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INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

C.C.I.R.

XIIth PLENARY ASSEMBLY

NEW DELHI, 1970

VOLUME VI

MOBILE SERVICES
(STUDY GROUP 8)

Published by the
INTERNATIONAL TELECOMMUNICATION UNION
GENEVA, 1970

INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

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MOBILE SERVICES

RECOMMENDATIONS AND REPORTS

8A Mobile services, general

8B Maritime mobile service

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QUESTIONS AND STUDY PROGRAMMES

RESOLUTIONS AND OPINIONS

(Study Group 8)

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DISTRIBUTION OF TEXTS OF THE XIIth PLENARY ASSEMBLY OF THE C.C.I.R. IN VOLUMES I TO VII

Volumes I to VII, XIIth Plenary Assembly, contain all the valid texts of the C.C.I.R.

1. Recommendations, Reports, Resolutions, Opinions

1.1 *Numbering of these texts*

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

When one of these texts is modified, it retains its number to which is added a dash and a figure indicating how many revisions have been made. For example: Recommendation 253 indicates the original text is still current; Recommendation 253-1 indicates that the current text has been once modified from the original; Recommendation 253-2 indicates that there have been two successive modifications of the original text, and so on.

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 VII of the C.C.I.R.

1.2 *Recommendations*

Number	Volume	Number	Volume	Number	Volume
45	VI	265, 266	V	374-376	III
48, 49	V	268	IV	377-379	I
77	VI	270	IV	380-393	IV
80	V	275, 276	IV	395-406	IV
100	I	279	IV	407-421	V
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182	I	310, 311	II	434, 435	II
205	V	313	II	436	III
214-216	V	314	IV	439-441	VI
218, 219	VI	325-334	I	442, 443	I
224	VI	335-340	III	444-446	IV
237	I	341	I	447-451	V
239	I	342-349	III	452, 453	II
240	III	352-359	IV	454-461	III
246	III	361	VI	462-466	IV
257, 258	VI	362-367	IV	467-474	V
262	V	368-373	II	475-478	VI

1.3 *Reports*

Number	Volume	Number	Volume	Number	Volume
19	III	226	IV	341-344	II
32	V	227-231	II	345-357	III
42	III	233-236	II	358, 359	VI
79	V	238, 239	II	361	VI
93	VI	241	II	362-364	III
106, 107	III	244-251	II	366	III
109	III	252	(1)	367-373	I
111	III	253-256	II	374-393	IV
112	I	258-266	II	394	VI
122	V	267	III	395-397	IV
130-137	IV	269-271	III	398-401	V
176-194	I	272, 273	I	403-407	V
195	III	275-282	I	409-412	V
196	I	283-290	IV	413-415	(1)
197, 198	III	292-294	V	416-423	I
200, 201	III	297-308	V	424-432	II
202	I	311-316	V	433-439	III
203	III	318-320	VI	440	(1)
204-214	IV	321	III	441	III
215	V	322	(1)	442-456	IV
216	VI	324-334	I	457-498	V
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222-224	IV	336-339	II	516	V
		340	(1)		

(1) Published separately.

1.4 *Resolutions*

Number	Volume	Number	Volume	Number	Volume
2-4	II	21-23	III	39, 40	VII
7, 8	II	24	VII	41-44	I
10	II	26, 27	VII	45-51	II
12, 13	II	30	II	52-54	III
14	III	33	VII	55, 56	IV
15, 16	I	36, 37	VII	57, 58	V
20	VI	38	V VII		

1.5 *Opinions*

Number	Volume	Number	Volume	Number	Volume
2	I	22, 23	II	32-35	I
11	I	24	VI	36, 37	III
13, 14	IV	26-28	III	38-41	V
15, 16	V	29, 30	I	42, 43	VI

2. Questions and Study Programmes

2.1 *Text numbering*

2.1.1 *Questions*

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

— Question 1/10 would indicate a Question of Study Group 10 with its text in the original state;

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

2.1.2 *Study Programmes*

Study Programmes are numbered to indicate the Question from which they are derived if any, the number being completed by a capital letter which is used to distinguish several Study Programmes which derive from the same Question. For example:

— Study Programme 1A/10, which would indicate that the current text is the original version of the text of the first Study Programme deriving from Question 1/10;

— Study Programme 1C/10, which would indicate that the current text is the original version of the text of the third Study Programme deriving from Question 1/10;

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

— Study Programme 3-1A/10 would indicate that the current text is the original and that this Study Programme is the first deriving from Question 3-1/10, which has itself been once modified from the original;

— Study Programme 3-1B-1/10 would indicate that the current text has been once modified from the original, and that this Study Programme is the second of the group deriving from Question 3-1/10, which has itself been once modified from the original.

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

Also, the up-to-date number of the Question concerned is used in assembling the number of a Study Programme: this is to facilitate reference to the Volumes, but does not exclude the possibility of the Study Programme having been evolved before the latest version of the Question.

2.2 *Arrangement of Questions and Study Programmes*

The plan shown on page 8 indicates the Volume in which the texts of each Study Group are to be found, and so reference to this information will enable the text of any desired Question or Study Programme to be located.

PLAN OF VOLUMES I TO VII
XIIth PLENARY ASSEMBLY OF THE C.C.I.R.

(New Delhi, 1970)

VOLUME I	Spectrum utilization and monitoring (Study Group 1).
VOLUME II (Part 1)	Propagation in non-ionized media (Study Group 5).
VOLUME II (Part 2)	Ionospheric propagation (Study Group 6).
VOLUME III	Fixed service at frequencies below about 30 MHz (Study Group 3). Standard frequencies and time signals (Study Group 7). Vocabulary (CIV).
VOLUME IV (Part 1)	Fixed service using radio-relay systems (Study Group 9). Coordination and frequency sharing between communication-satellite systems and terrestrial radio-relay systems (subjects common to Study Groups 4 and 9).
VOLUME IV (Part 2)	Fixed service using communication satellites (Study Group 4). Space research and radioastronomy (Study Group 2).
VOLUME V (Part 1)	Broadcasting service (sound) (Study Group 10). Problems common to sound broadcasting and television (subjects common to Study Groups 10 and 11).
VOLUME V (Part 2)	Broadcasting service (television) (Study Group 11). Transmission of sound broadcasting and television signals over long distances (CMTT).
VOLUME VI	Mobile services (Study Group 8).
VOLUME VII	Information concerning the XIIth Plenary Assembly. Structure of the C.C.I.R. Complete list of C.C.I.R. texts

Note.—To facilitate reference, page numbering is identical in all three versions of each Volume, that is, in English, French and Spanish.

VOLUME VI

INDEX *

MOBILE SERVICES

(Study Group 8)

* In this Volume, Recommendations and Reports dealing with the same subject are collected together. These texts are numbered in such a manner that they cannot be presented in numerical order and at the same time, in numerical sequence of pages. Consequently, this index, in numerical order of texts, does not follow the numerical sequence of pages.

QUESTIONS AND STUDY PROGRAMMES

RESOLUTIONS

OPINIONS

MOBILE SERVICES

STUDY GROUP 8

Terms of reference:

To study the technical and operating aspects of the aeronautical mobile, maritime mobile, land mobile and radiodetermination services, including the use of satellites.

Chairman: G.H.M. GLEADLE (United Kingdom)

Vice-Chairman: P. MORTENSEN (Norway)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP 8

1. Signal-to-interference protection ratios and minimum field strengths required in the mobile services (Question 1/8)

Report 358-1 has been improved, and, in particular, the protection ratios in Table I have been revised, and the Table extended to include interference from and to narrow-band F3 systems. The median values of field strength to be protected have also been reviewed. Considerably more information is necessary, however, especially for the maritime services, and Question 1/8 has been retained for further study.

2. Direction-finding and " homing " in the 2 MHz band on board ships

Additional material on the minimum facilities for " homing " has been added to Recommendation 428-2, and Question 2/XIII has now been cancelled. The Recommendation will doubtless be of interest also to the Intergovernmental Maritime Consultative Organisation (I.M.C.O.).

3. Selective-calling systems for use in the international maritime-mobile services (Study Programme 3A/8)

Additions were made to Recommendation 257-1 in connection with the " All ships call " and how it can be distinguished from a normal selective call in the design of the ship's decoder. The associated Report 320-2 was brought up to date, and Question 3/XIII has been cancelled. The Recommendation will be of interest to I.M.C.O. Study Programme 3A/8 has been retained.

4. Operational procedures for single-sideband radiotelephone systems in the HF maritime-mobile bands

A new Recommendation 477 has been adopted concerning operational procedures and facilities for setting up single-sideband radiotelephone calls between ships and coast stations. The Recommendation terminates the study of Question 4/XIII, which, together with Report 360, has been cancelled.

5. The introduction of direct-printing telegraph equipment in the maritime service (Question 5-1/8)

Minor amendments were made to Recommendation 440 which concerns the use of C.C.I.T.T. Code No. 2 on the inland connection, the modulation rate, the class of emission (F1) and the total frequency shift (170 kHz).

A new Recommendation 476 was adopted on an error-detecting and correcting system which employs a 7-unit code. The system can be used in an ARQ-mode and in a broadcast mode.

Question 5-1/8 was amended and retained for further study of operational matters and of the selective calling code used when the system is operated in the ARQ mode.

The Administrations of Bulgaria and the U.S.S.R. reserved their opinions on Recommendation 476.

Report 361-1 was also brought up to date.

6. **Self-supporting antennae for use on board ships** (Question 6/8)

A new Report 502, based on measurements on various types of ships, has been adopted. This Report includes a graph showing the cumulative distribution of the " shape factor " (i.e. the ratio of the effective height of the antenna to the height above the deepest load water line). It was felt, however, that further data on the performance of such antennae should be obtained before a firm Recommendation could be drawn up. In the meantime, Opinion 43 was addressed to I.M.C.O. drawing attention to the Report and advising that the table of metre-ampères in Chapter IV, Regulation 9(*g*) of the International Convention for the Safety of Life at Sea (SOLAS), London 1960, was not applicable to self-supporting antennae.

Study Programme 6A-1/8 was revised in order to give more detail on the various measurements concerned.

7. **Characteristics of equipment and principles governing the allocation of frequency channels in the land-mobile service between 25 and 500 MHz** (Question 7-1/8)

Considerable new material has been added to Report 319-2, which has been re-arranged into three parts. Part A deals with technical characteristics of equipment, Part B with the allocation of channels, and Part C with the relative merits of single-frequency and two-frequency operation. The three Tables have been brought up to date.

A new Recommendation 478 was adopted, relating to technical characteristics that are of international importance.

Small amendments were made to Question 7-1/8 and to Resolution 20-2 which have been retained for further study.

A new Study Programme 7-1D/8 was also adopted, concerning networks that would give extremely economical frequency utilization.

A new Opinion 42, addressed to the International Electrotechnical Commission, was adopted, dealing with methods of measurement.

8. **MF and HF land-mobile services** (Question 8-1/8)

A new Report 503 was adopted on the preferred technical characteristics of single-sideband equipment in the MF and HF land-mobile service.

Small amendments were made to Question 8-1/8 which has been retained for further study.

9. **Selective calling system for future operational requirements of the maritime-mobile service** (Question 9-1/8)

A new Report 501 was adopted concerning the operational requirements that a selective calling system should satisfy in the future, and the possible type and format of the signal. Future study of Question 9-1/8 should take into account also the selective calling facilities incorporated in the direct printing telegraphy system referred to in Recommendation 476, and also in Question 5-1/8. Question 9/8 was retained for further study.

10. Reduction of the frequency separation between adjacent channels in the VHF (metric) maritime-mobile band (Question 10-1/8)

Question 10-1/8, which was originally accepted by correspondence after the Special Meeting of Study Group XIII in 1967, was revised and retained.

Recommendation 425 for equipment designed for channels separated by 50 kHz was cancelled in view of the decisions taken by the Maritime World Administrative Radio Conference, 1967, concerning the introduction of channels with 25 kHz separation.

11. Improvements in the performance of radiotelephone circuits in the MF and HF maritime bands (Question 11/8)

Question 11/8 was adopted by correspondence following the Interim Meeting of Study Group XIII, 1968, and was published as an addendum to Volume III of the texts of the XIth Plenary Assembly.

A new Recommendation 475 was adopted on a linked compressor and expander system. The system is analogous to that accepted for the Fixed Service, but the ship's equipment has been simplified as much as possible and the audio-speech bandwidth has been restricted so that the emission can be accommodated in the narrower channels allocated to the HF radiotelephone maritime service in the Radio Regulations. The Administrations of Cuba and the Federal Republic of Germany reserved their opinions on this Recommendation.

A new Study Programme 11A/8 was adopted, concerning methods of assessing and comparing the performance of systems and Question 11/8 was retained.

A new Report 500 was adopted, summarizing the studies and tests that have been carried out.

12. Radio-paging systems (Question 12/8)

Question 12/8 was adopted by correspondence after the Interim Meeting of Study Group XIII, 1968, and was published as an addendum to Volume III of the texts of the XIth Plenary Assembly.

A new Report 499 was adopted, summarizing various existing radio-paging systems. Question 12/8 was retained for further study.

13. New Questions

The following new Questions were adopted:

- *Question 13/8:* Influence of the Doppler effect on radiocommunication in the aeronautical mobile service.
- *Question 14/8:* Direct printing and other data signals using voice frequency techniques on VHF radiotelephony channels.
- *Question 15/8:* Use of radiobeacon stations for communication.
- *Question 16/8:* Systems providing radiocommunication and/or radiodetermination using satellite techniques for aircraft and/or ships.

14. Texts transferred from former Study Group IV

As a result of the reorganization of C.C.I.R. Study Groups at the XIIth Plenary Assembly, New Delhi, 1970, the following texts dealing with satellite techniques for mobile services now concern Study Group 8:

— *Recommendation 361-2*: Frequency requirements of radiodetermination-satellite systems.

— *Question 17/8 (formerly 19/IV) and Study Programme 17A/8 (formerly 19A/IV):* Technical characteristics of systems providing communication and/or radiodetermination using satellite techniques for aircraft and/or ships.

— *Reports 216-2, 394-1 and 504 to 515*, in answer to Question 17/8 and Study Programme 17A/8.

SECTION 8A: MOBILE SERVICES, GENERAL

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 258-2 *

SINGLE-SIDEBAND AERONAUTICAL AND MARITIME MOBILE RADIOTELEPHONY SYSTEMS

The C.C.I.R., (1959 – 1966 – 1970)

CONSIDERING

(a) that the main advantages of single-sideband systems (SSB), as compared with double-sideband (DSB), for mobile radiotelephony, are as follows:

a.a reduction of bandwidth required per channel;

a.b. increase in signal-to-noise ratio, or, alternatively, reduction in transmitter power (and hence antenna voltage), for the same signal-to-noise ratio, improvements dependent upon the degree of carrier suppression;

a.c reduction of the distortion that is due to selective fading;

a.d reduction of interference, particularly that due to beat notes, between carriers dependent on the degree of carrier suppression;

a.e reduction of interference, due to cross-modulation between adjacent channel transmissions;

(b) that the disadvantages of SSB compared with DSB for mobile radiotelephony, are as follows:

b.a more rigorous requirements for transmitter and receiver frequency stability;

b.b greater complexity of apparatus;

b.c higher prices of the equipment;

b.d higher maintenance costs for the equipment;

b.e impracticability of conversion of existing mobile DSB equipment for SSB operation;

b.f Doppler effects, that are significant for very high-speed mobile units;

(c) that the MF-radiotelephony bands, used in the maritime services (i.e. world-wide, 1605 to 2850 kHz and additionally, in Region 1, 3155 to 3800 kHz):

c.a include the international calling and distress frequency 2182 kHz;

c.b are shared with fixed services;

c.c are used by many low tonnage ships, some compulsorily and others voluntarily fitted exclusively with DSB MF-radiotelephony equipment;

* This Recommendation is retained for reference purposes, although most of the technical content is now embodied in the Radio Regulations and the International Civil Aviation Organisation (I.C.A.O.) has adopted certain preferred technical characteristics for the aeronautical mobile service.

(d) that the parts of the HF bands (i.e. 4000 kHz to 23 000 kHz for mobile maritime and 2850 kHz to 24 000 kHz for aeronautical use), allocated to the respective services:

d.a do not include any international distress frequency;

d.b are exclusively allocated to these services;

(e) that in the maritime mobile services, the advantages of SSB operation predominate over the disadvantages;

(f) that although the introduction of class of emission A3J is a desirable objective it may be necessary to use class of emission A3A for public correspondence services for an indefinite period to obtain acceptable a.g.c. performance;

(g) that, in the maritime mobile services, in the interests of safety of life at sea, the introduction of SSB operation should not be allowed to discourage the extension of voluntary fitting of DSB MF-radiotelephony equipment;

(h) that Recommendation No. 3 of the Final Report of the Panel of Experts, set up under Resolution No. 3 of the Administrative Radio Conference, Geneva, 1959, urges introduction of SSB in the maritime mobile HF radiotelephony service;

UNANIMOUSLY RECOMMENDS

1. for the maritime mobile services (see also Appendices 15 and 17 to the Radio Regulations and Recommendation No. 28 of the Administrative Radio Conference, Geneva, 1959):

1.1 that SSB operation be introduced in the MF and HF radiotelephony bands;

1.2 that coast stations be prepared to communicate with both DSB and SSB ship stations;

1.3 that for SSB equipment the following technical characteristics be employed:

1.3.1 in coast and ship station transmitters facilities should be provided for both class of emission A3A having a carrier reduction of 16 ± 2 dB below peak envelope power, and class of emission A3J having a carrier reduction of not less than 40 dB below peak envelope power (Note 1);

1.3.2 the carrier frequency of the transmitters should be maintained within the following tolerances:

1.3.2.1 for coast stations: ± 20 Hz;

1.3.2.2 for ship stations: short-term limits (of the order of 15 min) ± 40 Hz;

1.3.2.3 for ship stations: within ± 100 Hz of the reference value;

1.3.3 the carrier frequency of the receivers should be maintained within the following tolerances:

1.3.3.1 for coast stations: ± 20 Hz;

1.3.3.2 for ship stations the short-term limits (of the order of 15 min) ± 40 Hz (Note 2);

1.3.4 the upper sideband should be used (see Nos. 445A, 1322A and Appendix 17A of the Radio Regulations (Note 3);

1.3.5 the channel arrangements should be such, that two SSB channels are accommodated within each existing DSB channel and the bandwidth of the SSB emissions should be kept within such limits as will permit this to be done;

1.3.6 the transmitter audio-frequency band should be 350 to 2700 Hz, with a permitted amplitude variation of 6 dB (Note 4);

1.3.7 the unwanted frequency-modulation of the SSB carrier should be sufficiently low to prevent harmful distortion;

1.3.8 in the MF maritime mobile radiotelephony bands, SSB ship stations should be able to insert a carrier at a level sufficient to permit satisfactory reception by DSB receivers when communicating with DSB stations;

1.3.9 in the particular case of transmissions on the radiotelephone calling and distress frequency 2182 kHz, all transmissions should be made either by DSB, or by SSB with a carrier level sufficient to permit satisfactory reception by DSB receivers;

1.4 that the attention of Administrations should be drawn to the fact that, there would be technical and operational advantages in designating certain frequencies for international common use for ship-shore and inter-ship working;

2. that for the aeronautical mobile service, the Director, C.C.I.R., should:

2.1 advise the I.C.A.O. of this Recommendation;

2.2 renew the invitation to the I.C.A.O. to advise the C.C.I.R. of any technical and operational problems on which they would like the assistance of the C.C.I.R.;

2.3 offer to keep the I.C.A.O. informed of progress made by the C.C.I.R. in the study of the application of SSB working in the maritime mobile services;

2.4 request the I.C.A.O. to keep the C.C.I.R. informed of progress made by the I.C.A.O. in the study of the application of SSB working in the aeronautical mobile services.

Note 1. — The normal method of operation for each coast station should be indicated in the I.T.U. " List of Coast Stations ".

Note 2. — This value may be maintained either manually or by other means.

Note 3. — Exceptionally, in the bands between 4 and 23 MHz independent-sideband (ISB) may be used by special arrangement between Administrations.

Note 4. — These limits may need to be modified when selective calling is introduced.

RECOMMENDATION 422

PULSE TRANSMISSION FOR RADIO DIRECTION-FINDING

The C.C.I.R., (1953 – 1963)

CONSIDERING

(a) that certain studies, extending over many years, of the errors of direction finders show that, under ideal conditions of site, equipment and operation, the use of pulse transmissions offers only a slight improvement in accuracy over the use of continuous-wave transmissions;

(b) that, in practice, unavoidable departures from the ideal conditions referred to in § *(a)* would tend to reduce this improvement in accuracy;

(c) that pulse transmissions occupy wide bandwidths;

UNANIMOUSLY RECOMMENDS

that the use of pulse transmissions for radio direction-finding at frequencies below 20 000 kHz is generally undesirable.

ANNEX

The following errors in high-frequency direction-finding can occur:

1. observational errors introduced by the operator;
2. instrumental errors, including polarization errors and those due to deficiencies of the direction-finder site;
3. errors due to radiation scattered from topographical features many wavelengths distant from the direction finder;
4. errors due to lateral deviation in the ionosphere;
5. errors due to wave interference caused by convergence of rays and by different modes of propagation.

The advantage of a pulse emission over a continuous-wave emission lies in its ability to allow signals arriving over different paths to be separated, and so to reduce errors arising from sources 4 and 5 above.

The degree of accuracy to be expected from the use of pulse emissions for radio direction-finding has been studied, and it is estimated that in most favourable circumstances, for a frequency of about 8000 kHz, the standard deviation of a single rapidly observed bearing might be about 3° for a continuous-wave emission and about 2° for a pulse emission. The corresponding figures for the mean of ten such bearings taken in a period of five minutes are: continuous-wave 2·5°, pulse 1·7°.

RECOMMENDATION 423-2

USE OF 8364 kHz FOR RADIO DIRECTION-FINDING

The C.C.I.R., (1951 – 1956 – 1959 – 1963 – 1966 – 1970)

CONSIDERING

(a) that Nos. 994, 997 (Mar) and 1179 of the Radio Regulations concern the use of the frequency 8364 kHz;

(b) that land stations keep watch during their hours of service in the band 8356 to 8374 kHz of which 8364 kHz is approximately the centre;

(c) that Regulations 12 and 13 of Chapter IV of the Safety of Life at Sea Convention, London, 1960, indicate minimum specifications for automatic distress transmitters;

(d) that tests and operational experience have shown that radio direction-finding at 8364 kHz may be a valuable aid (in conjunction with direction-finding at 500 kHz) in finding the position of both aircraft and ships in distress and survival craft;

(e) that complete coverage cannot be obtained with direction-finding on only one frequency in the HF (decametric) band because of the limitations caused by radio-propagation conditions;

(f) that HF (decametric) radio direction-finding requires apparatus as free as possible from local site error and polarization error;

(g) that the accuracy of the bearing will depend upon the field strength of the signal and the signal/noise ratio;

(h) that in view of the rapid variation of the apparent azimuth of the bearing which is frequently observed in HF (decametric) radio direction-finding, measurements should be

made over several minutes to obtain a more accurate mean bearing; and that the bearing and fix may be improved subsequently by a further series of measurements;

(j) that standardized distress transmissions are desirable;

(k) that it is essential to have a means of rapid communication between the watch-keeping station and the direction-finding stations;

UNANIMOUSLY RECOMMENDS

1. that the site of the HF (decametric) radio direction-finding station should be, as far as possible:

1.1 flat and horizontal for a radius preferably of at least 200 m, with the surrounding neighbourhood flat and free from obstruction;

1.2 of high and uniform ground conductivity;

1.3 free from large metallic masses and objects likely to resonate at frequencies near to 8364 kHz;

2. that the antenna system should be as free as possible from wave polarization error (e.g. Adcock systems and spaced-loop systems);

3. that the bandwidth of the direction-finding receiver, used when bearings are taken, should be as narrow as possible, compatible with the modulation and frequency stability of the signal on 8364 kHz and that a broader bandwidth position should also be incorporated in the receiver for watch-keeping purposes;

4. that the sensitivity of the direction-finding equipment should be such that it operates satisfactorily with a field strength as low as 5 μV/m;

5. that the bearing should be determined by an aural-null method or by any other method of comparable or better accuracy;

6. that the direction-finding equipment should be adjusted, balanced and calibrated at frequent intervals at the frequency of 8364 kHz;

7. that the signal radiated by survival craft should be as strong as possible and stable in frequency to ensure the greatest accuracy in determining the bearings;

8. that the signals transmitted by survival craft should preferably include long dashes sent over a period of not less than five minutes for direction-finding purposes;

9. that, to give as great accuracy of fix as possible, several widely-spaced and interconnected direction-finding stations should be employed (see Annex);

10. that the attention of Administrations concerned should be drawn to the advantage of their studying further:

10.1 the most suitable type of network for providing rapid communication between direction-finding stations and plotting centres;

10.2 the most suitable way in which information should be exchanged between different stations or networks (e.g. use of “ Q ” code);

10.3 the best way to evaluate the most probable fix (position) from bearings supplied by the direction-finding stations;

11. that the attention of Administrations should also be drawn to the fact that world-wide direction-finding coverage cannot be obtained with only one frequency in the HF (decametric) band.

ANNEX

ACCURACY OF BEARINGS AT 8364 kHz

At distances greater than about 1200 km the root-mean-square (r.m.s.) bearing error to be expected with a modern HF (decametric) direction-finding system is of the order of 3° to 5°.

At distances less than 1200 km the error progressively increases with decrease of distance to values of the order of 5° to 10°; at small distances, less than about 100 km, the error may be even greater than 10°.

The above figures refer to the arithmetic mean of bearings spread over an interval of not more than about 10 min.

8A: *Reports*

REPORT 93 *

HF (DECAMETRIC) AND VHF (METRIC) DIRECTION-FINDING **

(1956)

1. Introduction

Two documents, 67 (United States of America) and 232 (United Kingdom), were submitted to the VIIIth Plenary Assembly in response to Question 106. A summary of these two documents, and of the discussion on them, is given below.

It was generally agreed that, whenever possible, the accuracy of bearings and positions and their classification, should be based on the probability concept.

The United Kingdom document expresses bearing accuracies in the form of errors that are exceeded on only 1 occasion in 20 and the U.S.A. document gives the standard deviation error. For ease of comparison of results, all accuracies have been expressed in a common form in this Report.

2. Accuracy of HF (decametric) bearings

The accuracy of HF (decametric) bearings depends principally upon the following factors:

— type of direction-finding (DF) equipment, for example, Adcock type,
— type of site,
— frequency,
— range and signal strength,
— ionospheric conditions, particularly diurnal variations,
— amount of interference,
— number of bearings taken,
— skill of the operator.

By day, the error which is exceeded on only 1 occasion in 20 (referred to subsequently as the 95% error) lies between about 3° and 10° for ranges of the order of 500 to 4000 km, depending on the site, frequency, and whether a group of bearings is taken or only one snap bearing. More detailed data are given in the Annex. At night, errors are somewhat greater, by amounts of up to about 1°. At distances less than 500 to 1600 km (depending on ionospheric conditions), the error progressively increases, and may rise to as large as 10° to 20° until the ground wave or the E-layer mode of propagation predominates. In general, errors are less at the higher frequencies.

3. Accuracy of VHF (metric) bearings

In the United Kingdom, the 95% error of VHF aeronautical direction-finding stations is generally about 5°, but in the U.S.A. it has been found that the 95% error is usually about 12° on transmissions from aircraft. The difference is probably due mainly to the effects of differences of siting, since with refinements in siting, the 95% error is reduced to about 4° in the U.S.A. At long ranges, beyond the normal service area, VHF direction-finding bearings in the U.S.A. have been found to be sporadic but the accuracy is sometimes as good as 6°.

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* This Report was adopted unanimously.

** See also Appendix 23 to the Radio Regulations.

4. Accuracy of HF (decametric) position fixing

The accuracy of position fixing depends principally on the " geometry " of the direction-finding network, its size and its disposition with respect to the transmitting station concerned, the degree to which the various stations can take simultaneous bearings and act in unison, and the number of stations in the network. The greatest accuracy is obtained when the most probable position of the transmitting station can be evaluated statistically, although in certain applications it is recognised that statistical evaluation may not be practicable or of operational importance. The accuracy of a direction-finding fix can be expressed in terms of the size, position and orientation of the ellipse in which the transmitting station lies with a given probability. Various methods for deriving and plotting probability ellipses are given in the references in Doc. 232, Warsaw, 1956.

5. Accuracy of VHF (metric) position fixing

The accuracy of VHF position fixing can be determined in a manner similar to that for HF. But in the aeronautical mobile service, which is one of the main users of VHF direction-finding, there is not usually sufficient time to evaluate the accuracy of a fix because of the high speed of the aircraft. At VHF, the problem may be simpler than at HF because the direction-finding networks, in general, will be smaller and can more easily be controlled automatically and have a central automatic display.

6. Classification of bearings in general

It was considered that it would be very advantageous to have a common classification system of bearings for all frequency bands (MF, HF and VHF) and for all types of service, for example, the maritime mobile and aeronautical mobile.

7. Classification of HF (decametric) bearings

The U.S.A. proposed a subjective method of classification by the operator for describing to the plotting centre the conditions under which a bearing has been taken. The factors that the operator should take into account are strength of signal, sharpness of the null, amount of fading and interference, the amount of goniometer swing required in taking the bearing and the number of bearings that have been taken in the time available. The proposed system of classification is as follows:

Class A — Bearing appears GOOD, meeting the following requirements:

(1) strong signal,
(2) definite indication (sharp null, etc.),
(3) negligible fading,
(4) negligible interference,
(5) less than 3° of arc of bearing swing,
(6) observed repeatedly for an adequate period of time.

Class B — Bearing appears FAIR, being degraded by one or more of the following factors:

(1) marginal signal strength,
(2) blurr (blunting) of indication,
(3) fading and/or audio distortion,
(4) light interference,
(5) more than 3° but less than 5° of arc of bearing swing,
(6) short observation time.

Class C — Bearing appears POOR, being degraded by one or more of the following factors:

(1) inadequate signal strength,
(2) severe blurr (blunting) of indication,
(3) severe fading and/or audio distortion,
(4) strong interference,
(5) more than 5° of arc of bearing swing,
(6) insufficient observation time.

The United Kingdom proposed that the accuracy of a bearing should be evaluated statistically from a knowledge of the five component variances which make up the total variance of the bearing, namely, instrumental, site, propagation, random-sampling and observational components. The bearing would then be classified as follows:

Class A: probability of less than 1 in 20 that the error exceeds 2°,
Class B: probability of less than 1 in 20 that the error exceeds 5°,
Class C: probability of less than 1 in 20 that the error exceeds 10°,
Class D: bearings whose accuracy is less than that of Class C.

8. Classification of VHF (decametric) bearings

It was considered that time alone prevents the classification of VHF bearings taken on transmissions from aircraft and it is not possible for the operator to classify bearings. But the United Kingdom suggested that it would be helpful if VHF aeronautical *stations* were classified, based upon flight-checking procedures. All bearings would then be given the classification of the station, unless they were taken under conditions inferior to those under which the station was calibrated.

9. Classification of HF (decametric) position-fixes

It was generally agreed that the accuracy of a fix-position should, whenever time permits, be given in terms of probability ellipses. The United Kingdom proposed that no formal classification be adopted since the size and shape of the ellipse for a given probability depends upon the " geometry " of the network and the transmitting station, the ionospheric conditions, etc. Where time is important, the U.S.A. proposed that the most probable fix-position would be given in degrees and minutes of latitude and longitude and should be classified as the equivalent circle in which the transmitting station probably lies:

Classification	Limit of areas
Good	40 km radius, or less
Fair	80 km radius, or less
Poor	120 km radius, or less
Estimated	more than 120 km radius

10. Classification of VHF (metric) position-fixes

For the aeronautical mobile service, it was considered that classification in terms of probability ellipses was not likely to be practicable or useful. The United Kingdom made no proposals on this point; the U.S.A. proposed the following classification:

Classification	Limit of areas
Good	4 km radius, or less
Fair	8 km radius, or less
Poor	12 km radius, or less
Estimated	more than 12 km radius

11. Aeronautical aspects

It was considered that since VHF direction-finding stations are widely used in civil aviation, Administrations should be invited to seek the advice of the International Civil Aviation Organization (I.C.A.O.) on all the aeronautical aspects of VHF direction-finding and position-finding.

12. Type of signal for VHF (metric) direction-finding

In general, the signal for VHF direction-finding purposes should include long dashes of at least 5 s duration, but the direction-finding station should also be permitted to specify the duration of the signal in certain circumstances. In the aeronautical mobile service, the procedure laid down by the I.C.A.O. has been found satisfactory. This specifies two dashes of plain carrier, each of approximately 10 s duration, followed by the call sign of the aircraft, unless another signal has been requested or is known to be required by the direction-finding station.

ANNEX

APPROXIMATE ERROR (IN DEGREES) WHICH MAY BE EXPECTED TO BE EXCEEDED ON ONLY 1 OCCASION IN 20

Conditions: — HF Adcock direction-finder
— Daylight
— Ranges between about 500 and 4000 km.

Type of site	3 MHz		6 MHz		9 MHz	
	Single snap bearing	Mean of 10 bearings taken in 5 min	Single snap bearing	Mean of 10 bearings taken in 5 min	Single snap bearing	Mean of 10 bearings taken in 5 min
Very good	7	6	6	5	6	4
Good, average	10	9	8	7	7	6

REPORT 358-1 *

SIGNAL-TO-INTERFERENCE PROTECTION RATIOS AND MINIMUM FIELD STRENGTHS REQUIRED IN THE MOBILE SERVICES **

(Question 1/8)

(1966 – 1970)

1. The following documents were submitted in reply to Question 1/8:

1.1 for the period 1963–1966:

Doc. XIII/25 (United Kingdom)
Doc. XIII/41 (Federal Republic of Germany)
Doc. XIII/88 (Japan)
Doc. XIII/95 (I.F.R.B.)

1.2 for the period 1966–1969:

Doc. XIII/136 (Federal Republic of Germany)
Doc. XIII/141 (Sweden)
Doc. XIII/146 + Corrigendum 1 (Japan)
Doc. XIII/149 (Japan)
Doc. XIII/157 (I.F.R.B.)

2. VHF and UHF land and maritime mobile services

2.1 *Protection ratios based on internal noise and distortion in the receiver*

According to documents of the I.F.R.B. and the C.C.I.R. (for example, Recommendation 447), the radio-frequency protection ratio is the value of the radio-frequency wanted-to-interfering signal ratio to achieve a subjectively defined reception quality. This ratio may have different values according to the type of service desired.

However, in the absence of information submitted to Study Group 8 on subjective measurements made in the VHF and UHF land and maritime mobile services, several Administrations have submitted the results of measurements using an alternative concept of signal-to-interference protection ratio. This is based on electrical measurements, using appropriate test signals, of the degradation of the signal-to-noise ratio of the wanted test signal, when a co-channel interfering signal is superimposed on the latter. A degradation of the initial signal-to-noise ratio of 20 dB to a signal-to-noise + interference ratio of 14 dB is taken as the criterion. This criterion is considered to correspond with the minimum acceptable grade of service.

In the tests described by the various Administrations, the frequency deviations are 70% or 60% of the maximum specified frequency deviations, and for amplitude modulation the modulation percentages are 70% or 60%, for both wanted and unwanted signals. From a study of the documents submitted, it may be deduced that the slight differences in measurement conditions and in the characteristics of the receivers used in the different tests, may result in differences in the measured protection ratios, of up to about ± 3 dB.

Although these protection ratios may be dependent on the passband characteristics of the receivers, the frequency difference between the co-channel wanted and unwanted signals, the frequency deviation, etc., the protection ratios in Table I are proposed as approximate standards for the practical design of mobile systems for a minimum grade of service.

* This Report was adopted unanimously.

** The aeronautical mobile service above 30 MHz is dealt with in Recommendation 441.

If a higher grade of service is required, a higher protection ratio should be adopted, particularly in the case of amplitude-modulated wanted emissions.

TABLE I

Wanted emission (Note 1)	Unwanted emission (Note 1)	RF protection ratio (dB)
Wide-band F3	Wide-band F3	8
Narrow-band F3	Narrow-band F3	8
Wide-band F3	A3	8
Narrow-band F3	A3	10
A3	Wide-band F3	8-17 (Note 2)
A3	Narrow-band F3	
A3	A3	17

Note 1.—Wide-band F3 systems normally employ frequency deviations with a maximum value in the range ±12 kHz to ±15 kHz.

The narrow-band F3 systems considered here normally employ frequency deviations with maximum values of either ±4 kHz or ±5 kHz.

Note 2.—The protection ratio may vary within the range shown dependent upon the difference in frequency between the carriers of the wanted and unwanted emissions and the frequency deviation of the unwanted emission. In general, it will tend towards the higher figure as the frequency deviation of the unwanted emission decreases.

2.2 *Minimum values of field strength to be protected*

The minimum values of field strength to be protected are determined either by the internal noise generated in the receiver, or by the man-made noise and natural noise at the location of the receiver. For the land mobile service, at frequencies below about 200 MHz, in towns, industrial areas, and on main roads, man-made noise usually predominates. On the other hand, in rural areas, internal receiver noise may be the limiting factor. In the maritime mobile service the level of man-made noise depends on the amount of electrical and electronic equipment which is in operation on the ship; in general, for frequencies below 200 MHz, the minimum values of field strength to be protected in the maritime mobile service on ships may be intermediate between those determined by man-made noise in towns, and those determined by the internal noise generated in the receiver.

In the use of signal-to-interference protection ratios for mobile radio services it is often convenient to refer to median values of field strength; these may be supplemented by information on the statistical distribution, with time and locations of the vehicle, of the wanted and unwanted field strengths.

Table II gives tentative values of the median values of field strength to be protected, based on some assumed values of:

— the field strength of man-made noise (column (a)); however, attention is drawn to the Note which follows the Table; and

— the equivalent field strength (column (b)), corresponding to the internal noise generated in the receiver.

In many locations it will be appropriate to use the values (b) in Table II. The values (a) will only be appropriate in areas where man-made noise is high, for example in some urban and industrial areas. For reception on ships in the maritime mobile service, the values (b) of the median field strength to be protected, could be used or intermediate values might be appropriate.

The values given in Table II take into account receiver sensitivities, antenna effectiveness, and feeder loss over the various frequency bands.

