3 *Additional data*

Eleven additional data bits AD_0 to AD_{10} indicated in § 2.2 are reserved for future applications yet to be defined.

3.4 *Sound/data block*

Sampling frequency	32 kHz
Initial resolution	14 bits/sample
Companding characteristics	near-instantaneous, with compression to 10 bits/sample in 32-sample (1 ms) blocks
Coding for compressed samples	2's complement
Pre-emphasis	CCITT Recommendation J.17
Audio overload level	Systems B, G, H: + 12 dBu0 at 2.0 kHz System I: 14.8 dBu0 at 2.0 kHz
Error protection	1 parity bit/sample
Scale factor transmission	signalled in parity
Stereo sound signal transmission	odd-numbered samples of each block convey A-channel (left); even-numbered samples convey B-channel (right)
Mono sound signal transmission	mono signal M1 in odd-numbered frames; mono signal M2 in even-numbered frames. If only one mono signal is transmitted it will be M1
Bit transmission order	the bits of each sample are transmitted least significant bit first with parity following the m.s.b.

The control information described in § 3.6.2.3 of [CCIR, 1988] (Chapter 3, Part 3) is not used. However other information could be transmitted by the same means, i.e. two information bits modifying samples 55, 56, 57, 58, 59 and 60, 61, 62, 63, 64 respectively. Receivers should be designed to take advantage of this facility.

4. Modulation parameters

4.1 *Analogue signals*	*Systems B, G, and H*	*System I*
4.1.1 Vision component	As given in CCIR Report 624	
4.1.2 Analogue sound component	As given in CCIR Report 624 except for sound carrier power as given below	
4.1.3 Power ratio between peak vision carrier and analogue sound carrier	Approx. 20: 1	Approx. 10: 1

4.2 *Digital signal*	*Systems B, G and H*	*System I*
4.2.1 Type of modulation	Differentially encoded quadrature phase shift keying (QPSK)	
4.2.2 Bit rate	728 kbit/s ± 1 part/million	
4.2.3 Carrier frequency	5.85 MHz (unrelated to bit-rate) above the vision carrier frequency	6.552 MHz above the vision carrier frequency *
4.2.4 Signal level	Power ratio between peak vision carrier and modulated digital signal is approximately 100:1.	
4.2.5 Spectrum shaping	Impulses at the symbol rate of 364 kHz are filtered by a lowpass filter with the following amplitude-frequency response before quadrature modulation. The filter has constant group delay.	

Systems B, G and H

$$H(f) = \begin{cases} 1 & \text{for } f < \dfrac{1-k}{2t_s} \\ \cos\left[\dfrac{\pi t_s}{2k}\left(f - \dfrac{1-k}{2t_s}\right)\right] & \text{for } \dfrac{1-k}{2t_s} \leqslant f \leqslant \dfrac{1+k}{2t_s} \\ 0 & \text{for } f > \dfrac{1+k}{2t_s} \end{cases}$$

$$k = 0.4 \quad t_s = \frac{1}{364} \text{ ms}$$

Use of the same filter on reception gives 40% cosine roll-off overall

System I

$$H(f) = \begin{cases} \cos \dfrac{\pi t_s f}{2} & \text{for } f \leqslant \dfrac{1}{t_s} \\ 0 & \text{for } f > \dfrac{1}{t_s} \end{cases}$$

$$t_s = \frac{1}{364} \text{ ms}$$

Use of the same filter on reception gives 100% cosine roll-off overall

REFERENCES

CCIR [1988] Specifications of Transmission Systems for the Broadcasting-Satellite Service. CCIR Special Publication.

IBA/BREMA/BBC [August 1988] NICAM 728 Specification for two additional sound channels with System I television.

CCIR Documents

[1986-90]: 10/269 (EBU).

* In some countries the relative carrier frequency and bit rate may be locked to each other.

SECTION 10C: AUDIO-FREQUENCY CHARACTERISTICS OF SOUND-BROADCASTING SIGNALS

RECOMMENDATION 562-3*

SUBJECTIVE ASSESSMENT OF SOUND QUALITY

(Question 50/10, Study Programme 50C/10)

(1978-1982-1986-1990)

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, the composition of the team of assessors and the programme sequences 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 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 405-5 (Dubrovnik, 1986), 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. To ensure the comparability of test data obtained in different places and at different times, preferably the same programme sequences should be used. The subjective quality assessment material (SQAM) compact disk adopted and published by the EBU provides an appropriate source of high-quality digital programme material from which suitable items may be chosen for this purpose [1986-90a, b].

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. Choice of reproduction device

Depending on the category of impairment to be assessed, either headphones or loudspeakers may be used.

It has been shown that certain quality shortcomings are more clearly perceptible in the case of headphone reproduction than in the case of loudspeaker reproduction. For example, the signal-to-noise ratio required for noiseless listening using headphones exceeds the figure obtained using loudspeakers at the same sound intensity by as much as 10 dB. Similar differences occur in the case of the quality losses caused by clicks (caused by bit errors in digital transmission), by quantizing distortions, non-linearity distortions, phase distortions, etc.

However, other quality shortcomings are more clearly perceptible in the case of loudspeaker reproduction. Especially those influences which affect the characteristics of the stereophonic sound-image between the loudspeakers should be assessed by means of loudspeaker reproduction. For example, this is due to the quality losses caused by any difference between the A and B channels.

In order to make the assessments as far as possible comparable with one another, it may be advisable to use headphones. Because headphone reproduction is independent of the geometric and acoustic properties of listening and control rooms, it can, in principle, be defined with great accuracy and can easily be reproduced without systematic error. This does not apply to loudspeaker reproduction.

In addition, in the case of headphone reproduction, assessment tests can be carried out with a great number of listeners at the same time and under identical listening conditions.

6. Sound level

6.1 *Loudspeaker reproduction*

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.

6.2 *Headphone reproduction*

In order to avoid measuring the sound level in the ear canal in the case of headphone reproduction, the sound level should be adjusted in such a way that loudness equal to a reference sound field is achieved. To determine equal loudness, the listener should be positioned in a reference sound field according to § 6.1.

When comparing the loudness of the headphones with that of the reference sound field, the signals are presented to the listeners alternatively (not simultaneously). The headphones are supplied with an input signal of the same nature as that of the reference sound field and are adjusted to the same loudness according to the judgements of the listeners.

The mean value of all loudness comparison judgements should be used to ensure that the correct headphone sound level is used for the tests.

7. Listening conditions

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.).

7.1 *Loudspeaker reproduction*

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.

Technical requirements for the loudspeaker characteristics, which are in use in the USSR, are described in [CCIR, 1978-82a].

7.2 *Headphone reproduction*

Whenever the tests are conducted with headphones, all the essential information concerning the type designation of the headphones used should be given.

Technical requirements for the headphone characteristics have to be defined. A current EBU text proposes an action programme aimed at drawing up an international standard applicable to high-quality headphones [Theile, 1985].

* For acoustical properties of listening rooms, see Report 797.

8. Assessment of special characteristics of equipment *, programmes, studios, etc.

8.1 *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.

8.2 *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 USSR (listening conditions, choice of method, number of listeners and their selection).

8.3 *Applications of subjective assessment of sound quality*

Studies in the USSR have attempted to identify requirements for subjective tests in broadcasting [CCIR, 1982-86a]. The applications of subjective assessment were divided into three areas:

– sound recordings for programme exchange;
– studios, halls and other listening rooms;
– equipment.

These three areas were further broken down into groups and presented in a table.

The assessment requirements are based on international practice reflected in ISO, IEC and OIRT texts (i.e. for noise level, lighting, instructions, positions of loudspeakers and subjects, etc. in IEC Publication 543; for protocols in OIRT Recommendation No. 68/1 [CCIR, 1974-78a].

Note – During the discussions at the Final Meeting of Study Group 10 it was considered that a successful result from the international work in subjective assessment of programmes for exchange and the refinement of the categories proposed above, can be reached only after the determination of uniform definitions of subjective parameters. Therefore, Study Programme 50C/10 was amended. Further contributions are requested to improve this Recommendation.

9. Subjective assessments of multi-dimensional sound systems

In [CCIR, 1986-90c] it is argued that subjective assessments of signal distortion caused by non-linearities, interference or noise can appropriately be measured by the methods given in the body of this Recommendation.

However, in certain fields such as sound "surround-sound" or high definition television, the design problem is more complex. The subjective assessments are needed to design or choose a multi-channel sound system, and there are in this case new considerations which go beyond distortion of a sound channel alone. They include the extent to which localization is possible or the effectiveness of the reproduction of a multi-dimensional sound field at a given point. In this case, new assessment methods are needed, which go beyond those considered currently in this Recommendation.

As an example, in the study by Oghusi of NHK using multi-dimensional scaling, the following attributes were examined:

– apparent sound stage width,
– surround effect,
– apparent room size,
– horizontal and vertical localization,
– naturalness,
– sense of reality,
– agreeableness,
– correspondence of sound and image,
– appropriateness of sound image for pictures.

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* For example, apparatus such as compressors, compandors, recorders, etc.

Assessors were asked to grade a number of alternative systems for these attributes. A table of dissimilarities was prepared, from which two orthogonal perceptual axes seem to be associated with the perceived realism (strongest link to the number of channels) and the coincidence of sound and picture (strongest link to the provision of a central source). The choice of system in the NHK case was based on overall quality and Japan would advocate such an approach in such cases [CCIR, 1986-90c and d].

REFERENCES

THEILE, G. [March, 1985] On the standardisation of the frequency response of high quality studio headphones. 77th AES – Convention, Hamburg, Preprint No. 2207 (D-3).

CCIR Documents

[1974-78]: **a.** 10/26 (OIRT); **b.** 10/311 (USSR).

[1978-82]: **a.** 10/45 (USSR); **b.** 10/35 (OIRT).

[1982-86]: **a.** 10/181(Rev.1) + Corr.1 (USSR).

[1986-90]: **a.** 10/224 (EBU); **b.** 10/284 (Italy); **c.** 10/226 (EBU); **d.** 10/337 (Japan).

BIBLIOGRAPHY

OIRT [1985] Monography No. 3/1: Terms and definitions for the assessment of sound events by means of subjective evaluation of the quality of listening events.

REZVIAKOVA, Z. N. [1982] Predlozheniya po provedeniyu subyektivnoy otsenki kachestva zvuka (Proposal on subjective assessment of sound quality). *Radio i televidenye OEPT*, **5**, 17-29.

CCIR Documents

[1970-74]: CMTT/45 (France); 10/202 (United Kingdom).

RECOMMENDATION 644-1 *

AUDIO QUALITY PARAMETERS FOR THE PERFORMANCE OF A HIGH-QUALITY SOUND-PROGRAMME TRANSMISSION CHAIN

(1986–1990)

The CCIR,

CONSIDERING

(a) that the performance characteristics of international sound-programme circuits used for programme exchange are based on a hypothetical reference circuit (HRC) defined in Recommendation 502;

(b) that the performance of a realistic international sound-programme circuit shorter or longer than the HRC can be derived by calculation according to rules given in Recommendation 605;

(c) that the performance of the sound-programme transmission chain from the broadcasting house to the output of the receiver should therefore be based on a reference chain;

(d) that sound-programme signals intended for international exchange are conveyed from the broadcasting house to the international sound-programme centre (ISPC) on national circuits which are either the same as, or similar to, the national circuits which form part of the sound-programme transmission chain;

(e) that the performance of the sound-programme transmission chain should be described by a number of parameters;

(f) that for reasons of comparison, clearly defined parameters measured using test signals, should be used;

(g) that these parameters and their target values should be based on the perceptibility of the impairments by the human ear,

UNANIMOUSLY RECOMMENDS

1. that the performance characteristics of a high-quality sound-programme transmission chain should be based on the reference chain described in Annex I;

2. that the performance of the reference transmission chain from the output of the broadcasting house to the output of the receiver should be described by the parameters listed in Annex II;

3. that the limits given in Annex III be used as realistic target values for these parameters;

4. that for the purposes of planning the entire broadcasting chain from the microphone output to the receiver output, the subjective threshold values for quality parameters given in Annex IV should be taken for guidance.

ANNEX I

REFERENCE SOUND-PROGRAMME TRANSMISSION CHAIN

The reference sound-programme transmission chain is represented, for the purpose of this Recommendation, by Fig. 1 in which A, B, and C are 0 dBrs audio signal interface points, permitting performance comparison:

- A : interface between the programme source (broadcasting house) and the sound-programme circuit system;
- A-B : sound-programme circuit system comprising a single cable, radio, communication satellite or optical-fibre section;
- B : interface between the sound-programme circuit and emission-reception systems;
- B-C : emission-reception system, comprising a single broadcasting emitter or a single cable network and a high-quality monitoring receiver under optimum conditions;
- C : audio signal interface at the output of the receiver.

* This Recommendation, derived from Report 293 which has been cancelled, should be brought to the attention of the CMTT.

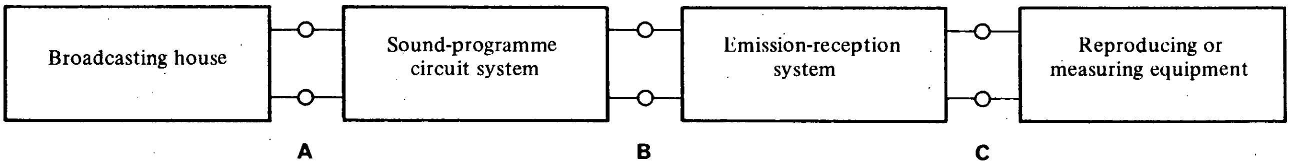

FIGURE 1 – *Reference sound-programme transmission chain*

The EBU [CCIR, 1986-90] has published Recommendation R.50 to define the polarity of acoustic signals, electrical audio signals, audio signals at connectors, magnetic signals on audio and video tapes, digital audio signals and acoustic pressure signals for loudspeakers.

REFERENCES

CCIR Documents

[1986-90]: 10/313 (EBU).

ANNEX II

LIST OF AUDIO QUALITY PARAMETERS

The audio quality parameters listed below are those which are considered to be the most important in the analogue environment. Some parameters are also appropriate for connections incorporating digital systems, but some further parameters need to be specified for testing these digital systems. *

All test signals should be at the measurement level (see Recommendation 645) unless otherwise stated. For stereo, measurements should be made in both A and B channels.

1. Nominal bandwidth

The effective transmitted frequency band (for both A and B channels, in the case of stereo).

2. Amplitude/frequency response

The response should be expressed relative to the level at the reference frequency of 1 kHz.

3. Group-delay variation

The results of measurements throughout the nominal bandwidth should be expressed relative to the minimum group delay.

4. Non-linear distortion **

Total harmonic distortion (THD) may be measured using a single-tone test signal at +9 dBu0s, at frequencies in the range from 40 Hz to 1 kHz, and the result expressed as a "separation" value (i.e. the difference in level between the test signal and the harmonics, expressed in dB).

* Administrations are requested to study quality parameters and testing methods for digital systems, and contribute to the work of the CCIR under Study Programme 51B/10. Report 1070 is alo relevant.

** Administrations are requested to consider these and other suitable distortion measurement methods, and contribute their conclusions to the CCIR under Study Programme 50E/10.

Distortion may, alternatively, be measured using the total difference frequency (TDFD) method [Thiele, 1975]. This is an intermodulation test in which the test signal comprises two tones at frequencies chosen so that second-order and third-order intermodulation products (i.e. one of each) occur close in frequency, and may be measured together by a meter with a selective filter. Tests in the UK [CCIR, 1986-90a] have shown that the TDFD method is less sensitive to noise than THD, and is not restricted to the use of test signals at frequencies below 5 kHz. This could be important when testing pre-emphasised connections, although care must be taken to avoid the possibility of overloading resulting from the pre-emphasis.