TABLE II

Frequency MHz	Assumed values of: (dB rel. 1 μV/m)		Median values of field strength to be protected (dB rel. 1 μV/m)	
	Man-made noise field strength	Receiver noise equivalent field strength	Based on the assumed values in (a)	Based on the assumed values in (b)
	(a)	(b)	(a)	(b)
30– 50	0	—16	+24	+ 8
50–100	0	—10	+24	+14
100–200	— 5	— 4	+19	+20
200–400	—10	+ 2	+14	+26
400–500	—13	+ 5	+11	+29

Note.—The values in this Table are tentative and require further study. The values in columns (a) are very tentative and depend on the levels of man-made noise which exist in the place considered; there is a wide variation in the levels of man-made noise in different locations.

For systems requiring other grades of service, different values of median field strengths to be protected and and different statistical distributions may be appropriate.

Some information on field strengths can be derived from Recommendation 370-1 and Report 244-2. Additional information can be found in Doc. XIII/146 (Japan), 1966–1969, and in the article " Field strength and its variability in VHF and UHF land mobile radio service ", by Okumari, Ohmori, Kawano and Fukada. (Review of the Electrical Communication Laboratory, Nippon Telegraph and Telephone Public Corporation, Tokyo, Vol. 16, **9-10** (1968)).

Information on protection ratios and minimum field strengths may also be found in the " Special Agreement between the Administrations of Belgium, the Netherlands, and the Federal Republic of Germany relating to the use of metric and decimetric waves for fixed and mobile services in border areas, Brussels, 1963 ", and in the Final Acts of the Special Regional Conference, Geneva, 1960. Similar information may be found in the Agreement between the Telecommunications Administrations of Austria, the Federal Republic of Germany, Italy and Switzerland, Vienna, 1969.

Doc. XIII/88 (Japan), 1963–1966, deals with the above questions for signal-to-noise ratios of 30 dB and 40 dB at the receiver output.

3. HF maritime mobile service

In Doc. XIII/95 (1963–1966), the International Frequency Registration Board (I.F.R.B.) gave an extract from the Technical Standards used by it when examining, in accordance with Article 9 of the Radio Regulations, notices concerning coast stations in the high-frequency bands.

Doc. XIII/157 (1966–1969) (I.F.R.B.) brings the above document up to date. The I.F.R.B. states that the purpose of this paper is twofold:

— to enable the C.C.I.R. to consider whether the technical standards used by the Board for the maritime mobile service in the high-frequency bands need to be amended, for example because of receiving conditions on board ships (level of local noise);

— to help Administrations to prepare for the Conference which, according to Recommendation No. Mar 6 of the 1967 Maritime W.A.R.C., is to be held in 1973 to establish a new Frequency Allotment Plan for coast high-frequency radiotelephone stations to replace the one in Appendix 25 to the Radio Regulations.

4. Conclusions

Considerable additional work concerning §§ 2 and 3 is necessary to determine more fully the appropriate protection ratios and the values of the field strengths to be protected, and also to determine and record the measurement methods which should be adopted.

REPORT 499 *

RADIO-PAGING SYSTEMS

(Question 12/8)

(1970)

1. Introduction

Five documents concerning radio-paging systems were submitted for consideration at the final meeting of Study Group XIII, Geneva, 1969. These documents are:

Doc. XIII/128 (Canada)
Doc. XIII/131 (U.S.A.)
Doc. XIII/144 (Sweden)
Doc. XIII/148 (Japan)
Doc. XIII/169 (Switzerland) **

Discussion of these documents revealed that further consideration should be given to the development of international radio-paging systems into which national radio-paging systems could be integrated and that there is a requirement for further information which could be submitted in the future in response to Question 12/8. It was therefore agreed that it would not be possible to make meaningful recommendations at this time and that further studies are required.

On the basis of the documents mentioned above and the opinions expressed during the meeting, the following general principles seem to be most relevant.

2. Definition

The radio-paging system referred to in this Report is described as a one-way selective signalling system without speech.

3. User requirements

The radio-paging system should be designed as an extension of the telephone service, thus permitting the assignment of numbers to paging subscribers, suitable for transmission over the telephone network.

The paging receiver should be as small as practicable.

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* This Report was adopted unanimously.

** The system described in this document is the subject of a recommendation of the C.E.P.T " Telecommunications " Committee, Rome, 1967.

In the case of multiple area paging systems, the user should be able to choose the area(s) where he desires to be paged.

The radio signal strength should be as uniform as practicable over the service area but restricted outside it.

4. Control terminal design concepts

For a high-capacity system, the use of a stored programme device seems to be desirable to perform the storing and forwarding functions of the paging calls.

It would be desirable for the control terminal to make a validity check of all calls entering the system.

A call-acceptance signal should be returned to the caller upon successful completion of the dialling operation.

The control terminal should return the necessary supervisory signals to the telephone switching network.

The control terminal should generate directly or indirectly the transmitter modulating signals.

5. Radio frequency considerations

The following factors need to be taken into account in the choice of a suitable class of emission and radio frequency:

— environmental noise level,
— antenna efficiency,
— coverage area required,
— equipment feasibility,
— interference-rejection capability of equipment,
— potential for causing interference to other radio systems.

There should be international agreement on the frequencies and classes of emission to be used to provide international radio-paging services. Some of the contributions mentioned frequencies of the order of 87 MHz with amplitude modulation, 96 MHz with frequency modulation, while others mentioned 150 MHz with frequency modulation.

6. Signalling format

The baseband-signalling format should be standardized. The choice of the appropriate coding techniques should take into account the required capacity of code combinations, speed of transmission and reliability of call reception (error rate).

7. Compatibility between international and national radio-paging systems

It was recognized that a high degree of compatibility would be necessary between the national and international radio-paging systems. However, this does not preclude the establishment of radio-paging systems in factories, buildings, etc., using different standards.

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SECTION 8B: MARITIME MOBILE SERVICE

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 45

AVOIDANCE OF INTERFERENCE FROM SHIPS' RADAR TO OTHER RADIOCOMMUNICATION APPARATUS ON BOARD

The C.C.I.R., (1951)

CONSIDERING

(a) that experience has proved that, with well-designed and properly installed radar, the possibility of interference occurring in practice is very remote;

(b) that the possibility of interference to radio reception and to direction-finding on a vessel, other than that upon which the radar is located, is exceedingly remote and that no instances of such interference have been reported;

(c) that, in the unlikely case where radar interference might result to radio reception aboard a radar equipped vessel, the presence of such interference may readily be detected and identified by listening on the radio receiver or direction-finder;

(d) that, where interference has occurred to radio reception aboard ships equipped with well designed radar, in each case the cause of the interference has been faulty initial installation and has been removed by correcting the installation;

UNANIMOUSLY RECOMMENDS

1. that Administrations shall see to it that radar equipment placed aboard ships is well designed and properly installed, so as not to cause interference to radio reception aboard the radar equipped vessel. In this regard, particular attention shall be paid to shielding, bonding and to fitting line filters, especially in the modulator circuits, for the conductors which are routed between the major components of the installation;

2. that the absence of interference shall be assured, either by test procedures of prototypes or by installation inspection procedures, whereby an investigation is made to determine whether or not there exists any noticeable interference to ships' radio receivers or direction-finders, under practical conditions of installation and operation.

RECOMMENDATION 77-2

CONDITIONS NECESSARY FOR INTERCONNECTION OF MOBILE RADIOTELEPHONE STATIONS AND INTERNATIONAL TELEPHONE LINES

The C.C.I.R., (1951 – 1966 – 1970)

CONSIDERING

(a) that the conditions concerning which international agreement is necessary appear to be few in number;

(b) that these conditions, if met, would permit suitable interconnection between mobile radiotelephone stations and international telephone lines;

UNANIMOUSLY RECOMMENDS

1. that mobile radiotelephone circuits, intended for connection to international telephone systems, should terminate (on a two-wire basis, for the present at least) in such a way that they may be connected to international lines in the same manner as other landline connections;

2. that the mobile radiotelephone circuits should accept from and deliver to the landline system speech volumes conforming, as far as possible, to the C.C.I.R. and C.C.I.T.T. standards for connections to international circuits;

3. that the attenuation-frequency characteristics of the radio system (including the landlines to the radio receiver and radio transmitter) should be such that the grade of transmission is not unduly affected; and, in particular, the effectively transmitted band should be not less than 300 to 2600 Hz (for single-sideband aeronautical and maritime radiotelephone equipment, see Recommendation 258-2, § 1.3.6 and Appendix 17A to the Radio Regulations);

4. that the noise from a radio circuit, connected to an international circuit, should not be unduly great and should be insufficient to operate echo suppressors or other devices on domestic or international circuits frequently;

5. that, for mobile radiotelephone stations, which may have to communicate with land stations in more than one country, consideration be given to the necessity for agreement as to a method of signalling for use between the land mobile stations.

RECOMMENDATION 218

PREVENTION OF INTERFERENCE TO RADIO RECEPTION ON BOARD SHIPS *

The C.C.I.R., (1951 – 1956)

CONSIDERING

(a) that the Maritime Regional Radio Conference, Copenhagen, 1948, recommended that the C.C.I.R. study the question of interference to radio reception caused by electrical installations on board ship;

* Interference from radar and other electronic equipment has not been specifically considered in framing this Recommendation. The prevention of radar interference is covered by Recommendation 45.

(b) that the International Conference on Safety of Life at Sea, London, 1960 (Chapter IV, Regulation 9), requested that all steps be taken to eliminate, as far as possible, the causes of radio interference from electrical and other apparatus on board ship;

(c) that electrical interference is caused by the unwanted excitation of the radio receiving equipment, including the antenna, by fluctuating electromagnetic fields set up by other electrical installations;

(d) that the fluctuation of electromagnetic fields, which gives rise to interference, is caused by abrupt changes in current in the source of interference, and by abrupt changes in the resistance of conductors situated in electromagnetic fields;

(e) that electrical interference may be transmitted by direct radiation and induction from the source of interference itself, and also by re-radiation and induction from conductors which carry interfering currents;

UNANIMOUSLY RECOMMENDS

1. that the design, construction and installation of electrical equipment in ships should be such that interference is minimized at its source (see also No. 959 of the Radio Regulations);

2. that electrical equipment installed in ships should be efficiently maintained to prevent any increase in the level of interference which it causes;

3. that antennae used for transmission or reception should be erected, as far above and as far away as possible from electrical machinery and from parts of the ship's structure such as funnels, stays and shrouds;

4. that the down-leads of antennae which are used exclusively for reception should be screened; that the screen should extend continuously from the receiver to a point which is as high as practicable above the ship's structure, and that the screen should be effectively connected to the earth terminal of the receiver;

5. that frame or loop antennae used for direction-finding, should be effectively screened against electrostatic interference;

6. that the radio receiving room should be effectively screened and situated as high as practicable in the ship;

7. that power converting plant, within the radio receiving room, should be housed in a separate screened enclosure, unless the plant is self-screened;

8. that the radio receiving equipment should be designed so that it is effectively screened;

9. that suppressor filters, to prevent the propagation of interference, should be fitted at the sources of interference, preferably built into the interference-producing equipment, and that in particular:

9.1 the electrical ignition systems of internal-combustion engines, including those which may be installed in lifeboats, should be fitted with suppressors;

9.2 the navigational instruments and associated equipment, which are installed in the neighbourhood of the receiving antennae or the radio receiving room should, if necessary, be fitted with suppressors, be screened, and the screen effectively earthed;

10. that cables in the vicinity of the receiving antennae or the radio receiving room, and cables within the radio room, should be screened by enclosing them in metal conduits, unless the cables themselves are effectively screened;

11. that twin cables should be used wherever possible: if single-core cable is necessary, the " lead " and " return " conductors should be fixed, as close to one another as possible, to avoid the formation of loops;

12. that suppressors should be fitted to cables at their point of entry into the radio receiving room, unless they terminate close to the point of entry in equipment which itself provides adequate screening and suppression;

13. that cables, ducts and pipes which do not terminate in the radio receiving room, should preferably not be installed in the radio receiving room; if it is essential for them to pass through the radio receiving room, the ducts and pipes and the screening of the cables should be effectively earthed;

14. that a copper earth-busbar should be fixed along the bulkheads and bonded at several points to the ship's structure and to the metal structure or screening of the radio receiving room; the screens of cables within and near to the radio receiving room, as well as the screens of apparatus in the radio receiving room, should be effectively connected to the busbar;

15. that rigging should be either insulated from or bonded to the ship's structure (stays that are subject to considerable tension can more conveniently be bonded);

16. that, for smaller vessels and those constructed of wood, the principles recommended should be applied as far as is practicable;

17. that particular care should be taken to minimize interference on the frequency bands used for distress, safety and direction-finding in the maritime service;

18. that Administrations should bring the above recommendations to the attention of naval architects, shipbuilders and those responsible for the manufacture, installation and maintenance of electrical equipment.

RECOMMENDATION 219-1

ALARM SIGNAL FOR USE ON THE MARITIME RADIOTELEPHONY DISTRESS FREQUENCY OF 2182 kHz

The C.C.I.R., (1951 – 1953 – 1956 – 1966)

CONSIDERING

(a) that it is desirable and practicable to establish an internationally agreed alarm signal for use on the calling and distress frequency of 2182 kHz (see Art. 36 of the Radio Regulations, as revised by the Maritime Conference, Geneva, 1967);

(b) that the alarm signal should be such as to:

— provide reliable operation of automatic alarm equipment;

— provide a distinctive signal, which is readily recognized aurally, when received on a loudspeaker or headphones;

— be capable of being received through interference from speech transmissions, through other kinds of interference, and through noise;

— avoid false responses when received either aurally or by automatic means:

— be capable of being produced by a simple manual device, as well as by automatic means;

(c) that the alarm signal should be such as to permit the construction of alarm equipment which is rugged, dependable, stable in performance, of low cost, of easy production, of long life with a minimum of maintenance, and which can be used with existing maritime radiotelephone equipment;

(d) that to help in clearing the calling and distress frequency channel of emissions from other stations the alarm signal and detecting device should be effective beyond the range at which speech transmission is satisfactory;

(e) that the automatic alarm equipment should be capable of operating, in as short a time as possible, consistent with the avoidance of false responses;

(f) that the results of the further examination of this problem by the Administrations which participated in Study Programme 29, Geneva, 1951, are sufficiently conclusive to determine the essential characteristics of the signal, including tolerances that should be recommended for international adoption;

(g) that it is possible to specify the minimum performance standards for automatic alarm equipment, for both transmission and reception, to such an extent that future progress and development are not hampered;

(h) that it is undesirable that the specification of performance standards for automatic alarm equipment should exceed in scope the requirements already established by international agreement for automatic alarm devices, intended for the reception of the international alarm signal or the international distress signal in radiotelegraphy, normally transmitted on the frequency 500 kHz (see Nos. 1475 and 1476, and Appendix 20, § 1 of the Radio Regulations, as revised by the Maritime Conference, Geneva, 1967; and Chapter IV, Regulation 10 of the Convention for the Safety of Life at Sea, London, 1960);

UNANIMOUSLY RECOMMENDS

1. that the alarm signal described below should be adopted internationally, for use on the maritime radiotelephony calling and distress frequency of 2182 kHz;

1.1 the alarm signal shall consist of two substantially sinusoidal audio-frequency tones, transmitted alternately. One tone shall have a frequency of 2200 Hz and the other a frequency of 1300 Hz. The duration of each tone shall be 250 ms;

1.2 the tolerance of the frequency of each tone shall be $\pm$ 1·5%; the tolerance on the duration of each tone shall be $\pm$ 50 ms; the interval between successive tones shall not exceed 50 ms; the ratio of the amplitude of the stronger tone to that of the weaker shall be within the range 1 to 1·2;

1.3 when generated by automatic means, the alarm signal shall be sent continuously for a period of at least 30 s but not exceeding one minute; when generated by other means, the signal shall be sent as continuously as is practicable over a period of approximately one minute;

2. that the automatic-devices, intended for the reception of the alarm signal in question, should fulfil the following conditions:

2.1 the frequencies of maximum response of the tuned circuits, and other tone selecting devices, shall be subject to a tolerance of $\pm$ 1·5% in each instance; and the response shall not fall below 50% of the maximum response for frequencies within 3% of the frequency of maximum response;

2.2 in the absence of noise and interference, the automatic receiving equipment shall be capable of operating from the alarm signal in a period of not less than four and not more than six seconds;

2.3 the automatic receiving equipment shall respond to the alarm signal, under conditions of intermittent interference caused by atmospheric and powerful signals other than the alarm signal, preferably without any manual adjustment being required during any period of watch maintained by the equipment;

2.4 the equipment shall not be actuated by atmospheric or by strong signals other than the alarm signal;

3. that the automatic alarm equipment for both transmission and reception, on the calling and distress frequency of 2182 kHz, shall fulfil the following conditions:

3.1 the equipment shall be effective beyond the range at which speech transmission is satisfactory;

3.2 the equipment shall be capable of withstanding vibration, humidity, changes of temperature and variations in power supply voltage equivalent to the severe conditions experienced on board ships at sea, and shall continue to operate under such conditions;

3.3 the equipment should, as far as practicable, give warning of faults that would prevent the apparatus from performing its normal functions during watch hours;

4. that, before any type of automatic alarm equipment for transmission and reception on the calling and distress frequency of 2182 kHz is approved for use on ships, the Administrations having jurisdiction over those ships should be satisfied by practical tests, made under operating conditions equivalent to those obtaining in practice, that the equipment complies with the provisions of §§ 1, 2 and 3 of this Recommendation.

RECOMMENDATION 224

TESTING OF 500 kHz RADIOTELEGRAPH AUTO-ALARM RECEIVING EQUIPMENT ON BOARD SHIPS

(1956)

The C.C.I.R.,

CONSIDERING

that it is important for the safety of life at sea, that radiotelegraph auto-alarm receiving installations (including the antenna) are always in good working order on board ships at sea;

UNANIMOUSLY RECOMMENDS

in addition to the requirements of Chapter IV of the International Convention for the Safety of Life at Sea, London, 1960;

1. that all radiotelegraph auto-alarm receiving equipment, for use on the international calling and distress frequency of 500 kHz should, wherever practicable, be provided specifically with means for automatic warning of the following:

1.1 failure of any valve filament, whether the cathode is directly or indirectly heated;

1.2 major variation or sustained failure of any source of voltage which is used for supplying valve elements, where this would seriously affect the proper functioning of the apparatus, as laid down in Chapter IV, Regulation 10 of the said Convention;

1.3 any drop in voltage, or complete failure, of the main power supply to the auto-alarm equipment that would seriously affect the proper functioning of the equipment and where such warning is not already given by other means;

2. that provision should be made for listening to the output of the auto-alarm receiver;

3. that the proper functioning of auto-alarm installations should be checked periodically by listening to signals on the auto-alarm receiver with its normal antenna connected, and by observing similar signals received on 500 kHz on the ship's main receiving installations;

4. that measures should be taken to ensure that the auto-alarm antenna is always in good condition;

5. that the design of auto-alarm equipment should be as simple as possible, consistent with reliable and efficient operation;

6. that, wherever practicable, measures should be taken to permit reception on the auto-alarm installation when the radio direction-finder is being used;

7. that live test transmissions of the radiotelegraph auto-alarm signal should *not* be made.

RECOMMENDATION 257-1 *

SELECTIVE-CALLING SYSTEM FOR USE IN THE INTERNATIONAL MARITIME MOBILE SERVICE

The C.C.I.R., (1959 – 1970)

CONSIDERING

(a) that selective calling of ships by coast stations would expedite the handling of traffic in the international maritime mobile service;

(b) that a selective-calling system has the following advantages:

— it is rapid and positive,
— it overcomes the disadvantage of ships having to listen to all calls,
— it reduces the difficulties caused by differences of language,
— it reduces the time taken by coast stations to establish contact with ships and thus reduces congestion on the channels used for calling,
— it increases operating efficiency generally;

(c) that a number of Administrations have an immediate requirement for selective-calling facilities;

(d) that ideally, a selective-calling system should be suitable for use in all maritime mobile bands;

(e) that a selective-calling system should have sufficient capacity of code numbers to accommodate all ships that desire to use it;

(f) that the Inter-Governmental Maritime Consultative Organization (I.M.C.O.) has expressed in its letter of 2 November 1966 the opinion that it would be desirable from the viewpoint of maritime safety, if selective-calling devices could include a facility for calling all ships;

(g) that there may be a need for a facility to call predetermined groups of ships;

(h) that it may be operationally desirable for a ship's operator to be able to ascertain either the identity of the coast station which has called him, or the VHF channel on which he should reply;

(j) that a selective-calling system should be suitable for use with normal types of radio equipment on ships;

UNANIMOUSLY RECOMMENDS

1. that, where there is a need to fulfil immediate requirements for selective calling, the system to be used should have the following characteristics:

1.1 the selective call signal should consist of five figures representing the code number assigned to a ship for selective calling;

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* This Recommendation terminates the study of Question 3/XIII.

1.2 the audio-frequency signal applied to the input of the coast station transmitter should consist of consecutive audio-frequency pulses conforming to the following:

1.2.1 the audio frequencies used to identify the figures of the code number assigned to a ship should conform to the following series:

Figure	1	2	3	4	5	6	7	8	9	0	Figure repetition
Audio frequency (Hz)	1124	1197	1275	1358	1446	1540	1640	1747	1860	1981	2110

For example, the series of audio-frequency pulses corresponding to the selective call 12133 would be 1124-1197-1124-1275-2110 Hz, and the series corresponding to the code number 22222 would be 1197-2110-1197-2110-1197 Hz;

1.2.2 if the series of numbers represented by the use of only two frequencies, chosen from those in § 1.2.1, are reserved for calling predetermined groups of ships, then 100 different groups of numbers are available for allocation, according to the needs of Administrations;

1.2.3 the waveforms of the audio-frequency generators should be substantially sinusoidal, not exceeding 2% total harmonic distortion;

1.2.4 the audio-frequency pulses should be transmitted sequentially;

1.2.5 the difference between the maximum amplitude of any audio-frequency pulses should not exceed 1 dB;

1.2.6 the duration of each audio-frequency pulse, measured between the half-amplitude points, should be 100 ms ± 10 ms;

1.2.7 the time interval between consecutive pulses, measured between the half-amplitude points, should be 3 ms ± 2 ms;

1.2.8 the rise and the decay time of each audio-frequency pulse, measured between the 10% and 90% amplitude points, should be 1·5 ms ± 1 ms;

1.2.9 the frequency tolerance of the audio frequencies given in § 1.2.1 should be ± 4 Hz;

1.2.10 the selective call signal (ship's code number) should be transmitted twice with an interval of 900 ms ± 100 ms between the end of the first signal and the beginning of the second signal (Fig. 1);

1.2.11 the interval between calls from a coast station to different ships should be at least 1 s (Fig. 1);

2. that if additional information is added to the selective call signal it should be as follows:

2.1 to identify the calling coast station four figures should be transmitted;

2.2 to identify the VHF channel on which a reply is required two " zeros " followed by two " figures " should be transmitted;

2.3 the characteristics of the signals should conform to §§ 1.2.1 and 1.2.3 to 1.2.9 inclusive;

2.4 the composition of the signal should be as shown in the diagram (Fig. 2), the tolerance on the 350 ms interval being ± 30 ms;

3. that an " all ships call " to actuate the receiving selectors on all ships, regardless of their individual code numbers, should consist of a continuous sequential transmission of the eleven audio frequencies given in § 1.2.1. The parameters of the audio-frequency pulses should be in accordance with §§ 1.2.3, 1.2.4, 1.2.5 and 1.2.9. The duration of each audio-frequency pulse, measured between the half-amplitude points, should be 17 ms ± 1 ms and the interval between consecutive pulses, measured between half-amplitude points, should not exceed 1 ms (Fig. 3). The total duration of this " all ships call " signal should be at least 5 s;

4. that receiving selectors on ships should operate reliably in any radio conditions acceptable for satisfactory communication;

5. that the receiving selector should be designed to accept the signals as defined in §§ 1 and 3. However, bearing in mind that coast stations may transmit additional signals (e.g. coast station identification), it is important to ensure that during reception of a selective call the decoder should be reset after 250 ± 40 ms if an incorrect digit or no digit is received;

6. that the receiving selector should be so designed, constructed and maintained that it is resistant to atmospherics and other unwanted signals including selective-calling signals other than that for which the decoder has been set up;

7. that the receiving selector should include an audible or visual means of indicating the receipt of a call and, if required, an additional facility allowing the determination of the identity of the calling station or the VHF channel on which to reply according to the needs of Administrations;

8. in order to distinguish whether an incoming call is a normal selective call or an " all ships call ", the multiple actuation of the ship's decoder by the " all ships call " signal (see § 3) can be used;

9. that the indicating means mentioned in § 7 should be actuated on correct reception of the calling signal, no matter whether the correct registration has occurred on the first, or the second, or both parts of the calling signal transmitted by the coast stations;

10. that the indicating means should remain actuated until re-set manually;

11. that the receiving selector equipment should be as simple as is practicable, be capable of reliable operation over long periods with a minimum of maintenance, and could, with advantage, include facilities for self-testing.

Note. — The Director, C.C.I.R., is requested to bring the contents of this Recommendation to the attention of I.M.C.O.

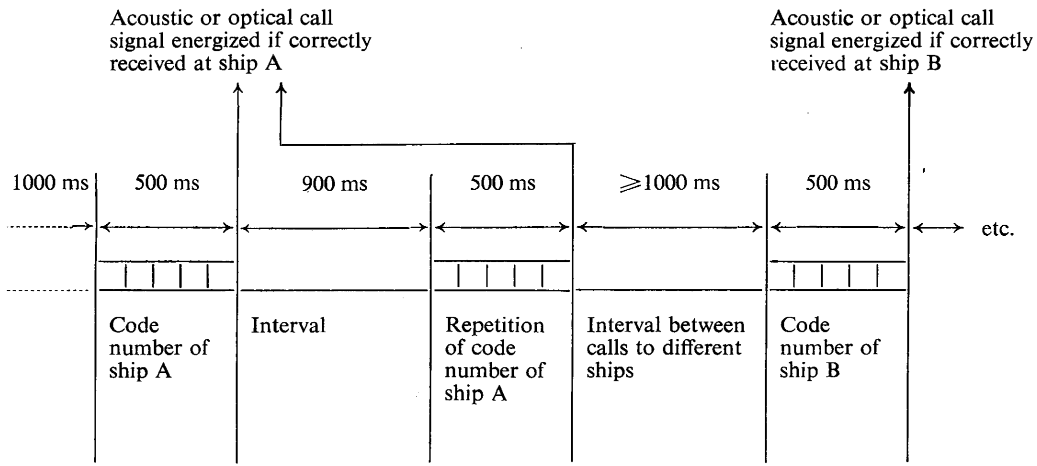

FIGURE 1

Composition of selective call signals without additional information

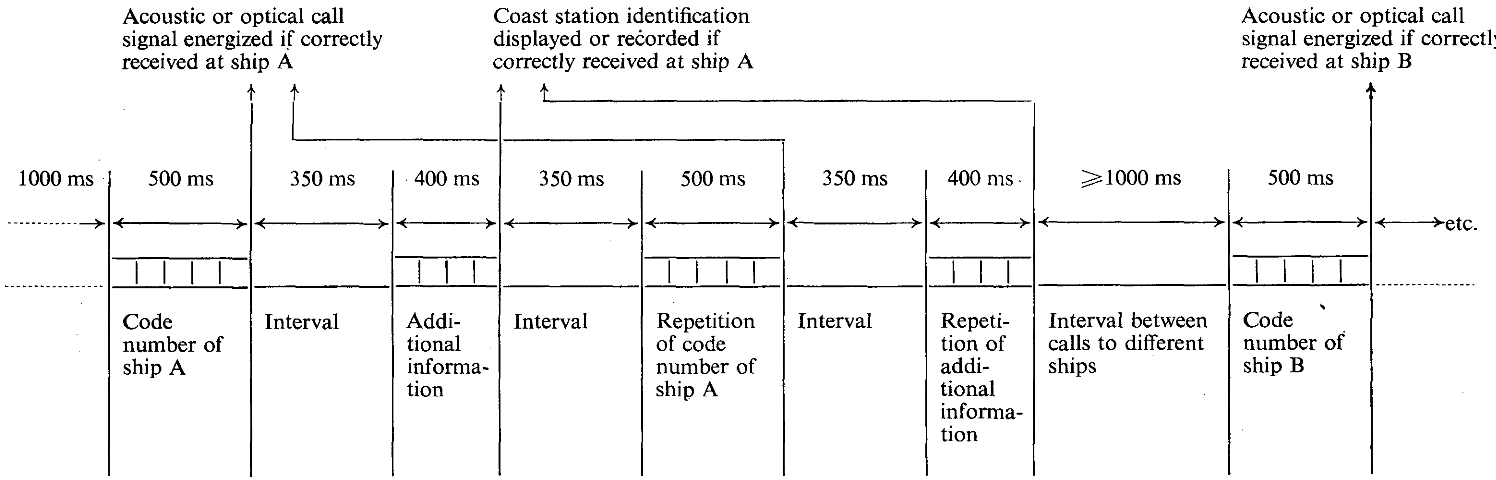

FIGURE 2

Composition of selective call signals with additional information

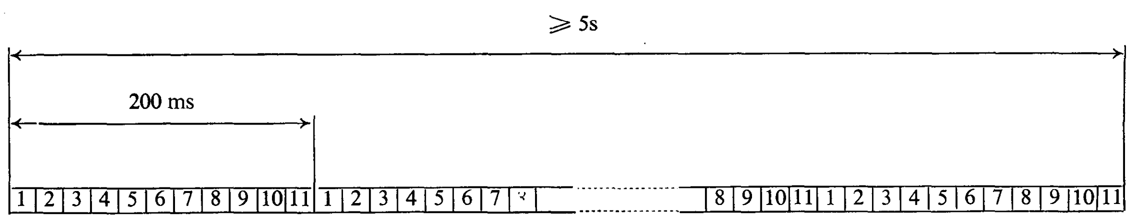

FIGURE 3

Composition of the " all ships call " signal

RECOMMENDATION 427

INTERFERENCE DUE TO INTERMODULATION PRODUCTS IN THE VHF (METRIC) MARITIME MOBILE RADIOTELEPHONE SERVICE

The C.C.I.R., (1959 – 1963)

CONSIDERING

(a) that intermodulation products may cause serious interference in the operation of the VHF mobile maritime radiotelephone service;

(b) that intermodulation products may be generated and radiated at receiving stations and transmitting stations, in the radio equipment itself or at external points (such as antenna systems), where there is electrical non-linearity;

(c) that practical measures can be taken to minimize the generation of such intermodulation products and to mitigate their harmful effects;

UNANIMOUSLY RECOMMENDS

1. that Recommendation 218, particularly §§ 3, 4 and 15, should be followed for the purpose of minimizing the generation of intermodulation products at points on ships external to the receiver;

2. that antennae, rigging, stays and structures, likely to cause intermodulation products, should be maintained in such condition as to minimize the generation of intermodulation products;

3. that care should be taken, in the design and development of receivers, to minimize the possibility of interference due to the generation of intermodulation products in the receivers themselves;

4. that the range of interference, due to radiated intermodulation products, should be limited to sea areas that are not normally navigated by ships and to shore areas that are clear of coast receiving stations;

5. that the siting of coast stations should take into account the factors mentioned in § 4 above (see also No. 695 of the Radio Regulations);

6. that frequency assignments in the VHF mobile maritime radiotelephone band should, as far as possible, take into account the possibility of interference from intermodulation products (see also No. 695 of the Radio Regulations);

7. that where the service area permits, coast stations should use directive antennae (see also No. 695 of the Radio Regulations);

8. that care should be taken in the use of the single-frequency channels to minimize interference, due to intermodulation products, to the common calling and safety channel 156·80 MHz and to the other channels specified in Appendix 18 (Mar) to the Radio Regulations, as revised by the Maritime Conference, Geneva, 1967 (see also No. 1363 (Mar) of these Regulations);

9. that frequency assignments to other services should, as far as possible, take into account the possibility of interference to the VHF mobile maritime radiotelephone service due to the generation of intermodulation products; in particular, powerful emissions from stations near coastal areas and with frequencies differing by about 4·6 MHz from one another, should be avoided if possible.

RECOMMENDATION 428-2 *

DIRECTION-FINDING AND/OR HOMING ** IN THE 2 MHz BAND ON BOARD SHIPS

The C.C.I.R., (1963 – 1966 – 1970)

CONSIDERING

(a) that, according to the Convention for the Safety of Life at Sea, London, 1960, the medium frequency radiotelephony calling and distress frequency of 2182 kHz will become of increasing importance to the safety of life at sea;

(b) that, in most distress cases, merchant ships and fishing vessels and other surface craft participate in search and rescue;

(c) that in addition to ships between 500 and 1600 tons gross tonnage, which are already required to be fitted with medium frequency radiotelephone equipment if they do not carry medium frequency radiotelegraph equipment, ships between 300 and 500 tons gross tonnage will also be required to fit such equipment, in accordance with Chapter IV, Regulation 4 of the Convention for the Safety of Life at Sea, London, 1960;

(d) that a large number of ships of more than 1600 tons gross tonnage (which are compulsorily fitted with medium frequency radiotelegraph equipment) are voluntarily fitted with medium frequency radiotelephone equipment and that the number of such ships is increasing;

(e) that the majority of deep-sea fishing vessels are fitted voluntarily with medium frequency radiotelephone equipment;

(f) that an increasing number of ships are being fitted with direction-finding equipment capable of taking bearings in the 2 MHz band;

(g) that direction-finding and especially homing by ships is important in cases of distress;

(h) that Recommendation No. 31 of the International Conference on Safety of Life at Sea, London, 1960, drew the attention of contracting governments to the studies being undertaken under Question 2/XIII of former Study Group XIII by the C.C.I.R.;

(j) that technical studies in several countries have shown:

j.a. that direction-finding, or at least homing, is usually possible in the 2 MHz band on many ships;

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* This Recommendation terminates the study of Question 2/XIII.

** For the purpose of this Recommendation " homing " means the taking of direction-finding bearings without ambiguity of sense within an arc of 30° on either side of the bow.

j.b. that compared with the problems of direction-finding by ships in the lower parts of the medium frequency band, the main cause of error in direction-finding in the 2 MHz band is re-radiation from various parts of the ship's super-structures, masts, downleads, halyards, stays, derricks, etc., and from other antennae;

j.c. that errors caused by re-radiation effects, however, should be constant if the disposition and electrical conditions of the re-radiators are constant and that such errors can be taken into account by calibrating the direction-finder;

j.d. that direction-finding and homing is easier on board small ships than on larger ones, because an increase in the size of ships and their super-structures, masts, etc., as given in § *j.b*, leads to an increase of disturbing resonance effects;

j.e. that a reliable direction-finder calibration can be more readily obtained if it is restricted to a specific frequency such as 2182 kHz, instead of a wide frequency band;

j.f. that even where omnidirectional direction-finding, even on a specific frequency, is difficult or impossible (such as on board large vessels with strong re-radiation effects), homing will nearly always be possible;

UNANIMOUSLY RECOMMENDS

1. that the following technical measures and precautions should be observed when installing direction-finders for taking bearings in the 2 MHz band, and in particular for homing on the frequency 2182 kHz;

1.1 the antenna system, including the sense antenna, of the direction-finder should be erected as far as possible away from any re-radiators;

1.2 the direction-finder antenna system should, preferably, be installed on the fore-and-aft line of the ship;

1.3 if the direction-finding antenna system is to be fitted on a mast it should, preferably, be installed symmetrically on top of the mast and not to one side of it; where a mast-head installation may require the use of longer cables, their possible influence on the bearing should be taken into consideration;

1.4 the mounting of the direction-finding antenna system may be considered satisfactory for homing purposes if the calibration in the sector ahead as in § 2.5 has proved to be possible;

1.5 if the resonance frequency of a mast and its rigging is within approximately $\pm 20\%$ of the frequency used for direction-finding, then the antenna system of the direction-finder should not in general be mounted on or near the top of the mast, unless the antenna system is one which is not influenced by the mast resonance. The calculation or assessment of the resonance frequency should take into account the effect of the antenna system of the direction-finder;

1.6 that the sense antenna should be mounted on or as near as is practicable to the central axis of the antenna system of the direction-finder;

1.7 the effects caused by re-radiating antenna wires can be minimized by providing properly located isolating switches for the antennae;

1.8 re-radiation from the rigging (e.g. stays, wire ropes, etc.) should be reduced by the insertion of insulators such that the resonance frequency of the longest portion is considerably above the highest frequency used for direction-finding or considerably above 2182 kHz where the installation is used for homing only;

1.9 the formation of " closed loops ", e.g. by the rigging, should be avoided by inserting insulators at appropriate points;

1.10 to avoid electrically-doubtful connections, the connecting points of movable parts of the rigging and connections between masts and derricks, wire ropes, etc., should be short-circuited as far as possible;

2. that the following measures and precautions should be observed in the calibration of direction-finders for the 2 MHz band and in particular for homing on the frequency 2182 kHz;

2.1 the rigging, downleads, derricks, halyards, etc. should be in their sea-going positions;

2.2 any antennae that affect the direction-finder should preferably be isolated and other antennae which cannot be isolated (for example, because of operational requirements), should be in the same condition as they will be when bearings are being taken or when homing is being done at sea; the condition and electrical arrangement of all antennae should be noted on the direction-finder calibration charts;

2.3 calibration in the forward direction for the purpose of homing (or a more complete calibration if so desired) should be carried out in an area well clear of the shore and of other ships. If a shore-based transmitter is used, calibration should be carried out on a line passing through that station and crossing the coast-line approximately at right angles. The transmitting antenna should radiate vertically polarized waves from a single element, and care should be taken to avoid re-radiation from any object in the vicinity. The distance between the transmitting antenna and the direction-finder should be great enough to avoid the calibration being affected by the induction field of the transmitting antenna;

2.4 care should be taken to ensure that the direction-finder gives the correct sense on all bearings and frequencies concerned and in particular for homing purposes on the frequency 2182 kHz, within a sector of 30° on both sides of the bow;

2.5 the calibration, if not complete, should at least cover a sector of 30° on both sides of the bow, and as far as possible should be made at sufficiently small bearing intervals (say, in steps of a few degrees) to detect any sudden changes (for example, re-entrant portions where two or more different corrections exist for the same indicated bearing);

2.6 calibration at 2182 kHz should be carried out at a frequency as near as possible to 2182 kHz, special attention being paid to No. 1325 (Mar) of the Radio Regulations, and to the avoidance of interference to established operations in adjacent channels;

3. that the calibration should be checked periodically, especially if the condition of the rigging, etc. has been altered since the last calibration;

4. that on board ships equipped with a direction-finder, the frequency range of which includes the 2 MHz band, a calibration should be made to determine if the direction-finder could be used without modification for omnidirectional direction-finding, or at least for homing on the frequency 2182 kHz;

5. that when Administrations encourage the use of direction-finders on board ship, capable of operating in the 2 MHz band, or at least on the international radiotelephony distress and calling frequency 2182 kHz, they should also encourage the provision of suitable facilities for the calibration of such direction-finder equipment;

6. that the Director, C.C.I.R., should be invited to bring this Recommendation to the attention of the I.M.C.O. (reference is made to Recommendation No. 31 of the Convention for the Safety of Life at Sea, London, 1960);

7. that Administrations should bring the above Recommendation to the attention of those responsible for the provision, installation and maintenance of direction-finders on ships.

ANNEX

Under good conditions, when the above precautions and technical measures have been taken, an accuracy of about $\pm 2°$ can be attained in taking bearings in the 2 MHz band by reception of " ground " waves on board ships of less than about 800 tons gross tonnage. In unfavourable conditions, for example, when the ship is pitching and rolling, an accuracy of about $\pm 5°$ can be obtained. On larger ships, the accuracy may be worse, but in most cases it should usually be possible to use the direction-finder for homing purposes on 2182 kHz. Bearings taken by reception of skywaves, although variable in azimuth and sharpness, are useful for homing into the ground wave range by utilizing their average value.

RECOMMENDATION 429-2

INTERFERENCE LEVEL ON THE RADIOTELEGRAPH DISTRESS FREQUENCY

The C.C.I.R., (1963 – 1966 – 1970)

CONSIDERING

(a) that the International Conference on Safety of Life at Sea, London, 1960, adopted the following Recommendation (No. 27):

" The Conference, recognizing that at present there is a tendency to increase the maximum power of radiotelegraph installations, and that this may lead to an increase in the interference level on the radiotelegraph distress frequency, which may considerably impair the use of this frequency for safety purposes, recommends that the International Telecommunication Union should be invited by the Organization—(i.e. Inter-Governmental Maritime Consultative Organization)—to consider what measures can be taken to prevent such an increase in the interference level ";

(b) the experience of coast station radio operators and ships' radio officers;

UNANIMOUSLY RECOMMENDS

that the following measures should be taken to reduce interference at 500 kHz;

1. messages prefixed by the Safety Signal, TTT, should be sent on a working frequency after an initial announcement at 500 kHz in accordance with Nos. 1107 and 1492 (Mar) of the Radio Regulations;

2. coast stations should use their working frequencies to reply to calls from ships at 500 kHz, in accordance with Nos. 1116 (Mar) and 1117 (Mar) of the Radio Regulations;

3. coast stations making calls to ships at 500 kHz should request ships to reply on their working frequencies, as permitted by Nos. 1023 (Mar) and 1116 (Mar) of the Radio Regulations;

4. No. 1092 of the Radio Regulations, which forbids " CQ " calls followed by the letter K to be made in congested areas, should be enforced by Administrations;

5. greater use should be made of the facilities provided under No. 972 of the Radio Regulations, for reducing power at ship stations, and coast stations as far as practicable should use the minimum necessary power, particularly at night, in accordance with No. 694 of the Radio Regulations;

6. steps should be taken by Administrations to prevent unnecessary signalling at 500 kHz, particularly during distress, in accordance with Nos. 693, 1107 to 1110, 1111 (Mar), 1112, 1113 (Mar) and 1445 of the Radio Regulations;

7. for Class A2 emissions at 500 kHz the note frequencies used by various stations should, as far as practicable, be spread over the range 450 to 1350 Hz;

8. prolonged calling at 500 kHz by ships endeavouring to establish contact with distant coast stations should be avoided by greater use of HF channels or by relaying of messages;

9. in areas where considerable use is made of 500 kHz for calls and replies, the calling frequencies assigned to coast stations should be spread over the band 497 to 503 kHz in accordance with No. 1115 (Mar) of the Radio Regulations;

10. the frequency 512 kHz may be used as a supplementary frequency for calls and replies when 500 kHz is being used for distress, in accordance with Nos. 1125 (Mar) and 1126 to 1129 inclusive of the Radio Regulations.

RECOMMENDATION 439

EMERGENCY POSITION-INDICATING RADIO BEACONS OPERATING AT THE FREQUENCY 2182 kHz

The C.C.I.R., (1966)

CONSIDERING

(a) Recommendation No. 48 of the International Conference on Safety of Life at Sea, London, 1960;

(b) Report of the Inter-Agency Working Group, June, 1962, on Coordination of Safety at Sea and in the Air, reproduced in Doc. 393, Geneva, 1963;

(c) the Resolution A.91 (IV), adopted on 27 September 1965 by the Fourth Session of the Assembly of the Inter-Governmental Maritime Consultative Organization (I.M.C.O.) and reproduced in Doc. XIII/71, 1963-1966;

(d) the Report of the Fourth Air Navigation Conference of the International Civil Aviation Organization (I.C.A.O.) (Montreal, 9 November – 3 December, 1965) and reproduced in Doc. XIII/103, 1963-1966;

(e) that there is an urgent need for a beacon to indicate the position of survivors and to facilitate search and rescue operations at sea;

(f) that ships compulsorily fitted for radiotelephony are required to keep continuous watch at the frequency 2182 kHz (see Regulation 7, Chapter IV of the International Convention for the Safety of Life at Sea, London, 1960);

(g) that it is desirable for the beacon signal to be received on the loudspeakers of the receiver which is equipped with filters for the two-tone alarm signal (1300 Hz and 2200 Hz respectively) and which is used for watch-keeping at 2182 kHz. This alarm signal is described in C.C.I.R. Recommendation 219-1 and Recommendation No. 33 of the International Conference on Safety of Life at Sea, London, 1960;

(h) that the type and sequence of the signal to be transmitted by the beacon should facilitate homing by ships as well as by SAR aircraft taking into account their different speeds;

(j) that the signal emitted by the beacon should as far as practicable be clearly distinguishable from the radiotelephone alarm signal transmitted by ships still afloat or by portable radio apparatus;

(k) that the signal emitted by the beacon should not create harmful interference to other distress calls and messages;

(l) that in the interest of high reliability and minimum expense the electronic and mechanical design of the beacon and especially of its keying device should be as simple as possible;

(m) that national and international trials under operational conditions have already been carried out successfully with such beacons;

UNANIMOUSLY RECOMMENDS

1. that emergency position-indicating radio beacons operating at the frequency 2182 kHz should be divided into two classes:

1.1 low-power beacons designated " Type L " producing a field strength equal to or less than 10 μV/m at a distance of 30 nautical miles at sea level;

1.2 high-power beacons designated " Type H " producing a field strength greater than 10 μV/m at a distance of 30 nautical miles at sea level;

2. that for both classes of beacon, class of emission A2 should be used;

3. that for both classes of beacon, the depth of modulation should be between 30% and 90%;

4. that the keying signal for " Type L " beacons should consist of a keyed emission modulated by a tone of 1300 Hz (±20 Hz) having a ratio of the period of the emission to the period of silence equal to or greater than 1, and an emission duration between 1 and 5 s* ;

5. that the keying signal for " Type H " beacons should either consist of the radiotelephone alarm signal (Radio Regulations, No. 1465) or be the same as in § 4 above; if the radiotelephone alarm signal be used, the Morse letter " B " and/or the call sign of the ship to which the beacon belongs, should be included by keying a carrier modulated by a tone of 1300 Hz (±20 Hz) or of 2200 Hz (±35 Hz)* ;

6. that for " Type L " beacons, the keying signal should be transmitted continuously;

7. that for " Type H " beacons, the keying cycle should consist alternately of the keying signal having a duration between 30 and 50 s, followed by a period of silence having a duration between 30 and 60 s;

8. that the keying cycles given in §§ 6 and 7 may be interrupted by speech transmission if Administrations permit such an additional facility;

9. that the minimum initial field strength produced by " Type L " beacons should be 2·5 μV/m at a distance of 30 nautical miles at sea level;

10. that after a period of 48 hours continuous operation the radiated power should not be less than 20% of the initial power;

11. that the beacons should be designed for the following temperature ranges:

— when stowed, at least —20° C to +55° C;

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* Beacons carried by ships of the U.S.A. may use, instead of the signals given in §§ 4 and 5, a tone sweeping from 1400 Hz to 300 Hz not faster than twice a second.

— when operating in the open air, at least —10° C to +45° C;

— when operating afloat, at least —3° C to +35° C (water temperature);

Note.—Exceptionally, for radio beacons carried by ships operating in limited areas only, other temperature ranges may, due to special conditions in such areas, be accepted.

12. that if the beacons are designed to come into operation automatically when floating, then overriding facilities should be provided to enable them to be switched on and off manually;

13. that beacons should be tested about every 12 months, care being taken to ensure that false alarms are not caused by radiating the signal;

14. that primary batteries for the beacons should have a minimum storage life of about 2 years, and primary batteries in the beacons should be replaced at intervals of about half the storage life;

15. that the mechanical design of the beacons should be such that it is small, light-weight, floatable, watertight and shock-resistant;

16. that the Administrations be invited to make provision in the Radio Regulations for the operation of emergency position-indicating radio beacons at the frequency of 2182 kHz.

Note 1. — The Director, C.C.I.R., is requested to transmit this Recommendation to the Inter-Governmental Maritime Consultative Organization (I.M.C.O.) and to the International Civil Aviation Organization (I.C.A.O.).

Note 2. — This Recommendation terminates the study of Question 318 and cancels Opinion 21.

RECOMMENDATION 440-1

THE INTRODUCTION OF DIRECT-PRINTING TELEGRAPH EQUIPMENT IN THE MARITIME MOBILE SERVICE

(Question 5-1/8)

The C.C.I.R., (1966 – 1970)

CONSIDERING

(a) that there is a requirement for communication in the maritime mobile service by means of direct-printing telegraph techniques for exchanging message and data information;

(b) that various systems have already been proposed to meet this requirement and tests have been carried out by different Administrations (see Report 361-1 and Recommendation 477);

(c) that further systems, especially forward-acting error-indicating and correcting systems, may be proposed;

(d) that whilst Study Group 3 has to deal with such systems from the point of view of the fixed services, Study Group 8 has to consider the special aspects concerning their application in the maritime mobile service;

(e) that the Maritime Conference, Geneva, 1967, adopted provisions concerning the use of direct-printing telegraph systems in the maritime mobile service;

UNANIMOUSLY RECOMMENDS

1. that a direct-printing telegraph system for the maritime mobile service should be suitable for:

1.1 exchanging messages and low-speed data information between two stations, i.e., between a coast station and a ship station or between two ship stations; and

1.2 broadcasting from one station to several other stations, i.e., from a coast or ship station to several other stations;

2. that the system should accept signals conforming to C.C.I.T.T. Code No. 2 at a modulation rate of 50 bauds and should provide similar signals at its output for extension to the Public Telegraph Network (see I.T.U. List of Definitions, Part I, Item 01.12) and vice versa (see Appendix 20B to the Radio Regulations);

3. that, bearing in mind the variations in propagation, the lowest modulation rate compatible with the grade of service required should be used over the radio path; in any case it should not exceed 100 bauds (see Appendix 20B to the Radio Regulations);

4. that class of emission F1, with a frequency shift of 170 Hz, should be used (see Appendix 20B to the Radio Regulations);

5. that the performance of the system should provide a sufficiently small character error rate to meet operational requirements, but shipborne equipment should not be unduly complex.

RECOMMENDATION 475 *

IMPROVEMENTS IN THE PERFORMANCE OF RADIOTELEPHONE CIRCUITS IN THE MF AND HF MARITIME MOBILE BANDS

(Question 11/8)

The C.C.I.R., (1970)

CONSIDERING

(a) that there is a need to improve the quality of transmission of MF and HF maritime mobile radiotelephone circuits;

(b) that methods presently used usually employ voice-operated devices to eliminate instability or unwanted retransmission;

(c) that such voice-operated devices frequently degrade the performance of the circuit;

(d) that the use of conventional compressors and expanders on MF and HF circuits is inhibited by the variability of the transmission path loss;

(e) that compressors and expanders may be linked to overcome this variability;

(f) that such a system is already in use by two Administrations **;

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* The Administrations of Cuba and the Federal Republic of Germany reserved their opinion on this Recommendation.

** The United States of America and the United Kingdom.

(g) that further tests of this system may be necessary, and further systems may be proposed;

(h) that when linked compressor and expander systems are used, it is necessary to ensure the compatibility of the equipment used by coast and ship stations;

RECOMMENDS

1. that systems used in the international maritime mobile radiotelephone service should as far as possible maintain optimum modulation of the transmitter despite variations in subscribers' speech volume and line losses;

2. that the speech and any control signals should both be contained within a 2700 Hz channel;

3. that Administrations should be encouraged to continue their studies, and in the meantime, when it is desired to use a linked compressor and expander system, then in order to ensure compatibility between the sending and receiving stations, the characteristics of the equipment should be in accordance with Annexes I and II; for optimum performance it is desirable that the characteristics of SSB radio equipment be in accordance with the minimum standards of Recommendation 258-2 and those contained in Annex III.

Annex I: Characteristics for ship stations.

Annex II: Characteristics for coast stations.

Annex III: Characteristics of SSB radio equipment.

ANNEX I

CHARACTERISTICS OF EQUIPMENT FOR SHIP STATIONS

1. Transmit side (Fig. 1*a*)

1.1 *Speech channel*

1.1.1 *Steady-state conditions*

For input levels between +5 dBm0 and —25 dBm0 the output levels should lie within the limits shown in Fig. 2.

The overall amplitude/frequency response for the speech path, under both fixed-gain and controlled conditions, at any level within the range +5 dBm0 to —25 dBm0 should be:

Frequencies	Attenuation relative to response at 800 Hz
Above 300 Hz	
For frequencies in the band 350 Hz to 2300 Hz	—1 to +3 dB
For frequencies in the band 2300 Hz to 2380 Hz	—1 to +6 dB
For frequencies in the band 2510 Hz and above	>50 dB
Below 300 Hz	
Increase in overall gain for frequencies below 300 Hz	⩽1 dB

1.1.2 *Transmit response* (Overall)

Attack time (Fig. 3*a*) (Note 1)	5 to 10 ms
Recovery time (Fig. 3*b*) (Note 1)	15 to 30 ms

1.2 *Control channel*

Frequency-modulated oscillator

Nominal centre frequency	2580 ±1 Hz
Maximum frequency deviation	+40 to —60 Hz
Change of frequency for each 1 dB change of input levels (Fig. 4)	2 Hz
Input level to transmit side to produce nominal centre frequency	—25 dBm0
Oscillator frequency resulting from an input level of +5 dBm0	2520 Hz
Oscillator frequency resulting from an input level of —45 dBm0	2620 Hz
Oscillator frequency when there is no input to transmit side	⩽2680 Hz
For sudden increases in input that exceed 3 dB the time taken for the oscillator to complete 80% (10% to 90%) of the corresponding change in frequency should be	5 to 10 ms
For sudden decreases in the input that exceed 10 dB the rate of change of the oscillator frequency should lie between	1·5 and 3·5 Hz/ms
Upper limit of output spectrum	2700 Hz
Output level relative to test tone level in the speech channel	—5 dB

3. Receive side (Fig. 1*b*)

2.1 *Speech channel*

2.1.1 *Fading regulator*

2.1.1.1 *Steady-state conditions*

For input levels between +7 dBm0 and —35 dBm0 the output should be within the limits shown in Fig. 5

2.1.1.2 *Transmit response*

Attack time (Fig. 3*a*) (Note 1)	7 to 13 ms
Recovery time (Fig. 3*b*) (Note 1)	24 to 40 ms

2.1.2 *Expander* (controlled by the discriminator output)

Effective dynamic range	60 dB

2.2 *Control channel*

2.2.1 *Amplitude/frequency and differential-delay characteristics of filter*

Attenuation within the band 2520 Hz to 2640 Hz (relative to that at 2580 Hz)	—1 to +3 dB
Attenuation below 2400 Hz and above 2770 Hz (relative to that at 2580 Hz)	>50 dB
Differential delay within the band 2520 Hz to 2640 Hz	⩽3·5 ms

2.2.2 *Discriminator* (Frequency/amplitude translator)
Characteristics at nominal control-tone level

Changes in the expander output with changes in the frequency of the control tone between 2520 Hz and 2640 Hz should be within the limits shown in Fig. 6	
Nominal change in expander loss resulting from each 2 Hz in control-tone frequency	1 dB
Control-tone frequency range over which 2 Hz per dB is maintained	2520 to 2640 Hz
Receive-side output level for control-tone frequencies of:	
2520 Hz	+5 dBm0
2640 Hz	—55 dBm0

2.2.3 *Amplitude range of discriminator*

A tolerance of ±1 dB may be added to the performance requirements of § 2.2.2 for control-tone input level variations of	30 dB
A tolerance of ±2 dB may be added to the performance requirements of § 2.2.2 for control-tone input level variations of	50 dB

2.3 *Overall attack and recovery time*

(A sudden change of 24 Hz in the frequency of the control tone is used to simulate a 12 dB step)

Attack time (Fig. 3*c*)	15 to 30 ms
Recovery time (Fig. 3*d*)	15 to 30 ms

3. Equalization of overall transmission time delay

To avoid the necessity for the coast radio station to vary the amount of time delay equalization to cater for different designs of equipment, the control signal should lag behind the corresponding speech signal:

3.1 at the output of the transmit side by	⩽4 ms
3.2 at the expander (when the speech and associated control signal are simultaneously applied to the receive-side input) by	16 to 24 ms (Note 2)

Note 1.—The definitions of attack and recovery time which are similar to those defined by the C.C.I.T.T. for compandors (Recommendation G.162) are as follows:

— the *attack time* of a compressor is defined as the time between the instant when a sudden increase of 12 dB in input is applied and the instant when the output voltage envelope reaches a value equal to 1·5 times its steady-state value;

— the *recovery time* of a compressor is defined as the time between the instant when a sudden decrease of 12 dB in input is applied and the instant when the ouptut voltage envelope reaches a value equal to 0·75 times its steady-state value.

Note 2.—This delay includes an allowance for the time-constants of the circuits preceding the expander, in addition to that for the band-pass filter itself.

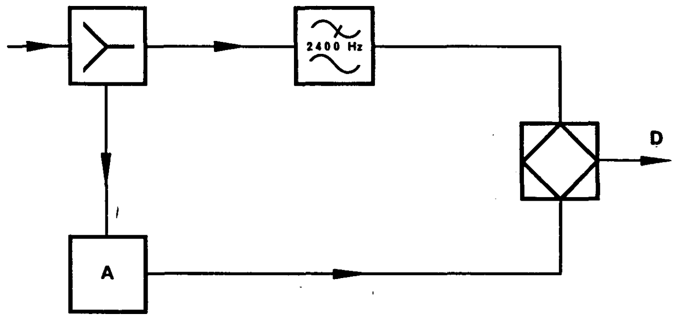


FIGURE 1*a*

Transmit side

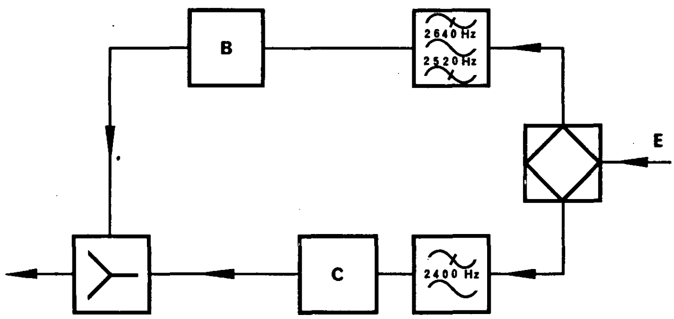
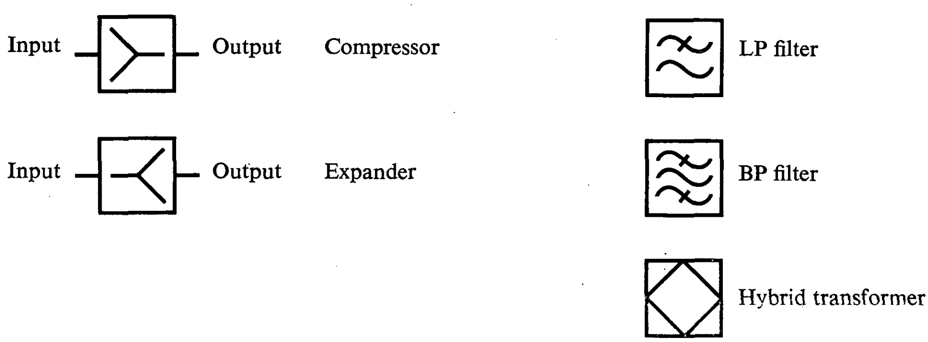


FIGURE 1*b*

Receive side

A: Frequency-modulated oscillator
B: Frequency discriminator
C: Fading regulator (constant volume amplifier)
D: To radio transmitter
E: From radio receiver



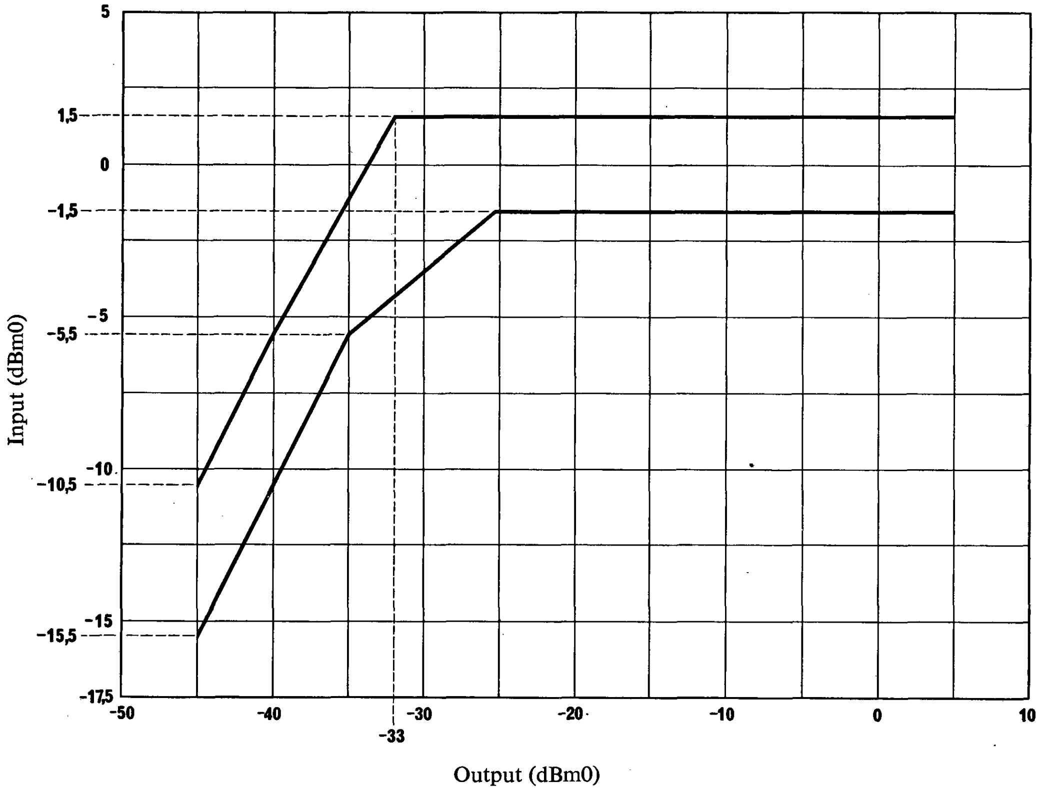


FIGURE 2

Input/output characteristic of transmit side

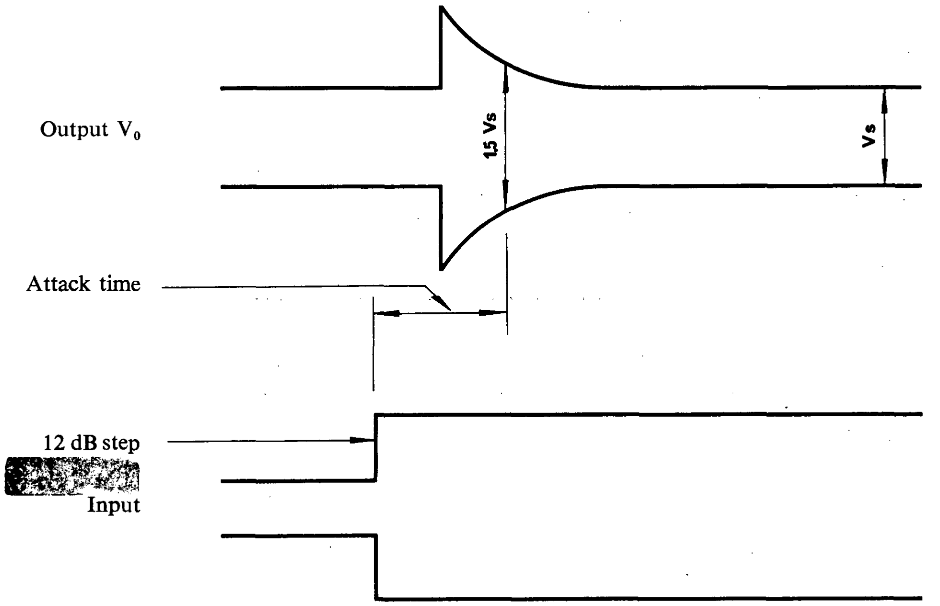


FIGURE 3*a*

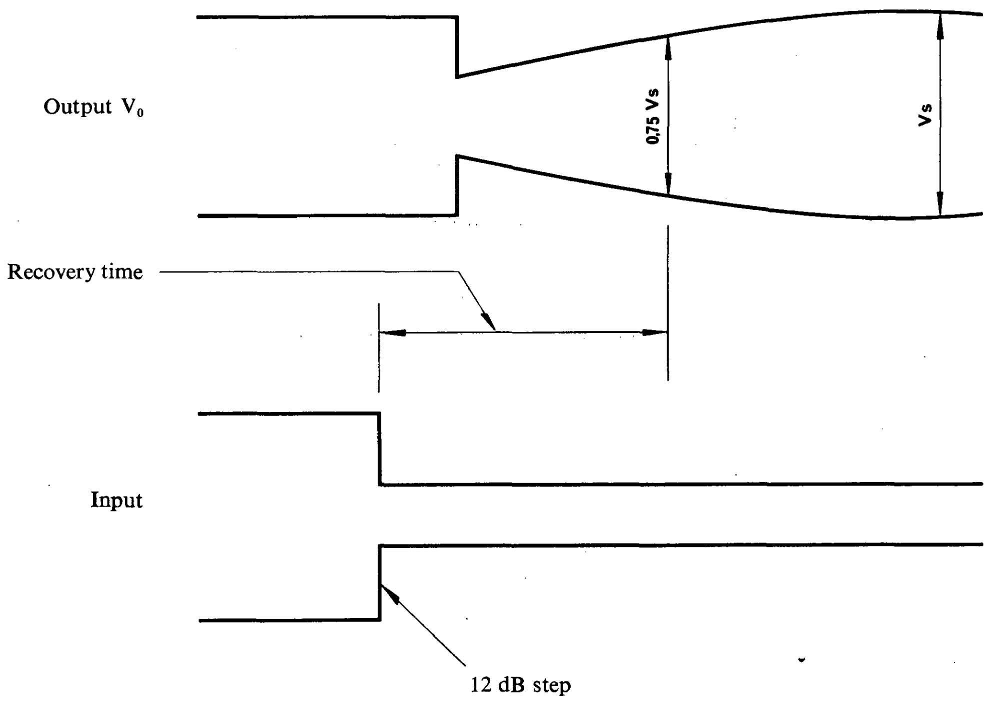


FIGURE 3*b*

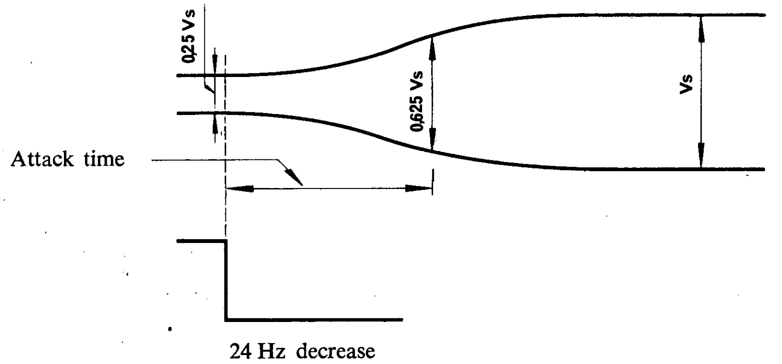


FIGURE 3*c*

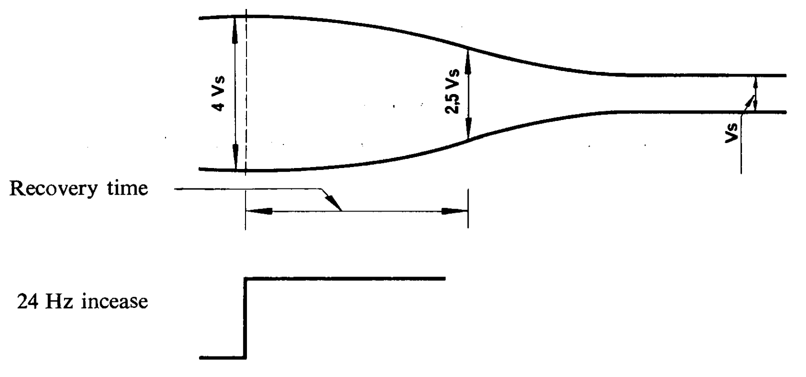


FIGURE 3*d*

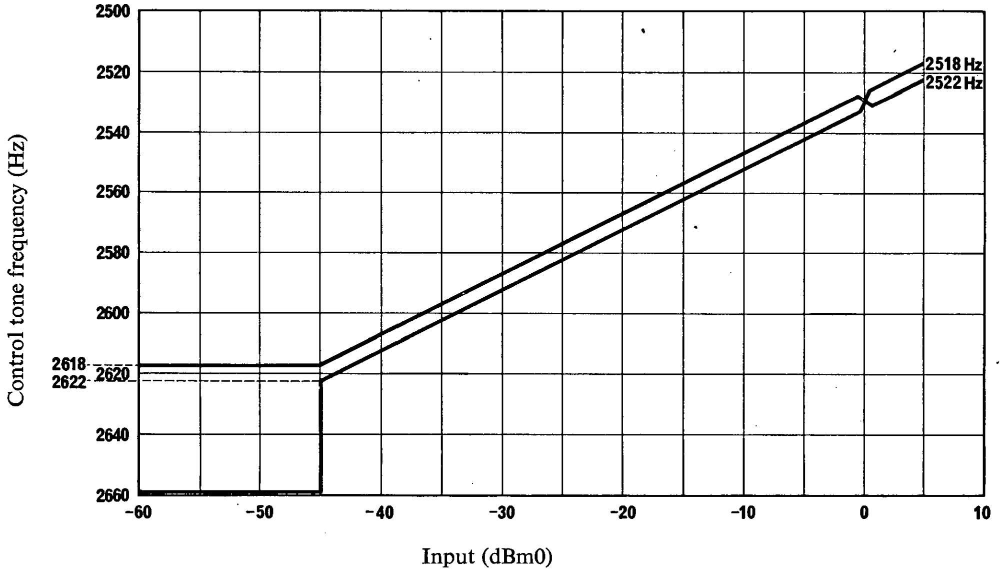


FIGURE 4

Variation of control tone frequency with changes of input level to the transmit side

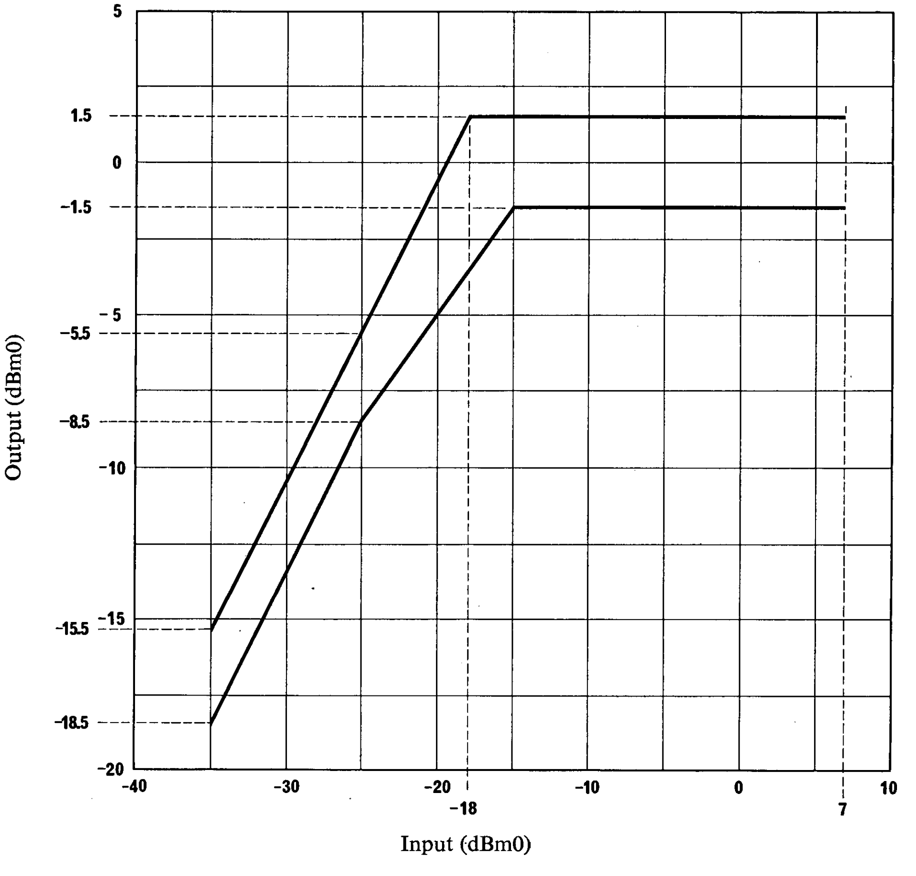


FIGURE 5

Input/output characteristic of fading regulator

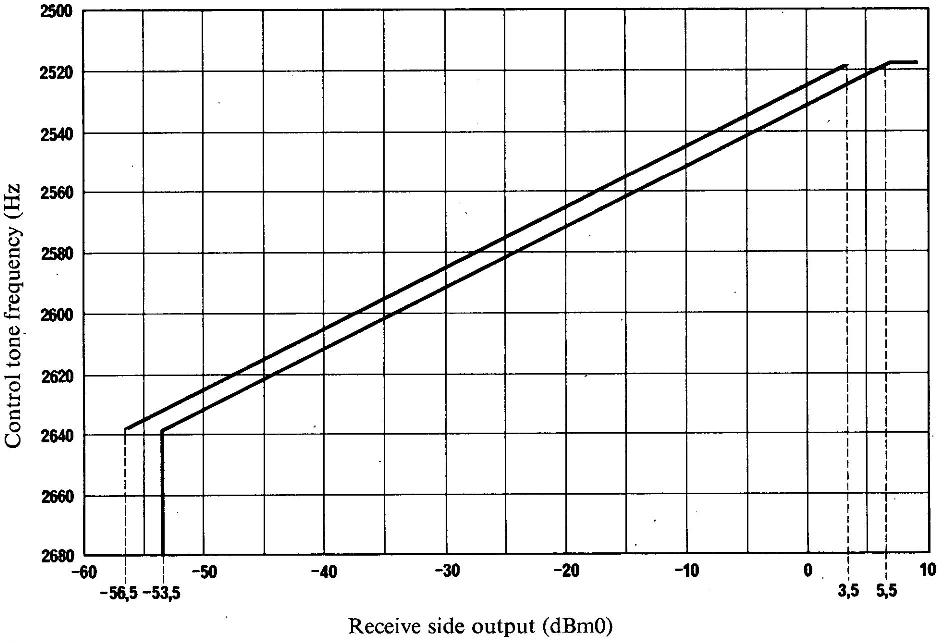


FIGURE 6

Variation of receive side output with changes of control tone frequency

ANNEX II

CHARACTERISTICS OF EQUIPMENT FOR COAST STATIONS

1. Transmit side (Fig. 7*a*)

1.1 *Speech channel*

1.1.1 *Steady-state conditions*

For input levels between +5 dBm0 and —35 dBm0 the output should lie between the limits shown in Fig. 8.

The overall amplitude/frequency response for the speech path, under both fixed-gain and controlled conditions, at any level within the range +5 dBm0 to —35 dBm0 should be:

Frequencies	Attenuation relative to response at 800 Hz
Above 300 Hz	
For frequencies in the band 350 to 2300 Hz	—1 to +3 dB
For frequencies in the band 2300 to 2380 Hz	—1 to +6 dB
For frequencies in the band 2510 and above	>50 dB
Below 300 Hz	
Increase in overall gain for frequencies below 300 Hz	⩽1 dB

1.1.2 *Transmit response* (Overall)

Attack time (Fig. 9*a*) (Note 1)	5 to 10 ms
Recovery time (Fig. 9*b*) (Note 1)	15 to 30 ms

1.2 *Control channel*

Frequency-modulated oscillator

Nominal centre frequency	2580 Hz
Maximum frequency deviation	±60 Hz
Change of frequency for each 1 dB change of input level (Fig. 10)	2 Hz
Input level to transmit side to produce nominal centre frequency	—25 dBm0
Oscillator frequency resulting from an input level of +5 dBm0	2520 Hz
Oscillator frequency resulting from an input level of —55 dBm0	2640 Hz
Oscillator frequency when there is no input to the transmit side	⩽2680 Hz
For sudden increases in input that exceed 3 dB the time taken for the oscillator to complete 80% (10% to 90%) of the corresponding change in frequency should be	5 to 10 ms
For sudden decreases in the input that exceed 10 dB the rate of change of oscillator frequency should lie between	1·5 and 3·5 Hz/ms
Upper limit of spectrum	2700 Hz
Output level relative to test tone level in the speech channel	—5 dB

2. **Receive side** (Fig. 7*b*)

2.1 *Speech channel*

2.1.1 *Fading regulator*

2.1.1.1 *Steady-state conditions*

For input levels between +7 dBm0 and —35 dBm0 the outputs should be within the limits shown in Fig. 11.