The TDFD method is described in Annex V.

The duration for which the test signals are transmitted should be restricted in accordance with the appropriate CCITT Recommendations of the N series.

5. Error in reconstituted frequency

The error in reconstituted frequency should not exceed the values in Annex III, for individual channels.

For stereo, any differential frequency shift between A and B channels is unacceptable.

A sensitive measuring method is described in [Thiele and Bonner, 1985].

6. Error in amplitude/amplitude response

A 1 kHz tone is applied to the input of the transmission chain at +9 dBu0s and at −31 dBu0s alternatively. The output levels should be measured selectively, and the difference should be within the limits specified in Annex III.

The duration for which the test signal is transmitted should be restricted in accordance with the appropriate CCITT Recommendations of N series.

7. Level stability

The difference in the level of a constant reference signal, at the measurement level, applied to the input of the transmission chain, from its nominal level should be determined for a 24 h period. This difference may vary over the 24 h period, and include a fixed adjustment error.

For stereo, the level stability should be determined concurrently for both A and B channels.

8. Noise (and single-tone interference)

Weighted noise voltage level (and, where appropriate, single-tone interference voltage level) is measured in accordance with Recommendation 468. The permitted maximum signal-to-(weighted) noise ratio (PMS/N, expressed in dB) is determined as the difference between the permitted maximum signal (PMS) and the weighted noise levels.

- Idle-channel noise.
- Programme-modulated noise, measured with a 60 Hz sinusoidal test signal applied to the input of the transmission chain at +9 dBu0s and −31 dBu0s. The fundamental and low-order harmonics are suppressed at the input to the measuring instrument by a high-pass filter with a cut-off frequency between 200 Hz and 400 Hz. The insertion loss of the filter should be at least 56 dB at 60 Hz, taking into account the attenuation of the weighting filter (24 dB at this frequency).

  The duration for which the test signal is transmitted should be restricted in accordance with the CCITT Recommendations of the N series.
- If necessary, steady single-tone interference should be measured selectively at the frequencies at which tones are detected or may be expected. The measurement should be made using a bandpass filter (having effectively 0 dB insertion loss in the passband) in conjunction with the noise measuring apparatus described in Recommendation 468, or using a spectrum analyzer and correcting the measured level by the corresponding weighting factor.

9. Disturbing modulation by power supply

This is the ratio of a 1 kHz sinusoidal test signal to the highest level unwanted side-component resulting from modulation of that test signal caused by interference from conventional a.c. (50/60 Hz) line power supply sources.

10. Stereo: level difference between A and B channels

The difference in level between the A and B outputs of the transmission chain should be measured with the same sinusoidal test signal applied to both channel inputs simultaneously.

11. Stereo: phase difference between A and B channels

The difference in phase between the A and B outputs of the transmission chain should be measured with the same sinusoidal test signal applied to both channel inputs simultaneously.

Conservation of the polarity [CCIR, 1986-90b] of audio signals is recommended.

12. Stereo: crosstalk between A and B channels

– *Linear cross-talk*

A sinusoidal test signal is applied to each channel in turn, and the level of the signal in the other channel is measured selectively. The cross-talk attenuation (expressed in dB) is the difference between the levels of the signal in the two channels.

– *Non-linear cross-talk*

The conventional test signal for simulating sound-programme signals specified in Recommendation 571 is applied to each channel in turn. If the other channel is influenced by non-linear cross-talk, an increase in the weighted noise level may be observed.

The increased noise voltage N_s formed by the sum of two noise contributions: the idle-channel noise N_0 and the non-linear cross-talk noise N_{cT}. The latter voltage can be calculated using the following formula:

$$N_{cT} = \sqrt{(N_s)^2 - (N_0)^2}$$

The non-linear cross-talk is expressed as the ratio of the permitted maximum signal to this level of non-linear cross-talk noise (i.e. PMS/N_{cT}).

REFERENCES

THIELE, A. N. [September, 1975] Measurement of non-linear distortion in a band-limited system. IREECON International Convention Digest, 480-482, Sydney, Australia.

THIELE, A. N. and BONNER, D. J. [September-October, 1985] Measuring reconstituted frequency error in f.d.m. sound-programme circuits. IREECON International Convention Digest, 684-686, Melbourne, Australia.

CCIR Documents

[1982-86]: **a.** 10/213 (Sweden); **b.** 10/224 (France).

[1986-90]: **a.** 10/236 (United Kingdom); **b.** 10/313 (EBU).

ANNEX III

TABLE I – *Realistic target values for the reference sound-programme transmission chain*

Parameter (for details see Annex II)	Test signal		Sound-programme circuit system (A-B) (1)	Emission-reception system (B-C) (1)	Whole reference chain (A-C) (1)
	Frequency	Level			
Nominal bandwidth (see § 1)	–	–	40 Hz-15 kHz	40 Hz-15 kHz	40 Hz-15 kHz
Amplitude/frequency response (see § 2)	40 Hz -125 Hz 125 Hz - 10 kHz 10 kHz- 14 kHz 14 kHz- 15 kHz	–12 dBu0s	+0.2/–1.0 dB +0.2/–0.2 dB +0.2/–1.0 dB +0.2/–1.4 dB	+0.4/–1.5 dB +0.4/–0.4 dB +0.4/–1.5 dB +0.4/–2.3 dB	+0.5/–2.0 dB +0.5/–0.5 dB +0.5/–2.0 dB +0.5/–3.0 dB
Group-delay/variation (see § 3)	40 Hz 15 kHz	–12 dBu0s	18 ms 4 ms	37 ms 8 ms	55 ms 12 ms
Total harmonic distortion (see § 4)	40 Hz -125 Hz 125 Hz - 1 kHz	+9 dBu0s	–46 dB –52 dB	–42 dB –48 dB	–40 dB –46 dB
Error in reconstituted frequency (see § 5)	Any	–12 dBu0s	0.2 Hz	0	0.2 Hz
Error in amplitude/amplitude response (see § 6)	1 kHz	+9 dBu0s –31 dBu0s	0.4 dB	0.8 dB	1.0 dB
Level stability (over 24-h period) (see § 7)	1 kHz	–12 dBu0s	0.6 dB	0.8 dB	1.0 dB
Noise and single-tone interference: – idle-channel noise – programme-modulated noise – programme-modulated noise – single-tone interference (see § 8)	 – 60 Hz 60 Hz –	 – –31 dBu0s +9 dBu0s –	 53 dB 53 dB 43 dB 73 dB	 56 dB 56 dB 46 dB 76 dB	 51 dB 51 dB 41 dB 71 dB
Disturbing modulation by power supply (see § 9)	1 kHz	0 dBu0s	51 dB	47 dB	45 dB
Level difference between A and B channels (see § 10)	40 Hz -125 Hz 125 Hz - 10 kHz 10 kHz- 14 kHz 14 kHz- 15 kHz	–12 dBu0s	1.0 dB 0.5 dB 1.0 dB 2.0 dB	1.0 dB 0.5 dB 0.5 dB 1.0 dB	1.5 dB 1.0 dB 1.5 dB 2.5 dB
Phase difference between A and B channels (see § 11)	40 Hz 40 Hz -125 Hz 125 Hz - 10 kHz 10 kHz- 15 kHz 15 kHz	–12 dBu0s	15° (2) 10° (2) 15°	10° (2) 8° (2) 10°	20° (2) 15° (2) 25°
Cross-talk between A and B channels: – linear cross-talk	40 Hz 40 Hz -300 Hz 300 Hz - 4 kHz 4 kHz- 15 kHz 15 kHz	0 dBu0s	46 dB (2) 56 dB (2) 46 dB	22 dB (2) (2) 26 dB	21 dB (2) 35 dB (2) 25 dB
– non-linear cross-talk (see § 12)	Sound programme simulating signal (see Recommendation 571)		60 dB	(3)	(3)

(1) The values given for sections A-B and B-C, and for the whole transmission chain (A-C) are desirable, and are to be taken into account when designing new national broadcasting networks.

(2) Values within this range are obtained by linear interpolation between the values for adjacent ranges on a graph with a logarithmic frequency scale.

(3) Administrations are requested to suggest target values.

ANNEX IV

Subjective threshold values are thresholds of perception, found by subjective statistical research under ideal listening conditions. They have been ascertained from test results obtained by CCIR members and from international literature.

TABLE II – *Subjective threshold values*

Parameter	Frequency of test signal	Subjective threshold value
Amplitude/frequency response (see § 2 of Annex II)	40 Hz -125 Hz 125 Hz - 10 kHz 10 Hz - 14 kHz 14 kHz- 15 kHz	±1.0 dB ±0.5 dB ±1.0 dB ±2.0 dB
Group delay variation (see § 3 of Annex II)	40 Hz-15 kHz	(see Note 1)
Non-linear distortion THD (see § 4 of Annex II)	40 Hz-1 kHz	−52 dB (see Note 2)
Error in reconstituted frequency (see § 5 of Annex II)	Any	0.25 Hz
Error in amplitude/amplitude response (see § 6 of Annex II)	1 kHz	(see Note 1)
Level stability (over a 24-h period) (see § 7 of Annex II)		1 dB (see Note 3)
Noise and single-tone interference: – idle-channel conditions – test signal level: +9 dBu0s – test signal level: −31 dBu0s – single-tone interference (see § 8 of Annex II)	 – 60 Hz 60 Hz –	 70 dB (see Note 1) (see Note 1) 80 dB
Disturbing modulation by power supply (see § 9 of Annex II)		(see Note 1)
Level difference between A and B channels (see § 10 of Annex II)	40 Hz -125 Hz 125 Hz - 10 kHz 10 kHz- 14 kHz 14 kHz- 15 kHz	2.0 dB 0.5 dB 1.5 dB 2.0 dB
Phase difference between A and B channels (see Note 4) (see also § 11 of Annex II)	40 Hz 40 Hz -125 Hz 125 Hz - 10 kHz 10 kHz- 15 kHz 15 kHz	45° (see Note 5) 30° (see Note 5) 90°
Cross-talk between A and B channels: – linear cross-talk – non-linear cross-talk (see § 12 of Annex II)	 40 Hz 40 Hz -300 Hz 300 Hz - 4 kHz 4 kHz- 15 kHz 15 kHz Sound-programme simulating signal (Recommendation 571)	 15 dB (see Note 5) 20 dB (see Note 5) 15 dB (see Note 1)

Note 1. – Administrations are invited to contribute figures for this value.

Note 2. – This figure assumes that the distortion is predominantly second and third harmonic.

Note 3. – A change of 1 dB is perceptible only if it is a sudden change.

Note 4. – The tolerances given for phase differences between A and B channels are for stereo listening, and they provoke unacceptable variations in the amplitude/frequency response of the mono (A + B) signal. The requirements for the mono signal therefore place a more stringent specification on the phase difference between A and B channels, and this is taken into account in the table of Annex III.

Note 5. – Values within this range are obtained by linear interpolation between the values for the adjacent ranges on a graph with a logarithmic frequency scale.

BIBLIOGRAPHY

HOEG, W. [1968] Beitrag zur Festlegung zulässiger Globalwerte für die Übersprechdämpfung stereophoner Übertragungssysteme (Contribution to the determination of admissible global values) (overall values) for cross-talk attenuation in stereophonic transmission systems). *Techn. Mitt. RFZ*, Vol. 12, **4**, 114-117.

OELMANN, J. [1983] Zur erforderlichen Übersprechldämpfung im Zweikanalton-Fernsehen (Required cross-talk attenuation for two-channel sound in TV). *Techn. Bei. IRT*, B 53-83.

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.

SPIKOFSKI, G. [March, 1985] Signal-to-noise ratio requirement for digital transmission systems. 77th AES Convention, Preprint No. 2196 (G-4).

STEFFEN, E. [1972] Untersuchungen zur Geräuschspannungsmessung (Investigations of noise measurements. *Techn. Mitt. RFZ*, Vol. 16, **3**, 81-84.

STOLL, G. [12-14 November, 1985] Experimente für Hörbarkeit von Aliasing-Verzerrungen (Experiments on the perceptibility of aliasing-distortions). Proc. Convention of NTG, Mannheim, Germany (Federal Republic of).

ANNEX V

SPECIAL METHODS FOR MEASURING AUDIO QUALITY PARAMETERS

1. **Measurement of non-linear distortion at high frequencies in preemphasized circuits** [CCIR, 1986-90a]

1.1 *Introduction*

Non-linear distortion in sound-programme circuits is most often measured by the total harmonic distortion (THD) method, in which a pure tone is input to the circuit as a test signal. At the output, the pure tone is removed from the signal by a filter, either high-pass or band-stop, and the signals remaining are measured as THD, with their magnitude expressed as a ratio with respect to the magnitude of the whole output signal.

Because non-linear distortion is commonly greatest at the highest levels in the circuit, it is usually tested at or very near to the maximum level of which the circuit is capable, in broadcasting practice, usually at the permitted maximum level (PML), i.e. +9 dBu0s.

If the frequency of the test signal is more than one-third the band limiting frequency, e.g. if in a 15 kHz circuit the testing signal is above 5 kHz, then any third harmonic components produced in the circuit will not reach the output, and the THD test is valueless.

Thus non-linearity in the upper half-decade of a band limited circuit, e.g. between 5 kHz and 15 kHz in a 15 kHz circuit, can be tested only by an intermodulation method, in which two tones at frequencies f_1 and f_2 are mixed together to produce the test signal, and the major in-band intermodulation products between them, at frequencies $f_2 - f_1$ for even-order distortion and $2f_1 - f_2$ for odd-order distortion, are measured and summed r.m.s. as a measure of the non-linearity of the circuit.

This test in fact measures the intermodulation, or "beat", products. It should be noted that it is the spurious inharmonic products that cause most, if not all, of the subjective degradation of sound quality due to non-linearity, rather than the harmonics which tend to simply add "brightness" to the sound.

The use of high-frequency preemphasis, for the purpose of reducing noise, increases the incidence and severity of such distortion and a method of measuring it is clearly essential.

1.2 *Test method*

Of the different methods that have been proposed for intermodulation testing, the preferred method is that in which the two test frequencies f_1 and f_2 are related as $2f_0$ and $3f_0 + \Delta$, where Δ is small [Thiele, 1983]. The major in-band intermodulation products are consequently at $f_0 + \Delta$ and $f_0 - \Delta$ for even-order and odd-order non-linearities respectively. These products are measured together through a band-pass filter of centre frequency f_0 and with a narrow pass-band of $\pm\Delta$, i.e. 2Δ wide. The filter removes the initial test signals and at the same time much of the in-band noise, making measurement possible to levels that are more than 10 dB below the broad-band noise in the circuit.

The test frequencies need to be as high in the band as possible, but not so high as to risk attenuation of the higher frequency components due to the roll-off of response near the band edge, which could affect the accuracy of the non-linearity measurement. In the test adopted in the draft revision of IEC Publication 268 - Sound system equipment: Part 3, Amplifiers - the two test frequencies are 8000 Hz and 11 950 Hz. In this configuration, f_0 is 4000 Hz and Δ is -50 Hz. This is shown schematically in Fig. 2.

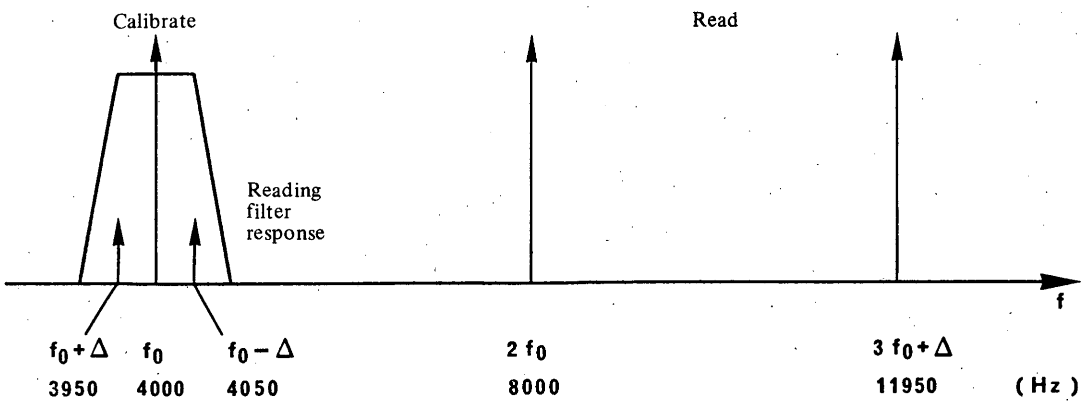

FIGURE 2 — *Frequencies of testing tones and in-band distortion products*

In the above method, the amplitudes of the two test tones at $2f_0$ and $3f_0 + \Delta$ are equal. The peak amplitude of a mixture of two equal amplitude tones, whose frequencies are not related by small whole numbers, is twice the peak amplitude of each individual tone. Thus, to test the circuit to a peak amplitude equal to that of a single sine wave at +9 dBu0s (PML), the amplitude of each tone must be +3 dBu0s. The power of this sum signal is twice that of each tone, i.e. equal to a single sine wave of +6 dBu0s in the above case. However it must be emphasized that the limitation on the level that can be carried by a programme circuit is always the peak amplitude, i.e. peak voltage, peak current, peak deviation, etc. which is twice the amplitude of each tone, i.e. 6 dB greater.

The r.m.s. magnitude of the sum of the in-band intermodulation products, measured through the band-pass filter, is expressed as a ratio with respect to the r.m.s. value of one of the component tones (sine waves) in the test signal, i.e. to a single sine wave at +3 dBu0s in the above case. This ratio is close numerically to that obtained by a THD measurement of the same non-linear mechanism, so that its significance is readily appreciated by staff more familiar with the older method. The magnitude of the test signal at the output may be measured directly by a true r.m.s. meter and using a level 3 dB lower for the reference level. This method is suitable when the magnitude of the level needs to be established only in the case of a measuring instrument, whose indicating device reads r.m.s.

1.3 *Need for calibration signal*

However, it is important that signals passing along sound-programme circuits can be monitored by the types of meters commonly used for level measurements in broadcasting studios. These do not read pure r.m.s. levels. Both the VU meter, which reads average, and the "peak programme meter" (PPM), which reads quasi-peaks, are calibrated using a sine wave signal and should therefore be sufficiently accurate for reading levels of single sine waves. They do not read true r.m.s., nor true peaks, for any other kind of signal, and in particular for a two-tone test signal. However this latter level can be inferred precisely from the readings of such meters by first sending, prior to the main test signal, a single sine wave calibrating signal whose level is standardized with respect to that of the two-tone test signal.

The calibrating sine wave is at frequency f_0, e.g. 4 kHz when $2f_0$ is 8 kHz. If its level was +3 dBu0s, it could be used directly to calibrate the reference level for the distortion measurements. However a signal at Alignment Level, 0 dBu0s, is more suitable, first for reading on vu meters, and secondly for testing circuits with high-frequency preemphasis, as is shown in Table III. As the signal is a sine wave, it can be read accurately by standard level meters, and with the frequency f_0, it passes directly through the band-pass filter used in measuring distortion, and thus provides a check on the calibration of the distortion reading instrument.

1.4 *Measurement in preemphasized circuits*

The two-tone method, measuring total difference-frequency distortion (TDFD), is superior to the THD method for measurements at all frequencies, but at high frequencies it is the only one that is effective. So far, it has been assumed that the transmission channel has a flat amplitude response, and that its peak amplitude capability is the same at all frequencies.

However, in broadcasting, such a capability can be expected only from amplifiers and studio quality digital equipment. In almost all other signal-handling processes, in recording, transmission and FM emission, the high frequencies are preemphasized to a standardized characteristic before passing through the main signal-handling process. At the output, the signal is deemphasized in a complementary manner. The purpose is to reduce the effect in the output of noise at the higher frequencies, on the implicit assumption that programme material rarely contains high-frequency components near the peak capability of the circuit. While this assumption may not be true for some kinds of programme material which is already preemphasized, especially some present-day programme material, the use of preemphasis is a convention which broadcasters have for a long time agreed to use.

A transmission circuit is tested conventionally by feeding a test signal into it at a point where the frequency response is flat, i.e. before any preemphasis. Likewise the output is read conventionally at a point where the frequency response is again flat, i.e. after deemphasis. Thus any test signal that is fed into the input of the circuit will reach the main transmission path in a preemphasized form. A high-frequency signal that is already optimized to fully load a flat circuit would therefore drastically overload the preemphasized path.

For example, if the IEC test signal comprised of a mixture of two tones at 8000 Hz and 11 950 Hz, each at +3 dBu0s, is passed through a circuit preemphasized to CCITT Recommendation J.17 with 6.50 dB loss at 800 Hz, its peak level, initially identical with that of a single sine wave at +9 dBu0s, will rise after preemphasis to the equivalent of +14.89 dBu0s. This is 2.89 dB above the overload point of +12 dBu0s specified for CCIR digital coding methods A1, A2, A3 and A4, and only 0.11 dB below the overload point of +15 dBu0s for Method B5 (see Report 647).

If however such a signal, optimized for testing a flat path, is first deemphasized to the same characteristic before feeding the input, it will reach the preemphasized path in exactly the same form, and test it to exactly the same extent, as it would have done unemphasized in a flat path. Such deemphasis does not require a frequency-sensitive network as the signal in comprised of only the two component tones at $2f_0$ and $3f_0 + \Delta$, the same effect is produced equally well by attenuating each by the appropriate deemphasis within the generator before they are mixed and fed to the input. At the output, the magnitude of the intermodulation products is compared with the reference level, which is taken as 3 dB below the r.m.s. sum of the two testing tones. Note that no complementary preemphasis is needed before reading the output signal. The ratio of distortion to total signal is measured as it appears in the output.

For the method in which the signal level is monitored by broadcasting level meters using a calibration tone at f_0, near 4 kHz, the level of the sum of the test tones, after deemphasis at the output, is inferred from the magnitude of the calibration tone. The difference is then estimated between the calibration level and the mean between the powers of the two testing tones, tabulated as "r.m.s. mean 8 kHz + 12 kHz" in Table III. The magnitude of the intermodulation products is then adjusted by this difference and read as a ratio to the calibration level. This involves attenuation of the distortion products by 3 dB in the flat condition and gains of various amounts for the different preemphasis standards. A schematic layout of the equipment is shown in Fig. 3.

Table III illustrates the levels in various parts of the circuit. It assumes that while no intermodulation products ($-\infty$ dBu0s) are present in the input test signal, intermodulation products at the same level, taken arbitrarily for the purpose of illustration as -37 dBu0s, are produced in each type of preemphasized path, when the test signal levels are identical. It thus demonstrates how, with increasing preemphasis, the same ratio of high-frequency intermodulation in the preemphasized path produces a greater ratio of in-band distortion products in the deemphasized output.

1.5 *Use with different preemphasis characteristics*

Although the frequencies of the test signals in the figures are those recommended in IEC Publication 268, Part 3, i.e. $2f_0$ at 8000 Hz and $3f_0 + \Delta$ at 11 950 Hz, slightly different sets of frequencies are used for the different preemphasis standards used in broadcasting. Figure 4 shows schematically how each set of frequencies is offset from its neighbour. An offset ratio of approximately 1.03 is sufficient to ensure that the signals for one preemphasis standard, with its special adjustments of level and gain, cannot be received by mistake in equipment set to receive another standard requiring different adjustments. With the pass-bands of the measurement filters each approximately $\pm$ 1% about f_0, any calibration signal received from a neighbouring channel will be attenuated by at least 30 dB. This procedure, if the control settings are inappropriate for the incoming signal, alerts the receiving operator, and makes measurement with the wrong preemphasis characteristic virtually impossible.

TABLE III – *Signal levels, gain adjustments and relative values for intermodulation measurements*

Pre-emphasis type		Flat	J.17	50 μs/15 μs	50 μs
Input level (dBu0s) before pre-emphasis					
calibration	4 kHz	0.0	0.0	0.0	0.0
component f_1	8 kHz	+3.0	−2.6	−3.7	−5.6
component f_2	≈ 12 kHz	+3.0	−3.1	−5.2	−8.8
distortion	≈ 4 kHz	−∞	−∞	−∞	−∞
Level (dBu0s) in pre-emphasized path					
calibration	4 kHz	0.0	+3.5	+3.5	+4.1
component f_1	8 kHz	+3.0	+3.0	+3.0	+3.0
component f_2	≈ 12 kHz	+3.0	+3.0	+3.0	+3.0
distortion	≈ 4 kHz	−37.0	−37.0	−37.0	−37.0
Output level (dBu0s) after de-emphasis					
calibration	4 kHz	0.0	0.0	0.0	0.0
component f_1	8 kHz	+3.0	−2.6	−3.7	−5.6
component f_2	≈ 12 kHz	+3.0	−3.1	−5.2	−8.8
r.m.s. mean	8 kHz + 12 kHz	+3.0	−2.8	−4.4	−6.9
distortion	≈ 4 kHz	−37.0	−40.5	−40.5	−41.1
Distortion ratio (dB)		−40.0	−37.7	−36.1	−34.2

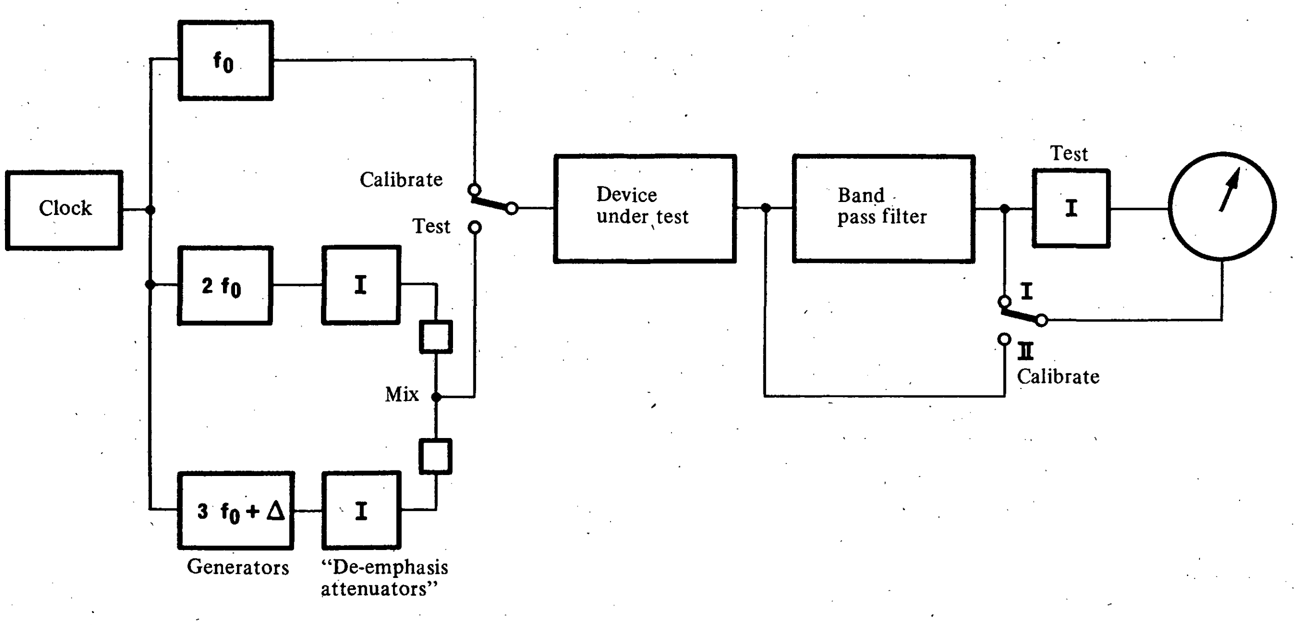

FIGURE 3 – *Block schematic of measuring equipment*

In mode I, calibrate and test signals are sent sequentially.

In mode II, test (two-tone) only signal is sent. Generator frequencies, attenuations and band-pass filters change with pre-emphasis.

It is anticipated that the flat or J.17 characteristics will be used in testing transmission chains, and the 50µs/15µs and 50µs characteristics in testing emission chains. A chain that is made up of links with different characteristics is tested for the one with the greatest high-frequency preemphasis.

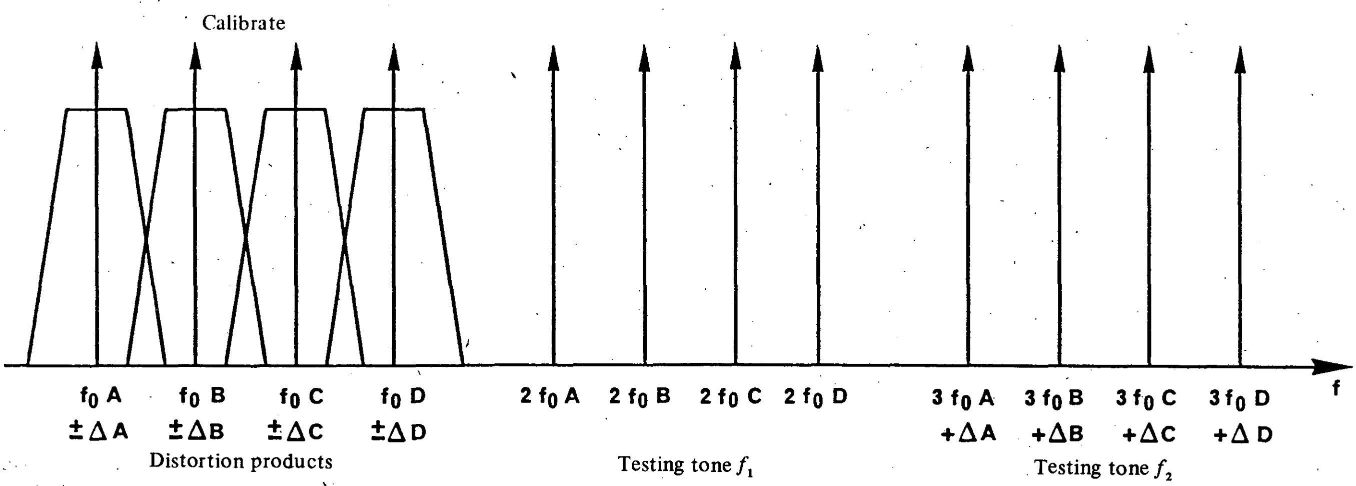

FIGURE 4 – *Testing tones and distortion products, with different pre-emphasis characteristics A, B, C and D*

1.6 *Conclusion*

The method described herein provides a straightforward method of measuring non-linear distortion at the upper end of the audio frequency band. It is easily used and allows measurements to be made in a variety of preemphasized circuits with a minimum risk of error in the alignment of levels or in the choice of preemphasis characteristics.

2. Method of measurement of impulsive noise [CCIR, 1986-90b]

During the transmission of sound signals, short duration noise frequently appears, which when acoustically reproduced is perceptible in the form of clicks and is disturbing to the listener. For the quality parameter "impulsive noise" there is at present no appropriate measuring procedure available which takes into account the subjective disturbing effect and the so-called annoyance factor.