2.1.1.2 *Transmit response*

Attack time (Fig. 9*a*) (Note 1)	7 to 13 ms
Recovery time (Fig. 9*b*) (Note 1)	24 to 40 ms

2.1.2 *Expander* (controlled by the discriminator output)

Effective dynamic range	50 dB

2.2 *Control channel*

2.2.1 *Amplitude/frequency and differential-delay characteristics of filter*

Attenuation within the band 2520 Hz to 2640 Hz (relative to that at 2580 Hz)	—1 to +3 dB
Attenuation below 2400 Hz and above 2770 Hz (relative to that at 2580 Hz)	>50 dB
Differential delay within the band 2520 Hz to 2640 Hz	<3·5 ms

2.2.2 *Discriminator* (Frequency/amplitude translator)

Characteristics at nominal control-tone level

Changes in the expander output with changes in the frequency of the control tone between 2520 Hz and 2620 Hz should be within the limits shown in Fig. 12

Nominal change in expander loss resulting from each 2 Hz change in control-tone frequency	1 dB
Control-tone frequency range over which 2 Hz per dB is maintained	2520 to 2620 Hz
Receive-side output level for control-tone frequencies of:	
2520 Hz	+5 dBm0
2620 Hz	—45 dBm0

2.2.3 *Amplitude range of discriminator*

A tolerance of ± 1 dB may be added to the performance requirements of § 2.2.2 for control-tone input level variations of	30 dB
A tolerance of ± 2 dB may be added to the performance requirements of § 2.2.2 for control-tone input level variations of	50 dB

2.3 *Overall attack and recovery time*

(A sudden change of 24 Hz in the frequency of the control tone is used to simulate a 12 dB step)

Attack time (Fig. 9*c*)	15 to 30 ms
Recovery time (Fig. 9*d*)	15 to 30 ms

3. Equalization (overall) of transmission time

Taking into account § 3 of Annex I for ship-station equipment, sufficient time delay shall be incorporated in the coast-station equipment to ensure that in both directions of transmission, the overall transmission times of the speech and control signals, as measured at the expanders, shall be equalized to within ±8 ms

Note 1.—The definitions of attack and recovery time which are similar to those defined by the C.C.I.T.T. for compandors (Recommendation G.162) are as follows:

— the *attack time* of a compressor is defined as the time between the instant when a sudden increase of 12 dB in input is applied and the instant when the output voltage envelope reaches a value equal to 1·5 times its steady-state value;

— the *recovery time* of a compressor is defined as the time between the instant when a sudden decrease of 12 dB in input is applied and the instant when the output voltage envelope reaches a value equal to 0·75 times its steady-state value.

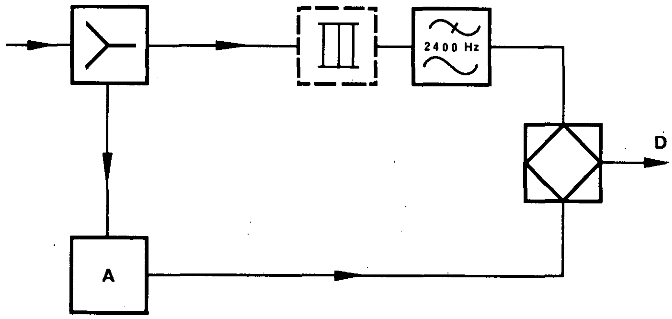


FIGURE 7*a*

Transmit side

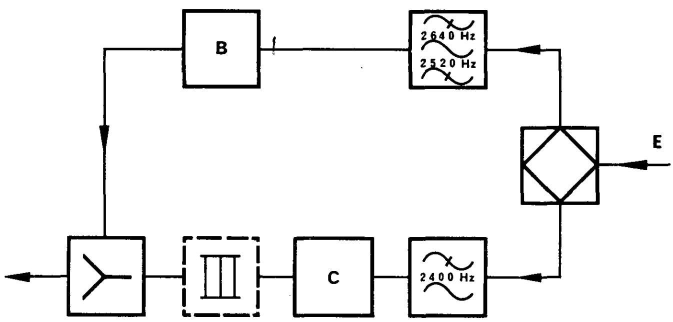
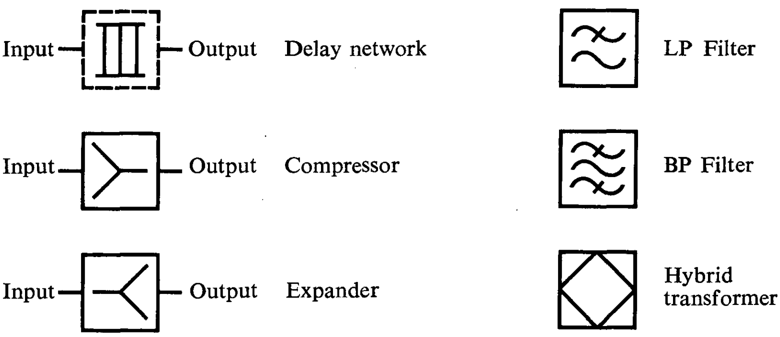


FIGURE 7*b*

Receive side

A: Frequency-modulated oscillator
B: Frequency discriminator
C: Fading regulator (constant volume amplifier)
D: To radio transmitter
E: From radio receiver



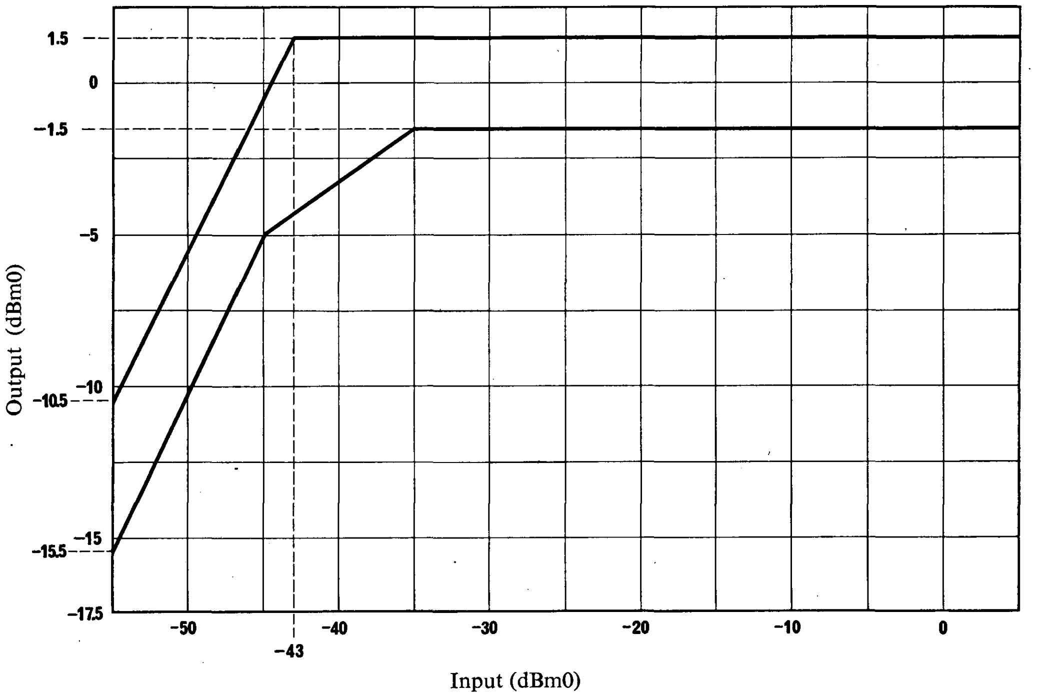


FIGURE 8

Input/output characteristic of transmit side

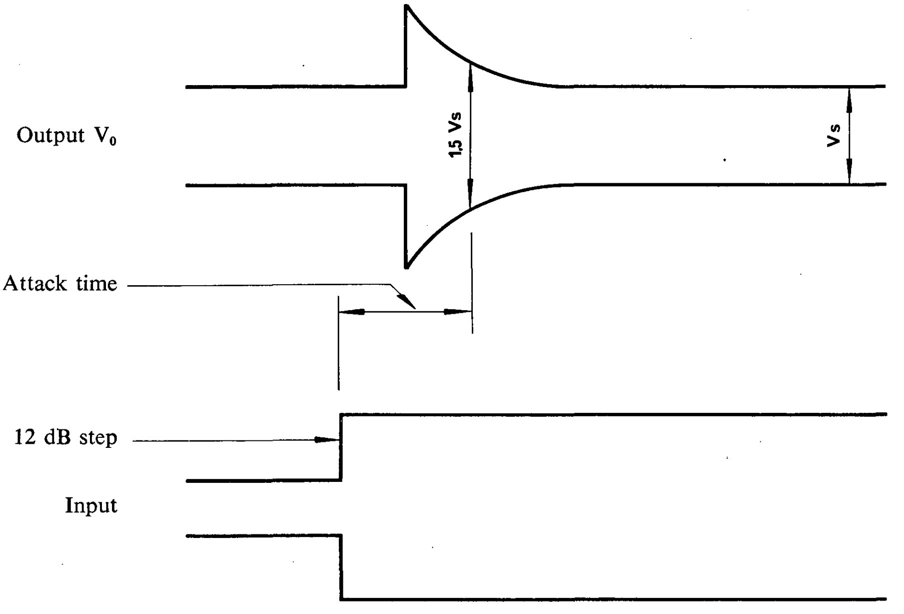


FIGURE 9*a*

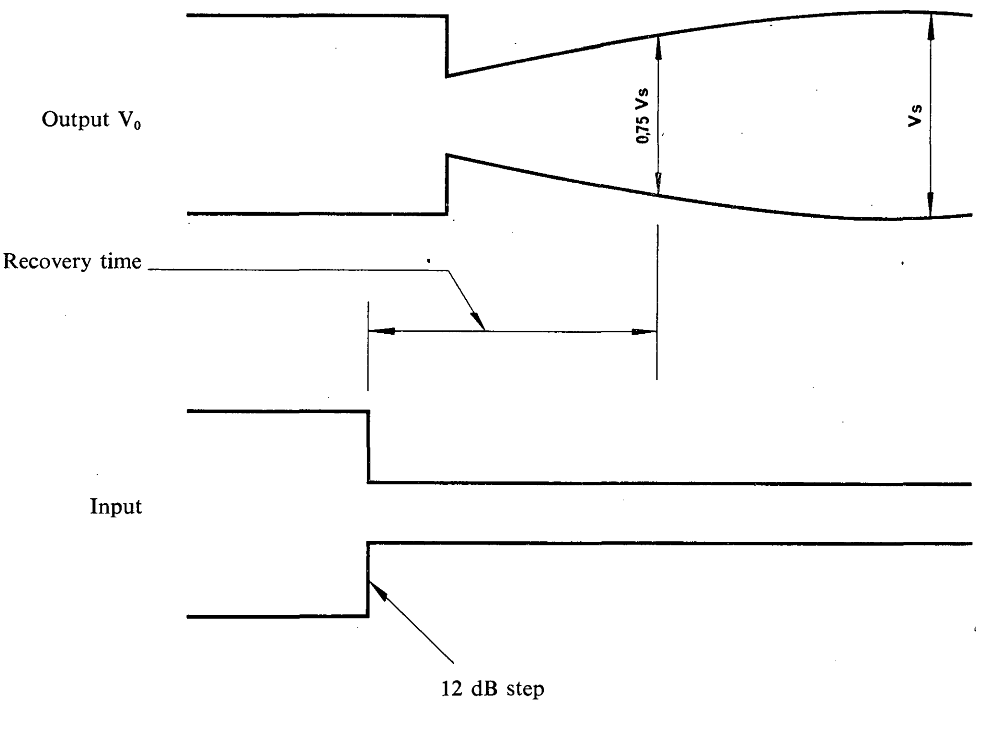


FIGURE 9*b*

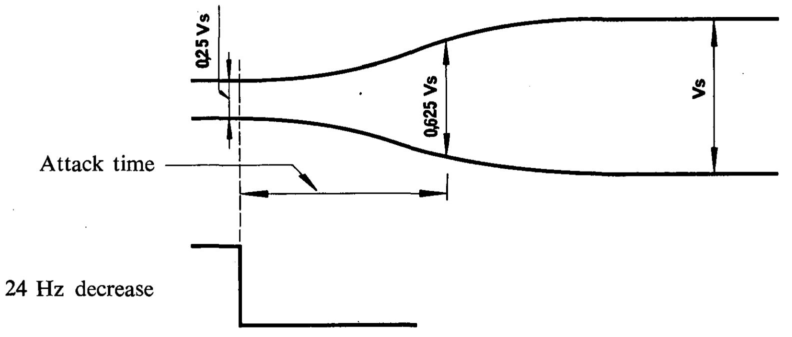


FIGURE 9*c*

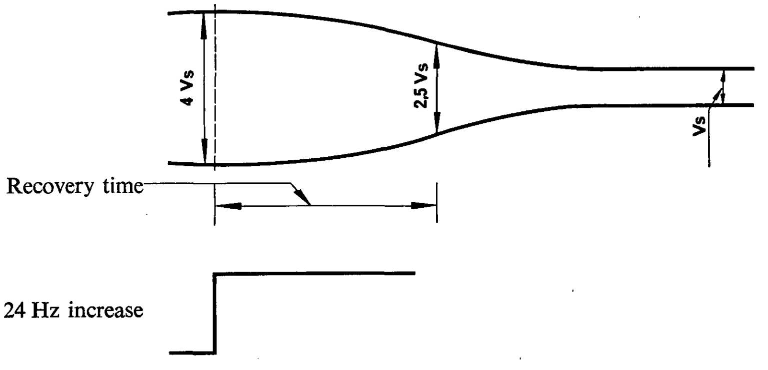


FIGURE 9*d*

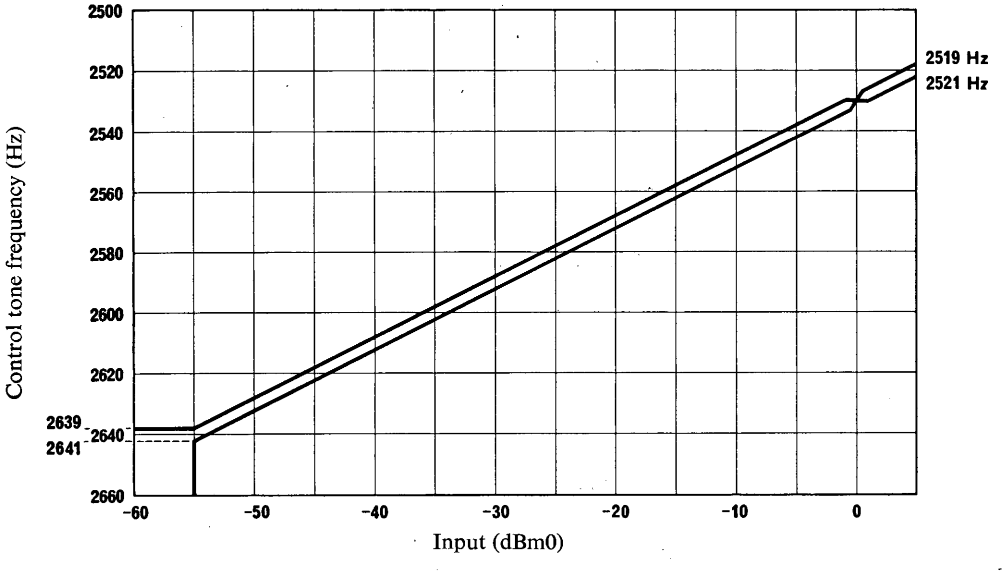


FIGURE 10

Variation of control tone frequency with changes of input level to the transmit side

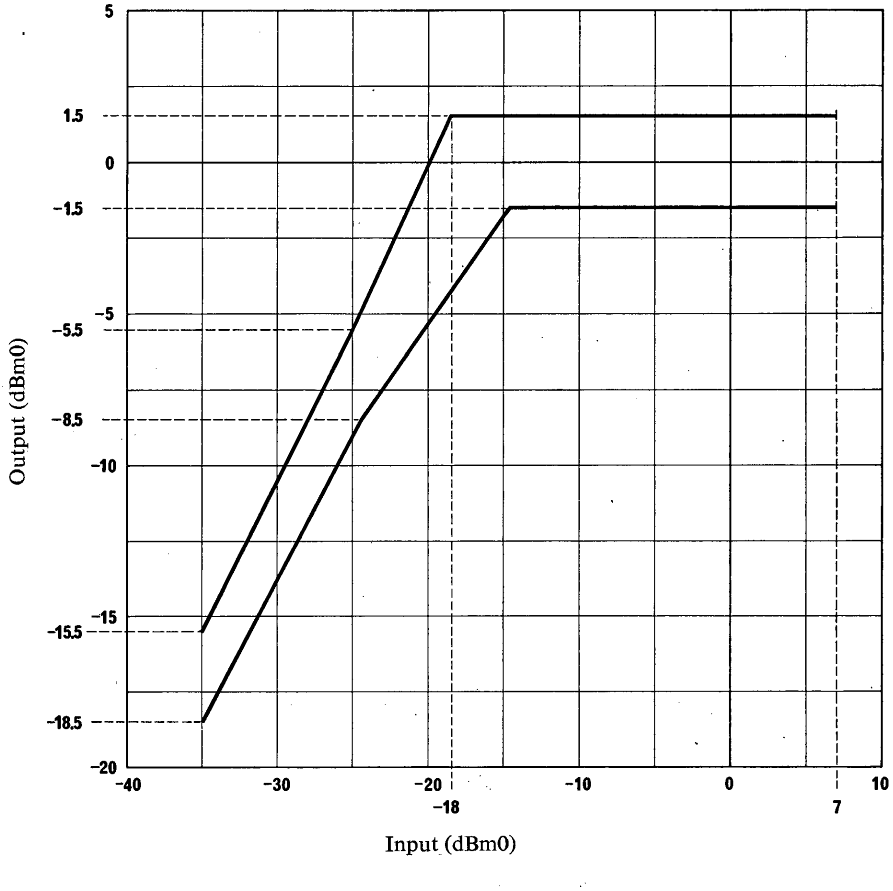


FIGURE 11

Input/output characteristic of fading regulator

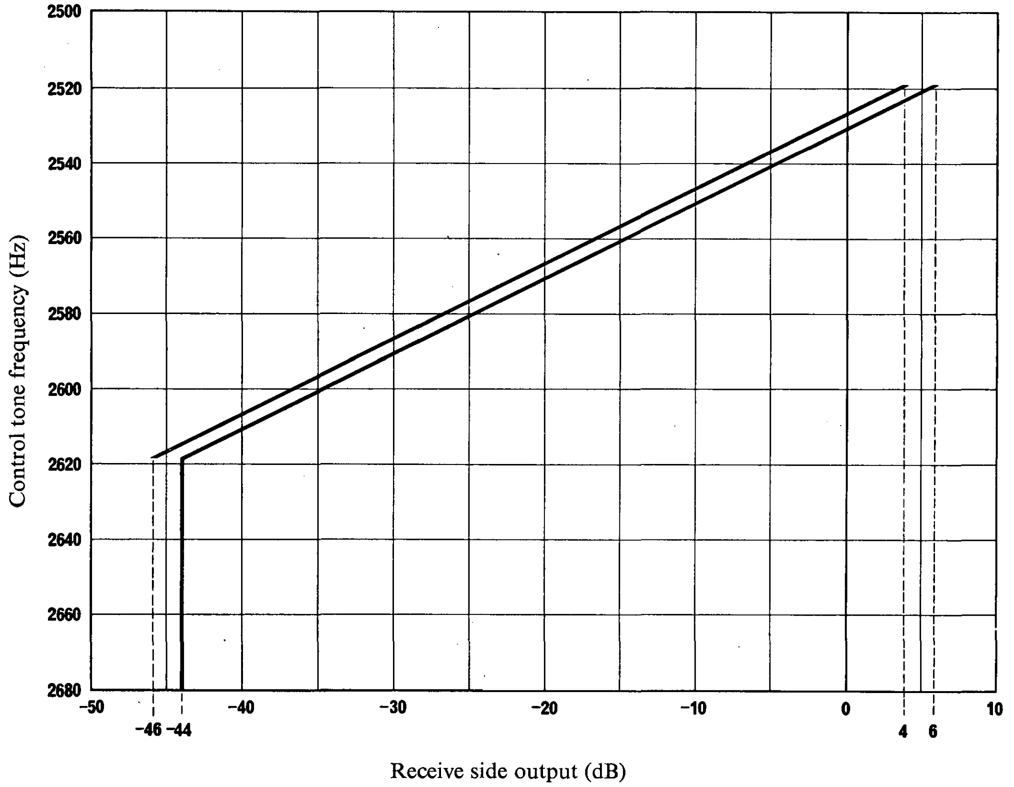


FIGURE 12

Variation of receive side output with changes of control tone frequency

ANNEX III

CHARACTERISTICS FOR SSB RADIO EQUIPMENT FOR OPTIMUM PERFORMANCE OF A LINKED COMPRESSOR AND EXPANDER SYSTEM

A linked compressor and expander system can be applied with full advantage to the maritime mobile service using either DSB or SSB systems.

To obtain the full advantages of the linked system when used with SSB radio equipment, the performance of the latter should be in accordance with Recommendation 258-2 and should, in addition, meet the following requirements:

1. The short-term frequency stability of coast station transmitters should be within ± 2 Hz over a period of the order of fifteen minutes.

2. The short-term frequency stability of a ship station transmitter should be within ± 4 Hz over a period of the order of fifteen minutes.

3. To ensure sufficient overall gain stability of the system, for the duration of a call, facilities should be provided in coast station receivers to keep the end-to-end frequency error within ± 2 Hz; similarly, facilities should be provided in ship station receivers to keep the end-to-end frequency error within ± 4 Hz.

4. The permitted total amplitude variation in the radio transmitter over the 300-2700 Hz audio-frequency band should be 2 dB and the differential delay should not exceed 3 ms. The receiver should have at least the same standards of performance in these respects.

5. If the pilot carrier of a Type A3A emission is not used to provide a continuous signal for frequency and gain control of the receiver, for example where Type A3J emission is used, the initial tuning procedure will require the provision, for a brief period, of a suitable reference tone as described in Recommendation 477.

RECOMMENDATION 476 *

DIRECT PRINTING TELEGRAPH EQUIPMENT IN THE MARITIME MOBILE SERVICE

The C.C.I.R., (1970)

CONSIDERING

(a) that there is a requirement to interconnect mobile stations or mobile and coast stations, equipped with start-stop apparatus, employing the International Telegraph Alphabet No. 2, by means of radiotelegraph circuits;

(b) that direct printing telegraphy communications in the maritime mobile service can be listed in the following categories:

b.a telegraph service between a ship and a coast station;

b.b telegraph service between a ship and an extended station (ship's owner) via a coast station (leased circuit);

b.c telex service between a ship and a subscriber of the (international) telex network;

b.d broadcast telegraph service from a coast station to one or more ships;

b.e telegraph service between two ships or between one ship and a number of other ships;

* The Administrations of Bulgaria and the U.S.S.R. reserved their opinion on this Recommendation.

(c) that those categories are different in nature and that consequently a different degree of transmission quality may be required;

(d) that the categories given in *b.a*, *b.b* and *b.c* above may require a higher transmission quality than categories *b.d* and *b.e* for the reason that data could be handled through the services in the categories *b.a*, *b.b* and *b.c*, while the messages passed through the service of category *b.d*, and via the broadcast service of category *b.e* are normally plain language, allowing for a lower transmission quality than those of coded information;

(e) that the service in category *b.d* and the broadcast service in category *b.e* cannot take advantage of an ARQ method, as there is in principle no return path;

(f) that for these categories of service which by their nature do not allow for ARQ, another mode, i.e. the broadcast mode must be used;

(g) that the period for synchronization and phasing should be as short as possible and should not exceed 5 seconds;

(h) that most of the ship stations do not readily permit simultaneous use of the radiotransmitter and radioreceiver;

(j) that the equipment on board ships should be neither unduly complex nor expensive;

RECOMMENDS

1. that when an error-detecting and correcting system is used for direct printing telegraphy in the maritime mobile service, a 7-unit ARQ system or a 7-unit forward acting, error-correcting and indicating, time diversity system, using the same code, should be employed;

2. that equipment designed in accordance with § 1 should meet the characteristics laid down in the Annex.

ANNEX

1. General (Mode A, ARQ and Mode B, Broadcast)

1.1 The system is a single channel synchronous system using the 7-unit error-detecting code as listed in § 2 of this Annex.

1.2 The modulation rate on the radio link is 100 bauds.

1.3 The terminal input must be able to accept the 5-unit start-stop C.C.I.T.T. No. 2 code at a modulation rate of 50 bauds.

2. Table of conversion

TABLE I

Traffic information signals

	International Alphabet No. 2	7-unit code	Emitted signal (1)
A	ZZAAA	ZZZAAAZ	BBBYYYB
B	ZAAZZ	AZAAZZZ	YBYYBBB
C	AZZZA	ZAZZZAA	BYBBBYY
D	ZAAZA	ZZAAZAZ	BBYYBYB
E	ZAAAA	AZZAZAZ	YBBYBYB
F	ZAZZA	ZZAZZAA	BBYBBYY
G	AZAZZ	ZAZAZZA	BYBYBBY
H	AAZAZ	ZAAZAZZ	BYYBYBB
I	AZZAA	ZAZZAAZ	BYBBYYB
J	ZZAZA	ZZZAZAA	BBBYBYY
K	ZZZZA	AZZZZAA	YBBBBYY
L	AZAAZ	ZAZAAZZ	BYBYYBB
M	AAZZZ	ZAAZZZA	BYYBBBY
N	AAZZA	ZAAZZAZ	BYYBBYB
O	AAAZZ	ZAAAZZZ	BYYYBBB
P	AZZAZ	ZAZZAZA	BYBBYBY
Q	ZZZAZ	AZZZAZA	YBBBYBY
R	AZAZA	ZAZAZAZ	BYBYBYB
S	ZAZAA	ZZAZAAZ	BBYBYYB
T	AAAAZ	AAZAZZZ	YYBYBBB
U	ZZZAA	AZZZAAZ	YBBBYYB
V	AZZZZ	AAZZZZA	YYBBBBY
W	ZZAAZ	ZZZAAZA	BBBYYBY
X	ZAZZZ	AZAZZZA	YBYBBBY
Y	ZAZAZ	ZZAZAZA	BBYBYBY
Z	ZAAAZ	ZZAAAZZ	BBYYYBB
Carriage return	AAAZA	AAAZZZZ	YYYBBBB
Line feed	AZAAA	AAZZAZZ	YYBBYBB
Figure shift	ZZAZZ	AZZAZZA	YBBYBBY
Letter shift	ZZZZZ	AZAZZAZ	YBYBBYB
Space	AAZAA	AAZZZAZ	YYBBBYB
Unperforated tape	AAAAA	AZAZAZZ	YBYBYBB

Service information signals

Mode A (ARQ)	Emitted signal	Mode B (Broadcast)
Control signal 1	BYBYYBB	
Control signal 2	YBYBYBB	
Control signal 3	BYYBBYB	
Idle signal β	BBYYBBY	
Idle signal α	BBBBYYY	Phasing signal 1
Signal repetition	YBBYYBB	Phasing signal 2

(1) B represents the higher emitted frequency and Y the lower.

3. Characteristics

3.1 *Mode A* (ARQ)

A synchronous system, transmitting blocks of three characters from an information sending station (ISS) towards an information receiving station (IRS), which stations can, controlled by the control signal 3 *, interchange their functions.

3.1.1. *The information sending station (ISS)*

3.1.1.1. emits blocks of three characters (3 × 7 signal elements) in 210 milliseconds after which a transmission pause of 240 milliseconds becomes effective;

3.1.1.2. numbers the blocks alternately " Block 1 " and " Block 2 " by a local numbering device, the numbering being interrupted at the reception of: *(a)* a request for repetition, *(b)* a mutilated signal, *(c)* a control signal 3 *;

3.1.1.3. emits the information of Block 1 on receipt of the control signal 1 *;

3.1.1.4. emits the information of Block 2 on receipt of the control signal 2 *;

3.1.1.5. emits a block of three " signals repetition " * on receipt of a mutilated signal;

3.1.1.6 emits the signal information sequence " *Figure Shift* " " *Plus* " (" *Z* "), " *Question Mark* " (" *B* ") to initiate the change in the direction of the traffic flow;

3.1.1.7 emits a block containing the signals: " Idle signal β, Idle signal α, Idle signal β " on receipt of a control signal 3.

3.1.1.8 changes subsequently to IRS after the reception of a " signal repetition ".

3.1.2 *The information receiving station* (IRS)

3.1.2.1 emits one of the control signals immediately after the reception of a " Block ", after which a transmission pause of 380 milliseconds becomes effective;

3.1.2.2 numbers the received blocks of three characters alternately " Block 1 " and " Block 2 " by a local numbering device, while the numbering is interrupted at the reception of:

- a block in which one or more characters are mutilated,
- a block of three " signals repetition ",
- a block in which the signal information sequence is " *Figure Shift Plus Question Mark* ";

3.1.2.3 emits the control signal 2 at the unmutilated reception of a " Block 1 " or at the mutilated reception of a " Block 2 ";

3.1.2.4 emits the control signal 1 at the unmutilated reception of a " Block 2 " or at the mutilated reception of a " Block 1 ";

3.1.2.5 emits the same control signal as at the reception of a mutilated block, on receipt of a block of " signals repetition ";

3.1.2.6 emits the control signal 3 on receipt of a block terminating in the signal information sequence " *Figure Shift Plus Question Mark* ";

3.1.2.7 changes subsequently to ISS after the reception of a block containing the signal sequence " β α β ";

3.1.2.8 emits one " signal repetition " as a master station or a block of three " signals repetition " as a slave station, after being changed into ISS.

3.1.3 *Master and slave arrangements*

3.1.3.1 The station that initiates the establishment of the circuit (the calling station) becomes the " master " station, and the station that has been called will be the " slave " station.

This situation remains unchanged during the entire time in which the established circuit is maintained.

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* See Table I.

3.1.3.2 The clock in the master station controls the entire circuit;

3.1.3.3 the master station transmitting time distributor is controlled by the clock in the master station;

3.1.3.4 the master station receiving time distributor is controlled by the transitions of the received signal;

3.1.3.5 the slave station transmitting time distributor is phase locked to the slave station receiving time distributor;

3.1.3.6 the slave station receiving time distributor is controlled by the transitions of the received signal.

3.1.4 *Phasing*

3.1.4.1 When no circuit is established, both stations are in the " standby " position. In this standby position no ISS or IRS and no master or slave position is assigned to either of the stations;

3.1.4.2 the station desiring to establish the circuit emits the " call " signal. This " call " signal is formed by either one or two blocks of three signals;

3.1.4.3 a one-block call signal is composed of " signal repetition " followed by any combination of the 32 information signals *;

3.1.4.4 a two-block call signal contains in the first block: " signal repetition " in the second character place and any combination of information signals * in the first and third character place, and in the second block: " signal repetition " in the third character place preceded by any combination of information signals * in the first and second character place;

3.1.4.5 on receipt of the appropriate call signal the called station changes from standby to the IRS position and emits the control signal 1 or the control signal 2;

3.1.4.6 on receipt of a control signal, the calling station changes into ISS and acts according to §§ 3.1.1.3 and 3.1.1.4.

3.1.5 *Rephasing*

3.1.5.1 When reception of information blocks or of control signals is continuously mutilated, the system reverts to the standby position after a pre-determined time (to be decided by the user) of continuous repetition;

3.1.5.2 the rephasing proceeds along the same lines as laid down in § 3.1.4; however:

3.1.5.3 if, at the time of interruption, the slave station was in the ISS position, it emits, after rephasing, the control signal 3.

3.1.6 *Output to line*

3.1.6.1 The signal offered to the line output terminal is a 5-unit start-stop signal at a modulation rate of 50 bauds.

3.2 *Mode B* (Broadcast)

A synchronous system, transmitting an uninterrupted stream of characters from a broadcast sending station (BSS) to one or more broadcast receiving stations (BRS).

3.2.1 *The broadcasting sending station* (BSS)

3.2.1.1 emits each character twice; the first transmission (DX) of a specific character is followed by the transmission of 4 other characters, after which the retransmission (RX) of that specific character takes place, allowing for time-diversity reception at 280 milliseconds time space;

* The composition of these signals and their assignment to individual ships require international agreement (see § 5 of Question 5-1/8).

3.2.1.2 emits signals before and between the broadcast messages; these signals consist of the phasing signal 1 * and the phasing signal 2 * whereby phasing signal 1 is transmitted in the RX, and phasing signal 2 in the DX position.

3.2.2 *The broadcasting receiving station(s)* (BRS)

3.2.2.1 checks both characters (DX and RX), printing an unmutilated DX or RX character, or printing an error symbol or space, if both are mutilated.

3.2.3 *Phasing*

3.2.3.1 When no broadcast reception takes place, the system is in the " standby " position as laid down in § 3.1.4.1.

3.2.3.2 On receipt of the phasing signal 1 followed by phasing signal 2 (in such a way that the phasing signal 2 determines the DX and the phasing signal 1 the RX position) the system changes from standby to the BRS position.

3.2.3.3 The BRS reverts to the standby position if during a predetermined time only mutilated signals have been received.

3.2.4 *Output to line*

3.2.4.1 The signal offered to the line output terminal is a 5-unit start-stop C.C.I.T.T. No. 2 code signal at a modulation rate of 50 bauds.

RECOMMENDATION 477 **

OPERATIONAL PROCEDURES FOR SINGLE-SIDEBAND RADIOTELEPHONE SYSTEMS IN THE HF MARITIME MOBILE BANDS

The C.C.I.R., (1970)

CONSIDERING

(a) the importance of minimizing delays in establishing radiotelephone calls between coast and ship stations;

(b) the desirability of providing the best possible quality of radiotelephone calls in the HF maritime service;

(c) the desirability of uniformity of operational procedures among coast and ship stations;

(d) the provisions of the Radio Regulations under which different modes of single-sideband emissions may be adopted by Administrations;

(e) the desirability of standardizing as far as possible the technical facilities necessary in ship and coast stations;

(f) the need for precise adjustment of frequency when lining up complex systems;

(g) the advantages of a relatively narrow audio filter for automatic signalling at some coast stations;

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* See Table I.

** This Recommendation terminates the study of Question 4/XIII.

UNANIMOUSLY RECOMMENDS

1. that, in addition to the provisions given in the Radio Regulations as revised by the Maritime Conference, Geneva, 1967, the following procedures should be observed:

1.1 unless it is known that the coast station will accept class of emission A3J, a ship station when initiating a call to a coast station, should transmit a reduced carrier signal (class of emission A3A);

Note. — Exceptionally, ship stations may in addition transmit for a brief period a tone frequency of 1000 Hz, with a tolerance of ± 1 Hz, to facilitate reception by the coast station with which they are establishing contact.

1.2 after initial contact has been established, the ship station should only transmit a reduced carrier, where it is required by the coast station, according to the List of Coast Stations;

1.3 a coast station, when establishing a call to a ship should, on request, include a brief period of transmission of a tone frequency of 1000 Hz, with a tolerance of ± 1 Hz (this tone may facilitate the final tuning adjustment of suitably equipped ship station receivers);

2. that Administrations be invited to consider, wherever appropriate, the limited use of a " channel engaged " signal from the coast station, for example, when a short delay occurs in establishing connection to the inland telephone network.

8B: *Reports*

REPORT 318 *

MARINE IDENTIFICATION DEVICES

(1956 – 1963)

1. General

Two documents, 53 (United Kingdom) and 71 (United States of America), were submitted to the VIIIth Plenary Assembly in answer to Question 105 on the identification of a response on a marine radar display.

This Report summarizes the nature of the problem, the work that has been done, as described in the two documents, and the main points arising out of the discussions at the VIIIth Plenary Assembly.

2. Nature of the problem

There is a growing use of radar on ships to assist navigation and to prevent collision. Ideally, it would be desirable for radar to give the navigator the same kind of information that he would obtain visually in clear weather. But, in the present state of radar development experience has shown that the radar information might, with advantage, be supplemented by additional information, although there is not, as yet, uniformity of opinion among those concerned with marine navigation, on the type of additional information that would be most helpful to the navigator.

The radar installation on a ship gives, at any instant, only the bearing and position of the other ships. The course and speed of another ship by this means can then be obtained only by plotting; and, in any case, the radar cannot give the future intentions of the other ship. This points to the need for an appropriate communication link as an element of any effective marine identification device employing the types of radar installation in current use.

An identification device should be unambiguous and should be at least as good as the resolution of the associated radar, so that there would be no confusion concerning the identification of two adjacent echoes on the same bearing or at the same range. The additional information required, for example, might be the call letters of the other ship, so that communication could be established; or it might be the course and speed, or the aspect, of the other vessel.

So far, research has been directed towards the development of devices that would identify uniquely a particular echo of a ship on the radar screen of another ship or of a shore-based station. Various proposals, e.g. the use of transponder techniques, have been given in the two documents mentioned and are described briefly in §§ 3 and 4.

3. Summary of Doc. 53 (United Kingdom)

3.1 *Harbour radar identification*

It was considered that suitable devices of the transponder type might facilitate the movement of vessels in the approaches to a port or in a harbour, so that the echo of the ship could be identified on the harbour radar and communication established as required. Identification in range and bearing would be essential, so that identification, by the use of

* This Report was adopted unanimously.

normal direction-finding (bearing only) would not normally be sufficient. There is less likelihood of confusion in harbour radar identification, because ships would be identifying themselves to a single harbour radar.

These transponder devices are used in conjunction with a radiocommunication link between the ship and the shore. On the ship either portable equipment or the ship's own radio installation may be used.

Portable radar transponders have been developed which operate in the 3 cm band of the harbour radar. The transponders and, if necessary, the portable radiocommunication equipment, are taken on board the ship by the pilot. Identification is established by the Harbour Controller requesting the pilot to switch on the transponder, when the response is seen on the harbour radar as a bright line on the bearing of the ship's echo, with a gap, corresponding to 1 mile range, commencing at the ship. The ship is thus identified in range and bearing. The range of the " black-gap " transponder is about 17 nautical miles.

This system would be suitable for use with any harbour radar operating in the 3 cm band and no modification of the harbour radar would be required.