Comprehensive subjective-statistical studies have been made in the German Democratic Republic on all the relevant factors that influence the subjective annoyance of pulses. As a result of these investigations the following method of measurement of impulsive noise has been suggested:

For the tone-compensated measurement of impulsive noise it is suggested that a "pulse weighted peak value $\hat{U}_{IW}$" which is defined as follows, should be determined:

$$\hat{U}_{IW}\,(\mathrm{dB}) = 20 \cdot \log \left(\frac{\hat{U}}{U_0}\right) + 20 \cdot \log (k_1 \times k_2 \times k_3)$$

where k_1, k_2 and k_3 are objective rating factors for the pulse duration t_i, pulse shape $u(t)$ and pulse repetition frequency f_p which result from predetermined subjective evaluation tables. The determination of the value $\hat{U}_{IW}$ can only be made with a computer-assisted method of measurement. To do this, the arriving pulse is first stored and analysed. The pulse amplitude U and the pulse duration t_i can directly be measured, likewise the period until the arrival of the next pulse. The pulse shape can be determined by spectral analysis by means of FFT analysers or (simpler) by comparison with previously determined standard pulse shapes. From the measured values for t_i, $u(t)$ and f_p the factors k_1, k_2 and k_3 can be determined using the subjective evaluation tables, and finally the value $\hat{U}_{IW}$ can be calculated.

When evaluating the quality of studio equipments and transmission links, the value $\hat{U}_{IW}$ may serve as a measure of the important parameter "impulsive noise". However, further studies are required to determine an admissible value.

REFERENCES

THIELE, A. N. [1983] Measurement of non-linear distortion in a band-limited system. Convention Digest, IREE International Electronics Convention, Sydney, Australia, 1975, 480-482: reprinted *JAES*, Vol. 31, **6**, June 1983, 443-445.

CCIR Documents

[1986-90]: **a.** 10/325 (Australia); **b.** 10/329 (German Democratic Republic).

BIBLIOGRAPHY

SCHAFFNER, H. [1988] Investigations of subjective assessment and objective measurement of impulsive noise in sound broadcasting channels (Untersuchungen zur subjektiven Beurteilung und objektiven Messung impulsartiger Störungen im Hörrundfunk-Tonkanal). Paper presented at the 8th "Broadcasting" meeting of ITG, Mainz, Federal Republic of Germany, November 1988 (see Proceedings).

WEINAUSE, N. [1988] Contribution to subjective assessment and objective measurement of impulsive noise in sound broadcasting channels (Beitrag zür subjektiven Bewertung und objektiven Messung impulsartiger Störungen im Hörrundfunk-Tonkanal). Dissertation at the College of Traffic and Telecommunication, Dresden, Federal Republic of Germany.

RECOMMENDATION 468-4*

MEASUREMENT OF AUDIO-FREQUENCY NOISE VOLTAGE LEVEL IN SOUND BROADCASTING

(Question 50/10)

(1970–1974–1978–1982–1986)

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.

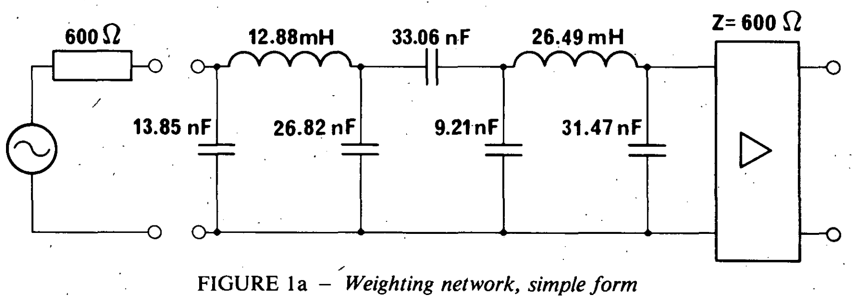

FIGURE 1a – *Weighting network, simple form*

(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 or by a different approach using an active filter [CCIR, 1982-86a].)

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

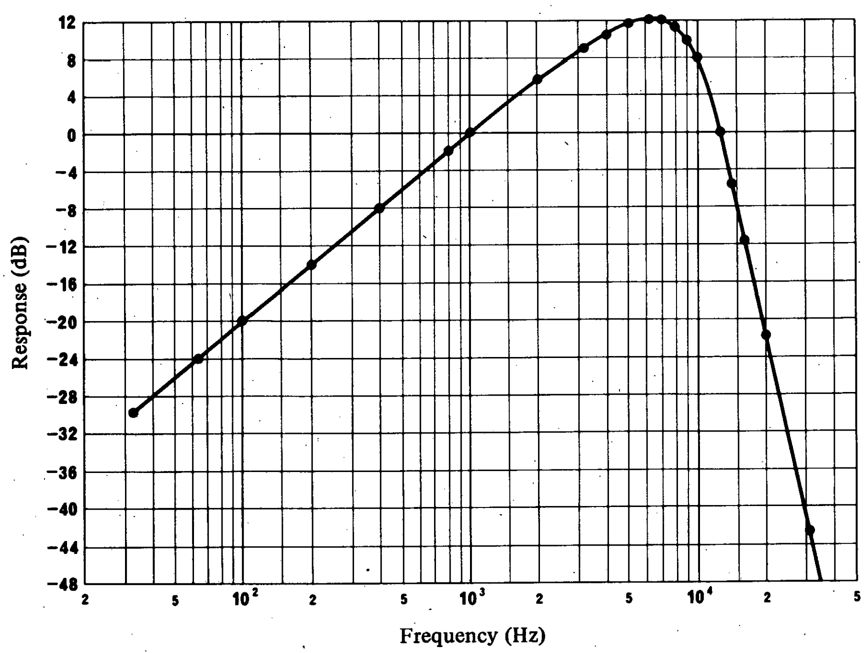

FIGURE 1b – *Frequency response of the weighting network shown in Fig. 1a*

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 (1)
400	− 7.8	±0.7 (1)
800	− 1.9	±0.55 (1)
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.

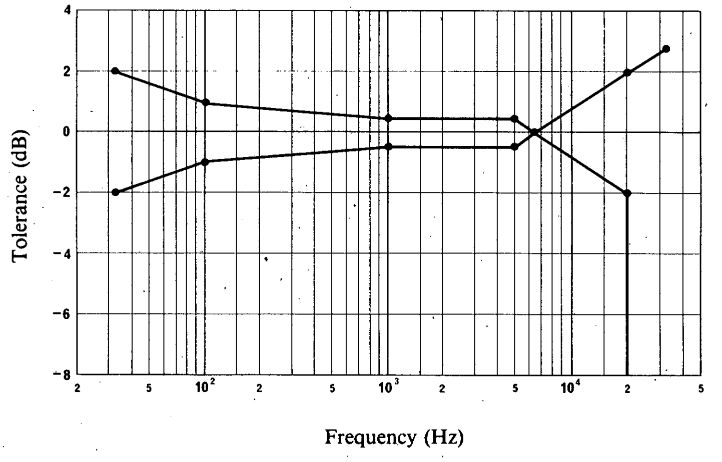

FIGURE 2 – *Maximum tolerances for the frequency response of the weighting network and the amplifier*

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).

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].

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 II.

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.

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 II

Burst duration (ms)	1 (1)	2	5	10	20	50	100	200
Amplitude reference steady signal reading (%)	17.0	26.6	40	48	52	59	68	80
(dB)	−15.4	−11.5	−8.0	−6.4	−5.7	−4.6	−3.3	−1.9
Limiting values								
– lower limit (%)	13.5	22.4	34	41	44	50	58	68
(dB)	−17.4	−13.0	−9.3	−7.7	−7.1	−6.0	−4.7	−3.3
– upper limit (%)	21.4	31.6	46	55	60	68	78	92
(dB)	−13.4	−10.0	−6.6	−5.2	−4.4	−3.3	−2.2	−0.7

(1) The Administration of the USSR intends to use burst durations ⩾ 5 ms.

TABLE III

Number of bursts per second	2	10	100
Amplitude reference steady signal reading (%)	48	77	97
(dB)	−6.4	−2.3	−0.25
Limiting values			
– lower limit (%)	43	72	94
(dB)	−7.3	−2.9	−0.5
– upper limit (%)	53	82	100
(dB)	−5.5	−1.7	−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 $\geqslant 20$ kΩ and if an input termination is provided then this should be 600 Ω ± 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).

[1982-86]: **a.** 10/248 (Australia).

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

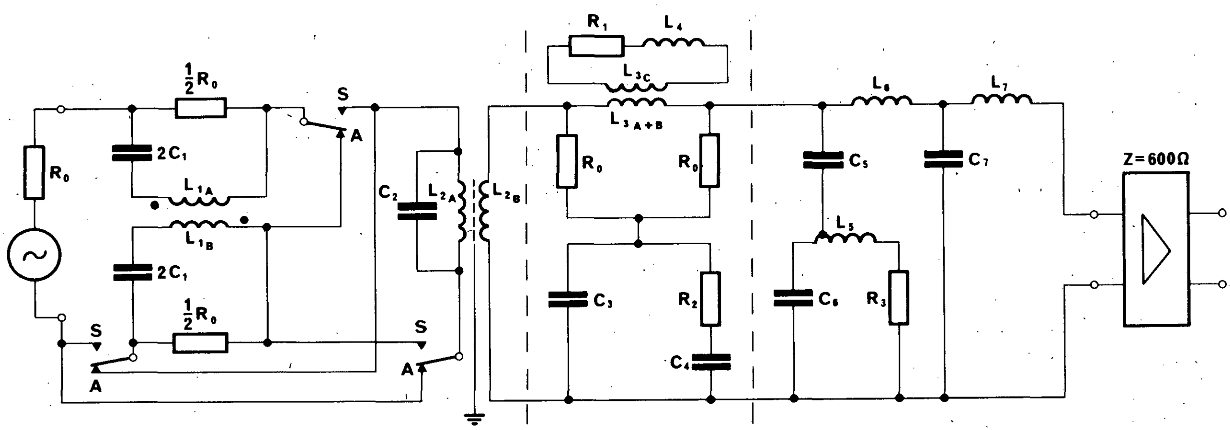

FIGURE 3 – *Constant resistance realization of weighting network*

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
A: unbalanced		L_7:	8.00
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.

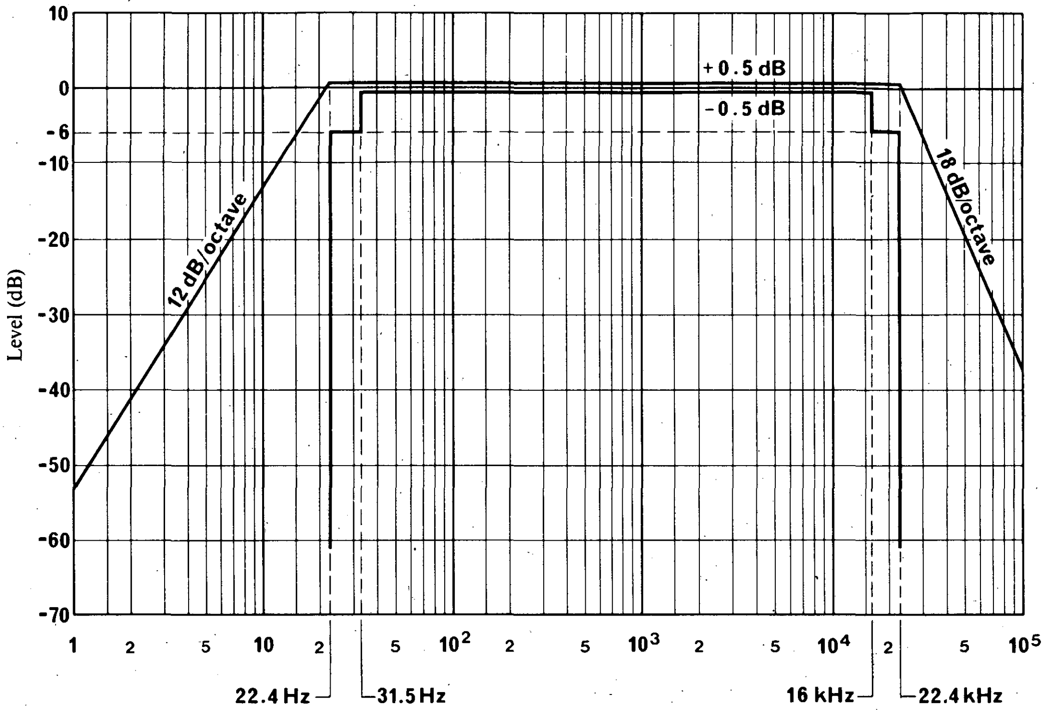

FIGURE 4

BIBLIOGRAPHY

CCIR Documents

[1978-82]: 10/76 (CMTT/14) (Canada).

RECOMMENDATION 645-1 *

TEST SIGNALS TO BE USED ON INTERNATIONAL SOUND-PROGRAMME CONNECTIONS

(Questions 50/10 and 19/CMTT, Study Programmes 50B/10 and 50E/10)

(1986-1990)

The CCIR,

CONSIDERING

(a) that many impairments in international programme exchange on sound-programme connections are attributed to different national test signal definitions;

(b) that some existing definitions are found in different Recommendations of the CCITT and the CCIR;

(c) that for clarification, a list of those definitions should be available,

UNANIMOUSLY RECOMMENDS

that for an international sound-programme connection only the test signals defined below should be used:

1. Alignment signal (AS)

Sine-wave signal at frequency of 1 kHz, which is used to align the international sound-programme connection. The signal level corresponds to dBu0s (see Note) (i.e. 0.775 V r.m.s at a zero relative level point). In accordance with CCITT Recommendation N.13, the period of sending the alignement signal should be kept as short as possible – preferably to less than 30 s.

Note – The notation "dBu0s" is defined in Recommendation 574. Other related texts of the CMTT use the notation "dBm0s" also defined in Recommendation 574.

2. Measurement signal (MS)

Sine-wave signal at a level 12 dB below the alignment signal level which should be used for long-term measurements and measurements at all frequencies (see CCITT Recommendations N.12, N.13, N.21 and N.23).

3. Permitted maximum signal (PMS)

Sine-wave signal at 1 kHz, 9 dB above the alignment signal level, equivalent to the permitted maximum programme-signal level. The sound-programme signal should be controlled by the sending broadcaster so that the amplitudes of the peaks only rarely exceed the peak amplitude of the PMS.

Note – Under these conditions a peak programme meter will indicate levels not exceeding the level of the permitted maximum signal.

A numerical example may serve to clarify this definition. The alignment signal has an r.m.s. voltage of 0.775 V and a peak amplitude of 1.1 V at a zero relative level point. The instantaneous peak amplitude of the sound-programme signal at this point should only rarely exceed 3.1 V.

Although it is intended that the peaks of the sound-programme signal should not exceed the permitted maximum signal level, an overload margin must be provided so that rare excursions of the sound-programme signal above the permitted maximum signal level may be tolerated.

Note – Annex I describes the response of peak programme and vu meters to these test signals.

* The CMTT and Study Group 10 will coordinate the future development of this Recommendation. This Recommendation should be brought to the attention of Study Group IV of the CCITT.

ANNEX I

ALIGNMENT USING THE RECOMMENDED TEST SIGNALS WITH PEAK PROGRAMME METERS AND VU METERS

1. Broadcasters have evolved, over a period of forty years, procedures for using both types of meter to control programme levels. These procedures are satisfactory to the organizations using them, so that they produce neither over-modulation, leading to distortion, nor under-modulation, leading to impairment from noise.