Another type of equipment has also been developed in which the output of a crystal receiver is used to modulate a VHF " walkie-talkie " transmitter which also serves to provide communication with the shore. At the harbour station, the VHF response from the ship is fed into the video stage of the harbour radar. This gives a long radial echo along the bearing of the ship, commencing at a range slightly greater than the ship's echo.

3.2 *Inter-ship radar identification*

The former type of transponder mentioned above would not be satisfactory for inter-ship identification, because it might well be impossible to establish communication with a particular unknown ship to request that the transponder be switched on; and, moreover, ambiguity would be unavoidable, when several independent identification processes were taking place on the same channel.

4. Summary of Doc. 71 (United States of America)

4.1 Doc. 71 (United States), Warsaw, 1956, is based upon limited experience in the use of marine radar identification devices but also covers considerable study of the problem by the R.T.C.M., whose report thereon is attached to the document cited as Annex 3. In summary it is observed that:

4.1.1 There are a number of technical methods for the identification of a radar response as coming from a particular source. All known methods, however, require that the source have an active radar beacon to co-operate with the calling vessel. One solution might be in the direction of a system similar to that used by the military (IFF, Identification Friend or Foe) and now coming into use for civil aviation in the United States of America for identification of aircraft to airport radars.

4.1.2 In this type of system, each ship-borne radar should be capable of emitting a particular calling or interrogating pulse or code. All vessels would maintain a beacon on continuous alert so that, on receipt of the interrogating pulse, each beacon would reply with a specific code identifying the vessel. This code, when displayed on the interrogating vessel's PPI adjacent to the radar echo from the vessel carrying the beacon, would positively identify that echo. Having identified all ships in the vicinity, a radar observer could then contact any one of them directly by whatever communication means are available. Considerable experimentation has been carried out to realize a simplified version of this method.

4.1.3 The use of a radar beacon system of the IFF type for marine identification would require considerable expansion of the coding and display features of any equipment known to be currently available. It appears that no attempts to do this have as yet been made in the commercial marine field.

The relatively simplified technique where identification is obtained by energizing the radar beacons one at a time in response to a demand via a communications link, has been reduced to a practical method and considerable related experimentation has been carried out in connection with harbour radar installations. The feasibility of this system has therefore been demonstrated, although the necessary beacons are not yet commercially available.

4.1.4 The principal practical aspect is, that there is no need to identify a particular radar echo unless it is desired to communicate with the vessel associated with the echo. In narrow congested waters this must be practically instantaneous. This seems to require a radiotelephone circuit connecting the observer of the ship-borne radar directly to his counterpart on the bridge of the associated vessel. Ocean-going vessels, however, are not generally equipped with such means of communication. Further, the multiple language problem requires consideration in any international study of this subject. The Great Lakes area of North America, where nearly all merchant ships are fitted with radar and radiotelephone and navigators speak the same language, is an outstanding exception. Operational investigations of ship-to-ship identification devices have been carried out therefore only in this area.

4.1.5 The number of vessels involved poses a technical difficulty in adapting an IFF system for marine use, if each vessel were to have a distinct identifying code.

4.1.6 A system of the IFF type in its present form, due to its cost even in a comparatively simple version, presents an economic factor of importance. The complexity of the microwave components which contribute most to the cost of such equipment would be double that required for primary radar alone. The economic factor, however, will undoubtedly be eased as time passes and new technical developments occur, as they have, for instance, in the field of television.

4.2 A number of different types of devices or methods suggested for accomplishing identification of a positive or limited nature are outlined in the R.T.C.M. study referred to above. These include:

— responder beacons of various design,
— passive devices,
— DF identification using radar antennae,
— suggestions other than identification.

For further details on such types of devices, see Annex 3 to Doc. 71 (Warsaw).

5. Discussion of documents

The discussion of the documents has brought out certain important differences in inter-ship identification and shore-based radar identification. In the former case, after the identity of the unknown ship has been established, there may well be difficulty in establishing communication because of differences in language, type of radio installation and watch-keeping. At present, there is no international code on navigational manoeuvres, and " navigation by communication " would probably necessitate revision of the International Rules for the Prevention of Collision at Sea; it would probably raise new legal problems, if, for example, a ship were involved in a collision while executing a manoeuvre agreed in advance with another ship. On the other hand, the type of identification which is employed for harbour control does not usually involve such difficulties because the ship has on board a pilot who is receiving advice from, and may communicate with, his own harbour radar station. Rapid identification is also very desirable in all such devices.

An inter-ship identification system would only become effective when the majority of ships were suitably equipped; and it should be borne in mind that the ship does not receive any direct benefit from its own identification device. Thus, ships which themselves do not carry radar are not likely to fit identification devices, particularly if the cost of the device is comparable with that of a radar installation.

6. Future work

It was generally agreed in the discussions that it would be most desirable for the C.C.I.R. to obtain from responsible shipping and administrative authorities, their views on the navigational requirements that should be met by radar identification devices. However, at the IXth Plenary Assembly, Los Angeles, 1959, the responsible authorities had not, in fact, advised the C.C.I.R. of any operational requirements for such devices and consequently the studies were terminated.

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REPORT 320-2 *

SELECTIVE-CALLING SYSTEMS FOR THE INTERNATIONAL MARITIME MOBILE SERVICES

(Study Programme 3A/8)

(1963 – 1966 – 1970)

1. Study Programme 3A/8 states that Recommendation 257-1 does not give a full reply to Question 271 and the trials of selective calling systems, described in Docs. XIII/10, 18, 26 and 189 of the IXth Plenary Assembly, Los Angeles, 1959, were carried out with a view to coming to a decision on the type of system that should be adopted internationally.

The Administrations of the Federal Republic of Germany and the U.S.A. carried out comparative tests. Reference is made to Docs. 229 and 235, Geneva, 1963.

Study Group XIII studied the results of these tests during the session of the Xth Plenary Assembly, and took into consideration Docs. XIII/6, 8, 9, 11, 15, 19 and 21, Geneva, 1963.

The results of further tests carried out by several Administrations are given in the report of an International Working Party set up by the Xth Plenary Assembly (Doc. XIII/19, 1963–1966).

2. The Study Group has further studied the subject during the session of the XIth Plenary Assembly, on the basis of the work of the International Working Party on selective calling devices, and took into consideration further information contained in additional documents considered at the Interim Meeting of Study Group XIII, Geneva, 1965, listed in the Conclusions of that meeting, and documents submitted to the XIth Plenary Assembly, listed in the Chairman's Report (Doc. XIII/107, 1963–1966).

3. Study Group XIII has come to the conclusion that it is important that the operational and technical characteristics of a world-wide maritime selective calling system should be standardized as soon as possible.

No decision can be taken at present regarding the selective calling system to be adopted on a world-wide basis. The operational requirements should be defined more precisely and further tests, including tests under practical operating conditions, should be made.

Account should be taken of the fact that different national selective calling systems, already in operation on a limited scale, may expand in the absence of early international agreement and, for economic reasons, preclude international standardization.

4. The discussions during the Xth Plenary Assembly made it clear that all selective calling systems tested by the Administrations of the Federal Republic of Germany (Doc. 229) and the U.S.A. (Doc. 235) are capable of operating satisfactorily in the VHF band with class of emission F3.

They also indicated that it would be advantageous for the world-wide selective calling system to be suitable for operation in the radiotelephone maritime MF and HF bands, having regard to the probable additional requirement for SSB operation in accordance with Recommendation 258-2.

* This Report was adopted unanimously.

5. Discussions at the XIth Plenary Assembly showed the desirability for the system to be suitable for operation in both the maritime radiotelegraph and radiotelephone services. In addition, a different type of system was described in Doc. XIII/76 (U.S.A.).

6. After discussion, it was decided that operational requirements and technical characteristics should be defined more precisely and that further tests should be carried out and that for this purpose an International Working Party should again be set up.

7. The requirements of the further tests to be carried out may be summarized as follows:

7.1 as far as possible, the tests should be extended to include all classes of emission used in the maritime mobile services;

7.2 tests should also be carried out under practical operating conditions, including the effects of fading, interference and atmospherics, and the report should contain information with regard to:

7.2.1 reliability (ratio of calls received to calls transmitted) for high and low field strengths;

7.2.2 immunity against false calls (ratio of false calls received to calls transmitted), caused by such phenomena as speech modulation, intermodulation, etc. and interference from other selective calls;

7.2.3 an indication of the complexity of the different receiving selectors, such as number of tubes, transistors, relays and frequency-selective elements; also whether any components used are special or critical, especially as regards adjustment and maintenance;

7.2.4 an indication of the relative cost of typical equipment tested should, as far as possible, be given.

8. An indication of the patent situation should be included in the report by the International Working Party.

9. Further study of this subject was made at the Special Meeting of Study Group XIII, Geneva, 1967, on the basis of the additional tests carried out by the International Working party in The Hague in February 1967, as reported in Doc. XIII/11.

Discussion at the Special Meeting indicated a general acceptance of the sequential single-frequency code (SSFC) system to meet the immediate and urgent needs of Administrations. Recommendation 257-1 was prepared.

The Meeting also agreed the text of a Question, later adopted by correspondence and numbered 9/8, for further study of digital or other systems which may prove necessary for use with communication systems in the future.

The special Meeting prepared a draft Resolution drawing the attention of the Maritime Conference, Geneva, 1967, to the need for revision of the Radio Regulations to provide for the introduction of a selective-calling system.

10. The Maritime Conference, Geneva, 1967, amended the Radio Regulations to permit the introduction of selective calling and adopted C.C.I.R. Recommendation 257-1 to meet immediate requirements in the maritime mobile service (see Appendix 20C to the Radio Regulations, as amended by the Maritime Conference, Geneva, 1967). It also noted that the C.C.I.R. was undertaking a further study of selective-calling systems which might be required in the future (Question 9/8) and urged the C.C.I.R. to complete its studies as soon as possible (see Recommendation No. Mar. 8 of the Maritime Conference, Geneva, 1967).

11. At the Interim Meeting of Study Group XIII, Geneva 1968, Doc. XIII/71 (Federal Republic of Germany) and Doc. XIII/78 (U.S.S.R.), 1966–1969 were considered.

Doc. XIII/71 (Federal Republic of Germany) describes measures by which the immunity of receiving selectors in the SSFC system against false calls might be increased. It recommends:

— an interval of 30 ms between the termination of the decoding of a signal element and the beginning of the decoding of the following element;

— a period of not much less than 16 ms for the decoding of a signal element.

Studies have shown that, providing the receiving selectors are suitably designed, no special measures need be taken against false operation by speech.

The document also refers to results of investigations into the possibility of interference between radiotelephone and radiotelegraph alarm signals and SSFC signals. The results indicate that the risk of false operation is negligible. There is only a very slight possibility that the radiotelephone alarm signal could simulate selective code numbers 33333 and 44444.

It is recommended that for economy reasons the selective elements in decoders should allow for a frequency tolerance of $\pm 0{\cdot}4\%$.

Doc. XIII/78 (U.S.S.R.) draws attention to two main difficulties in the use of the " all ships call " signal as proposed in Recommendation 257-1; one difficulty is operational and the other technical.

Operationally, when a selective call is received by a ship, it is impossible to determine whether the call is an " all ships call " or a normal selective call.

Technically, the filters in the decoder which are designed to accept the 100 ms pulses of the selective call have insufficient bandwidth to accommodate the 17 ms pulses of the " all ships call ".

A new type of " all ships call " is suggested which consists of the emission of a continuous 2110 Hz tone for approximately 1·4 s. This would not involve any material increase in the complexity of the equipment and it is also suggested that this might be used as an inter-ship safety signal.

12. Note was taken of the fact that there was some similarity in the matters discussed in the two documents and it was considered that there might be a need for more than one type of " all ships call ".

Administrations are invited to give consideration to the matters raised in the documents and to submit their views to the C.C.I.R.

13. At the Final Meeting of Study Group XIII, Geneva, 1969, the following documents were submitted: Doc. XIII/137 (Federal Republic of Germany) and Docs. XIII/163 and 164 (U.S.S.R.).

13.1 Doc. XIII/137 describes tests to compare the " all ships call " as proposed in Recommendation 257-1 with that proposed in Doc. XIII/78 (see § 11 above). The results showed that both types of signal gave adequate reliability of decoding, the single repetition frequency being the better of the two. The repetition frequency, however, gave a somewhat larger number of false calls at high input levels of noise or speech.

13.2 Doc. XIII/164 proposes a means for providing an " all ships call " and a safety signal in the VHF maritime RT service. In order to distinguish reception of an " all ships call " from a selective call, the " all ships call " would be decoded in a separate decoder responding to repetitions of two frequencies only, namely f_{11} and f_9. The safety signal would be decoded in the same decoder, using only one of the elements for " all ships call ". This principle would allow separate indication of individual calls, the multi-tone " all ships call " and the single-tone safety signal.

13.3 After discussion, the Meeting agreed to amend Recommendation 257-1 in order to amplify the information concerning the " all ships call " to ensure the reliability of its reception and to enable it to be distinguished from a normal selective call.

13.4 Doc. XIII/163 describes tests of a method of determining the operating threshold for selective calling signals so that the maximum range obtainable is comparable to that of VHF radiotelephone communications.

13.5 The Meeting agreed to the principle set forth in Doc. XIII/163 but found it desirable that more tests should be carried out before the actual value of the operating threshold could be determined.

14. The Meeting agreed that Recommendation 257-1 should be brought to the attention of I.M.C.O. and included a note to this effect in the Recommendation.

Note. — The Director of the C.C.I.R. is requested to bring this Report to the attention of I.M.C.O.

REPORT 359 *

USE OF A CONTROL TONE ** FOR AUTOMATIC GAIN CONTROL OF RECEIVERS IN SINGLE-SIDEBAND RADIOTELEPHONE SYSTEMS OPERATING IN THE HF MARITIME MOBILE BANDS

(1966)

In Question 282, the C.C.I.R. has been asked to consider what arrangements should be adopted in an A3J emission to control the gain of the receiver in the absence of speech. This problem was considered at the Interim Meeting of Study Group XIII, Geneva, 1965 (see Docs. XIII/12 (United Kingdom), XIII/32 (Japan) and XIII/44 (Federal Republic of Germany), 1963 - 1966). The following conclusions have been reached:

1. for some Administrations, and for some types of ship equipment, it is essential that continuous information should be available in SSB transmissions on which the gain (and in some cases frequency) of the receiving equipment can be automatically controlled, and in those cases the following arrangements should be adopted:

1.1 in the direction ship-shore this information should be in the form of a continuous signal at a level of approximately - 16 dB relative to peak envelope power;

1.2 in the direction shore-ship the information should also be in the form of a continuous signal at a level of approximately - 16 dB relative to p.e.p;

1.3 in both directions the information should be emitted at a radio-frequency corresponding to the nominal carrier frequency.

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* This Report, which was adopted unanimously, can, together with Recommendation 258-2, be considered as an answer to Question 282, which is thereby terminated.

** The Study Group's interpretation of the Question is that the term " control tone " means " control signal ".

REPORT 361-1 *

THE INTRODUCTION OF DIRECT-PRINTING TELEGRAPH EQUIPMENT IN THE MARITIME MOBILE SERVICE

(Question 5-1/8)

(1966 – 1970)

1. Introduction

At the Interim Meeting of Study Group XIII, Geneva, 1965, the following papers were submitted and discussed: Doc. XIII/38 (Norway); Doc. XIII/45 (C.C.I.R. Secretariat) containing Doc. III/82 (Netherlands). This resulted in Question 5-1/8 being formulated and adopted by correspondence.

The following additional documents were submitted to the XIth Plenary Assembly (Oslo): Docs. XIII/73 (Senegal); XIII/82 (U.K.); XIII/93 and XIII/94 (Canada); XIII/105, XIII/106, XIII/119 (Netherlands); XIII/113, XIII/114 (Federal Republic of Germany); XIII/120 (Norway), 1963 – 1966. Reference should also be made to Report 349-1.

1.1 Doc. XIII/73 (Senegal) proposes that the direct-printing system should be an error indicating type, that the maximum modulation rate should be 50 bauds, that the radio circuit should use class of emission F1 and that the quality of transmission should be 1 error per 10 000 characters.

1.2 Doc. XIII/82 (United Kingdom) describes an automatic one-way error-correcting system used for ship-shore and shore-ship transmission of messages, data and press. The system accepts start-stop signals which conform to C.C.I.T.T. standards and produces similar signals at the receiver output.

The ten-unit code used for transmission consists of the 5 elements of the International Teleprinter Code No. 2 followed by 5 parity check elements. The 5 parity elements are either an erect or an inverse repetition of the information elements, depending on whether the Z count in the information elements is odd or even. This system is capable of correcting all single element errors in the characters in the text and of detecting all double element errors as well as most multiple element errors introduced by the transmission path. Errors which are detected, but cannot be corrected, are indicated by the printing of " error " symbols, usually combination 31 or 32. A synchronous mode of transmission is employed. The modulation rate is then 62·3, 68·5 or 102 bauds for teleprinter circuits operating at modulation rates of 45·45, 50 and 75 bauds respectively. At the lower modulation rates the system is capable of extension over the public telegraph network using conventional 50-baud circuits.

No special phasing signals are required as the system is capable of fully automatic phasing during periods of traffic as well as during periods of idling.

The system reported in Doc. XIII/82 is currently in commercial service. Over the period 7 August 1965 to 27 November 1965 a total number of 1099 data tapes, each containing between 1500 and 1800 characters, were transmitted from ships at sea to an office in London. Of these, 889 were accepted without need for later re-transmission (i.e. contained no errors).

* This Report was adopted unanimously.

It is further reported that tests between ship and shore stations with plain language messages, and ship-borne reception of broadcast services (e.g. press transmission) were considered satisfactory, provided some measure of diversity reception is used.

1.3 Doc. XIII/93 (Canada) proposes an addition to the considerings of Question 320 (XIII).

1.4 Doc, XIII/94 (Canada) proposes specific families of tones for mark and space (including provision for frequency diversity). A unidirectional system with an error indicating and correcting 10-unit code is preferred to an ARQ system. An average error-rate of 1 in 1000 characters at the C.C.I.T.T. preferred standard of 50 bauds is proposed. Suggestions for operational procedures are given.

1.5 Doc. XIII/45 (Netherlands) describes a single-channel simplex ARQ system according to Report 348 which is used for ship-shore communication to pass messages, data and press.

It accepts signals in any 5-unit code and produces similar start/stop signals at the receiver output at a modulation rate of 50 bauds, and a 150 ms character cycle. The code used for transmission consists of seven elements per character with a constant A to Z ratio. This code is used for error detection. All detected errors are automatically corrected by means of ARQ.

A synchronous mode of transmission is employed at a modulation rate of 100 bauds.

The system provides automatic, error-free phasing, within one second. In addition, the phasing signals are used to provide selective calling facilities. The system provides for rapid reversal of traffic flow thus enabling the user of this system to participate in the telex network.

The system is capable of using one frequency for both the transmission paths. It is in commercial service and has been for about 4 years.

1.6 Doc. XIII/105 (Netherlands) is a report on a one-way system for message broadcasting with error-correcting and indicating facilities. The system accepts and produces at the receiver the 5-unit start-stop International Telegraph Alphabet No. 2, at a modulation rate of 50 bauds. For radio transmission, the start-stop code is converted into a synchronous, 7-unit code at a modulation rate of 100 bauds. Each character is transmitted twice with an interval of 350 ms, thus giving a time diversity effect. At the receiving terminal, the first character is checked for correct 3/4 ratio of A/Z elements, and if correct, is fed to a delay storage circuit. If the character is mutilated, the second transmission is examined, and if correct, is printed. If both transmissions are mutilated, then a space symbol is sent to the teleprinter. Before starting the transmission of information and in the idle time between successive messages or message blocks, the transmitting station emits idle time signals which are also used for phasing. Equipment designed for a 3-character ARQ system (see Docs. XIII/45 or III/82, 1963–1966) has been modified to include the new unidirectional transmission system. Its performance when tested in the laboratory, under conditions simulating various types of fading, is shown in Report 349-1.

1.7 Doc, XIII/106 (Netherlands) contains proposed answers to Question 5-1/8, based on Docs. XIII/45 and XIII/107, 1963–1966. In particular, it is proposed that the system should be suitable for communication between ships and one coast station, and from one coast station to a number of ships; the modulation rate should be about 100 bauds; the class of emission F1, with a shift between 85 and 400 Hz or class of emission A3J, and the average efficiency should be between 70% and 100%.

1.8 Doc. XIII/119 (Netherlands) tabulates the results of ship-shore and shore-ship tests with a simplex-ARQ system described in § 1.5. Details of the equipment used are given. The undetected error-rate was better than 1×10^{-5}. The mean efficiency factor was generally of the order of 80%. These figures indicate that the undetected error-rate is better than that obtained with conventional ARQ systems used in the fixed service.

1.9 Doc. XIII/113 (Federal Republic of Germany) observes that, when duplex operation is possible, a conventional ARQ system on a single channel basis as described in Report 350 is preferred.

1.10 Doc. XIII/114 (Federal Republic of Germany) expands on Doc. XIII/113 as far as duplex and simplex operations are concerned; it concludes that the ARQ method is preferred to forward error correction. It also concludes that transmission quality is improved if the modulation rate is not more than 100 bauds and that class of emission F1 is preferable. It is suggested that the efficiency factor should not fall below 70-80%.

1.11 Doc. XIII/120 (Norway) describes tests between ship and shore and shore and ship, using the two systems described in Docs. XIII/82 (United Kingdom) and XIII/45 (Netherlands), 1963–1966. The equipment used is listed. The results are tabulated. For the forward error-correcting system, the undetected error-rate was of the order of $3\text{-}5 \times 10^{-4}$. For the ARQ system the average error rate is approximately $2{\cdot}6 \times 10^{-5}$ and the average efficiency 75-77%. The tests with both systems are being continued.

2. At the Special Meeting of Study Group XIII, Geneva, April 1967, the following documents were submitted: XIII/1 (United Kingdom) and XIII/6 (U.S.A.).

2.1 Doc. XIII/1 (United Kingdom) deals with the class of emission for direct-printing telegraphy in the maritime service. A comparison is made between frequency shift emission (using 170 Hz shift) and a frequency exchange emission (using 170 Hz spacing between the frequencies). Both types of emission are capable of similar performances, both can be generated at audio frequency and applied to single-sideband transmitters operating with the class of emission A3J, and both can be accommodated in the recommended bandwidth of 340 Hz (Recommendation 440-1). However, frequency exchange emission necessitates reception by demodulators using filter-assessor techniques, whereas filter assessor and limiter-discriminator techniques are both capable of use with frequency shift emission.

2.2 Doc. XIII/6 (U.S.A.) outlines the need for error-detection and error correction equipment to improve radio teleprinter communications and it describes the principles of feedback (ARQ) and forward acting techniques for error correction and detection. Convolutional codes (or time diversity codes) are considered to be simpler and more powerful than block codes. An example is given of a forward acting system employing convolutional coding which, typically, will reduce the channel error rate to between 1/10th and 1/100th. The degree of reduction in error rate depends upon the performance of the basic radio circuit so that the improvement afforded by an error correcting system can best be assessed by measuring the error rate with and without the system in circuit.

2.3 To give guidance to the Maritime Conference, Geneva, 1967, additions were drafted to Recommendation 440 (Annex VII, Report of Special Meeting of Study Group XIII, Geneva, April, 1967).

3. At the Maritime Conference, Geneva, 1967, it was decided that the equipment shall accept signals conforming to International Telegraph Alphabet Code No. 2 at a modulation rate of 50 bauds and shall provide similar signals at its output for extension to the Public Telegraph Network. It was also decided that the modulation rate over the radio path shall not exceed 100 bauds and that class F1 emissions shall be used, with a total frequency shift of 170 Hz (Appendix 20B (Mar) to the Radio Regulations, as revised by the Maritime Conference, Geneva, 1967).

Channels for narrow-band printing telegraph systems were provided in the HF bands (Appendix 15 (Mar) to the Radio Regulations, as revised by the Maritime Conference, Geneva, 1967).

4. At the Interim Meeting of Study Group XIII, Geneva, 1968, the following documents were submitted: XIII/44 (Netherlands), XIII/45 (Canada), XIII/63 (U.S.A.), XIII/67 (Netherlands) and XIII/77 (Japan). Further modifications were drafted to Recommendation 440 (Doc. XIII/84).

4.1 Doc. XIII/44 (Netherlands) contains comments on Doc. XIII/6 (U.S.A.) which, in the opinion of the Netherlands Administration, fails to fulfil the intended scope to serve as a preliminary study of the need and feasibility of using error-detection and correction equipment to improve radio teleprinter communications.

4.2 Doc. XIII/45 (Canada) proposes that error control facilities should be optional, as equipment for this purpose may be economically unattractive for use in small ships.

4.3 Doc. XIII/63 (U.S.A.) comments on the present information available on various types of error-detecting and correction systems for direct printing telegraphy in the maritime mobile service. It is considered that a Recommendation cannot yet be formulated, because more study should be made of operational requirements, the extent to which existing techniques can meet requirements, and the comparative performance and cost of proposed systems.

4.4 Doc. XIII/67 (Netherlands) describes a technique for combining the use of the ARQ (§ 1.5) and broadcast (§ 1.6) modes by automatic switching on the ship from the shore station.

4.5 Doc. XIII/77 (Japan) describes a system in which the information is divided into blocks. A pseudo-random noise synchronizing code and a check " Fire " code are added before and after each information block. Burst errors can be detected and corrected effectively and transmitted signals synchronized correctly in each frame because of the use of a pseudo-random noise code. Although it seems inefficient to synchronize frame by frame, it is very effective as the synchronizing errors deteriorate the error rate remarkably. Field tests have shown that overall character error rates between 1×10^{-3} and 4×10^{-3} have been achieved. It was also shown that the shorter block codes having limited burst error capability actually performed better than longer codes. The system is applicable to both printing telegraph and selective calling systems.

5. When the characteristics of error control systems and the methods of comparative testing are being considered, the following points are amongst those to be taken into account (Interim Meeting of Study Group XIII, Geneva, 1968).

5.1 As it is difficult to compare results which have been obtained under different conditions of operation, initial comparisons of error control systems can best be carried out with propagation simulators. It is not possible to establish standard propagation test conditions for such comparisons as there is insufficient information available. The results of any tests should be accompanied by a detailed account of the simulator characteristics and the ranges of its operating conditions used during the tests. Information is required regarding the number of paths, the time delays and their distributions, the amplitude variations, the noise and interference characteristics. In making future comparison tests on simulators the performance of an unprotected start-stop system should be measured under the same conditions to provide a reference against which any improvement can be assessed.

5.2 As the traffic is likely to be intermittent it is desirable that any period which may be necessary before correct decoding is established shall be as short as possible. At present it is considered that this phasing and synchronizing period should not exceed 5 seconds.

5.3 When considering error correction capabilities the following factors are of importance:

5.3.1 the proportion of undetected errors,

5.3.2 the proportion of detected, but uncorrected errors, in systems which do not correct all detected errors,

5.3.3 the number of repetitions in systems which do correct all detected errors.

5.4 Further consideration should be given to the definition of the character error rate in the maritime service, bearing in mind the intermittent nature of the traffic. It is not possible to adopt a single value of desired character error rate in view of the variations in radio propagation conditions, shipborne radio installations and operational requirements. For circuits which are extended to the Public Telegraph Network, the character error rate should preferably be of the same order as that obtained on inland circuits.

6. At the Final Meeting of Study Group XIII, Geneva, 1969, the following documents were submitted: XIII/115 (Federal Republic of Germany), XIII/126 (Canada), XIII/134 (United Kingdom), XIII/135 (United Kingdom), XIII/152 (Netherlands) and XIII/158 (Netherlands).

6.1 Doc. XIII/115 (Federal Republic of Germany) proposes that the introduction of direct-printing telegraph techniques in the maritime service should take place over three stages: (1) use of unprotected C.C.I.T.T. Alphabet No. 2 with F1 emissions; (2) application of diversity methods; (3) application of error-correcting methods, e.g., with ARQ C.C.I.T.T. 7-unit code No. 3. The document lists a bibliography of three German papers.

6.2 Doc. XIII/126 (Canada) urges the need for standardization of a system for machine telegraphy. Reference is made to an existing system using a family of audio frequencies to give a degree of in-band frequency diversity in place of space diversity. A combination of audio frequencies is suggested which fit into the bandwidth of the 500 Hz allocations. It concludes that early standardization of an economical system as described might make the introduction of direct-printing telegraphy attractive to low-traffic ships.

6.3 Doc. XIII/134 (United Kingdom) gives results of ship-shore tests with Systems *A* and *B* as described in Doc. XIII/135 and an unprotected start-stop radio teleprinter system used as a reference system. Results were obtained from 68 tests and an undetected error rate of better than 1 in 1000 characters was obtained for 73% of the time on System *B*, for 57% of the time on System *A*, and for only 12% of the time on the reference system. In order to achieve the marginal circuit conditions required to compare the error-correcting capabilities of the two systems, the power of the ship's transmitters (1 kW p.e.p.) was deliberately reduced by up to 25 dB on all but two occasions.

6.4 Doc. XIII/135 (United Kingdom) gives results of comparison tests carried out using a fading simulator [1] between six forward error-correcting systems (some of which have been described previously in this Report) and a reference system. The systems tested were:

System A: A 10-unit block code as described in § 1.2.

System B: As in System *A* but with blocks of 10 characters element-interleaved to provide 145 ms burst error-correction.

System C: A recurrent half-rate code giving 145 ms burst error-correction capability [2].

System D: A 7-unit constant ratio block code as described in § 1.6 with burst error correction capability of 280 ms.

System D′: As system *D*, but using a built-in limiter-discriminator demodulator with zero position (third decision detector) [3].

System E: A diffuse convolutional ½-rate code with threshold decoding and a burst error-correction capability of 350 ms [4, 5].

Reference System: An unprotected 6-unit synchronous transmission.

Tests were made using filter-assessor demodulation with filter bandwidths of 140 Hz (3 dB) and limiter-discriminator demodulation with a filter bandwidth of 180 Hz (3 dB). F1 modulation was used with a total frequency shift of 170 Hz. When testing System *D′* it was necessary to use the built-in limiter-discriminator demodulator which had a filter bandwidth appreciably wider than that used in the other systems.

Both flat and selective fading were used at rates of 10 and 40 fades/minute and measurements taken in both diversity and non-diversity conditions. Only non-diversity operation was possible with System *D′*.

Detailed results and curves are contained in Report 349-1 but the test showed that the method of demodulation had a marked effect on the performance of the systems; under selective-fading conditions the filter-assessor method gave better results; that under the test conditions described System *B* gave the best all-round performance although the performance differences between the systems were not very great; only Systems *D* and *E* phased within 1 second and therefore satisfied the criterion in § 5.2; all the systems gave a better error-correcting performance at 40 fades/minute than at 10 fades/minute.

6.5 Doc. XIII/152 (Netherlands) sets out a draft Recommendation for a combined ARQ/Broadcast System as described in §§ 1.5 and 1.6 and designed to meet the requirements of Recommendation 440-1.

6.6 Doc. XIII/158 (Netherlands) gives results of performance measurements using a fading simulator on the single-channel ARQ equipment working in the Broadcast Mode as described in § 1.6, and also the effect of applying the third decision detection process [3]. Tests were carried out using a limiter-discriminator detector with a filter bandwidth of 500 Hz (3 dB) and with F1 modulation with a total frequency shift of 200 Hz. The limiter-discriminator detector had a built-in possibility to mark a zero position (third decision) and the tests were carried out with the detector operating both normally and with the zero position marking set at 33% of the peak-detection output. Measurements were taken under both flat and selective-fading conditions with fading rates of 10 and 40 fades per minute. The curves contained in the report are reproduced as part of Report 349-1 and the document concludes that for all the fading conditions tested the undetected error rate is reduced by using the zero-position detector process. Under flat-fading conditions the reduction in undetected errors reduces also the residual errors since at high signal/noise ratios most of the residual errors (i.e., undetected plus indicated errors) tend to be undetected. For selective-fading conditions the total number of residual errors increases because at favourable signal/noise ratios the majority of residual errors are indicated.

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REPORT 500 *

IMPROVEMENTS IN THE PERFORMANCE OF RADIOTELEPHONE CIRCUITS IN THE MF AND HF MARITIME BANDS

(Question 11/8)

(1970)

1. Introduction

At the Interim Meeting of Study Group XIII in Geneva, 1968, new techniques for improving the maritime radiotelephone service were discussed and as a result a new Question was accepted and was later adopted by correspondence and numbered 11/8. This Question deals with the application to the maritime services of the compandor techniques that have been applied so successfully to the point-to-point services. The system using these techniques has been called " Lincompex ".

* This Report was adopted unanimously.

The United Kingdom submitted Doc. XIII/80, which indicated that tests had shown that the use of Lincompex in the maritime service would give the same advantages as those obtained on the point-to-point services. Moreover, the ability of the system to suppress interference would be of greater advantage in the maritime services where interference is more frequently the limitation than it is in the point-to-point services. Furthermore, a linked compressor-expander system can be used to improve both DSB and SSB circuits.

It was pointed out in Doc. XIII/80 that the existing design of Lincompex equipment for point-to-point services required an upper limit of 3000 Hz whereas the audio bandwidth of the SSB maritime equipment was limited to 2700 Hz, in accordance with Appendix 17A of the Radio Regulations. The document contained proposals for a modified version of Lincompex specially designed to fit into the maritime channel allocations. In addition, it was considered reasonable to fit as many parts of the equipment as possible at the coast station and the document proposed a rearrangement of the basic parts of the equipment so that the ship station installation would be as cheap and simple as possible.

Equipment has been manufactured conforming to the proposals set out in Docs. XIII/80 and XIII/133 and full duplex tests have been satisfactorily completed in both the MF and HF maritime bands. In addition, extensive use has been made of the equipment fitted earlier on the RMS " Queen Elizabeth 2 ", RMS " Franconia " and RMS " Carmania ".

2. Tests in the MF bands (1·6–3·8 MHz)

Lincompex equipment conforming to the proposals in Docs. XIII/80 and XIII/133 has also been fitted on a passenger liner (SS " Orcades ") sailing between the United Kingdom and Australia, via the Cape of Good Hope.

As the ship steamed down the English Channel, tests were conducted on the MF band using SSB emissions from the coast station at Niton. Test calls * were set up to both engineering and traffic personnel and comparisons were made between Lincompex and the conventional system.

The tests indicated that during daylight a good commercial SSB telephony circuit was obtained over a distance of about 650 miles (off Cape Finisterre) with the Lincompex system, compared with less than 400 miles using the conventional SSB arrangement. During darkness, the advantages appeared to be even greater because interference made the conventional system uncommercial whereas the new system was, in general, satisfactory for commercial communications extended over the inland network.

3. Tests on the HF bands (4–27·5 MHz)

Tests on the HF bands were also made with SS " Orcades " and daily contacts were made. The results fully confirmed the improvement expected with the new system.

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* Tape recordings of the test calls were made, and were demonstrated at the Final Meeting of Study Group XIII, Geneva, 1969.

REPORT 501 *

SELECTIVE CALLING SYSTEM FOR FUTURE OPERATIONAL REQUIREMENTS OF THE MARITIME MOBILE SERVICE

(Question 9/8)

(1970)

1. Seven documents concerning selective calling systems for future operational requirements were submitted for consideration during the period 1966–1969.

   The documents are: Docs. XIII/47 (Canada), XIII/48 (Canada), XIII/60 (U.S.A.), XIII/61 (U.S.A.) and XIII/77 (Japan) (also related to Question 5-1/8), XIII/122 (Canada), XIII/139 (Federal Republic of Germany).

2. Discussion of these documents revealed that further consideration should be given to basic operational requirements before a technical solution can be realized. It was therefore agreed that it would not be possible to make meaningful recommendations at this time and that further studies are required.

   The documents mentioned above could provide guidance in these studies.

3. As a result of the discussion of Doc. XIII/61, it was decided to amend Question 9/8.

   This Report summarizes the common views expressed in the other documents on a number of general system parameters to satisfy foreseeable operational requirements for selective calling. Where different views were expressed in the documents, they have been indicated separately in the relevant sections. In addition, opinions expressed during discussion at the Interim Meeting, 1968, have been shown in the relevant sections.

4. Economy

The system should be designed so that the cost is related to the complexity required by the user, without imposing undue cost or complexity upon users with simple requirements.

5. Compatibility

The selective-calling system should be suitable for use:

— with all classes of emission used in the maritime mobile service. (However, Doc. XIII/48 suggests that if a pair of audio frequencies are used to modulate the transmitter they should differ in frequency by 170 Hz and the same pair of frequencies should be recoverable at the receiver);

* This Report was adopted unanimously.

— in all the maritime mobile bands;
— with radiocommunication equipment on board ships;
— by all categories of users.

Users of the simplest form of signalling and users of the more complicated forms should be able to share the same channel.

A signal, in digital form, with a variable number of characters in the call, and in a start-stop format, would satisfy all types of present and foreseeable requirements:
— with future communication systems;
— with error-control systems.

Normally, narrow-band F1 systems may be used satisfactorily without error correction at signal-to-noise ratios at which radiotelephony could not be accomplished, even with repetitions and experienced operators. From an operational standpoint, however, the effective range of the signalling system should not be substantially greater than that of radiotelephony communications. Error correction would be particularly useful when used with a direct printing service. The signalling system should be designed so that it may be used in conjunction with error-control, as and when required.

One Administration expressed the opinion that from an operational point of view it might be advantageous if the calling system were designed for a particular communication service for which it is intended (e.g. a teleprinting system might have its own characteristic selective-calling system, including error-control function, whereas a radiotelephone system might have a simpler system).

6. Flexibility

The signalling system should provide facilities for identification of the calling station, the working channel, self-identification and acknowledgement (" answer back ").

It should also be suitable for use with direct-printing systems; with unattended receiving stations, with remote monitoring and transponding schemes.

It should also cater for identifying the desired channel when used on multi-channel communication systems.

7. Referring to § 4, economies can be made if modular techniques are used in the construction of equipment so that additional functions can be provided by adding units.

8. The system should have a large identification capacity (not less than 1 000 000), to allow for unique identification of sending and receiving stations, group calling facilities and " all-ships " calls and, if desired, geographically-zoned calling for safety or distress.

9. The necessary bandwidth should be narrow to conserve frequency space and to allow the system to be used on narrow-band telegraph channels. A narrow bandwidth would also facilitate the division of some of the international calling channels into sub-channels, for example, for allocation to routes or areas.