Although different kinds of programme material deflect the two meters differently, the organizations using them have evolved techniques that produce satisfactory level control and artistic balance within the programme.

2. The sensitivity of peak programme meters (PPM) is such that a sine wave signal at the alignment level, 0 dBu0s, indicates "test" on an EBU PPM (this corresponds to "4" on the BBC PPM and "−9" on the PPMs of the Federal Republic of Germany and the OIRT (see Fig. 1)).

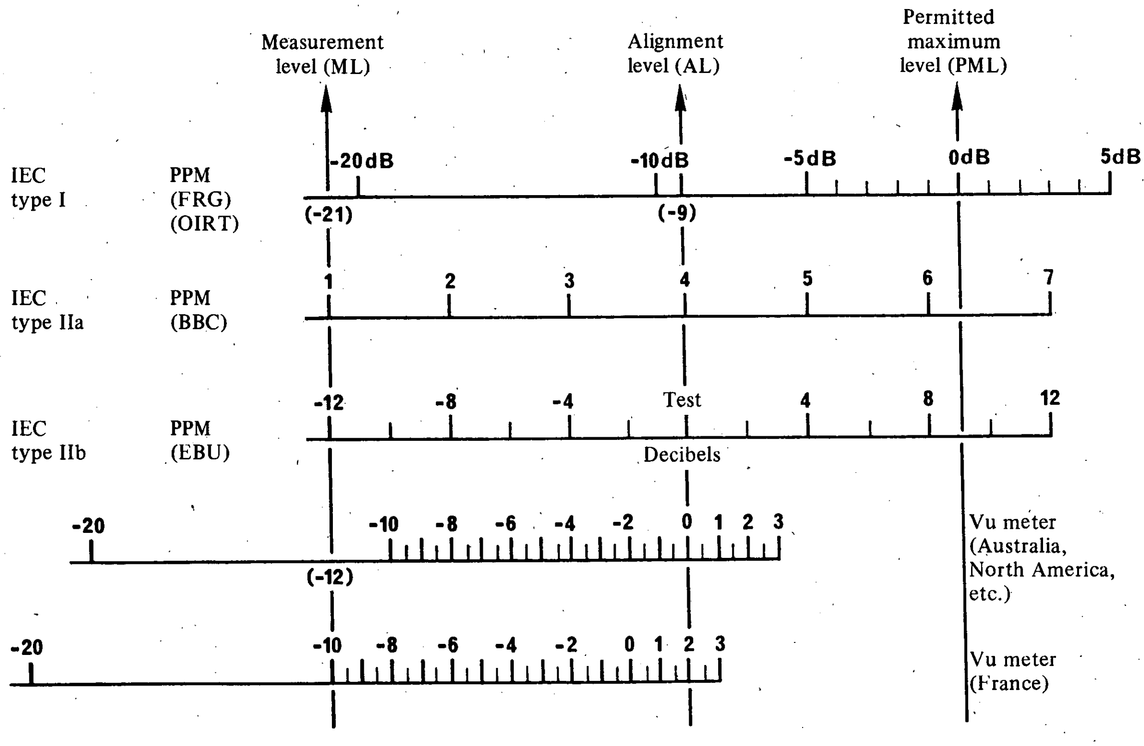

FIGURE 1 – *Indications produced by various types of programme meter with the recommended test signals*

Note. – Meter indications are schematic – not to scale.

3. The sensitivity of the vu meter is such that a sine wave signal at the alignment level, 0 dBu0s, produces nearly full indication, 0 vu in Australia and North America and +2 vu in France (see Fig. 1).

4. The PPM reads "quasi-peak", that is, its peak indication on programme signals reads a little lower than true peaks. Operators are instructed to make the programme peaks give the same indication as a sinusoidal tone at +9 dBu0s (+8 dBu0s in some organizations). The true peaks of the programme are higher than indicated by up to 3 dB. When, additionally, operator errors are taken into account, the true peaks of the programme signal may reach the amplitude of a sinusoidal tone at +15 dBu0s.

5. The vu meter indicates the mean level of the programme, which is generally much lower than the true peak. Operators are instructed to make programmes peak generally to the 0 vu reading. Experience has shown that the true programme peaks are higher than indicated by between +6 dB and +13 dB, depending on the programme material. When, additionally, operator errors are taken into account, the true peaks of the signal may be up to 16 dB higher than indicated, corresponding to the peak amplitude of a sinusoidal tone at +16 dBu0s, or alternatively +14 dBu0s when application of the alignment level signal results in +2 vu indication.

6. Thus, although the dynamic characteristics of the two meters are different, the highest peak levels encountered after control using either meter are very similar.

7. Thus, an international connection between broadcasters will be correctly aligned regardless of the type of meter employed when a sinusoidal signal at alignment level, 0 dBu0s, produces the indication appropriate to that level at both the sending and receiving ends of the circuit.

To avoid any confusion between alignment level and other levels that might be used, it is recommended that the three level tone test signal described in Recommendation 661 be used for the alignment of an international sound-programme connection.

Figure 1 illustrates the indications given by a number of programme level meters when the recommended test signals are applied to them.

RECOMMENDATION 708*

DETERMINATION OF THE ELECTRO-ACOUSTICAL PROPERTIES OF STUDIO MONITOR HEADPHONES

(Question 50/10, Study Programme 50F/10)

(1990)

The CCIR,

CONSIDERING

(a) that unified and closely specified reference listening conditions are an essential prerequisite for subjective assessment and quality control;

(b) that there are great difficulties in harmonizing the acoustical characteristics of existing control rooms and listening rooms;

(c) that some aspects of the audio signal are more clearly perceptible by using headphones than by using loudspeakers;

(d) that the frequency response of studio monitor headphones should provide the same sound-colour neutrality as required for loudspeaker monitoring in control rooms and high-quality listening rooms,

UNANIMOUSLY RECOMMENDS

1. that the frequency response curve measured in accordance with Annex II should be flat within the limits specified in Annex I;

2. that the frequency response of studio monitor headphones should be measured in accordance with Annex II;

3. that the difference of frequency response between left and right earphone should not exceed 1 dB in the frequency range 100 Hz-8 kHz and 2 dB in the frequency range 10 kHz-16 kHz.

ANNEX I

SPECIFICATION OF TOLERANCES

The frequency response requirement for studio monitor headphones is defined by Fig. 1. The tolerance mask for the diffuse-field frequency response shown in Fig. 1 is based on measuring accuracy achievable by means of 16 test subjects.

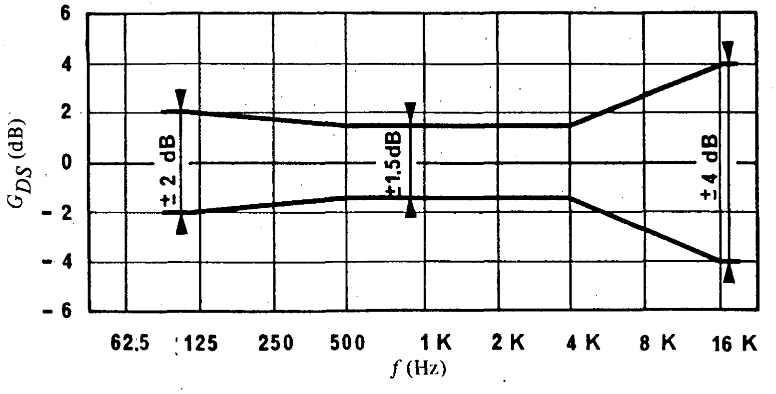

FIGURE 1 – *Tolerance mask for the diffuse-field frequency response of studio monitor headphones*

G_{DS}: diffuse-field earphone response (dB(Pa/V))

* This Recommendation should be brought to the attention of the IEC and the Audio Engineering Society (AES).

ANNEX II

DIFFUSE-FIELD FREQUENCY RESPONSE OF STUDIO MONITOR HEADPHONES

Measurement specification

1. General

The measurement procedure is used to determine the frequency response of the individual earphones of a headphone as a function of the frequency by means of sound-pressure measurements in the auditory canals of test subjects. In the direct measurement procedure the sound pressure in the auditory canal caused by the headphone is compared with that caused by the reference sound field. In the indirect procedure, the sound field is replaced by a reference headphone calibrated by means of the direct method. The reference sound field is the diffuse sound field [CCIR, 1986-90a].

The measuring set-up consists of signal source and signal receiving equipment. The source comprises a noise generator, third-octave filters, at least one loudspeaker or a reference headphone and the headphone to be tested. It is also possible to use a real-time third-octave analyser to which a suitable wideband noise signal is applied. The receiving equipment contains a miniature or probe-mounted microphone to measure the sound pressure in the outer auditory canals of the test subjects and, if the direct procedure is used, a calibrated microphone with a known diffuse-field frequency response to measure the unweighted sound-pressure level in the reverberation chamber. The signal voltages of the microphones and loudspeakers should be determined by means of an r.m.s.-reading voltmeter with a sufficient integration time.

2. Probe microphone

The following requirements apply to the probe-mounted microphone, which is called "probe" in this text:

- the sound pickup should take place within the auditory canal at least 4 mm away from its beginning;
- in the area of the auricle and the outer 4 mm of the auditory canal the probe should not have a cross-section of more than 5 mm^2;
- in the following part of the auditory canal the ratio between the probe cross-section and the auditory canal section should be less than 0.6. (The average auditory canal cross section of an adult is approximately 45 mm^2.) The probe volume including fixing elements should be smaller than 130 mm^3;
- no special requirements are made for the transfer function of the probe. However, the response of the probe should be free of resonances. It is sufficient that the response of neighbouring third octaves does not differ by more than 3 dB;
- it should be guaranteed that, with an occluded ear, the probe output level is at least 15 dB below that obtained with an open ear;
- fixing elements are necessary to keep the probe at a central position in the auditory canal. The spring suspension of these elements should be dimensioned such that the probe fits sufficiently well into auditory canals with different cross-sections and can still be inserted and removed easily;
- the probe should be inspected and certified for use with regard to medical aspects by a physician.

3. Direct method of measurement

This method is based on a comparison of output voltage levels of a probe placed in the outer auditory canal of a test subject when a noise signal is produced by alternating sources, namely the headphone under test and a diffuse sound field of a reverberation chamber.

3.1 *Test signals*

The preferred sound signals are filtered noise signals that are obtained from pink noise by means of third-octave filters, specified in IEC Publication 225 (type b). The probe output has to be measured selectively in third octave steps. This can be done successively or at the same time with a real-time third octave analyser. The sound pressure levels of the test signals should be such that the input signals at the microphone amplifier are at least 10 dB above the inherent electric noise level and the noise level ensuing from body noise in the auditory canal. The sound pressure level at the reference point must not exceed 85 dB. The headphone voltage should be adjusted such that, at a third octave centre frequency of 500 Hz, the output level of the probe matches the output for the diffuse sound field within 3 dB.

3.2 *Diffuse sound field*

The sound field in the reverberation chamber is considered sufficiently diffuse if the following requirements are satisfied: *

- In the absence of the test subject the sound pressure level measured by means of an omnidirectional microphone at a distance of 15 cm before, behind, right and left of, above and below the reference point (entrance of the auditory canal of the test subject) must not deviate from the sound pressure level at the reference point by more than 2 dB;
- in the absence of the test subject the sound pressure level should be measured at the reference point using a directional microphone which has a directivity index of at least 8 dB above 500 Hz. The sound pressure level in each third-octave band $\geqslant$ 500 Hz must not deviate by more than 3 dB independent of the direction of the microphone.

3.3 *Test subjects*

The measurements in the auditory canal have to be done with at least 16 persons. Spectacles and earrings etc., have to be taken off, and the ear should not be covered by hair. There are no special requirements on the hearing ability of test subjects, but the measured outer ear should not show abnormalities. If the probe does not fit sufficiently well into the auditory canal due to its dimensions, the person concerned cannot be employed as a test subject.

The test subjects should move as little as possible during measurements. The headphone has to be worn as intended by the mechanical construction especially regarding right and left hand earphones. The test subject should take care that the headphone fits as comfortably and at the same time as tightly as possible, and should carefully put the headphone on and off himself.

3.4 *Measurement procedure*

Before the measurement the probe is inserted into the test subject's auditory canal. The position in the auditory canal is uncritical provided that it lies at least 4 mm inwards. The microphone cable or the probe tube is fixed below the auricle, e.g. by a strip of plaster. The probe in the auditory canal should not change position perceptibly when the headphone is put on and off.

The probe output voltage is measured for each frequency band when the test subject is exposed to sound waves in the sound field (first sound-field measurement). Immediately afterwards the test subject carefully puts on the headphone, and the voltage received from the probe is then measured for each frequency band (first earphone measurement). After the test subject has put off the headphone and put it on again, the second earphone measurement is carried out. Then measurements on a different type of headphone may follow. Finally, the measurement in the sound field is repeated (second sound-field measurement).

In order to make sure that the probe has not moved during the whole measurement cycle — which is an indispensable prerequisite for a correct result — the probe voltage levels of the first and second sound-field measurement are compared. If the value measured in one of the frequency bands deviates by more than 2.5 dB, the whole measurement cycle must be repeated. If the repeated measurements also show differences of more than 2.5 dB, the test subject should be replaced by another one.

3.5 *Determination of individual diffuse-field frequency responses*

The arithmetic mean value of the probe voltage levels of the first and second sound-field measurement is calculated for each frequency band. The same applies to the voltage levels of the two earphone measurements. These mean values are then used to determine the individual diffuse-field frequency response of the tested earphone by means of:

$$G_{DSi}\,(\text{re } 1\ \text{Pa/V}) = 20 \log \frac{U_{SK}}{U_{SD}}\ \text{dB} + L_D - 94\ \text{dB} - 20 \log \frac{U_K}{U_0} \qquad \text{dB}$$

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* These requirements are met in reverberation chambers intended for acoustical measurements. If such a chamber is not available, the diffuse-field frequency response of studio monitor headphones should be determined by means of the indirect measurement procedure (see § 4).

where:

G_{DSi} : individual diffuse-field earphone response per frequency band,

U_{SK} : r.m.s. probe output voltage with earphone as sound source,

U_{SD} : r.m.s. probe output voltage in the diffuse field,

U_K : r.m.s. input voltage in the earphone,

U_0 : reference voltage 1 V,

L_D : diffuse-field sound pressure level at reference point.

3.6 *Determination of the diffuse-field frequency response*

The diffuse-field frequency response of the earphone G_{DS} is determined by arithmetically averaging the results G_{DSi} of the test persons in each frequency band. Also the standard deviation should be calculated.

4. Indirect method of measurement

If the diffuse-field frequency response of a headphone was determined by means of the direct procedure, this headphone can be used as a reference instead of the diffuse sound field. The methods of direct measurements then apply correspondingly. The individual diffuse-field frequency response of the tested earphone is determined by:

$$G_{DSi}\,(\text{re } 1\ \text{Pa/V}) = G_{DSr} + 20\log\frac{U_B}{U_K}\ \text{dB} - 20\log\frac{U_{SB}}{U_{SK}} \qquad \text{dB}$$

where:

G_{DSr} : individual diffuse-field response per frequency band of the reference earphone,

U_{SB} : r.m.s. probe output voltage with reference earphone as sound source,

U_B : r.m.s. input voltage at the reference-earphone.

If the indirect method of measurements has been chosen, the type and diffuse-field frequency response of the reference headphone has to be indicated.

REFERENCES

CCIR Documents

[1986-90]: **a.** 10/281 (Germany (Federal Republic of)).