10. Calling signal

The calling signal should:
— be of binary form;
— be of short duration (less than 2·5 s);

— be repeatable automatically on the MF and HF bands;

— be composed of a variable number of characters to provide flexibility for future expansion.

However, Doc. XIII/48 presents the view that all calls should contain the same number of characters;

— be alphanumeric to allow for direct use of the radio call signs of all ships and to provide also for a larger number of calls with a limited number of characters per call; however, Docs. XIII/48, XIII/122 and XIII/139 proposed numeric calls only to facilitate integration with national and international telegraph and telephone networks; Doc. XIII/122 also suggests a possible method of achieving this by converting the ships' call signs to an all numeric code by assigning two numbers to each letter of the alphabet. Discussion showed that some Administrations preferred synchronous transmission to start-stop.

11. Format of calling signal

The format of the call should consist of:

— start information,

— an " address " portion,

— stop information.

The calling signal should also provide for additional successive codes and data as necessary.

Doc. XIII/48 suggested the use of a constant-ratio block code (two out of five) derived from C.C.I.T.T. Alphabet No. 2.

Doc. XIII/77 suggested the use of a one-way error detecting and correcting code based on cyclic codes, previously described in Doc. XIII/16.

Doc. XIII/139 suggested that, when applying selective calling in connection with direct printing, the format of the new calling signal should be such as not to prohibit the automatic establishment of connections, i.e. receiver, transmitter and selective calling equipment should form one functional unit. The document also suggests that some 100 special codes would be sufficient for automatic selection of the requested operating frequency and that a new frequency plan will be required for automatic working.

12. The encoder should accept signals conforming to C.C.I.T.T. Alphabet No. 2 at a modulation rate of 50 bauds.

13. Reliability

The system should be reliable and false calls negligible.

Doc. XIII/139 indicated that if a decision is made to use a binary-coded selective calling system, then due to the need for a high reliability of decoding and immunity against false calls, the use of error detection seems more important than for the direct printing service itself. The document also suggests that the use of earth satellite techniques may ease the technical problems associated with error control in the selective call.

REPORT 502 *

SELF-SUPPORTING ANTENNAE FOR USE ON BOARD SHIPS

Performance at 500 kHz

(Study Programme 6A-1/8)

(1970)

1. The first part of this Report sets forth data on performance of self-supporting antennae, and illustrations, as compiled by Administrations for the Study Programme. The tabulated data were measured unless otherwise indicated.

2. The second part of this Report explains a theoretical method for calculating new values of metre-amperes and total antenna power for modifications of Chapter IV, Regulation 9 *(g)* of the International Convention for Safety of Life at Sea, London, 1960, to take into account the performance at 500 kHz of self-supporting shipboard antennae.

3. Part I of this Report is based on Docs. XIII/56 (Norway), XIII/58 (Japan), XIII/132 (U.S.A.), XIII/138 (Federal Republic of Germany), XIII/147 (Japan) and XIII/153 (Rev. 1) (U.S.S.R.). Part II is based on Doc. XIII/79 (Rev. 1) (U.S.S.R.).

4. When presenting further contributions, the instructions contained in Study Programme 6A-1/8 should be borne in mind.

* This Report was adopted unanimously.

PART I

TABLE I

Electrical characteristics, as determined by measurement of self-supporting antennae for use at 500 kHz

No. (a)	Figure (antenna) (b)	Length of feeder (m) (1) (c)	Overall height (m) (2) (d)	Length of mast (m) (1) (e)	Diameter of top (m) (3) (f)	Current (A) (4) (g)	Current (A) (5) (h)	Capacitance (pF) (6) (j)	Capacitance (pF) (7) (k)	Radiation resistance (ohms) (8) (l)	Resonant frequency (kHz) (9) (m)
1	1	9	26·5	16	4·6	5·3	3·9	820	—	5·0	720
2	1	14	26·5	16	4·6	8·0	5·9	730	—	3·0	820
3	1	14	30·5	20	4·6	8·6	6·4	790	—	3·0	910
4	1	4·5	19·3	13	4	5·5	4·1	620	—	3·3	2 850
5	1	13	31	18	4·6	5·7	4·2	705	—	2·5	2 300
6	2	2	15·8	10·5	1·0	6·4	4·7	270	—	1·8	3 700
7	2	2	15·3	10·4	1·0	6·6	4·9	310	—	1·6	3 200
8	3	3	25	12·4	1·5	9·0	6·7	410	—	1·7	4 200
9	6	2	21·6	9	3·0	8·0	6·0	330	253	—	—
10	6	1·5	25	12	4·0	5·5	4·8	425	330	—	—
11	5	7	36	13·5	—	8·0	5·6	442	297	—	—
12	5	3·6	29	13·5	—	5·8	4·2	407	343	—	—
13	4	5	30	15·0	2·5	7·0	5·6	464	—	—	—
14	4	0·7	30	15·0	2·5	7·4	7·0	446	—	—	—
15	4	4	34·4	16·0	2·5	7·5	7·4	395	—	—	—
16	5	27	29	13·5	—	6·6	2·0	590	340	—	—
17	—	—	28·3	14·7	4·9	15·0	10·0	—	—	—	—
18	—	—	28·3	14·7	4·9	12·6	8·1	—	—	—	—
19	—	—	—	12·2	3·1	9·1	6·7	—	—	—	—
20	—	—	—	12·2	3·1	9·5	7·0	1 060	—	—	2 580
21	—	—	—	14·7	4·9	11·0	8·1	—	785	—	9 200
22	—	—	—	14·7	4·9	13·0	12·4	361	—	—	9 000
23	—	—	25·9	12·2	3·1	4·1	3·0	—	172	—	4 150
24	—	—	29·6	12·2	3·1	—	3·4	—	1 030	—	—
25	—	—	25·4	12·2	3·1	6·0	3·9	—	965	—	—
26	—	—	40·5	13·1	4·3	10·0	8·8	—	—	—	—
27	4	—	40	16·2	2·5	6	4·4	—	—	4·8	—
28	4	—	31	16·2	2·5	5·5	4·1	—	—	5	—
29	4	—	35	16·2	2·5	6	4·4	—	—	4·3	—
30	4	—	33	16·2	2·5	10	7·4	—	—	4	—
31	6	—	25	10	4	3	2·2	—	—	17·2	—
32	6	—	33·5	10	4	13·8	10·2	—	—	2·1	—
33	7	—	30	10	4	6·3	4·7	—	—	4	—
34	7	—	27	10	4	3·2	2·4	—	—	15·1	—
35	7	—	25	10	4	5·2	3·9	—	—	5·7	—
36	2	4·0	17	10·4	1·0	10	9	292	—	4·0	—
37	10	—	29·0	17·0	4·5	11·0	8·1	—	430	1·16	2 700
38	11	9·6	27·3	15·6	5·0	17·0	10·0	550	435	2·1	1 070

No. (a)	Effective height (m) (10) (n)	Radiation resistance (ohms) (11) (p)	Antenna efficiency (%) (12) (q)	Weather conditions and relative humidity (r)	Shape factor (13) (s)	Test frequency (kHz) (14) (t)	Field strength mV/m (15) (u)	Tonnage of ship (GRT) (v)	Doc. of former S.G.XIII (period 1966-1969) (w)	Country (x)
1	9·7	0·45	9·0	—	0·37	520	13·4	3 000	58	Japan
2	7·9	0·31	10·3	—	0·30	530	16·8	1 900	58	Japan
3	11·2	0·60	20·0	—	0·37	520	25·1	1 900	58	Japan
4	2·7	0·39	11·8	—	0·14	530	4·0	500	58	Japan
5	10·1	0·47	18·8	—	0·33	520	15·0	4 700	58	Japan
6	4·0	0·78	4·3	—	0·25	520	6·7	370	58	Japan
7	4·0	0·06	3·8	—	0·26	470	6·3	390	58	Japan
8	7·5	0·27	15·9	—	0·30	520	18	10 000	58	Japan
9	7·7	—	—	Dry (42%)	0·36	512	16·4	3 468	56	Norway
10	9·8	—	—	Dry (41%)	0·39	512	16·1	8 781	56	Norway
11	9·8	—	—	Dry	0·27	512	19·2	11 734	56	Norway
12	11·3	—	—	Rain	0·39	512	17·3	8 055	56	Norway
13	6·0	—	—	Dry	0·20	512	11·8	8 189	56	Norway
14	6·85	—	—	Dry	0·23	512	16·7	5 854	56	Norway
15	8·0	—	—	Dry (41%)	0·23	512	20·5	10 928	56	Norway
16	10·4	—	—	Dry (50%)	0·36	512	7·2	7 638	56	Norway
17	11·7	0·61	—	—	0·41	—	40	7 210	132	U.S.A.
18	12·5	0·69	—	—	0·37	—	35	7 737	132	U.S.A.
19	7·0	0·22	—	Damp	—	—	16	9 927	132	U.S.A.
20	10·9	0·52	—	—	—	—	26	9 927	132	U.S.A.
21	10·5	0·48	—	—	—	—	29	11 420	132	U.S.A.
22	11·3	0·56	—	—	—	—	48	11 420	132	U.S.A.
23	9·8	0·42	—	Humid	0·38	—	10	10 325	132	U.S.A.
24	6·0	0·16	—	—	0·20	—	7	7 885	132	U.S.A.
25	4·1	0·07	—	—	0·16	—	5·5	10 654	132	U.S.A.
26	8·5	0·32	—	Clear	0·21	—	25	24 471	132	U.S.A.
27	5·2	1·26	2·6	—	0·13	512	8·0	20 000	138	F.R. of Germany
28	7·4	0·26	5·2	—	0·24	512	10·6	4 000	138	F.R. of Germany
29	9·8	0·45	10·4	—	0·28	512	15·0	30 500	138	F.R. of Germany
30	9·0	0·37	9·3	—	0·27	512	23·2	6 000	138	F.R. of Germany
31	8·7	0·35	2·0	—	0·35	512	6·7	9 300	138	F.R. of Germany
32	10·5	0·51	24·0	—	0·31	512	37·6	10 500	138	F.R. of Germany
33	12·1	0·68	17·0	—	0·40	512	19·9	294	138	F.R. of Germany
34	6·0	0·17	1·1	—	0·22	512	5·0	14 650	138	F.R. of Germany
35	7·0	0·23	4·0	—	0·28	512	9·45	6 900	138	F.R. of Germany
36	4·4	0·088	2·2	Dry	0·26	512	13·7	370	147	Japan
37	10·5	0·5	—	—	0·37	515	—	6 600	79(Rev.1) 153(Rev.1)	U.S.S.R.
38	8·93	0·32	15·2	—	0·32	468	19·2	3 500	153 (Rev.1)	U.S.S.R.

NOTES TO TABLE I

(1) For the first five values, the number indicated is the length of the radiating parallel wire feeder (C) in Fig. 1. In addition a feeder 3 m long connects the transmitter to the base of the parallel wire feeder.

(2) Overall height above deepest load waterline (m).

(3) Diameter of top-loading device (m).

(4) Current delivered by transmitter to antenna system (A).

(5) Current at base of antenna (A).
The currents in lines 1 to 8, 19 to 21, 23 and 37 were calculated by multiplying the currents in column (g) with a reduction factor of 0·74 (see also Conclusions). The values in the other lines were derived from measurements at base of antenna.

(6) Capacitance as seen from transmitter (pF).

(7) Capacitance as seen from base of antenna (pF).

(8) Measured from transmitter (ohms).

(9) Resonant frequency of antenna system as seen from transmitter (kHz).

(10) Calculated by the following formula: Effective height in metres $= \frac{\lambda DE}{120 \pi A}$

where λ = wavelength of test frequency (m),
D = distance from ship (m),
E = field strength measured at distance D (V/m),
A = current at base of antenna.

(11) Radiation resistance is calculated by the formula: Radiation resistance $= 160 \pi^2 \left(\frac{h_e}{\lambda}\right)^2$

where radiation resistance is in ohms
h_e is effective height (m),
λ is wavelength at test frequency (m).

(12) Antenna efficiency is calculated by the formula: efficiency in percent $= \left(\frac{\text{radiation resistance}}{\text{resistance of antenna system (measured from transmitter)}}\right) \times 100$

(13) Ratio of effective height to height above deepest load water-line.

(14) The test frequencies in lines 17 to 26 lay between 410 and 510 kHz. When calculating the effective heights and shape factors, a test frequency of 500 kHz was assumed.

(15) Adjusted to 1 nautical mile in accordance with Recommendation 368-1.

Conclusions

The table of metre-amperes in the International Convention for Safety of Life at Sea, 1960, was based on the ratio of effective aerial height to height above the deepest load water-line. This ratio equals 0·47.

In calculating a corresponding factor for self-supporting antennae, for convenience this ratio, which is derived from measurements, is called shape factor. The values are to be found in column (s) of Table I.

The cumulative distribution (Y) of the values of the shape factor (X) is shown in Fig. 8. From the curve it can be seen that the median value is 0·29 and that 90% of the installations have a shape factor of less than 0·385 and 10% have a shape factor of less than 0·165. The values in Fig. 8 were based on currents at the base of antennae (measured or calculated).

If derived from the current measured at the output of the transmitter, the shape factor will be reduced to an extent dependent on the feeder losses. From a relatively small amount of data given in Table I, an average value of 0·74 can be calculated as a reduction factor. It can be seen from the Table, columns (c), (g) and (h), that these feeder losses are considerable for some installations and do not only depend upon the length of the feeder. The results of the measurements indicate that the feeder losses are also dependent upon the construction and installation of the feeder.

PART II

The three types of self-supporting antennae shown in Figs, 9. 10 and 11 are most widely used on board ships of the U.S.S.R.

Calculations carried out for these three types of self-supporting antennae show that whereas for main wire-antennae suspended between masts the mean ratio between the effective height and the length of the vertical downlead is

$$h_e/h = 0{\cdot}9,$$

while the same ratio for self-supporting antennae is

$$h_e/h = 0{\cdot}7,$$

or 22% less.

This decrease of the h_e/h ratio for self-supporting antennae as against main wire-antennae is equivalent to the same decrease of the ratio between the effective height h_e and the maximum height H, calculated from the top of the antenna to the deepest load waterline of the vessel.

If the mean value of this ratio for main wire-antennae at 500 kHz is

$$h_e/H = 0{\cdot}47,$$

the ratio for self-supporting antennae will be

$$h_e/H = 0{\cdot}37.$$

In this way, the table of metre-amperes given in the Safety Convention can be improved and adapted to determining the normal range of self-supporting ship antennae.

The formula for determining radiation power

$$P_\Sigma = 1580(aH/\lambda)^2 I_0^2$$

where: $a = h_e/H$

may be expressed by: $P_\Sigma = (MA/K_1)^2$

In this case: $(K_1)^2 = \lambda^2/(160\,\pi^2 a^2)$

$MA = HI_0$ (metre-amperes),

where: I_0 = antenna current (amperes),

H = maximum height of antenna (m),

λ = wavelength (m).

For instance, for frequency $f = 500$ kHz, when $a = 0{\cdot}37$,

coefficient $K_1 = 40{\cdot}5$

Accordingly, the metre-ampere values in Table **II** may be calculated for self-supporting antennae, by taking the ratio

$$\frac{\text{antenna radiation power}}{\text{total antenna power}} = 0{\cdot}05$$

with the ratio

$$\frac{\text{effective height of antenna}}{\text{maximum height of antenna}} = 0{\cdot}37$$

TABLE II

Normal range (miles)	Metre-amperes	Total antenna power (W)
200	162	320
175	129	204
150	96	112
125	74	66
100	57	44
75	43	22

The data in Table III may be used to determine the approximate range of transmitters in the MF band under operational conditions, when the current and height of the antenna are easy to establish, and also to determine the height of the self-supporting antenna required to attain a given range.

TABLE III

Normal range (miles)	150	100	75	50
Metre-amperes	96	57	43	32
Maximum height of antenna above the deepest load waterline (m)	Current at base of antenna (amperes)			
14	6·85	4·1	3·1	2·3
16	6·0	3·6	2·7	2·0
18	5·35	3·2	2·4	1·8
20	4·8	2·85	2·15	1·6
22	4·35	2·6	1·95	1·45
24	4·0	2·4	1·8	1·35
26	3·7	2·2	1·65	1·25
28	3·4	2·0	1·55	1·15
30	3·2	1·9	1·45	1·07
32	3·0	1·8	1·35	1·0
34	2·8	1·7	1·25	0·95
36	2·65	1·6	1·2	0·9

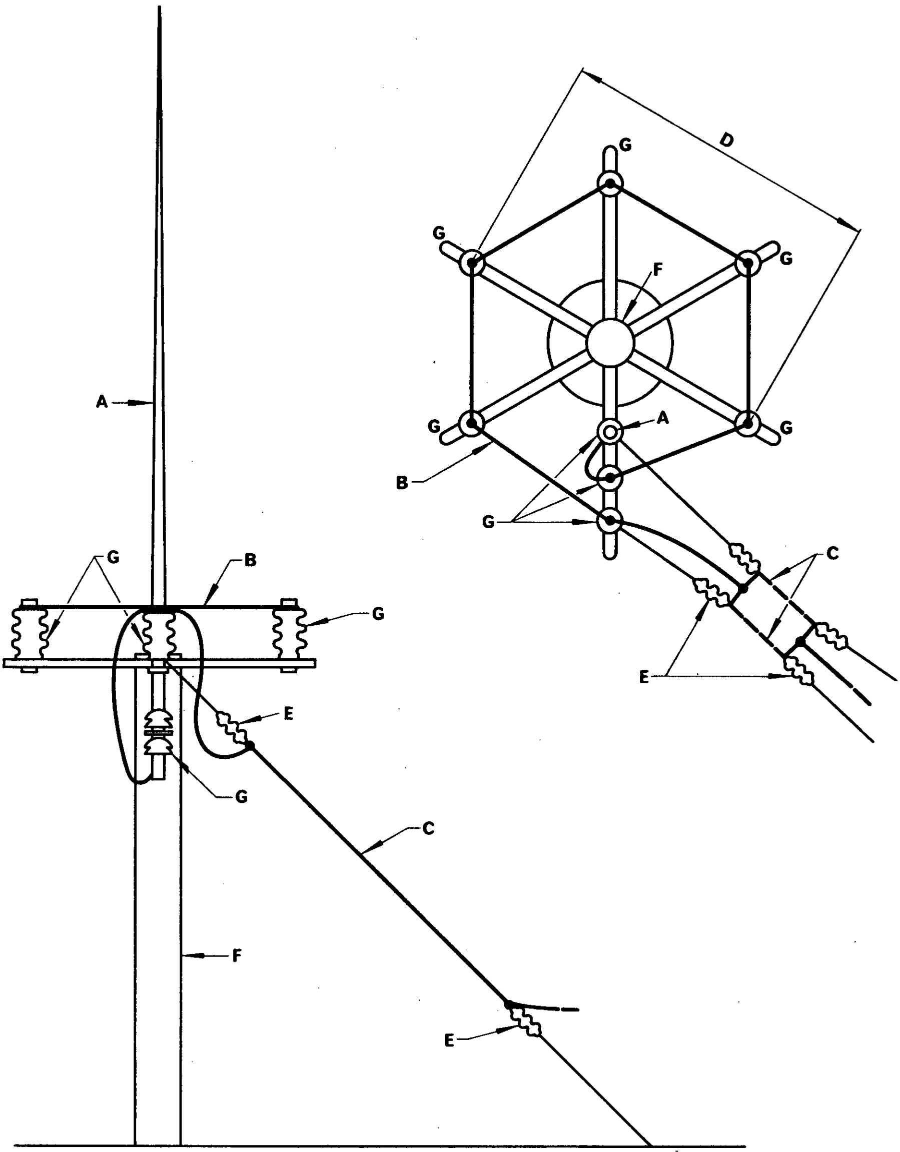

FIGURE 1

Top-loading antenna

A: vertical part of antenna (helical-coil conductor)
B: horizontal-loop part of antenna (helical-coil conductor)
C: parallel wire
D: diameter of the horizontal-loop part
E: antenna lead-in insulator
F: antenna post
G: insulator

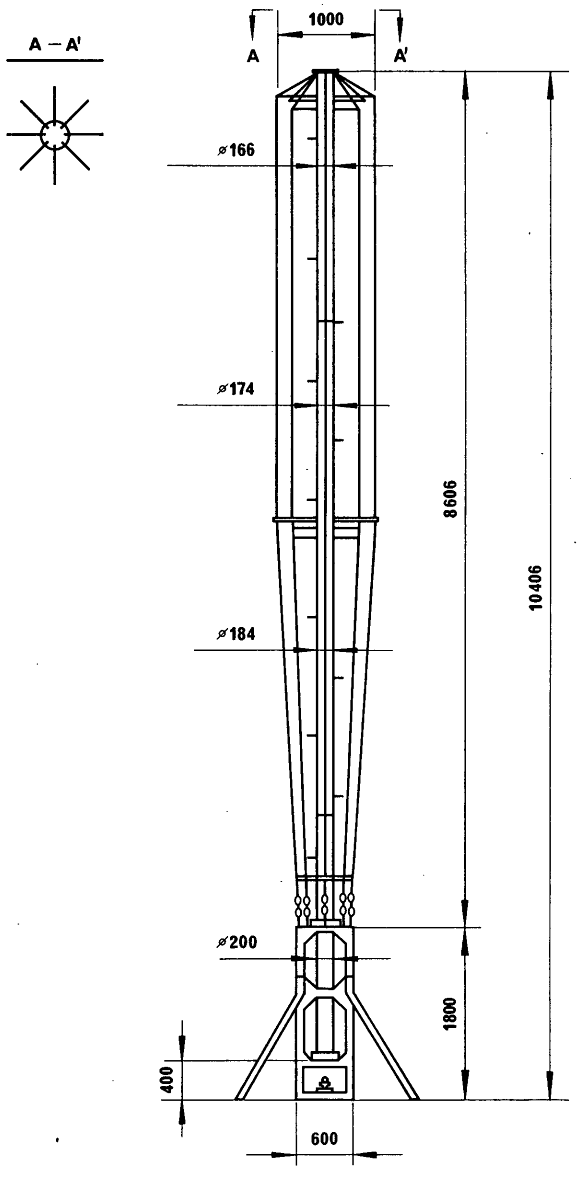

FIGURE 2

Cage antenna
(All dimensions in mm)

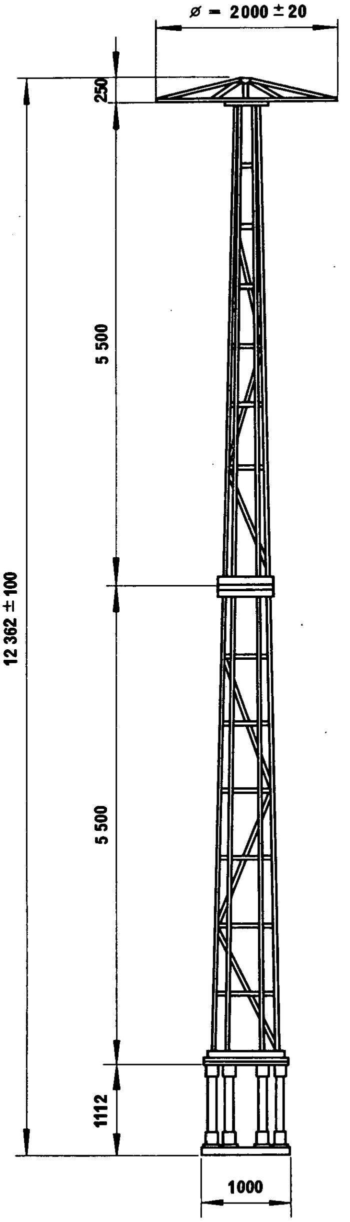

FIGURE 3

Top-ring cage antenna
(All dimensions in mm)

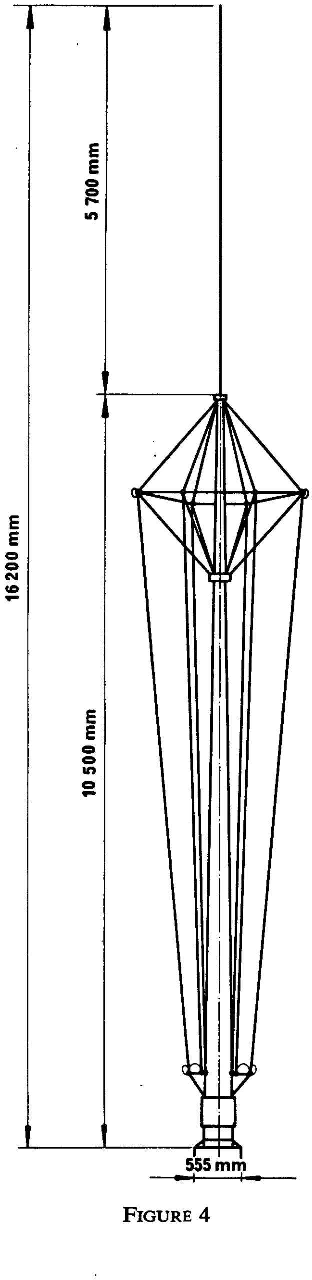

FIGURE 4

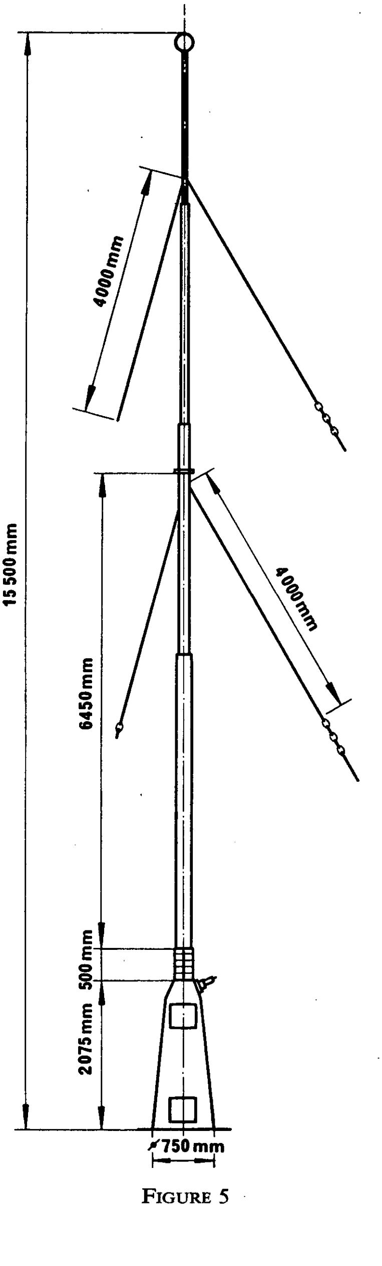

FIGURE 5

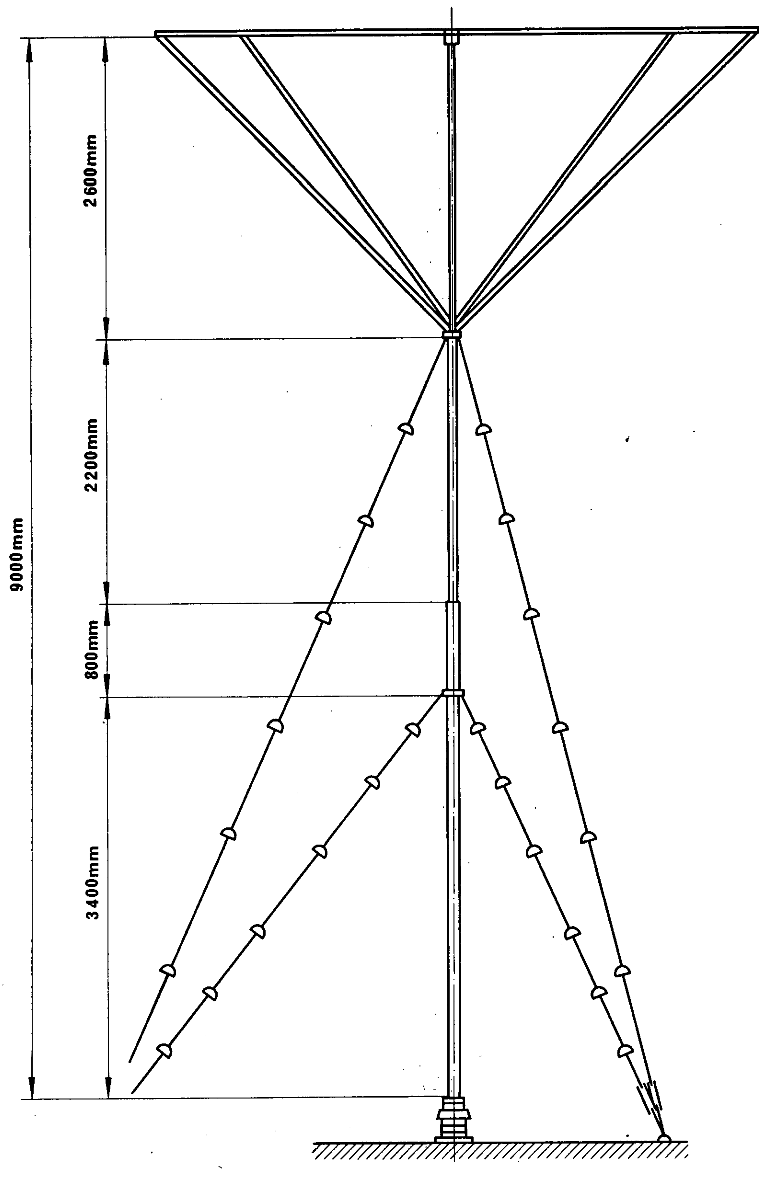

FIGURE 6

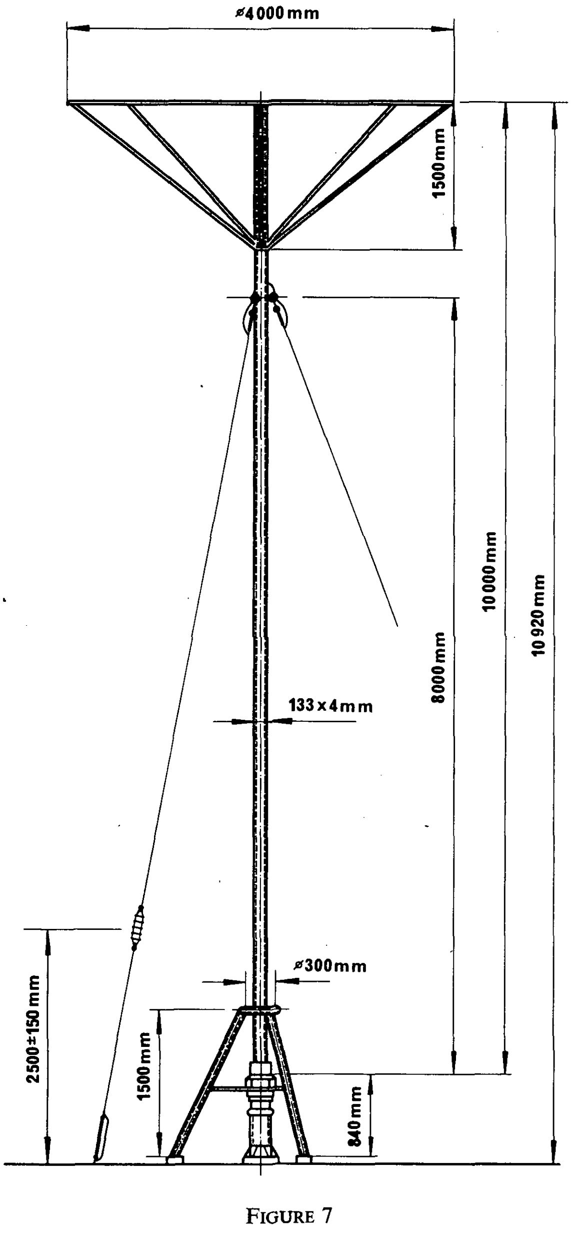
⌀4000 mm
1500 mm
10 000 mm
10 920 mm
8000 mm
133 x 4 mm
⌀300 mm
2500±150 mm
1500 mm
840 mm

FIGURE 7

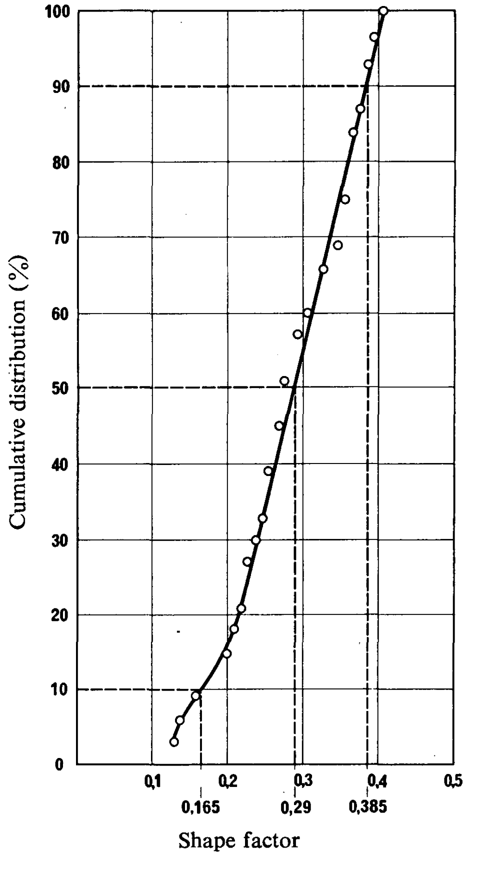
100
90
80
70
60
50
40
30
20
10
0
Cumulative distribution (%)
0,1
0,2
0,3
0,4
0,5
0,165
0,29
0,385
Shape factor

FIGURE 8

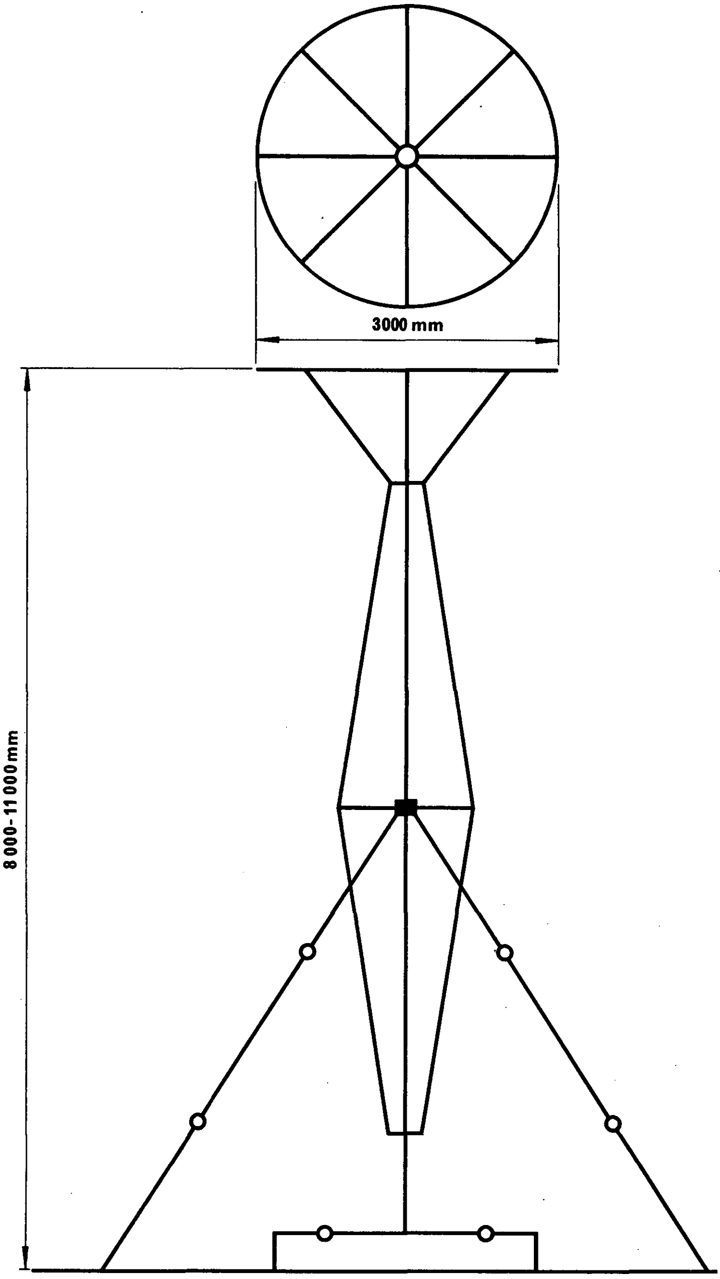

FIGURE 9

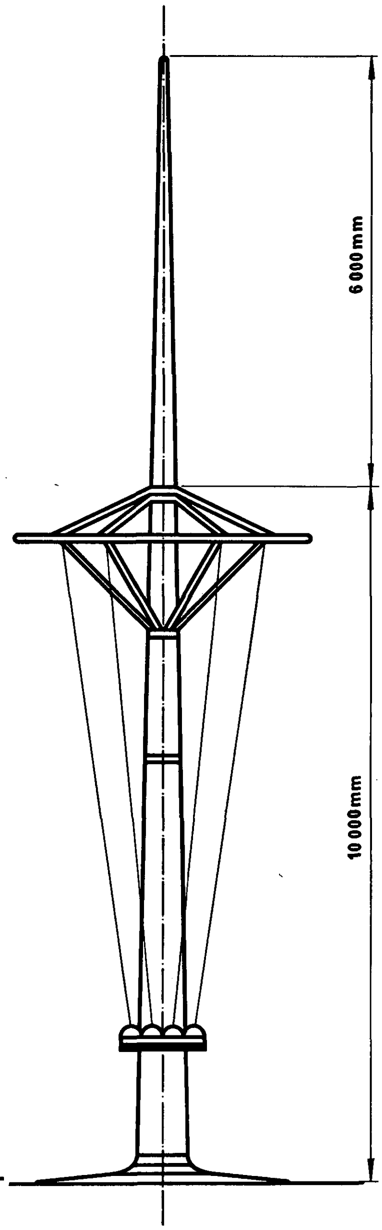

FIGURE 10

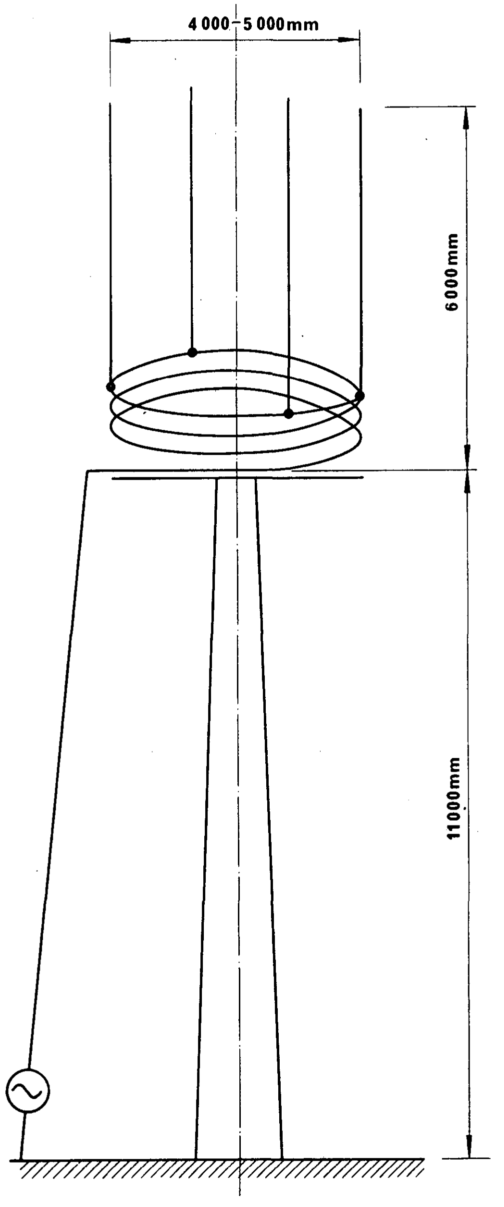

FIGURE 11

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SECTION 8C: LAND MOBILE SERVICE

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 478

TECHNICAL CHARACTERISTICS OF EQUIPMENT AND PRINCIPLES GOVERNING THE ALLOCATION OF FREQUENCY CHANNELS BETWEEN 25 AND 500 MHz FOR THE LAND MOBILE SERVICE

(Question 7-1/8)

The C.C.I.R., (1970)

CONSIDERING

(a) that certain technical characteristics of equipment and stations in the land mobile service are of importance in connection with radio interference between the stations of different countries;

(b) that agreement is desirable on the characteristics of land mobile equipment, in order to minimize mutual interference, and to facilitate the use of the same types of equipment in different countries in a geographical region;

(c) that agreement is desirable on the practices governing the allocation of channels in the land mobile services, in order to minimize mutual interference and to obtain economy of use of the frequency spectrum;

UNANIMOUSLY RECOMMENDS

1. that the technical characteristics of equipment and stations in the land mobile service that should be considered of international importance are:

1.1 *Transmitter characteristics*

1.1.1 Effective radiated power of base stations and of mobile stations.

1.1.2 Bandwidth and class of emissions.

1.1.3 Frequency tolerance.

1.1.4 Out-of-band power; especially the out-of-band power in the neighbouring channels (see Note 1).

1.1.5 Power of non-essential oscillations (see Note 1).

1.1.6 Cabinet radiations.

1.2 *Receiver characteristics*

1.2.1 Sensitivity.

1.2.2 Selectivity (see Note 2).

1.2.3 Spurious responses.

1.2.4 Overall frequency stability, including tuning stability.

1.2.5 Spurious emissions.

2. that it is desirable to standardize values for most of the characteristics listed above. Attention is drawn to the information in Part A of Report 319-2.