BIBLIOGRAPHY

SPIKOFSKI, G. [1988] The diffuse-field probe transfer function of studio-quality headphones. *EBU Rev. Tech.*, **229**, 111-126.

THEILE, G. [1986] On the standardisation of the frequency response of high-quality studio headphones, *J. Audio Eng. Soc.*, Vol. 34, 956-969.

RECOMMENDATION 646*

SOURCE ENCODING FOR DIGITAL SOUND SIGNALS IN BROADCASTING STUDIOS

(Question 51/10, Study Programme 51B/10)

(1986)

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-programmes and for sound accompanying television programmes in studio applications;

(c) that this sampling frequency should be simply related to the 32 kHz sampling frequency recommended for transmission links, and for satellite broadcasting by the CCIR in order to reduce the cost of transcoding equipment;

(d) that the dynamic range has to provide adequate headroom for processing, taking account that at least a 14 bits dynamic range is recommended for transmission links and satellite broadcasting,

UNANIMOUSLY 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;

3. that when an item of digital audio equipment is operating in a free-running mode, the maximum tolerance for the internal sampling frequency should be $\pm 1 \times 10^{-5}$. When items of digital audio equipment are interconnected, in sound broadcasting or television applications, provision must exist for locking the internal sampling frequency clocks to an external sampling frequency (e.g. television synchronizing signals, broadcasting house master clock, high-accuracy clock from a telecommunication network);

4. that the coding used should have a minimum resolution equivalent to 16 bits per sample uniform coding;

5. that no pre-emphasis should be used.

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* This Recommendation should be brought to the attention of Study Group 11 and the CMTT.

RECOMMENDATION 647-1 *

A DIGITAL AUDIO INTERFACE FOR BROADCASTING STUDIOS

(1986–1990)

The CCIR,

CONSIDERING

(a) that there will be a need to interconnect in the digital domain the various different items of digital audio equipment that will be found in broadcasting studios; these will include digital audio tape recorders, the audio system of digital video tape recorders, mixers, etc.;

(b) that there would be advantages if all equipment used the same interface connections;

(c) that the interface should make allowance for processing headroom in terms of resolution;

(d) that the interface should allow for auxiliary data of various kinds;

(e) that changes to this Recommendation should be made only after due consideration and study,

UNANIMOUSLY RECOMMENDS

1. that the interface described in the Annexes I and II should be adopted.

2. that proposals for the amendment of this Recommendation should first be attached to Annex III to this Recommendation for consideration prior to their possible adoption by the CCIR and the consequent amendment of Annex I or Annex II.

ANNEX I

1. Introduction

This Recommendation describes a serial interface for the interconnection of digital audio equipment within a broadcasting complex, using cables up to a few hundred metres in length.

This interface is primarily designed to carry monophonic or stereophonic programmes in a studio environment, at a 48 kHz sampling frequency and with a resolution of up to 24 bits per sample (source signals should be sampled and encoded in accordance with Recommendation 646). The interface may also be used to carry one or two channels sampled at 32 kHz. Clock references and auxiliary information are transmitted along with the programme.

A number of these interfaces may be used for the interconnection of multi-channel equipment.

Note – In this interface specification for professional applications, mention is also made of an interface for consumer applications. The two interfaces are not identical.

2. Terminology

2.1 *Sampling frequency*

The sampling frequency is the frequency of the samples representing an audio signal. When two signals are transmitted through the same interface, the sampling frequencies must be identical.

2.2 *Audio sample word*

The audio sample word represents the amplitude of a digital audio sample. Representation is linear in 2's complement binary form. Positive numbers correspond to positive analogue voltages at the input of the analogue-to-digital convertor.

The number of bits allocated per word is either 24 or 20. If the source provides fewer bits than the interface format requires, the unused least significant bits shall be set to the logical 0.

If the number of bits allocated is 20, the 4 bits which become available may be used to provide up to two voice-quality audio channels, one in the "A" sub-frames and one in the "B" sub-frames. Further details are given in Annex II.

* This Recommendation should be brought to the attention of the IEC and the Audio Engineering Society (AES).

2.3 *Validity flag*

The validity flag is associated with each audio sample word and indicates whether its value is reliable or not.

2.4 *Channel status*

The channel status carries, in a fixed format, information associated with each audio channel which is decodable by any interface user. Examples of information to be carried in the channel status are: length of audio sample words, pre-emphasis, sampling frequency, time codes, alphanumeric source and destination codes.

2.5 *User data*

A user data channel is provided to carry any other information. The organisation of user bits is not constrained; however, there are advantages in adopting a block structure similar to that of channel status (see § 2.10 and 3.6).

2.6 *Parity bit*

A parity bit is provided to permit the detection of an odd number of errors resulting from malfunctions in the interface.

2.7 *Preambles*

Preambles are specific patterns used for synchronization. There are three different preambles, which are described in § 3.4.

2.8 *Sub-frame*

The sub-frame is the fixed structure used to carry the information described in § 2.2 to 2.7 above. Two sub-frames, one for each audio channel, are transmitted in sequence in any period of the source sampling frequency.

2.9 *Frame*

The frame is a sequence of two sub-frames.

2.10 *Block*

The block consists of a group of 192 consecutive frames, providing for each channel the 192 channel status data bits and 192 user data bits. The start of a block is designated by a special sub-frame preamble.

2.11 *Channel coding*

The channel coding describes the method by which the binary digits are represented for transmission through the interface.

3. Interface format

3.1 *Sub-frame format*

Each sub-frame is divided into 32 time slots, numbered from 0 to 31 (Fig. 1).

- *Time slots 0 to 3* carry one of the three permitted preambles denoted by X, Y, or Z. These are used to effect synchronization of sub-frames, frames and blocks.
- *Time slots 4 to 27* carry the audio sample word in linear 2's complement representation. The most significant bit is carried by time slot 27.
- When a 24-bit coding range is used, the least significant bit is in time slot 4.
- When a 20-bit coding range is sufficient, the least significant bit is in time slot 8, and time slots 4 to 7 may be used for other applications (to carry voice-quality signals for commentary, coordination or talk-back for example) as described in Annex II. Under these circumstances, the bits in the time slots 4 to 7 are designated auxiliary sample bits.

If the source provides fewer bits than the interface allows (24 or 20), the unused least significant bits must be set to a logical 0. By this procedure, equipment using different numbers of bits may be connected together.

- *Time slot 28* carries the validity flag associated with the audio sample word. This flag is set to 0 if the audio sample is reliable. It is set to 1 if unreliable.
- *Time slot 29* carries one bit of the user data channel associated with the audio channel transmitted in the same sub-frame.
- *Time slot 30* carries one bit of the channel status word associated with the audio channel transmitted in the same sub-frame.
- *Time slot 31* carries a parity bit such that time slots 4 to 31 inclusive will carry an even number of ones and an even number of zeros.

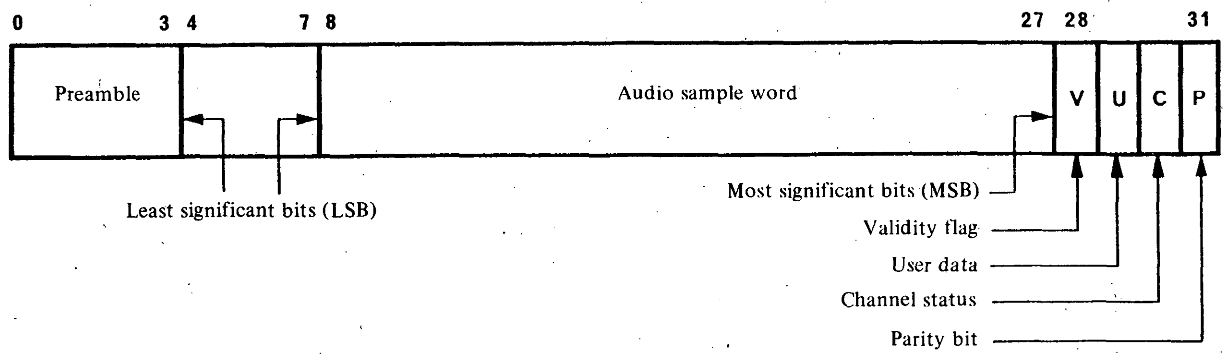

FIGURE 1 – *Sub-frame structure*

3.2 *Frame format*

A frame is uniquely composed of two sub-frames (Fig. 2). The rate of transmission of frames will correspond exactly to the source sampling frequency.

In the two-channel operation mode, the samples taken from both channels are transmitted by time multiplexing in consecutive sub-frames. Sub-frames related to the channel 1 (left of "A" channel in stereophonic operation and primary channel in monophonic operation) normally use preamble X. However, the preamble is changed to preamble Z once every 192 frames. This defines the block structure used to organize the channel status information (see § 3.5).

Sub-frames of channel 2 (right or "B" in stereophonic operation and secondary channel in monophonic operation) always use preamble Y.

In the single-channel operation mode, only channel 1 is used. In the sub-frames devoted to channel 2, time slot 28 (validity flag) has to be set to 1 (sample not valid).

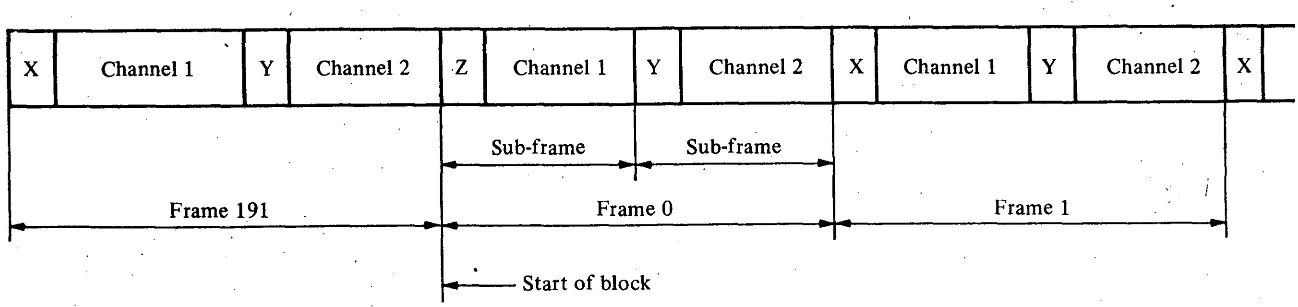

FIGURE 2 – *Frame structure*

3.3 *Channel coding*

To minimize the d.c. component on the transmission line, to facilitate clock recovery from the data stream and to make the interface insensitive to the polarity of connections, time slots 4 to 31 are encoded in biphase-mark.

Each bit to be transmitted is represented by a symbol comprising two consecutive binary states. The first state of a symbol is always different from the second state of the previous symbol. The second state of the symbol is identical to the first if the bit to be transmitted is 0. It is different if the bit is 1 (Fig. 3).

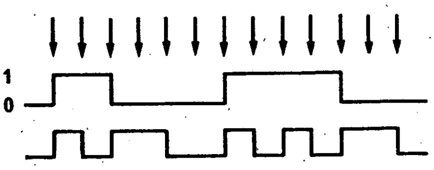

FIGURE 3 – *Channel coding*

3.4 *Preambles*

Preambles are specific patterns providing synchronization and identification of the sub-frames, frames and blocks. To achieve synchronization within one sampling period, and to make this process completely reliable, these patterns violate the biphase-mark code rules, thereby avoiding the possibility of data imitating the preambles.

A set of three preambles is used. These preambles are transmitted in the time allocated to four symbols (time slots 0 to 3) and are represented by eight successive states. The first state of the preamble is always different from the second state of the previous symbol (representing the parity bit). Depending on this state (see Note), the preambles are:

either:	preamble X:	11100010	(sub-frame 1)
	preamble Y:	11100100	(sub-frame 2)
	preamble Z:	11101000	(sub-frame 1 and block start)
or:	preamble X:	00011101	
	preamble Y:	00011011	
	preamble Z:	00010111	

Like biphase code, these preambles are d.c. free and provide easy clock recovery. They differ in at least two states from any valid biphase sequence or on any biphase sequence offset by one state, as illustrated in Fig. 4 for preamble X.

Note – Owing to the even parity bit in time slot 31, all preambles will start with a transition in the same direction (see § 3.1). Thus only one of these sets of preambles will, in practice, be transmitted through the interface. However, it is necessary for either set to be decodable because a polarity reversal may occur in the connection.

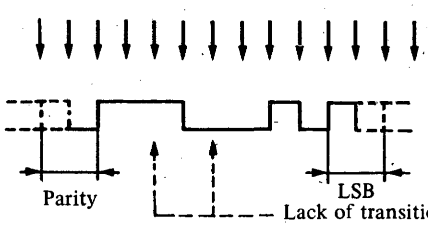

FIGURE 4 – *Preamble X (11100010)*

3.5 *Channel status data format*

The channel status for each audio signal carries information associated with that audio signal. Thus, it is possible for different channel status data to be carried in the two channel status signals.

The channel status data is organized into byte-wide increments. There will thus be 24 bytes per block (Fig. 5).

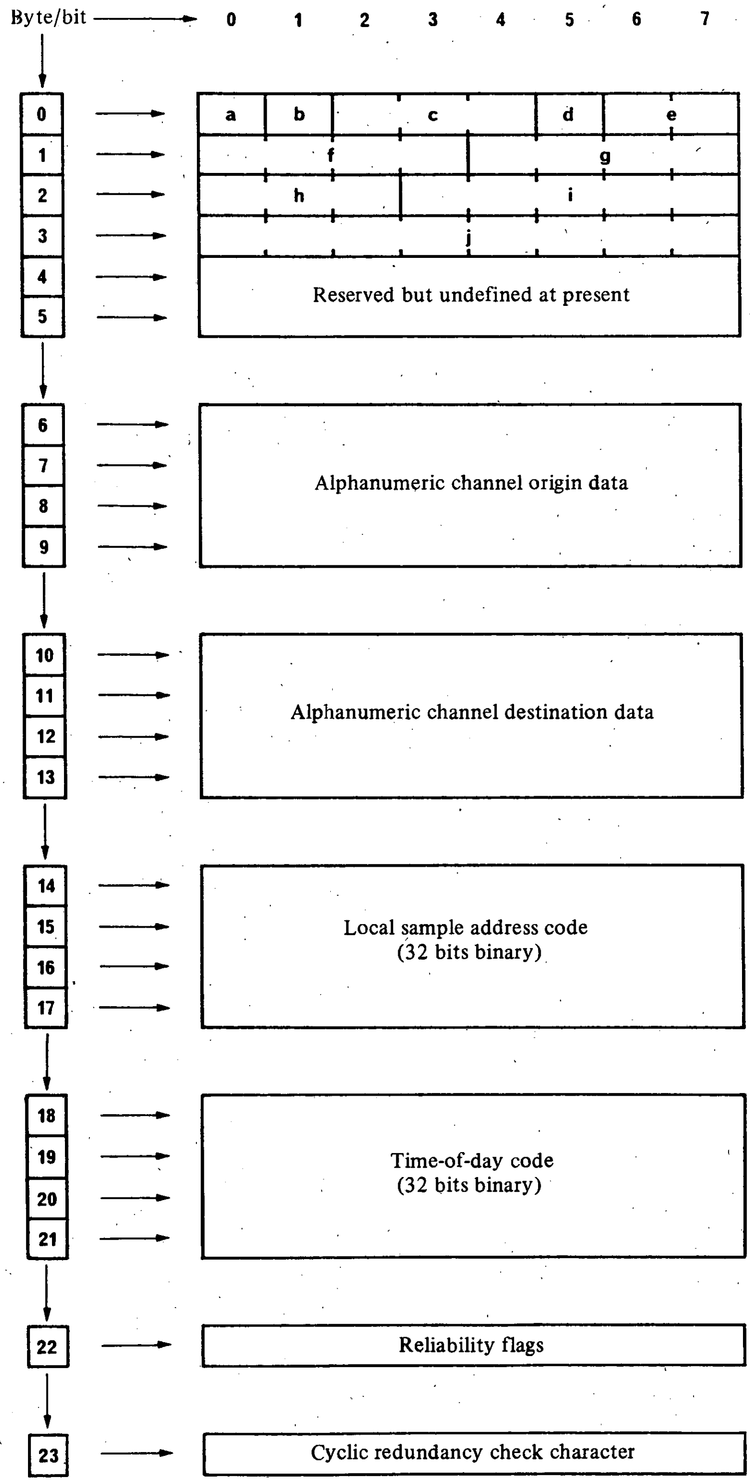

FIGURE 5 – *Channel status data format*

a: use of channel status block
b: audio/non-audio mode
c: audio signal emphasis
d: locking of source sampling frequency
e: sampling frequency
f: channel mode
g: user bits management
h: use of auxiliary sample bits
i: source word length and source encoding history
j: future multi-channel function description

The specific organization follows, wherein the suffix 0 designates the first of any byte or bit:

Byte 0:

bit 0	0	Consumer use of channel status block.
	1	Professional use of channel status block.
bit 1	0	Normal audio mode.
	1	Non audio mode.
bits 2 to 4		Encoded audio signal emphasis.
bit	2 3 4	
state	0 0 0	Emphasis not indicated. Receiver default to no emphasis with manual override enabled.
	1 0 0	No emphasis, receiver manual override disabled.
	1 1 0	50/15 µs emphasis. Receiver manual override disabled.
	1 1 1	CCITT Recommendation J.17 emphasis (with 6.5 dB insertion loss at 800 Hz). Receiver manual override disabled.