3. that for information on some of the practices adopted by Administrations in the allocation of channels in the land mobile service between 25 and 500 MHz, reference should be made to § 1 of Part B of Report 319-2.

4. that international agreement should be reached on as many aspects as possible of the practices for the allocation of channels in the land mobile service between 25 and 500 MHz and that reference should be made to § 2 of Part B of Report 319-2 for advice on some of the relevant principles.

Note 1. — For definition of these terms, reference should be made to IEC Publication 244-2, 1969.

Note 2. — Selectivity is here intended to include: adjacent channel selectivity, adjacent signal selectivity, intermodulation and blocking characteristics, as indicated in Recommendation 332-2.

REPORT 319-2 *

CHARACTERISTICS OF EQUIPMENT AND PRINCIPLES GOVERNING THE ALLOCATION OF FREQUENCY CHANNELS BETWEEN 25 AND 500 MHz FOR LAND MOBILE SERVICES

(Question 7-1/8)

(1970)

1. The following documents were submitted in reply to Question 7-1/8:

1.1 *During the period 1956–1959*: XIII/4 (New Zealand), XIII/2 and XIII/11 (Federal Republic of Germany), XIII/30 (Japan), XIII/32 (United Kingdom), XIII/180 (Sweden).

1.2 *During the period 1959–1963*: XIII/1 (S.F.R. of Yugoslavia), XIII/4 (Greece), XIII/10 and XIII/259 (P.R. of Poland), XIII/24 (Federal Republic of Germany), XIII/222 (Australia).

1.3 *During the period 1963–1966*: XIII/24 and XIII/80 (United Kingdom), XIII/29 (Japan), XIII/33 (P.R. of Poland), XIII/39 (Rev. 1) and XIII/83 (Federal Republic of Germany), XIII/86 (Denmark), XIII/96 (Switzerland), XIII/110 and XIII/111 (Japan), XIII/116 (France), XIII/121 (New Zealand), XIII/123 (U.S.A.).

1.4 *During the period 1966–1969*: XIII/43, XIII/70, XIII/72 and XIII/74 (Federal Republic of Germany), XIII/49, XIII/51, XIII/52, XIII/53 and XIII/55 (United Kingdom), XIII/57 (Japan), XIII/59 and XIII/62 (U.S.A.), XIII/65, XIII/66, XIII/73 and XIII/75 (P.R. of Poland), XIII/76 (Denmark), XIII/112, XIII/113 and XIII/116 (Federal Republic of Germany), XIII/130 (U.S.A.), XIII/142 (Sweden), XIII/143 (Denmark and Sweden), XIII/145 (Sweden), XIII/159, XIII/160 and XIII/161 (U.S.S.R.), XIII/162 (France), XIII/167 (O.I.R.T.), XIII/168 (New Zealand), XIII/176 (P.R. of Poland).

2. In the present Report, the following questions are dealt with separately:

— technical characteristics of equipment;
— existing practices with regard to the allocation of frequency channels;
— the relative merits of single-frequency and two-frequency operation.

3. The Resolution 20-2 invites Administrations to continue to send to the C.C.I.R. for circulation details of performance specifications and measuring methods and also to send details of practices for the allocation of channels between 25 and 500 MHz to the land mobile services in operation in their respective countries.

4. The Recommendation 478 is only a very partial reply to Question 7-1/8, study of which should be continued.

* This Report was adopted unanimously.

PART A

TECHNICAL CHARACTERISTICS OF EQUIPMENT USED IN THE LAND MOBILE SERVICE BETWEEN 25 AND 500 MHz

1. The technical information furnished by Administrations, either in the documents mentioned above or directly during Assemblies, is reproduced in the table shown in Annex I to this Report. It is arranged according to the separation between adjacent channels adopted in the various countries, the names of which are replaced by the appropriate symbols shown in Table I in the Preface to the International Frequency List.

It would be desirable for frequency tolerances and spurious emission levels to be expressed in absolute values in future.

The information given in this Annex shows that it is difficult at present to reach complete international standardization of the performance characteristics of land mobile equipment operating between 25 and 500 MHz. However, it is desirable that countries with common borders should reach agreement on some common characteristics, which would be helpful in planning for the land mobile service.

The following technical characteristics give some idea of recent equipment (without taking into account citizen band equipment in the 27 MHz band).

Transmitter characteristics

Channel spacing

25 kHz or less.

Class of emission

A3 or F3 (F3 in the majority of cases).

Nominal bandwidth of emission

— class A3: 6 kHz
— class F3: 16 kHz for 25 kHz channel separation, and generally less for smaller channel separation.

The audio-frequency bandwidth should normally not exceed 3 kHz.

Mean output power

No values for power levels are given.

Note is taken of the fact that the effective radiated power is of great importance in the planning and coordination of land mobile services; further information is needed.

Frequency tolerance

±2 kHz for 25 kHz channel separation.

There is a trend towards tighter tolerances, typically ±1 kHz, for base stations. Mobile stations usually have slightly wider tolerances. Tighter tolerances are required for equipment operating with channel separations of less than 25 kHz.

Power of non-essential oscillations

(for P less than 50 Watt)

Harmonics: typically $\leqslant$ 20 μW

Non-harmonics: typically $\leqslant$ 2·5 μW

Out-of-band power

No values can be quoted at present for this important characteristic.

Receiver characteristics

Sensitivity

Between 1 and 2 μV EMF input signal for 12 dB $S+N+D/N+D$ ratio.

Selectivity

—65 to —80 dB by the two-signal method.

Spurious responses

—70 dB or better.

Intermodulation responses

—60 dB or better.

Overall frequency stability

±2 kHz for 25 kHz channel separation.

There is a trend towards tighter tolerances, typically ±1 kHz, for base stations. Mobile stations usually have slightly wider tolerances. Tighter tolerances are required in equipment operating with channel separations of less than 25 kHz.

Spurious emissions

Less than 0·02 μW; preferably 0·002 μW.

2. Doc. XIII/167 (O.I.R.T.) deals with a special aspect of the land mobile service, i.e. mobile links used for on-the-spot broadcasting (radio) communications. It gives the technical characteristics of various types of equipment designed for this purpose.

3. The methods of measuring the technical characteristics of transmitters and receivers used in the land mobile service between 25 and 500 MHz are the subject of the following documents:

— *Period 1963–1966:*

XIII/24 (United Kingdom), XIII/110 (Japan).

— *Period 1966–1969:*

XIII/55 (United Kingdom), XIII/59 (U.S.A.),
XIII/70 (Federal Republic of Germany), XIII/73 (P.R. of Poland),
XIII/74 (Federal Republic of Germany), XIII/75 (P.R. of Poland),
XIII/159, 160 and 161 (U.S.S.R.), XIII/176 (P.R. of Poland).

For further study of these measurement methods, reference should be made to Opinion 42 and Recommendation 478, which give a list of the technical characteristics which are important internationally.

PART B

1. Existing practices with regard to the allocation of frequency channels between 25 and 500 MHz for land mobile services

1.1 The information on separations between adjacent channels furnished by Administrations, either in the documents mentioned above or directly during Assemblies, is reproduced in Tables I and II shown in Annex II to this Report. The names of countries are replaced by the appropriate symbols shown in Table I in the Preface to the International Frequency List.

1.2 Docs. XIII/39 (Rev. 1) 1963–1966, XIII/112 and XIII/113 (1966–1969) (Federal Republic of Germany) deal with methods of the assignment and coordination of frequencies of public and private land mobile services. The described planning method is, among others, based on the assumption, that in an extended network the distance between stations using the same frequencies (co-channel spacing) should for the benefit of a good frequency economy be as small as possible. This can be reached on the one hand by reducing the transmitter range as far as possible and on the other hand by using so-called lattice plans. These lattice plans are set up in such a way, that the co-channel spacing is the same for all frequencies and that the number of frequencies for one complete coverage of an extended area is as small as possible. Doc. XIII/112 contains a lattice plan for a public land mobile service using 7 duplex-frequencies for a complete coverage and Doc. XIII/113 explains a plan for a private land mobile service using 9 simplex-frequencies. Furthermore, the above-mentioned documents describe two different methods, by which—when lattice plans are used—also the frequency-requirements of high traffic areas can be fulfilled. The described planning methods have been used in the Federal Republic of Germany with good results for the frequency assignment of about 80 000 land mobile stations. Another 60 000 stations will therefore be treated in the same manner in the near future.

1.3 Some special information concerning the coordination of frequencies on a multilateral basis is given in the Special Agreement between the Administrations of Belgium, the Netherlands and the Federal Republic of Germany, relating to the use of metric and decimetric waves for fixed and mobile services in border areas (Brussels, 1963).

Doc. XIII/143 (Denmark and Sweden) gives information about an agreement between Denmark and Sweden on the assignment of frequencies for land mobile services in the two countries.

1.4 Some information concerning interference between mobile services and broadcasting services is given in the Final Acts of the Special Regional Conference, Geneva, 1960.

1.5 Doc. XIII/151 (United Kingdom) deals with the separation between adjacent channels; in view of the tendency to reduce this separation, it suggests:

— that, whenever possible, a separation of 12·5 kHz should be adopted;

— that equipment designed for wider channel separations should be readily adaptable for smaller separations without total replacement.

1.6 Doc. XIII/72 (Federal Republic of Germany) deals with the minimum separation between channels and optimum systems of modulation for land mobile services between 25 and 500 MHz. This study is based on the fact that frequency modulation requires broader bands but lower protection ratios than amplitude modulation. It concludes that, generally speaking, frequency modulation is more desirable than single-sideband amplitude-modulation (classes of emission A3A and A3H).

1.7 Doc. XIII/43 (Federal Republic of Germany) develops a rule which can be used to determine the channels that may be chosen from a number of evenly spaced channels, in such a way that third-order intermodulation products are avoided. According to the rule, channels should be chosen so that the frequency differences between sequential channels and also the various sums of differences between channels, occur only once. For example, if the evenly spaced channels are numbered 1, 2, 3 etc., then their frequency differences are proportional to the differences between the channel numbers themselves. Thus, assuming that adjacent channels are not to be used, then the chosen channels would be 1. 3. 6. 10, 16, etc., to avoid third-order intermodulation products according to the rule. A proof of the rule is given in the Annex to the document.

1.8 Doc. XIII/62 (U.S.A.) describes the way in which interference is caused by intermodulation products in the land mobile service between 25 and 500 MHz. In areas where there are large concentrations of such services, intermodulation interference is more serious than co-channel interference. Methods are given for predicting the expected level of intermodulation products; these procedures are applied to special transmitters and receivers, but they may be applied generally.

1.9 Doc. XIII/162 (France) studies the assignment of channels to land mobile networks in which the mobile stations have access to several channels. Its conclusion is that when a given number of channels is available it is of advantage to diversify the blocks of channels assigned to the mobile stations in order to increase the volume of traffic handled per channel.

1.10 Doc. XIII/168 (New Zealand) gives information on the planning methods adopted in New Zealand for the assignment of channels to stations in the land mobile service, indicating in particular the transmit frequencies assigned for base stations and mobile stations.

2. Principles for the allocation of frequency channels between 25 and 500 MHz for land mobile services

2.1 The following broad principles are suggested for use in the allocation of frequencies in the land mobile service.

— The choice of the most advantageous mode of operation, i.e., single-frequency or two-frequency operation, according to the type of service, bearing in mind the need for co-ordination between Administrations in border areas. (Attention is drawn to Part C of this Report.)

— The gradual adoption, as opportunity occurs, of the same blocks of frequencies for base stations by all Administrations, and similarly the same blocks of frequencies for mobile stations, in order to minimize interference between services of different Administrations.

— The gradual adoption by all Administrations, as opportunity occurs, of the same blocks of frequencies for the same types of service or at least for those services required to provide similar coverage.

— The adoption of compatible frequency plans, with the same channel separations and the same centre frequencies of the channels, especially in areas where mutual interference might occur between the services of different Administrations.

— The use of common channel separation, preferably 25 kHz (Note 1) and the use of equipments which are readily adaptable for a reduction in channel separation without replacement of the whole equipment.

— The allocation of channels in such a way as to minimize the production of interference due to intermodulation products.

— The adoption of optimum sizes and shapes for service areas in relation to frequency economy (Study Programme 7-1D/8 refers to this subject)) (Note 2).

— The use of the minimum effective radiated power compatible with the required service range.

— The use of the minimum height of base station antennae compatible with the required service range.

— The siting of co-channel stations with the minimum geographical separation compatible with the protection ratios and minimum field strengths to be protected which are appropriate to the service. Information on this subject is given in Report 358-1.

— The use by all Administrations of common propagation data. References to C.C.I.R. documents on this subject are included in Report 358-1.

— The assignment of the same frequency channel to a number of users in the same area, in such a manner as to permit optimum use of the channel.

2.2 These principles can be applied to full advantage when planning land mobile services, only if all are applied, since they are highly interdependent.

Note 1. — It is recognized that some Administrations use other channel separations. Every opportunity should be taken to achieve the use of common channel separations.

Note 2. — In some cases it may be advantageous to use several base stations of low power to provide the coverage required.

PART C

THE RELATIVE MERITS OF SINGLE-FREQUENCY AND TWO-FREQUENCY * OPERATION

1. The following documents deal with this subject:

Doc. XIII/53 (United Kingdom), 1966–1969,

Doc. XIII/145 (Sweden), 1966–1969.

2. General remarks

It is not usually possible to use all the available frequencies in a given, restricted area

* By two-frequency operation different blocks of frequencies are used for base transmitters and mobile transmitters and in the block for mobile transmitters no base transmitters are permitted.

owing to intermodulation problems, adjacent channel disturbances, receiver desensitization, etc. The problems which arise may be somewhat different with single-frequency and two-frequency operation. However, from the administrative point of view, coordination in border areas is easier for single-frequency simplex than for two-frequency assignments.

3. Advantages with respect to frequency economy

As regards frequency economy, it appears, from the documentation and the discussions, that single-frequency operation is preferable under some circumstances and two-frequency operation under others.

3.1 *Even geographical distribution of stations*

If the geographical distribution of base stations is approximately even over a moderately large area, then the two modes appear to be equally advantageous if the service range is about 40 km, but two-frequency operation seems to have advantages when the service range is 25 km.

3.2 *Concentration of base stations*

— Where base stations are concentrated round a centre but are separated by more than a few hundred metres, and where the density of stations diminishes rapidly as the distance from the centre increases, then single-frequency operation is usually preferable.

— However, where there are high concentrations of base stations separated by distances of less than a few hundred metres, then two-frequency working is often preferable; for this mode it is possible to have the base stations close together, while single-frequency stations must normally be separated by between a hundred and several hundred metres, or must have the transmitting and receiving antennae separated by such distances, even when the frequency separation is several hundred kHz.

3.3 Although the figures given in §§ 3.1 and 3.2 apply specifically to frequency-modulation systems, the general conclusions drawn apply also to amplitude-modulation systems.

4. Operational merits

4.1 Two-frequency operation permits:

— Talk-through, i.e. communication between mobile stations relayed via the base station, extending their communication distance.

— Operation in duplex networks, e.g. public telephone networks.

— Use of repeater stations for extended range. (The short-distance traffic could use either one or two-frequency operation.)

4.2 Single-frequency operation permits:

— Direct mobile to mobile communication without talk-through.

— Permanent knowledge of the occupancy of the channel. (Facilitates frequency-sharing.)

ANNEX I

Table I

Technical characteristics of equipment (8)

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Transmitter: Class of emission	Transmitter: Max. deviation ± (kHz)	Transmitter: Occupied bandwidth (2) (kHz)	Transmitter: Frequency tolerance ± (3)	Transmitter: Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (µV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (3)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (µW)	Receiver: Inter-modulation (dB)	Remarks (9)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18	19
10	25–50	D	(O)	Private	0	0·1 (m)	A3 F3		7 7	1·5 kHz 1·5 kHz	4×10^{-3} µW in bands: 47–68 MHz 174–230 470–790 In all other bands: 10 µW						2×10^{-3}		
		DNK	XIII/86 (O)	Private	0	0·1 (M)	A3		6	1·5 kHz	4×10^{-3} µW in bands: 47–68 MHz 174–230 470–790 In all other bands: 10 µW						4×10^{-3}		Frequency 27·12 MHz±0·6% only
						Max input: 5 (B M)	A3		6	3 kHz	Input up to 1 W: −40 dB Input up to 5 W: −50 dB						0·01		In the band 29·7—31·7 MHz only
		NOR	(O)	Private	0	0·5	A3		6	1·5 kHz	RR						RR		
		S	(O)	Private	0	0·5 (mMB) 5 (mMB)	A3		6	50×10^{-6}	20 µW −40 dB (H) 0·2 µW −60 dB (NH)			Super-regenerative receivers not permitted					Frequency 27·12 MHz±0·6% and in the bands 29·7–31·7 MHz
		SUI	(O)	Private	0	0·5 (m)			40 *	5 kHz	8 µW						0·02 (H) 2×10^{-3} (NH)		* between −40 dB points

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Class of emission	Max. deviation ± (kHz)	Occupied bandwidth (5) (kHz)	Frequency tolerance ± (2)	Spurious emissions (3) (4)
1	2	3	4	5	6	7	8	9	10	11	12
12·5	50–100	G		Private	10 13·5	5 or 25 (M) 5 or 25 (B)	A3 or F3	2·5	6 or 11	1 kHz (B) 2 kHz (M)	2·5 µW
	100–200	G		Private	4·8	5 or 25 (M) 5 or 25 (B)	A3 or F3	2·5	6 or 11	1 kHz (B) 2 kHz (M)	2·5 µW
15	50–100	J	(O)	Public and Private	2 4·5	50	F3	5	16	0·6 kHz	−80 dB (IB) −60 dB (OB)
	100–200	USA	XIII/123 (O)								
20	25–50	USA	XIII/130 (1966— 1969)	Public and Private	0·5–8	330 (B) 100 (M)	F3	5	20 to 25 dB	20×10⁻⁶	50 µW
	50–100	D	XIII/83 (O)	Private	9·8	1 6	F3	4	14	1·2 kHz	20 µW (H) 0·2 µW (NH)
	100–200	D	XIII/24 (G)	Private	4·6	1 6	F3	4	14	1·6 kHz (M) 0·8 kHz (B) 1·8 kHz (m)	20 µW (H) 0·2 µW (NH)

Receiver: Sensitivity (e.m.f.) (µV)	For a signal-to-noise ratio of (dB)	Selectivity (dB)	Frequency tolerance ± (2)	Spurious responses (dB)	Spurious radiations (µW)	Inter-modulation (dB)	Remarks (6)
13a	13b	14	15	16	17	18	19
2	10	Min. −50 at 10·5 kHz (B) −50 at 11·5 kHz (M) −64 at 22 kHz (B) −64 at 23·5 kHz (M)	1 kHz (B) 2 kHz (M)	−64	0·02	50 *	(2S) * 3 signal test. Wanted signal level to produce 10 dB signal-to-noise ratio. Unwanted signals of equal amplitude; levels adjusted to reduce signal-to-noise ratio to 7 dB.
2	10	Min. −50 at 10·5 kHz (B) −50 at 11·5 kHz (M) −64 at 22 kHz (B) −64 at 23·5 kHz (M)	1 kHz (B) 2 kHz (M)	−64	0·02	50 *	(2S) * 3 signal test. Wanted signal level to produce 10 dB signal-to-noise ratio. Unwanted signals of equal amplitude; levels adjusted to reduce signal-to-noise ratio to 7 dB.
2	20	−70 at 12·5 kHz	0·6 kHz	−80	4×10⁻³		(2S) (IB) = in-band (OB) = out-band
							The 15 kHz separation is occasionally permitted but with the same equipment characteristic as for the 30 kHz separation.
[0·6]	12 *	[−80 at 20 kHz]	[20×10⁻⁶]	[−100]	5×10⁻²	[60] **	* (2S) $(S+N+D)/(N+D)$ ** Unwanted signals of equal amplitude to produce a signal equivalent to receiver sensitivity.
[2]	20	−70 at 20 kHz	1·2 kHz	−70	2×10⁻³		
[2]	20	−70 at 20 kHz	1·6 kHz (M) 0·8 kHz (B) 1·8 kHz (m)	−70	2×10⁻³		

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. [1]	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power [2] (W)	Class of emission	Max. deviation ± (kHz)	Occupied bandwidth [6] (kHz)	Frequency tolerance ± [2]	Spurious emissions [3] [4]
1	2	3	4	5	6	7	8	9	10	11	12
		F	XIII/116 (O)	Public and Private	4·6	30 (M) 50 (B)	F3	4	14	1·6 kHz (M) 0·8 kHz (B)	RR
		J	(O)	Public and Private	2 4·5	50	F3	5	16	1·5 kHz	−80 dB (IB) −60 dB (OB)
	200–500	D	XIII/83 (O)	Private	10	1 6	F3	4	14	2·5 kHz (mM) 1·0 kHz (B)	20 µW (H) 0·2 µW (NH)
25	25–50	AUS	222 (G)	Private		25 (M) 50 (B)	A3 and F3	5	6 or 16	20×10^{-6}	Less than 2·5 µW at 50 kHz from carrier
		DNK		Private	0·6–5	10 (M) 25 (B)	A3 or F3	5	6 or 16	3 kHz (M) 1·5 kHz (B)	2·5 µW
		F	XIII/116 (O)	Private	4·4	30 (M) 50 (B)	F3	5	16	0·8 kHz	RR
		NOR	(O)	Private	5–10	25 (M) 100 (B)	A3 or F3	5	6 or 16	1 kHz	2·5 µW (H) 0·25 µW (NH)
		POL		Private		10 (M) 50 (B)	F3	5	16	2·2 kHz (M) 1·2 kHz (B)	25 µW (H) 2·5 µW (NH)
		S	(O)	Private	0	40 (M) 70 (B)	F3 (and A3)	5	16	20×10^{-6} (M, m)* 10×10^{-6} (B) **	20 µW / −40 dB (H) 0·2 µW / −60 dB (NH)

Countries	Receiver: Sensitivity (e.m.f.) (µV)	For a signal-to-noise ratio of (dB)	Selectivity (dB)	Frequency tolerance ± [2]	Spurious responses (dB)	Spurious radiations (µW)	Inter-modulation (dB)	Remarks [5]
3	13a	13b	14	15	16	17	18	19
F	2	20	−80 at 20 kHz		−60			
J	2	20	−70 at 12·5 kHz	1·5 kHz	−80	4×10^{-3}		(2S) (IB) = in-band (OB) = out-band
D	[3]	20	−70 at 20 kHz	2·5 kHz (mM) 1·0 kHz (B)	−70	2×10^{-3}		
AUS	11	10	−80 at 25 kHz		−80 at 25 kHz			
DNK			−70 at 25 kHz		−75 at 25 kHz	0·01		(2S)
F	2	20	−80 at 25 kHz		−60			
NOR	1·5	10	−70 at 22 kHz	1 kHz		0·02		
POL	3	20 *	−70 at 25 kHz	2·2 kHz (M) 1·2 kHz (B)	−60	0·02	50 **	(2S) * $(S+N+D)/(N+D)$ ** 3 signal test
S			−80 at 25 kHz	20×10^{-6} (M, m) * 10×10^{-6} (B) **	−70	0·01	70 ***	(2S) In the band 31·7–41 MHz. * −25° to +40°C and −15% to +10% voltage variations. ** −25° (or 0° for equipment indoors with heating) to +40°C and −15% to + 10% voltage variations. *** 3 signal test, EIA STANDARD RS-204.

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Class of emission	Max. deviation ± (kHz)	Occupied bandwidth (3) (kHz)	Frequency tolerance ± (4)	Spurious emissions (5) (6)	Receiver: Sensitivity (e.m.f.) (µV)	For a signal-to-noise ratio of (dB)	Selectivity (dB)	Frequency tolerance ± (4)	Spurious responses (dB)	Spurious radiations (µW)	Inter-modulation (dB)	Remarks (7)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18	19
	25–108	MLA		Public and Private	5·8	25	F3	5	16	1·5 kHz	2·5 µW	2	10	−70 at 25 kHz	1·5 kHz	−70	0·02		A3 systems to be replaced by F3 systems in due course.
	68–87·5	D				20 (M) 100 (B)	F3												◆ *German Democratic Republic* (see also Notification No. 995 of the General Secretariat of the I.T.U).
	50–100	AUS	222 (G)	Private		25 (M) 50 (B)	A3 or F3	5	6 or 16	20×10^{-6}	Less than 2·5 µW at 50 kHz from the carrier	1	10	−80 at 25 kHz		−80 at 25 kHz			
		DNK	XIII/76 (O)	Private	0·6–5	10 (M) 25 (B)	A3 or F3	5	6 or 16	3 kHz (M) 1·5 kHz (B)	2·5 µW			−70 at 25 kHz		−75 at 25 kHz	0·01		(2S)
		F	XIII/116 (O)	Private	4·05–5	30 (M) 50 (B)	F3	5	16	1·6 kHz	RR	2	20	−80 at 25 kHz		−60			
		G		Private	10 13·5	5 or 25 (M) 5 or 25 (B) 0·5 (m)	A3 or F3	5	6 or 16	1·5 kHz (B) 3·0 kHz (M)	2·5 µW	5	10	Min. −56 at 22 kHz (B) −56 at 23·5 kHz (M)	1·5 kHz (B) 3·0 kHz (M)	−56	0·02	50 *	(2S) * 3 signal test. Wanted signal level to produce 10 dB signal-to-noise ratio. Unwanted signals of equal amplitude; levels adjusted to reduce signal-to-noise ratio to 7 dB.
				Public	15·3	25 (M) 250 (B)	A3 or F3	5	6 or 16	1·5 kHz (B) 3·0 kHz (M)		1	10	−85	1·5 kHz (B) 3·0 kHz (M)	*			* Field strength ⩾10 µV/m at 10 m (B) or 30 yards (M) from all sources.
		NOR	(O)	Public and Private	5–10	25 (M) 100 (B)	A3 or F3	5	6 or 16	1·5 kHz	2·5 µW (H) 0·25 µW (NH)	1·5	10	−70 at 22 kHz	1·5 kHz	−70	0·02		
		NZL	(O)	Public and Private	4	25	A3		6	3 kHz (M) 1·5 kHz (B)	2·5 µW	2·5	10	−70 at 25 kHz	3 kHz (M) 1·5 kHz (B)	−70	0·02		(2S)

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (3) (W)	Transmitter: Class of emission	Transmitter: Max. deviation ± (kHz)	Transmitter: Occupied bandwidth (2) (kHz)	Transmitter: Frequency tolerance ± (3)	Transmitter: Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (µV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (3)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (µW)	Receiver: Inter-modulation (dB)	Remarks (5)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18	19
		S	(O)	Public and Private	0 0·6 4·8 5·0	40 (M) 70 (B)	F3 (and A3)	5	16	20×10^{-6} (M, m)* 10×10^{-6} (B)**	20 µW, −40 dB (H) 0·2 µW, −60 dB (NH)			−80 at 25 kHz	20×10^{-6} (M, m)* 10×10^{-6} (B)**	−70	0·01	70 ***	(2S) In the band 68–87·5 MHz. * −25° to +40°C and −15% to +10% voltage variations. ** −25° (or 0° for equipment indoors with heating) to +40°C and −15% to +10% voltage variations. *** 3 signal test, EIA STANDARD RS-204.
		SUI		Public	9·8	20 (M) 50 (B)	A3 or F3		16	1·5 kHz	8 µW (H) 2 µW (NH)	1	20	−60 at 20 kHz	2 kHz		2×10^{-4}		(2S)
				Private		10 (M) 20 (B)		4·5		2 kHz		no specifications					2×10^{-3}		
		YUG	(O)	Private	0 0·5 to 0·7	10 to 15 (M) 20 to 30 (B)	F3	5	16	1·8 kHz (M) * 0·9 kHz (B) **	12 µW (H) 2 µW (NH)	0·7	12 ***	Min. −76 at 25 kHz	1·8 kHz (M)* 0·9 kHz (B)**	−80	0·02	60 ****	(2S) In the band 68–87·5 MHz. * −20°C to +50°C and −15% to +20% voltage variations. ** −20°C to +50°C and −20% to +10% voltage variations. *** *(S+N+D)/(N+D)*. **** 3 signal test.
	150–174	D				20 (M) 100 (B)	F3												◆ *German Democratic Republic* (see also Notification No. 995 of the General Secretariat of the I.T.U.)

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Transmitter: Class of emission	Transmitter: Max. deviation ± (kHz)	Transmitter: Occupied bandwidth (2) (kHz)	Transmitter: Frequency tolerance ± (2)	Transmitter: Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (μV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (2)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (μW)	Receiver: Inter-modulation (dB)	Remarks (5)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18	19
	100–200	DNK	XIII/76 (O)	Public and Private	4–9	10 (M) 25 (B)	A3 or F3	5	6 or 16	3 kHz (M) 2·5 kHz (B)	2·5 μW			−70 at 25 kHz		−75 at 25 kHz	0·01		(2S)
		G		Private	4·8	5 or 25 (M) 5 or 25 (B) 0·5 (m)	A3 or F3	5	6 or 16	1·5 kHz (B) 2·0 kHz (M)	2·5 μW	5	10	Min. −56 at 22 kHz (B) −56 at 23·5 kHz (M)	1·5 kHz (B) 3·0 kHz (M)	−56	0·02	50 *	(2S) * 3 signal test. Wanted signal level to produce 10 dB signal-to-noise ratio. Unwanted signals of equal amplitude; levels adjusted to reduce signal-to-noise ratio to 7 dB.
				Public	4·5	25 (M) 50 (B).	F3	5	16	1·5 kHz (B) 2·0 kHz (M)	2·5 μW	2	20	Min. −70 at 22 kHz (B) −64 at 23 kHz (M)	1·5 kHz (B) 2·0 kHz (M)	−70	0·02	50 *	(2S) * 3 signal test. Wanted signal level to produce 10 dB signal-to-noise ratio. Unwanted signals of equal amplitude; levels adjusted to reduce signal-to-noise ratio to 7 dB.
								10	26	1·5 kHz (B) 2·0 kHz (M)	2·5 μW	2	20	Min. −64 at 47 kHz (M and B) −34 at 22 kHz (B) −34 at 23 kHz (M)	1·5 kHz (B) 3·0 kHz (M)	−70	0·02	50 *	(2S) * 3 signal test. Wanted signal level to produce 10 dB signal-to-noise ratio. Unwanted signals of equal amplitude; levels adjusted to reduce signal-to-noise ratio to 7 dB.
		NOR	(O)	Public and Private	4·5 8	25 (M) 100 (B)	A3 or F3	5	6 or 16	3·0 kHz (M) 1·0 kHz (B)	2·5 μW (H) 0·25 μW (NH)	1·5	10	−70 at 22 kHz	3·0 kHz (M) 1·0 kHz (B)	−70	0·02		
		NZL	(O)	Public and Private	4 and 2	25	A3 or F3	5	6 or 16	2 kHz (M) 1 kHz (B)	2·5 μW	2·5	10	−70 at 25 kHz	2 kHz (M) 1 kHz (B)	−70	0·02		(2S)
		POL	(1966–1969)	Private		10 (M) 50 (B)	F3	5	16	2·2 kHz (M) 1·2 kHz (B)	25 μW (H) 2·5 μW (NH)	3 *	20 *	Min. −70 to 25 kHz	2·2 kHz (M) 1·2 kHz (B)	−60	0·02	50 **	(2S) * $(S+N+D)/(N+D)$ ** 3 signal test.

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. [1]	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power [2] (W)	Transmitter: Class of emission	Transmitter: Max. deviation ± (kHz)	Transmitter: Occupied bandwidth [3] (kHz)	Transmitter: Frequency tolerance ± [3]	Transmitter: Spurious emissions [2] [4]
1	2	3	4	5	6	7	8	9	10	11	12
	100–200	S	XIII/142 (1966–1969)	Public and Private	0 and 8	40 (M) 70 (B)	F3 (and A3)	5	16	10×10^{-6} (M, m)* 5×10^{-6} (B)**	20 µW, −40 dB (H) 0·2 µW, −60 dB (NH)
		SUI		Public	4·6	20 (M) 50 (B)	A3 or F3		16	1·5 kHz	8 µW (H) 2 µW (NH)
				Private		10 (M) 20 (B)		4·5		2 kHz	
		YUG	(O)	Public and Private	0 and 4·5	10 to 15 (M) 20 to 30 (B)	F3	5	16	2·0 kHz (M)* 1·0 kHz (B)**	12 µW (H) 2 µW (NH)

Countries	Receiver: Sensitivity (e.m.f.) (µV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± [5]	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (µW)	Receiver: Inter-modulation (dB)	Remarks [6]
3	13a	13b	14	15	16	17	18	19
S			−80 at 25 kHz	10×10^{-6} (M, m)* 5×10^{-6} (B)**	−70	0·01	70 ***	(2S) In the band 156–174 MHz. In the band 100–103·5 MHz: Column 7: 3 Columns 11 and 15: 20×10^{-6} (M, m)* 10×10^{-6} (B)** * −25° to +40°C and −15% to +10% voltage variations. ** −25° (or 0° for equipment indoors with heating) to +40°C and −15% to +10% voltage variations. *** 3 signal test, EIA STANDARD RS-204.
SUI (Public)	1	20	−60 at 20 kHz	2 kHz		2×10^{-4}		
SUI (Private)	no specifications					2×10^{-3}		(2S)
YUG	0·8	12 ***	Min. —76 at 25 kHz	2·0 kHz (M) * 1·0 kHz (B) **	−80	0·02	60 ****	(2S) In the band 146–174 MHz: * −20° C to +50° C and −15% to +20% voltage variations. ** −20° C to +50° C and −20% to +10% voltage variations. *** $(S+N+D)/(N+D)$. **** 3 signal test.