All other states of bits 2 to 4 are undefined at present but reserved.

bit 5	1	Source sampling frequency unlocked.
	0	Default and source sampling frequency locked.
bits 6 to 7		Encoded sampling frequency.
bit	6 7	
state	0 0	Sampling frequency not indicated. Receiver default to 48 kHz and manual override or auto set enabled.
	0 1	48 kHz sampling frequency. Manual override or auto set disabled.
	1 0	44.1 kHz sampling frequency. Manual override or auto set disabled.
	1 1	32 kHz sampling frequency. Manual override or auto set disabled.

Note – The significance of bits 0 to 4 is such that a transmission from a consumer interface can be recognized and a receiver conforming only to the consumer format will correctly receive an appropriately formatted signal from a professional transmitter.

Byte 1:

bits 0 to 3		Encoded channel mode.
bit	0 1 2 3	
state	0 0 0 0	Mode not indicated. Receiver default to two-channel mode. Manual override enabled.
	0 0 0 1	Two-channel mode. Manual override disabled.
	0 0 1 0	Single channel mode (monophonic). Manual override disabled.
	0 0 1 1	Primary/secondary mode (channel 1 is primary). Manual override disabled.
	0 1 0 0	Stereophonic mode with simultaneous samples in channel 1 and channel 2 (channel 1 is the left channel). Manual override disabled.
	0 1 0 1	Stereophonic mode with alternate sampling (channel 1 is the left channel, and is sampled before channel 2). Manual override disabled.
	0 1 1 0 to 1 1 1 0	Reserved but undefined.
	1 1 1 1	Vector to byte 3 for future applications.
bits 4 to 7		Encoded user bits management. Reserved but not defined at present.

Note – For any channel, if the channel status is implemented, then all data in byte 0 and byte 1 of that channel status block shall be transmitted.

If the channel status is not implemented, then all data of the channel status block shall be set to logical 0. In this event, the receiving interface shall default to 48 kHz sampling frequency, two-channel mode use, with 20 bits audio sample data, and no emphasis assumed.

In this state, it should be noted that no communication from a consumer transmitter can be received.

Byte 2:

bits 0 to 2		Encoded use of auxiliary sample bits.
bit	0 1 2	
state	0 0 0	Auxiliary sample bits use not defined. Audio sample word length is 20 bits.
	0 0 1	Auxiliary sample bits used for main audio sample data. Audio sample word length is 24 bits.
	0 1 0	Auxiliary sample bits in this channel used to carry a single coordination signal.
	0 1 1	Auxiliary sample bits in both sub-frames used to carry two coordination signals.
	1 0 0 to 1 1 1	Reserved but not defined.
bits 3 to 7		Encoded source word length and source encoding history. Reserved but undefined.

Byte 3:	Vectored target byte from byte 1 reserved for future multi-channel function description. Default value 0 0 0 0 0 0 0 0.
Bytes 4 to 5:	Reserved but undefined at present. Default value 0 0 0 0 0 0 0 0.
Bytes 6 to 9:	Alphanumeric channel origin data. 7 bits ASCII data with odd parity bit. (First character in message is byte 6.)
Bytes 10 to 13:	Alphanumeric channel destination data. 7 bits ASCII data with odd parity bit. (First character in message is byte 10.)
Bytes 14 to 17:	Local sample address code* (32-bit binary). Least significant bits are sent first. Value is of first sample of current block.
Bytes 18 to 21:	Time of day code** (32-bit binary). Least significant bits are sent first. Value is of first sample of current block.

Note. – A value of all zeros for the binary sample address code shall, for the purposes of transcoding to real time, or to time codes in particular, be taken as midnight (i.e. 00 h, 00 min, 00 s, 00 frame).

Transcoding of the binary number to any conventional time code will then only need the prevalent sampling frequency information to provide sample-accurate time code or other timing information of conventional form.

Byte 22:		Flag used to identify whether the information carried by the channel status data is reliable.
bits 0 to 3		Reserved, set to zero.
bit 4	1	Bytes 0 to 5 are unreliable.
bit 5	1	Bytes 6 to 13 are unreliable.
bit 6	1	Bytes 14 to 17 are unreliable.
bit 7	1	Bytes 18 to 21 are unreliable.
Byte 23:		Channel status data cyclic redundancy check character (CRCC). Generating polynominal is: $G(x) = x^8 + x^4 + x^3 + x^2 + 1$. The CRCC conveys information to test valid reception of the entire channel status data block (bytes 0 to 22 inclusive), with an initial state of all 1's.

* This has the same function as a recording index counter.

** This is the time-of-day laid down during the source encoding of the signal and it should remain unchanged during subsequent operations.

3.6 *User data format*

User data bits may be used in any way required by the user. It is, however, advantageous in many applications to adopt a block structure similar to that of the channel status, with block boundaries aligned with those of the channel status blocks.

For example, in some synchronizing schemes, where it may be necessary to repeat or discard samples to maintain long term synchronism, the disturbance to both channel status and user data can be minimized by arranging for the repetition or discarding to involve samples in blocks of 192 as defined by the block structure of the interface.

The default value of the user bits is logical 0.

4. Electrical characteristics

4.1 *General*

The electrical parameters of the interface are based on those defined in Recommendation V.11 of the CCITT for balanced voltage digital circuits. In order to improve the balance of the transmitter or the receiver, or both, beyond that recommended by the CCITT, the transmission circuit configuration shown in Fig. 6 may be used. In this version of the interface, using transformers both at the transmitter and receiver, the series capacitors isolate the transformers from d.c. Although equalization is employed at the receiver, no equalization prior to transmission is permitted.

The interconnecting cable shall be screened and have a characteristic impedance in the range of 90 to 120 Ω at the data transmission rates used. These rates can be calculated by multiplying the source sampling frequency by 64, that is the number of bits per frame.

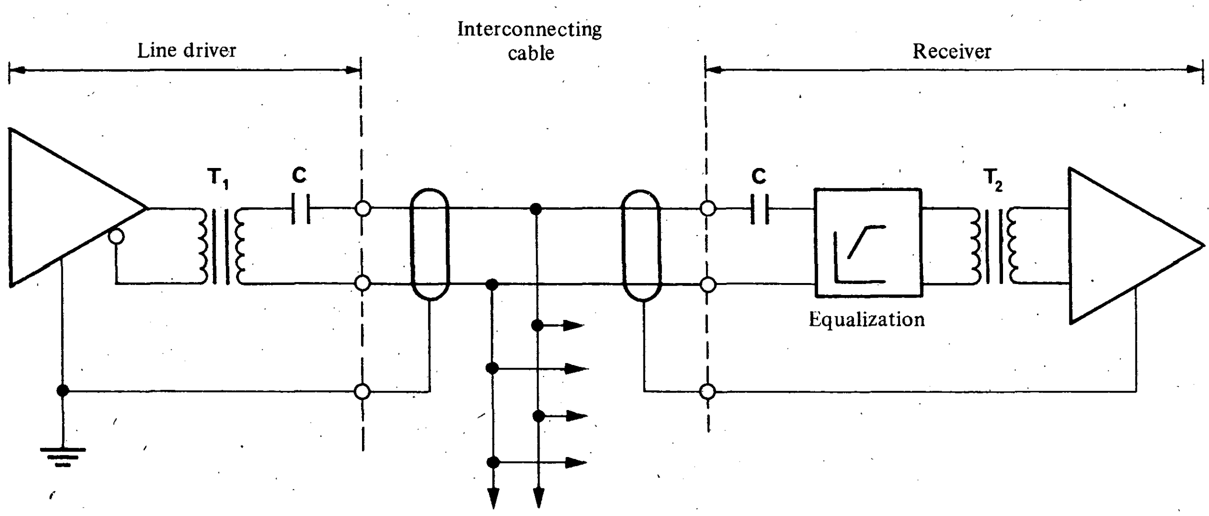

FIGURE 6 – *General configuration of the circuit*

4.2 *Line driver characteristics*

4.2.1 *Output impedance*

The line driver shall have a balanced ouput with an internal impedance of 110 Ω ± 20%, when measured at the terminals to which the line is connected, at frequencies from 0.1 to 6 MHz.

4.2.2 *Signal amplitude*

The signal amplitude shall lie between 3 to 10 V peak-to-peak when measured across a 110 Ω resistor connected to the output terminals, without any interconnecting cable present.

4.2.3 *Rise and fall times*

The rise and fall times, determined between the 10% and 90% amplitude points, shall be between 10 and 30 ns when measured across a 110 Ω resistor connected to the output terminals, without any interconnecting cable present.

4.2.4 *Clock jitter*

Data transitions shall occur within ± 20 ns of the nominal clock period measured at the half-voltage points.

4.3 *Line receiver characteristics*

4.3.1 *Terminating impedance*

The receiver shall present a substantially resistive impedance of 250 Ω to the interconnecting cable over the frequency band of 0.1 to 6 MHz. No more than four receivers shall be connected across the interconnecting cable from any one line driver. However, at the longer cable lengths, this number may have to be reduced to meet the requirements of § 4.3.3.

4.3.2 *Maximum input signals*

The receiver shall correctly interpret the data when connected directly to a line driver working between the extreme voltage limits specified by § 4.2.2.

4.3.3 *Minimum input signals*

The receiver shall correctly sense the data when a random input signal produces the eye diagram characterized by a V_{min} of 200 mV and a T_{min} of 50% of T_{nom} (Fig. 7).

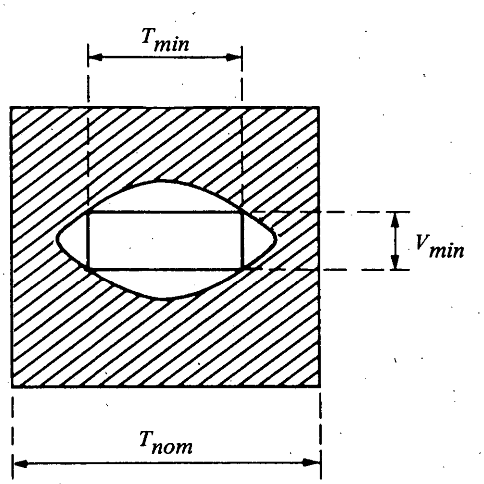

FIGURE 7 – *Eye diagram*

T_{min} = 0.5 x T_{nom}
V_{min} = 200 mV
T_{nom} = one half of the biphase symbol period

4.3.4 *Receiver equalization*

Equalization shall be applied in the receiver to enable interconnecting cables longer than 100 m to be used. A suggested frequency equalizing characteristic is shown in Fig. 8. The receiver must still meet the requirements specified in § 4.3.2 and 4.3.3.

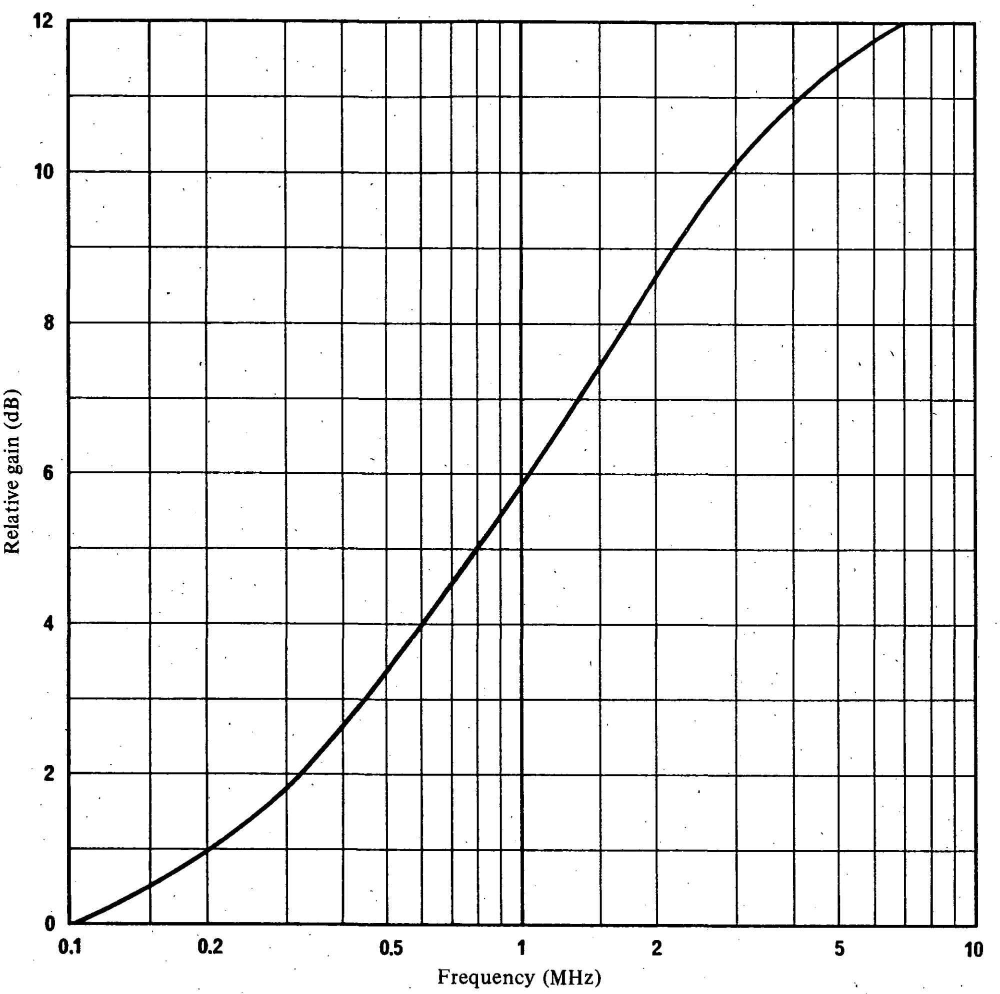

FIGURE 8 – *A suggested equalizing characteristic for the receiver*

5. Connectors

The standard connector for both outputs and inputs shall be the circular latching three pin connector described in IEC Publication 268-12, Sound system equipment, Part 12, Connectors for broadcast and similar use (this type of connection is sometimes referred to as "XLR").

The standard convention of the IEC shall be followed with respect to pin and shell for inputs, outputs and pin usage.

That is:

An output connector fixed on an equipment shall use male pins with female shell. The corresponding cable connector will thus have female pins with a male shell.

An input connector fixed on an equipment shall use female pins with a male shell and the corresponding cable connector will have male pins with a female shell.

The pin usage shall be:

– Pin 1: cable shield or signal ground,
– Pin 2: signal,
– Pin 3: signal.

(Note that relative polarity of pins 2 and 3 is not important in the digital case.)

Equipment manufacturers should clearly label digital audio inputs and outputs as such, including the terms "digital audio input" or "output" as appropriate.

In such cases, where panel space is limited or the function of the connector might be confused with an analogue signal connector, the abbreviation "DI" to "DO" should be used to designate digital audio inputs or outputs, respectively.

ANNEX II

THE PROVISION OF ADDITIONAL, VOICE-QUALITY CHANNELS VIA THE DIGITAL AUDIO INTERFACE

When the digital audio interface is carrying 48 kHz-sampled audio in the studio environment, and when the number of bits allocated to the audio sample word is 20 (for example, at the output of a studio where signal levels will have been controlled by the studio operator) 4 bits are available for use as auxiliary sample bits. The latter may be used to carry voice-quality signals. The provision of voice-quality channels through the same interfaces which are carrying the programme audio permits "co-ordination" or "talk-back" signals which are used in broadcasting for communication between studios, continuity, recording areas, etc., in the studio centre to be connected via the same routing system as is used for the programme audio. This leads to a simpler and more economical digital routing system than would be needed if the programme and voice-quality signals were to be routed separately [Gilchrist *et al*, 1986].

The voice-quality signals are sampled at 16 kHz (i.e. at exactly one-third of the sampling frequency for the programme audio) coded uniformly with 12 bits/sample and sent 4 bits at a time in the auxiliary sample bits of the interface sub-frames, as shown in Fig. 9. One such signal may be sent in the "A" sub-frames and another in the "B" sub-frames. The "Z" preamble at the start of each block is used as a frame-alignment word for the voice-quality signals, with the 4 least-significant bits of the first sample following immediately, as shown in Fig. 10. Figure 10 shows also the interleaving of the two voice-quality signals, 4 bits at a time.

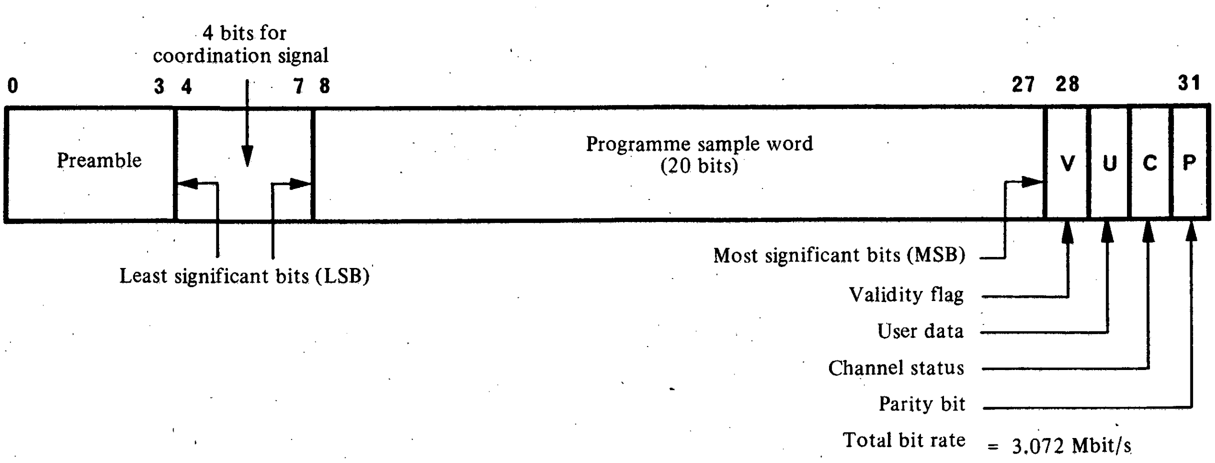

FIGURE 9 – *32-bit sub-frame*

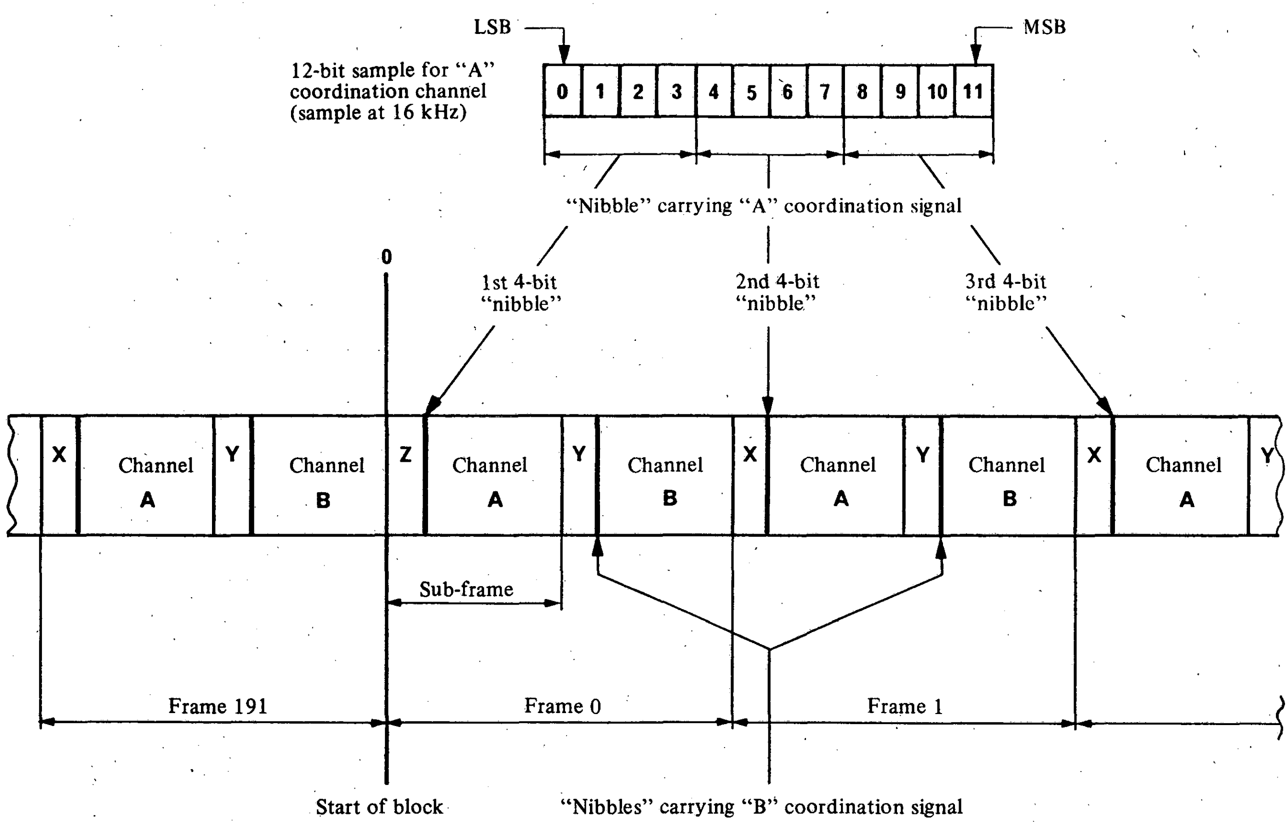

FIGURE 10 – *Frame and block structure*

REFERENCES

GILCHRIST, N. H. C., CROWE, G. W. and LEGG, G. R. [1986] Routing of digital audio signals in a radio broadcasting centre. IEE Conference Publication No. 268, 114-117. *International Broadcasting Convention*, 1986 (IBC 86).

ANNEX III

EVOLUTION OF THE DIGITAL AUDIO INTERFACE

1. Introduction

Changes may be proposed in order to improve the facilities offered by the interface, or to enable it to meet the requirements of particular applications. It is important that the advantages and disadvantages of making such changes be thoroughly examined, not only by those proposing the changes, but also by other users of the interface.

This Annex presents a number of amendments and ideas which have been proposed but not necessarily adopted. The publication of this information is intended to fulfil a number of purposes:

– to draw the attention of the user to possible future problems;
– to draw the attention of the user to possible new requirements and facilities;
– to help the user make effective use of the interface in present and future applications;
– to alert the makers of interface equipment to possible areas of change;
– to stimulate further study.

2. Alternative time codes

The original specification of the digital audio interface stipulates the use of "sample address codes"; these are binary counts of samples (i.e. at the audio sampling frequency). This is an ideal form of time code for many purely audio applications in the digital environment, and disk-based audio editing equipment using sample-address time codes has been developed by a number of organizations.

However, in some applications (e.g. television and recording [CCIR, 1986-90a] there may be the need to interconnect two items of apparatus which both use a BCD (binary coded decimal) time code (sometimes termed "SMPTE/EBU" time-code). The items of apparatus could be compatible in respect of the time code, but unable to exchange time-code information via the digital audio interface without transcoding to and from sample-address form.

Possible solutions to this problem are described below.

2.1 *Replacement of sample address by BCD time code*

The sample address time codes may be replaced directly by BCD time codes, using the same number of bytes in the same positions in the channel status words of the interface (4 bytes per time code). To enable the interface to carry either type of time code, it is advisable to use one of the bits in channel status to "flag" the substitution of BCD time code for the sample address code [CCIR, 1986-90b].

2.2 *Use of a time code incorporating elements of both BCD and sample address codes in channel status*

It is possible to devise a time code which combines elements of both types of time code. For example, the most significant part of the time code could be a BCD representation of hours, minutes and seconds, and time within the seconds could be indicated by a binary count of samples. Another possibility would be for television fields and interface blocks to be indicated in the BCD count, with the binary count of samples operating within the interface block count [DuBoyce, 1989].

Thus, it would be possible to provide a time code satisfying the requirements of apparatus using BCD time code, incorporating the resolution of the sample-address code. However, the disadvantages with this proposal are that more bytes would be needed in channel status for this type of code, necessitating a re-organization of channel status, and the requirement for equipment using sample-address code to encode and decode the BCD part of the time code at the interfaces.

2.3 *The provision of additional time codes in the user channel*

The user data channel of the interface could be used to carry BCD time codes, in addition to the sample address codes in channel status. The user data channel is likely to be too valuable to dedicate solely to the transport of time codes, but an HDLC (high level data link control) system for carrying time codes and other data in the user channel has been developed [Komly and Viallevieille, 1989] and this may be suitable as a possible standard for carrying a wide range of information in the user data channel.

3. Signalling the number of inactive bits in the audio sample

It is often beneficial to add digital "dither" to digital audio signals before they are truncated or rounded, to avoid introducing granular distortion. However, the correct application of "dither" is not possible unless the audio word length (i.e. the number of active bits in the audio word) is known.

The facility for indicating the audio word length is provided by bits 3 to 7 in byte 2 of channel status. These bits are reserved for this purpose, and for the purpose of indicating the "source encoding history". A proposal has been made for using a 3-bit code, carried in bits 3, 4 and 5 of byte 2, for signalling the number of inactive bits [CCIR, 1986-90c]. The number of active bits (i.e. the audio word length) may be deduced from this information.

4. Copying

A proposal from the International Electrotechnical Commission (IEC) [CCIR, 1986-90d] gives details of copyright protection and the means of indicating whether a recording is the original or a copy, in the consumer interface. Consideration should be given to the possibility of incorporating such information in the channel status of the professional interface.

REFERENCES

DuBOYCE, T. [October, 1989] A proposal for a sample-block format AES-EBU channel status time code. Document submitted to AES Standards Subcommittee on Digital Audio, Working Group on Input/Output Interfacing.

KOMLY, A. and VIALLEVIEILLE, A. [September, 1989] Programme labelling in the user channel. Digest of the AES Interface Conference. London, United Kingdom.

CCIR Documents

[1986-90]: **a.** 10/344 (10-11R); **b.** 10/246 (United Kingdom) **c.** 10/214 (United Kingdom); **d.** 10/324 (IEC).

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SECTION 10D: RECORDING OF SOUND PROGRAMMES

The texts will be found in Part 3 of Volumes X and XI.

SECTION 10E: BROADCASTING SERVICE (SOUND) USING SATELLITES

The texts will be found in Part 2 of Volumes X and XI.

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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 76-1

PRESENTATION OF ANTENNA DIAGRAMS

(1982–1990)

The CCIR,

CONSIDERING

(a) that the WARC HFBC-87 in Resolution No. 516 invites the CCIR to update the CCIR Book of Antenna Diagrams and the IFRB to base its Technical Standards on this publication;

(b) that new types of antennas as used by administrations for HF broadcasting are needed to complement the publication CCIR, Antenna Diagrams, edition 1984;

(c) that a considerable amount of work in this respect was already carried out by Study Group 10 in preparation of the WARC HFBC-84 and WARC HFBC-87;

(d) that Study Group 10 under its Study Programmes 44H/10 and 45F/10 has the task to evaluate the radiation patterns of HF antennas, including consideration of their performance in terms of coverage and interference,

UNANIMOUSLY DECIDES

1. that the results of the studies carried out by Study Group 10 and the related antenna diagrams should be contained in a CCIR Recommendation separately published;

2. that this Recommendation while ensuring a certain continuity with the previous CCIR publications on antenna diagrams, should also contain both sufficient technical background and complementary information to guide in the selection of the antenna appropriate to the desired service together with other possible data relevant to its practical operation;

3. that a suitable set of antenna patterns covering as far as possible the range of the types of antennas used by administrations should appear in this Recommendations;

4. that suitable computer programs for calculating antenna radiation patterns should complement this Recommendation and be made available by the CCIR Secretariat who will also be responsible for the software maintenance;

5. that the participants in the work of the CCIR should be invited to cooperate to maintain and update this new Recommendation submitting relevant contributions to the CCIR.

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 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;

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.

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* The Director, CCIR, is requested to bring this Opinion to the attention of the IEC and the CCITT.

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.

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* See Report 798.

OPINION 74-1 *

SYSTEMS FOR SIGNAL INTERFACE CONNECTION BETWEEN SOUND-BROADCASTING RECEIVERS AND ASSOCIATED EQUIPMENT

(1982–1990)

The CCIR,

CONSIDERING

(a) the importance of facilitating the enhancement and greater efficienty of broadcast systems;

(b) that the introduction of such improvements has heretofore often been delayed by the need to wait until equipment in the hands of the public has become obsolete;

(c) that such delays could be shortened if appropriate means were provided for the connection of associated equipment;

(d) the CCIR studies decided in Study Programme 46G/10 and 46H/10,

IS UNANIMOUSLY OF THE OPINION

that the IEC should be invited to study and set standards for signal interface connection between sound broadcasting receivers, audio recorders and players, decoders for sound broadcasting supplementary services, and other associated equipment intended for use by the public, taking into appropriate account the studies that will be carried out by the CCIR on this subject.

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* The Director, CCIR, is requested to bring this Opinion to the attention of the CCITT and the IEC. This Opinion has also been brought to the attention of Study Group 11.

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