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. (¹)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (³) (W)	Transmitter: Class of emission	Transmitter: Max. deviation ± (kHz)	Transmitter: Occupied bandwidth (²) (kHz)	Transmitter: Frequency tolerance ± (⁵)	Transmitter: Spurious emissions (³) (⁴)	Receiver: Sensitivity (e.m.f.) (μV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (⁵)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (μW)	Receiver: Inter-modulation (dB)	Remarks (⁶)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18	19
	108–500	MLA		Public and Private	4·6	25	F3	5	16	1·5 kHz	2·5 μW	2	10	−70 at 25 kHz	1·5 kHz	−70	0·02		A3 systems to be replaced by F3 systems in due course.
	200–500	DNK	XIII/76 (O)	Private	8·15	5–10 (M) 100 (B)	A3 or F3	5	6 or 16	3 kHz (M) 2·5 kHz (B)	25 μW			−70 at 25 kHz		−75 at 25 kHz	0·01		(2S)
		J	(O)	Public		4 (M) 100 (B)	F3	5	16	0·9 kHz (B) 2·3 kHz (M)	−60 dB	1·6	20	−70 at 15 kHz	0·9 kHz (B) 2·3 kHz (M)	−80	4×10^{-3}		(2S)
			XIII/111 (O)	Private		50	F3	5	16	2·3 kHz	−60 dB	2·5	20	−70 at 15 kHz	2·3 kHz	−80	4×10^{-3}		
		SUI	(O)	Public	10	20 (M) 50 (B)	A3 or F3	4·5	20	1·5 kHz	8 μW (H) 2 μW (NH)	1	20	−60 at 20 kHz	2 kHz		2×10^{-4}		(2S)
				Private		10 (M) 20 (B)				2 kHz		no specifications					2×10^{-3}		
		USA	XIII/130 (1966–1969)	Public and Private	5·0	250 (B) 50 (M)	F3	5	20 at 25 dB	$2·5\times10^{-6}$ (B) 5×10^{-6} (M)	50 μW	[1·4]	12 *	[−80 at 25 kHz]	[5×10^{-6}]	[−90]	5×10^{-2}	[60] **	(2S) * $(S+N+D)/(N+D)$ ** Unwanted signals of equal amplitude to produce a signal equivalent to the receiver sensitivity.
30	50–100	AUS	222 (G)	Private		25 (M) 50 (B)	A3 or F3	5	6 or 16	20×10^{-6}	Less than 2·5 μW at 50 kHz from carrier	1·5	10	−76 at 30 kHz		−76 at 30 kHz			
		J	XIII/30 (L.A.) (O)	Public and Private	2–4·5	50	F3	10	26	1·2 kHz	−80 dB (IB) −60 dB (OB)	2	20	−70 at 25 kHz	1·2 kHz	−80	4×10^{-3}		(2S) (IB) = in-band, (OB) = out-band.
	100–200	AUS	222 (G)	Private		25 (M) 50 (B)	A3 or F3	5	6 or 16	20×10^{-6} (M) 10×10^{-6} (B)	Less than 2·5 μW at 60 kHz from carrier	2·5	10	−72 at 26 kHz		−72 at 26 kHz			
		USA	XIII/130 (1966–1969)	Public and Private	0·5–5·26	330 (B) 100 (M)	F3	5	20 at 25 dB	5×10^{-6}	50 μW	[0·8]	12 *	[−80 at 30 kHz]	[5×10^{-6}]	[−95]	5×10^{-2}	60 **	(2S) * $(S+N+D)/(N+D)$ ** Unwanted signals of equal amplitude to produce a signal equivalent to receiver sensitivity.

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. (¹)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (²) (W)	Transmitter: Class of emission	Transmitter: Max. deviation ± (kHz)	Transmitter: Occupied bandwidth (³) (kHz)	Transmitter: Frequency tolerance ± (³)	Transmitter: Spurious emissions (³) (⁴)	Receiver: Sensitivity (e.m.f.) (μV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (³)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (μW)	Receiver: Inter-modulation (dB)	Remarks (⁵)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18	19
40	100–200	J	XIII/30 (L.A.) (O).	Public and Private	2–4·5	50	F3	12	30	3 kHz	−80 dB (IB) −60 dB (OB)	2	20	−70 at 25 kHz	3 kHz	−80	4×10^{-3}		(2S) (IB) = in-band (OB) = out-band.
50	25–50	F	XIII/116 (O)	Private	4·4	30 (M) 50 (B)	F3	15	36	2 kHz	RR	2	20	−80 at 50 kHz		−60			
		POL	XIII/10 and 259 (G) XIII/33 (O)	Private		10 (M) 50 (B)	F3	15	42	3 kHz (M) 2 kHz (B)	25 μW (H) 2·5 μW (NH)	2	20 *	−70 at 50 kHz	3 kHz (M) 2 kHz (B)	−60	0·02	50 **	(2S) * $(S+N+D)/(N+D)$ ** 3 signal test.
	50–100	NZL	(O)	Public and Private	4	25	A3		6	5 kHz (M) 1·5 kHz (B)	2·5 μW	2·5	10	−70 at 50 kHz	5 kHz (M) 1·5 kHz (B)	−70	0·02		(2S)
	100–200	D	XIII/83 (O)	Public	4·5	10 (M) 20 (B)	F3	15	36	2·5 kHz	20 μW (H) 0·2 μW (NH)	2	20	−70 at 50 kHz	2·5 kHz	−70	2×10^{-3}		
		G		Public	4·5	50 (B) 25 (M)	F3	15	36	2·0 kHz (B) 3·0 kHz (M)	2·5 μW	6	25	Min. −60 at 47 kHz	2·0 kHz (B) 3·0 kHz (M)	−70	0·02	50 *	(2S) * 3 signal test. Wanted signal level to produce 10 dB signal-to-noise ratio. Unwanted signals of equal amplitude; levels adjusted to reduce signal-to-noise ratio to 7 dB.
		NZL	(O)	Public and Private	4	25	A3 or F3		6 or 16	5 kHz (M) 1·5 kHz (B)	2·5 μW	2·5	10	−70 at 50 kHz	5 kHz (M) 1·5 kHz (B)	−70	0·02		(2S)
		POL	XIII/10 and 259 (G) XIII/33 (O)	Private		10 (M) 50 (B)	F3	15	42	3 kHz (M) 2 kHz (B)	25 μW (H) 2·5 μW (NH)	2	20 *	−70 at 50 kHz	3 kHz (M) 2 kHz (B)	−60	0·02	50 **	(2S) * $(S+N+D)/(N+D)$ ** 3 signal test.
	200–500	F	XIII/116 (O)	Private	12·5		F3	15	36	5·6 kHz (M) 3·3 kHz (B)	*	2	20	−80 at 50 kHz		−60			* Same tolerance as RR for the 30–235 MHz band

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Transmitter: Class of emission	Transmitter: Max. deviation ± (kHz)	Transmitter: Occupied bandwidth (3) (kHz)	Transmitter: Frequency tolerance ± (2)	Transmitter: Spurious emissions (3) (4)	Receiver: Sensitivity (e.m.f.) (µV)	Receiver: Sensitivity (e.m.f.) For a signal-to-noise ratio of (dB)	Receiver: Selectivity (dB)	Receiver: Frequency tolerance ± (2)	Receiver: Spurious responses (dB)	Receiver: Spurious radiations (µW)	Receiver: Inter-modulation (dB)	Remarks (5)
1	2	3	4	5	6	7	8	9	10	11	12	13a	13b	14	15	16	17	18	19
		G		Private	5·5 6·5 14	5 or 50 (B) 25 (M) 0·5 (m)	A3 or F3	15	6 or 36	3·5 kHz (B) 5·0 kHz (M, m)	25 µW	10	10	Min. −60 at 45 kHz (2S) (B) −60 at 46·5 kHz (2S) (M)	3·5 kHz (B) 5·0 kHz (M)	−60	0·02	50 *	(2S) * 3 signal test. Wanted signal level to produce 10 dB signal-to-noise ratio. Unwanted signals of equal amplitude; levels adjusted to reduce signal-to-noise ratio to 7 dB.
				Public	14	8 (B) 0·5 (m)	F3	15	36	3·5 kHz (B) 5 kHz (m)	25 µW	10	10	Min. −60 at 45 kHz (2S) (B) −34 at 46·5 kHz (2S) (m)	3·5 kHz (B) 5·0 kHz (m)	−60 (B) −54 (m)	0·02 (B) 0·2 (m)	50 *	(2S) * 3 signal test. Wanted signal level to produce 10 dB signal-to-noise ratio. Unwanted signals of equal amplitude; levels adjusted to reduce signal-to-noise ratio to 7 dB.
		J	XIII/29 (O)	Public and Private		50	F3	12	30	9·4 kHz	−60 dB	2·5	20	−70 at 30 kHz	9·4 kHz	−80	4×10^{-3}		Single signal selectivity. See also Notes (6) and (7).
		NOR	(O)	Private	5	15 (M) 50 (B)	F3	15	36	5 kHz (M) 3 kHz (B)	2·5 µW	1·5	10	−70 at 50 kHz	5 kHz (M) 3 kHz (B)	−70	0·02		
		NZL	(O)	Public and Private	10	50	A3 or F3	15	6 or 36	5 kHz (M) 2·5 kHz (B)	2·5 µW	2·5	10	−70 at 50 kHz	5 kHz (M) 2·5 kHz (B)	−70	0·02		(2S)
		POL	XIII/10 and 259 (G) XIII/33 (O)	Private		15 (M) 50 (B)	F3	12	30	3 kHz	25µW (M) } (H) -60 dB (B) } 2·5 Wµ (NH)	2·5	20 *	−70 at 50 kHz	3 kHz	−60	0·02	50 **	* $(S+N+D)/(N+D)$ ** 3 signal test.

Channel separation (kHz)	Frequency range (MHz)	Countries	Doc. (1)	Public or Private	Separation of transmit and receive frequencies (MHz)	Transmitter: Typical mean power (2) (W)	Class of emission	Max. deviation ± (kHz)	Occupied bandwidth (5) (kHz)	Frequency tolerance ± (2)	Spurious emissions (3) (4)
1	2	3	4	5	6	7	8	9	10	11	12
		S	XIII/142 (1966– 1969)	Private	0 7 10 15 21 30	15	F3	15	36	10×10⁻⁶ (M, m)* 5×10⁻⁶ (B)**	20 μW, −40 dB (H) 0·2 μW, −60 dB (NH)
		USA	(O)	Public		250 (B)	F3	15	40 at 25 dB	5×10⁻⁶	50 μW
		YUG	(O)	Private	0; 10	5–10 (M) 10–20 (B)	F3	15	40	5 kHz (M)* 3·5 kHz (B)**	25 μW (H) 2·5 μW (NH)
66	100–200	GRC	XIII/4 (G)	Private		20 (M) 50 (B)	F3	15	36	3 kHz	−70 dB

Countries	Receiver: Sensitivity (e.m.f.) (μV)	Sensitivity: For a signal-to-noise ratio of (dB)	Selectivity (dB)	Frequency tolerance ± (2)	Spurious responses (dB)	Spurious radiations (μW)	Inter-modulation (dB)	Remarks (9)
3	13a	13b	14	15	16	17	18	19
S			−70 at 50 kHz		−70	0·01	70 ***	(2S) In parts of the range 300–470 MHz * −25° to +40° C, and −15 % to +20% voltage variations. ** −25° (or +5° for equipment indoors with heating) to +40°C and ±10% voltage variations. *** 3 signal test, SEN 470601 similar to the test in EIA STANDARD RS-204.
USA	[0·8]	12 *	[−70 at 50 kHz]	[5×10⁻⁶]	[−90]	5×10⁻²	60 **	(2S) * *(S+N+D)/(N+D)* ** Unwanted signals of equal amplitude to produce a signal equivalent to receiver sensitivity.
YUG	1·4	12 ***	Min. −76 at 50 kHz	5 kHz (M) * 3·5 kHz (B) **	−80	0·02	60 ****	(2S) In the band 420–470 MHz: * −20° C to +50° C and −15% to +20% voltage variations. ** −20°C to +50°C and −20% to +10% voltage variations. *** *(S+N+D)/(N+D)* **** 3 signal test.
GRC	0·5 1	12 (M) 12 (B)	−86 at 60 kHz	3 kHz	−70			

(1) L.A. = Los Angeles, 1959; G = Geneva, 1963; O = Oslo, 1966.

(2) B = base station; M = mobile vehicle station; m = mobile portable station.

(3) H = on harmonic frequencies; NH = on frequencies other than harmonics.

(4) RR = Radio Regulations.

(5) In some cases, the bandwidth is specified at the 20 dB points.

(6) Under the condition of injecting the desired frequency signal which is 6 dB higher than the 20 dB noise quieting level, the undesired frequency signal in the adjacent channel that is injected to the receiver and makes again 20 dB noise quieting, shall be above 80 dB (1 μV = 0 dB).

(7) In the absence of the desired signal and when the undesired signals of the adjacent and next adjacent channel frequencies are injected to the receiver at a level of 65 dB (1 μV = 0 dB), the noise quieting of the receiver shall be less than 20 dB.

(8) The values given in square brackets [. . .] are considered optional by the Administrations which have supplied them.

(9) (2S) = receiver selectivity with 2-signal test.

◆ The publication of information marked by this symbol implies no recognition by the I.T.U. of the status of the sender in relation to the I.T.U. (Resolution No. 88 (amended) of the Administrative Council).

ANNEX II

ADJACENT-CHANNEL SEPARATION IN THE VARIOUS FREQUENCY BANDS

TABLE I

Separations now in use but considered out of date

Channel separation (kHz)	Frequency ranges (MHz)			
	25–50	50–100	100–200	200–500
10				
12·5				
15				
20				
25	NZL(1)	G(4) NZL(1)	G(4) (6) NZL(1)	
30		J		
40			J	
50	BEL-DNK-F-POL-S(3)-SUI	BEL-D-DNK-F-NOR-NZL(1)-S(2)-SUI	BEL-D-DNK-G(5)-NOR-NZL(1)-POL-S(3)-SUI	DNK-J-SUI-USA
66				
100	D-NOR-SUI			

(1) An allocation plan with interleaved channels is used and alternate channels only are allocated in any one geographical area. Consequently, the equipment is designed for twice the channel separation shown above.

(2) No new assignments have been made since 1959. Old stations are permitted to stay until 1970.

(3) No new assignments have been made since 1960. Old stations are permitted to stay until 1971.

(4) In respect of private services only; no new assignments made after 1 January, 1968, except for low-power hand portable equipment.

(5) In respect of the South Lancashire Radiophone service, which will continue in use until replaced by a newly developed system operating with 25 kHz channel separation.

(6) The London Radiophone Service operates on channels separated by 25 kHz but base station assignments are on a 50 kHz basis. Frequency deviation = ± 10 kHz: receiver selectivity corresponds to that which would be required for a channel separation of approximately 40 kHz.

TABLE II

Separations for present and/or future use

Channel separation (kHz)	Frequency ranges (MHz)			
	25–50(1)	50–100	100–200	200–500
6·25	NZL(2)	NZL(2)	NZL(2)	
10	D*-DNK-DNK*-NOR*-S*-SUI*-USA			NZL(2)
12·5		G	G	
15		J	USA(2)	
20	D-USA	D-BEL(8)	BEL(8) D-F-J	BEL(9)-D
25	DNK-F-NOR-POL-S(5)-SUI	BEL(10)-DNK-F-G(7)-NOR-S(4)-SUI	BEL(10)-DNK-G(7)-NOR-POL-S(5)-SUI	DNK-G(2) (3)-J-NOR-SUI-USA
30			USA	
40	USA*			BEL
50	BEL			F-G(3)-NOR-POL-S(6)
66				
100				

(1) *When a country symbol is followed by an asterisk, the value given for the separation refers to low-power portable equipment.
(2) An interleaved channel allocation plan is to be used and only alternate channels allocated in any one geographical area. Consequently the equipment is designed for double the separation shown above.
(3) The choice between the separations 20, 25 and 50 kHz is still under study.
(4) In use since 1959.
(5) In use since 1960.
(6) In use since 1965. 25 kHz channel separation under consideration.
(7) Certain public services will continue to operate with 25 kHz channel separation.
(8) 20 kHz separation is being introduced gradually for new equipments.
(9) 20 kHz separation will not be introduced for some time.
(10) 25 kHz separation is still accepted in certain parts of the bands reserved for the fixed and mobile services.

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REPORT 503 *

PREFERRED TECHNICAL CHARACTERISTICS OF SINGLE-SIDEBAND EQUIPMENT IN THE MF AND HF LAND MOBILE RADIOTELEPHONE SERVICE

(Question 8-1/8)

(1970)

1. Introduction

1.1 The growing use of single-sideband equipment in the land mobile service makes standardization increasingly important if mutual interference with other services is to be minimized.

1.2 Study Group XIII decided at its Final Meeting in 1969 that a draft which would form the basis of a recommendation should be prepared in report form and offered to Administrations and recognized private operating agencies for consideration and comment (see § 2).

1.3 § 2 has been prepared using as a basis the following documents:

1.3.1 Doc. XIII/125 (Canada) which suggests basic requirements and technical performance standards in reply to the question.

1.3.2 Appendix 17A to the Radio Regulations—Technical characteristics of single-sideband transmitters used in the maritime mobile service.

1.3.3 Appendix 27 of the Radio Regulations—Frequency allotment plan for the aeronautical mobile (R) service and related information.

1.4 Administrations are invited to submit comments on the preferred technical characteristics listed below.

2. Proposed technical characteristics

The following preferred technical characteristics may form the basis of a future Recommendation in reply to Question 8-1/8:

2.1 *Classes of emission*

For class of emission A3J the power of the carrier should be at least 40 dB below the peak envelope power.

2.2 *Sideband selection*

The sideband transmitted should be the upper sideband.

2.3 *Transmitter power*

The peak envelope power should be measured in accordance with Recommendation 326-1.

* This Report was adopted unanimously.

2.4 *Frequency stability*

2.4.1 For transmitters ±40 Hz short-term (for a period of the order of 15 minutes).

2.4.2 For receivers ±60 Hz short-term (for a period of 15 minutes).

2.5 *Audio response*

The upper limit of the audio-frequency band should not be higher than 3000 Hz with a total permitted amplitude variation of 6 dB.

2.6 *Unwanted emissions*

The power of any unwanted emission supplied to the antenna transmission line on any discrete frequency should, when the transmitter is driven to full peak envelope power, be in accordance with the following table:

Separation Δ in kHz between the frequency of the unwanted emission and the assigned frequency	Minimum attenuation below peak envelope power (dB)
$2 \leqslant \Delta < 6$	28
$6 \leqslant \Delta < 10$	38
$10 \leqslant \Delta$	43, without exceeding 50 milliwatts

Transmitters may, as far as spurious emissions are concerned, be tested for compliance with this table by means of a two-tone audio input signal with a frequency separation between the tones such that all intermodulation products occur at frequencies at least 1·6 kHz removed from the assigned frequency.

2.7 *Additional technical characteristics to be specified for receivers*

2.7.1 Sensitivity.

2.7.2 Selectivity.

2.7.3 Spurious emission at the antenna terminals.

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SECTION 8D: AERONAUTICAL MOBILE SERVICE

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 441

SIGNAL-TO-INTERFERENCE RATIOS AND MINIMUM FIELD STRENGTHS REQUIRED IN THE MOBILE SERVICES

Aeronautical mobile service above 30 MHz

(Question 1/8)

The C.C.I.R., (1966)

CONSIDERING

(a) that the Administrative Radio Conference, Geneva, 1959, in Recommendation No. 3, invited the C.C.I.R. to continue its study of signal-to-interference ratios and minimum field strengths;

(b) that there are partial data relating to interference protection ratios and minimum field strengths required in certain documents of conferences of the I.T.U., such as those of the Final Acts of the International Administrative Aeronautical Radio Conference, Geneva, 1948–1949;

(c) that the International Civil Aviation Organization has adopted standards and recommended practices for the best use of VHF frequencies and the avoidance of harmful interference;

UNANIMOUSLY RECOMMENDS

that the provisions made by the International Civil Aviation Organization should be considered as adequate for the planning and protection of aeronautical mobile (R) service frequencies above 30 MHz; the provisions are contained in Annex 10, Chapter 4, § 4.1.5, to the Convention of the International Civil Aviation Organization, supplemented by the instructions contained in the attachment A to Part II of the same document.

8D: *Reports*

There are no Reports in this section.

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SECTION 8E: SATELLITE APPLICATIONS FOR MOBILE SERVICES

RECOMMENDATIONS AND REPORTS

Recommendations

RECOMMENDATION 361-2

FREQUENCY REQUIREMENTS OF RADIODETERMINATION-SATELLITE SYSTEMS

(Question 17/8)

The C.C.I.R., (1963 – 1966 – 1970)

CONSIDERING

(a) that there are four basic technical principles to radiodetermination by satellites and that each has variations in its frequency requirements;

(b) that, for systems using low and medium altitude satellites which are in motion relative to the surface of the Earth, the bandwidth requirements will be largely determined by the Doppler frequency shift and the frequency stability of transmitters and receivers;

(c) that, for systems using high altitude satellites which are essentially stationary relative to the surface of the Earth, the bandwidth requirements will be largely determined by the modulation techniques which may be employed and the frequency stability of transmitters and receivers;

(d) that antenna systems and operating frequencies of individual radiodetermination satellites should be chosen on the basis of technical and operational requirements;

(e) that equipment and techniques are at present available at frequencies in bands 8 and 9;

(f) that it is possible to reduce errors caused by ionospheric refraction by the use of two frequencies well separated from each other, and that in this case, system design may be simplified by the use of harmonically related frequencies;

(g) that for systems based on the principle of angle discrimination, the use of narrow beamwidth receiving antennae is required; that it is desirable to minimize the physical size of such antennae; and that for a given antenna size, the directivity and resulting accuracy increase with frequency;

(h) that for systems based on the principle of angle discrimination, a study of desirable antenna size and the required accuracy indicates that frequencies above 10 GHz should be used; studies to date indicate that the atmospheric absorption due to water vapour and oxygen is significantly less in the region below 20 GHz and in a narrow region near 35 GHz;

(j) that this service would require a high degree of radio-frequency protection;

(k) that, in the interests of spectrum economy, it is desirable, and may prove possible, to accommodate maintenance space telemetering signals required for radiodetermination-satellite systems on the radio-frequency channels provided for radiodetermination satellites;

(l) that time measuring and range difference systems use the principles of either pulse or phase ranging which require wider emission bandwidths than Doppler systems;

UNANIMOUSLY RECOMMENDS

1. that for radiodetermination-satellite systems:

1.1 frequencies in bands 8, 9 and 10 are technically suitable for the application of one or more of the technical principles to radiodetermination by satellites;

1.2 where techniques permit, the use of narrow-band systems is preferable;

1.3 where frequency combination is feasible, the maintenance telemetering signals for radiodetermination-satellite systems should be accommodated on frequency channels provided for the radiodetermination functions;

1.4 experimentation to investigate the feasibility of several possible systems be conducted in appropriate radiodetermination frequency bands;

2. that for Doppler, time measuring and range difference radiodetermination-satellite systems:

2.1 frequencies in bands 8 and 9 are technically suitable. Implementation, however, in band 8 may be constrained by bandwidth requirements;

3. that for radio-sextant radiodetermination systems:

3.1 frequencies of the order of 35 GHz are technically suitable. Where lower accuracy is acceptable, frequencies between 10 and 20 GHz are technically suitable.

8E: *Reports*

REPORT 216-2 *

TECHNICAL CHARACTERISTICS OF SYSTEMS PROVIDING COMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR AIRCRAFT AND/OR SHIPS

Use of satellites for terrestrial radiodetermination

(Question 17/8)

(1963 – 1966 – 1970)

1. Introduction

Terrestrial radiodetermination systems have been developed capable of providing continuously available services which are accurate, reliable and simple. However, in the terrestrial radiodetermination systems in operational use today, the coverage provided is restricted, due either to the curvature of the Earth or the characteristics of the ionosphere. The coverage limitations can be overcome by the use of satellite-relayed transmissions because line-of-sight conditions exist over a much greater area and because frequencies can be used which are not adversely affected by the ionosphere. Satellite technology offers a first opportunity to provide large area coverage with a single system that combines several services such as radiocommunications, radionavigation and radiolocation with economy of cost and spectrum usage.

2. Requirements for a radiodetermination satellite system

The primary purpose of a radiodetermination satellite system should be to provide adequate position-fix accuracy, with a degree of service availability determined by the needs of the type of mobile unit involved, over large regions of the Earth and at all altitudes. A radiodetermination service should have sufficient capacity to handle all of the craft that desire to use it. In oceanic areas, ships would require a position-fixing service at relatively long intervals of time (up to several hours). Aircraft, surveying and research ships and ships in coastal waters would require a position-fixing service which operates at shorter intervals of time or on a continuous basis.

Equipment for use in the mobile craft must be small, lightweight, reliable and, where possible, compatible with existing on-board equipment.

3. Technical considerations

3.1 *Orbits*

Information concerning the types of orbit most suitable for a particular system is given in Report 506.

* This Report was adopted unanimously.

3.2 *Propagation, antennae and noise*

A discussion on the propagation and noise characteristics and the types of antennae likely to be used in a particular system as factors affecting frequency choice is given in Report 504.

3.3 *Multipath fading*

A theoretical treatment of multipath fading together with experimental data is given in Report 505.

4. Basic radiodetermination techniques

There are four basic position-fixing techniques; measurement of distance, rate of change of distance, angle, rate of change of angle. Within each technique a number of variations is possible. A system may incorporate some combination of the four basic techniques.

4.1 *Measurement of distance*

The distance between a satellite and an observer can be determined by measuring the time of propagation of a radio signal from one to the other. Such a measurement requires either synchronized clocks at each end of the link or alternatively, the use of a repeater of known delay at one end of the link.

For some applications a line-of-position may meet the operational requirement in which case a single satellite only will be required (assuming that the craft altitude is known). For example a geostationary satellite can be used to provide across-track station-keeping for E-W routes or along-track station-keeping for N-S routes. There will however be reduced accuracy due to geometrical dilution near the subsatellite point. The line-of-position is determined by the intersection of two spheres, one centred at the satellite and having the radius of the distance measurement, the other co-centred with the Earth and having a radius equal to the Earth's radius plus the altitude.

A position-fix is obtained if two satellites are employed whose positions are continuously known. Distance-measurement between a craft and each of the satellites will yield a position-fix which is the point of intersection of three spheres, one co-centred with the Earth, each of the other two being centred on a satellite. In fact three spheres yield two points of intersection. Careful choice of satellite orbits in relation to the required coverage area will ensure that the two points are widely separated so that resolution of the ambiguity is possible. Careful choice of the satellite orbits will also ensure that for the required coverage area the three spheres intersect as nearly orthogonally as possible so that geometrical dilution is minimized.

For synchronized-clock systems, signals originating at the satellites will yield navigational information to a craft fitted with a receiver. Such systems will have unlimited traffic capacity and can provide a limited capacity radiolocation service if the craft transmits the positional information to a ground station. Conversely, if the craft originates the signals, a limited capacity radiolocation service is obtained which can be converted to a navigation service if the positional information is transmitted to the craft.

Repeater systems will provide either radionavigation service to a craft which originates transmissions or a radiolocation service if the transmissions are originated at the satellites or at a fixed point on Earth. Such systems have finite capacity and as in the previous instance can provide the alternative service by use of data links.

Thus, both types of systems give services of finite capacity and require a transmit facility at the craft except for the service of radionavigation using synchronized clocks and transmissions originated at the satellite or at a fixed station on the Earth.

An unlimited capacity radionavigation system which requires neither the use of synchronized clocks nor a transmit facility from the craft can be achieved at the cost of requiring an additional satellite. The radionavigation information is obtained by measuring the distance differences between pairs of satellites, the transmissions from which are time-synchronized, this synchronization being achieved, for example, by ground to satellite links. Three satellites will yield two independent distance-difference measurements, each such measurement defines a hyperboloidal surface of position with the two satellites as foci. The intersection of the two hyperboloids with the earth-centred sphere yields a position-fix. Ambiguity resolution and geometrical dilution may be greater problems than in the case of direct distance-measurement systems. Distance-difference measurement systems can also be used to provide a radiolocation service of finite capacity.

Other system variants are possible involving distance and distance-difference measurements; one system has been proposed which includes measurement of the sum of the distances to a pair of satellites thus giving an ellipsoid as a surface of position.

A variety of modulation techniques has been proposed for the distance-measuring transmissions. Wideband techniques have been proposed to overcome narrow-band interference, narrow-band techniques to overcome ionospheric dispersion and differential Faraday rotation, spread-spectrum techniques to allow simultaneous access and interference rejection and specialized techniques to overcome multipath transmission effects. The choice of modulation technique is dependent on many of the system parameters and must be determined by study in the light of the specific system requirements, geometry and frequency of operation.

The system accuracies of both synchronized-clock and repeater systems are broadly the same for a given geometry and modulation technique. The system accuracy is strongly dependent on the accuracy with which satellite position is known. The distance-measurement accuracy is dependent on ionospheric and tropospheric effects which influence the velocity of propagation and/or cause ray-path bending to occur; to some extent compensation can be made for these effects.

The choice of frequency for distance-measuring systems is broadly within the range 100 to 2000 MHz. The lower limit is determined by ionospheric effects. The upper limit is determined by the practicability of constructing aircraft antennae of sufficient aperture to overcome the large space loss and also having the capability of pointing their beams at two or more satellites.

Although not a radiodetermination system for mobile vehicles, the operational SECOR system for geodetic survey [1] uses the distance-measuring technique and by using harmonically related frequencies (224·5 and 449 MHz) incorporates first order correction for ionospheric errors. Position-fix accuracies of better than 15 m have been consistently obtained using these medium altitude satellites.

Experimental position-fix determinations using the geostationary ATS-1 and ATS-3 satellites (135·6 and 149·22 MHz) have demonstrated a measurement precision of better than a few microseconds under average ionospheric conditions [2].

The use of distance-measuring techniques to provide a radiodetermination service is thus of proven merit. The large number of possible system variants give scope for system selection to meet a specific operational requirement, though the choice of an optimum system may be constrained by the problems of frequency allocation. In general, distance-measuring systems are suitable for both maritime and aeronautical application [3].

4.2 *Measurement of rate of change of distance*

An observer's position can be established relative to a satellite from measurement of rate of change of distance. Either pulses or CW is transmitted from a satellite of accurately known orbit.

The pulses would be generated at a predetermined repetition rate. A user of the system would measure the changing time interval between successive pulses.

The usual technique of determining rate of change of distance is based on the measurement of the Doppler frequency shift effect on CW transmissions from the satellite. The operational U.S.A. VHF/UHF navigation satellite system [4, 5, 6, 7] uses this technique. Such a measurement enables a navigational fix to be obtained for each transit of the satellite. In a system of this type each user compares the frequency of signals from a satellite with a frequency standard aboard the user craft during a period up to several minutes to determine the Doppler frequency shift. Each satellite is tracked and its orbital parameters kept up to date at a computing centre on the ground. The orbital information is transmitted to the satellite at appropriate intervals, where it is stored and re-transmitted at precise intervals to the user. Computation of positions of the satellite and user are made by the user. From the maximum rate of change of the Doppler shift the instant of closest approach to the observer and the minimum range can be deduced. To obtain a position-fix, the satellite's orbit position at that instant must be known or determined from the orbit parameters. Actually two possible positions result; the ambiguity is resolved by observing the effect of the Earth's rotation on the Doppler shift.

Alternatively, the number of Doppler cycles can be counted (integrated) during a known interval of time to determine the difference in the range to the satellite during this interval. This locates the user on a hyperbolic surface of position. A subsequent Doppler count will similarly locate the user on a second hyperbolic surface, the intersection of these two hyperbolic surfaces with the Earth's geoid at the user's altitude fixes the user's position.

A Doppler navigation system depends on the use of a satellite in nearly circular orbit and containing a long-life radio beacon, having a known stable frequency (better than 1×10^{-10}) during the observational period. It has been shown that the Doppler shift in the received CW radiation at a given point on the Earth, due to the relative velocity between transmitter and receiver, can be measured accurately as a function of time to 2×10^{-10}.

Because of the need for large Doppler shifts this technique is generally limited to orbits of the order of 500 to 2000 km in altitude. Somewhat higher orbits could be used with reduced accuracy; medium and synchronous altitudes are not suitable.

The choice of operating frequency for the satellite CW transmitter for a Doppler navigation system is a compromise between the avoidance of ionospheric influences and the provision of an adequate signal level at the receiving station. In a system employing rate of change of distance, omnidirectional antennae are used for reception. Hence, the required satellite transmitter power increases rapidly as the wavelength is decreased. Having regard to the variation with operating frequency of galactic emissions, receiver input noise level, and of the efficiency of available transmitting oscillators and amplifiers, it appears that a choice of frequency between 100 and 1000 MHz would require the minimum required transmitter power. The satellite transmitter antenna should be as non-directive as possible. The use of circularly-polarized antennae for transmission will minimize, but not eliminate, signal fading due to rotation of the satellite. Under those circumstances, a transmitter power output in the range 100 mW to 1 W is adequate. If the satellite is stabilized in one or more axes the radiation pattern, and hence the equivalent isotropic radiated power, could be greatly improved.

Frequencies near the low end of the range are less desirable because of ionospheric effects, which include fading due to Faraday rotation, deviations of the ray-path due to refraction, and variations in both of these effects due to irregularities in the density and distribution of ionization.

If the Doppler shifts of two frequencies, transmitted coherently, are received simultaneously then first order correction can be made for the inaccuracy caused by ionospheric retardation. The U.S.A. VHF/UHF navigation satellite system uses satellites which transmit very stable CW signals at two frequencies, 150 and 400 MHz. The positional accuracy obtainable by such a technique is reported to be better than 100 metres for ships. For a receiving station which has a velocity component towards the satellite an additional Doppler shift arises which must be allowed for in the determination of position. Thus, in the case of aircraft, the ground speed and heading must be known with high accuracy and included in the position-fix computation. This becomes particularly difficult because an observation period of several minutes is required to determine the user's position which is changing during this time.

4.3 *Measurement of angle*

Measurement of angle can be made either at the user craft or at the satellite.

4.3.1 *The radio sextant*

The user's radio sextant [8], which measures the elevation angles of the satellites, consists of a radio receiver and a very highly directive antenna mounted on a very stable platform referenced to the local vertical. The measurements are made at the user craft, each satellite transmitting a narrow-band CW signal. Each measured elevation angle locates the user on a conical surface. Two elevation angle measurements, on different satellites, locates the user on two conical surfaces which intersect the geocentric sphere at the user's altitude in two points, one of which may be eliminated by a knowledge of the user's general position. This ambiguity resolution is not possible unless there is a significant separation between the two satellites.

In a radionavigation system of this type the computation of position is made by the user. Existing sight-reduction tables could be used if desired. The system would be non-cooperative and of unlimited capacity. The complex, expensive, bulky equipment would probably preclude its use by aircraft and some ships. However, a highly accurate directional (north) reference would be available and the same user equipment might be used with the Sun and possibly the Moon to increase the coverage. For radiolocation applications the navigational data would be relayed to a land station.

Due to the problems of acquisition in position and frequency, angular measurements on fixed or slowly moving bodies are not easy, and the difficulty is much greater in the case of rapidly moving bodies such as a satellite at a height of the order of 2000 km. Because of the difficulty in making angular measurements on moving satellites, unless the user craft has acquired the satellite from a known start position of the earth station, it is preferred that the radio sextant be used only with stationary satellites and slowly moving celestial bodies such as the Sun and the Moon.

Because of the high directivity required in the receiving antenna of the sextant, the use of frequencies in the range of 10 to 300 GHz (e.g. the window at 35 GHz) for the satellite beacon appears desirable if the aperture of the antenna is to be kept to reasonable proportions. (Even so, the use of split-beam or similar techniques for improving antenna discrimination may be necessary for a high-precision system.) The use of such frequencies would eliminate propagation difficulties due to refraction in the ionosphere, but difficulties could arise as a result of absorption and scattering in the troposphere due to clouds, rain, etc. The practical range of frequencies for all-weather coverage is considered to be between 10 and 20 GHz.

In this technique, the transmitted power requirement could be minimized by the use of a very narrow bandwidth in a phase-lock type of receiver. If the system is also to be used for sun tracking, a very wide radio-frequency bandwidth is involved. Hence, a receiver designed for operation with both artificial satellites and the Sun should be able to operate in both the narrow-bandwidth and wide-bandwidth modes. A number of components could be common to both modes of operation. The use of the phase-lock technique provides the optimum method of extracting the Doppler signal if this is desired.

4.3.2 *The radio interferometer*

The angle to the user from a satellite can be measured by employing satellite-borne radio interferometers [9].

For radiolocation applications, the user transmits a signal to the satellite, and the angle is determined by measuring the difference in phase of the carrier signal as it arrives at the two antennae of the satellite interferometer. For radionavigation applications, distinguishable signals are transmitted from each antenna of the interferometer and the difference in phase of the signals is measured by the user. The converse systems in which the interferometer is mounted on the mobile craft are theoretically possible but have technical disadvantages and considerable economical disadvantages.

In practice the phase measurement is ambiguous since the phase difference at the two antennae may exceed 360°. The ambiguity may be resolved either by using two interferometers of different baseline length or by using two different carrier frequencies and measuring the phase difference at each frequency.

Measurement of a single angle locates the user on a conical surface whose axis is the axis of the interferometer. A second satellite-borne interferometer, perpendicular to the first, can be employed to measure a second angle locating the user on a second conical surface. The intersection of these two conical surfaces with a sphere centred on the Earth and corresponding to the user's altitude identifies the user's position.

For accuracy of position-fix, the orientation, variation in time and baseline length must be known with high accuracy. This information can be obtained by periodically making angle measurements with respect to fixed stations at known locations on the Earth.

Frequencies in the range 800 to 8000 MHz are technically suitable for an interferometer satellite system. If the gain of the antenna on the satellite and on the user craft are held constant, a relatively low frequency would be desirable in order to minimize the power requirements. However, at low frequencies the physical length of the interferometer baseline becomes too large for a practicable system, thus, and because of ionospheric refraction, 800 MHz is considered a minimum. If the gain were constant at one end of the link and the effective aperture fixed at the other end, the required power would be independent of frequency. If the aperture of the antenna were fixed at both ends of the link, the required power would be inversely proportional to the square of the frequency. In either of the second or third alternatives, higher frequencies would be desirable because the beamwidth of a constant aperture antenna decreases with higher frequency, and hence the discrimination accuracy improves. Above 8 GHz, however, attenuation due to precipitation becomes increasingly significant. The optimum frequency is near 8 GHz.

The accuracy of measurement of an angle would decrease with height of the satellite, but at low altitudes the ephemeris problem would be greater, and the coverage would be limited unless a large number of satellites were used or intermittent fixing were acceptable. High-inclination orbits at 7000 to 10 000 km would be suitable for world-wide coverage with eight satellites. Continuous coverage of the entire Atlantic Ocean up to 70° could be provided by one equatorial satellite at the synchronous height of 36 000 km.

There are several very complex satellite design problems associated with this technique. In radiolocation applications the RF equipment which process the received information from the users and telemeter it back to the ground are much more complex than those associated with the other techniques. In an interferometric angle measuring system when range information is used at synchronous altitude, 28 microradians of attitude error will cause approximately 1 km error in position determination. The stability of the booms on which the interferometer antennae are deployed and the design of the attitude control system to attain pointing accuracies of this order present difficult problems. The error of an interferometer system in the presence of a given phase measurement error is inversely proportional to the baseline (boom) length and to the carrier frequency. However, the complexity of the staellite attitude control system design tends to increase with the boom length.

The problems associated with attitude control, boom bending and design of a satellite interferometer system put this technique in a position where its feasibility must be investigated further, and additional experiments undertaken. In addition, if an interferometer system is employed for radionavigation applications user equipment will be complex. It has the attraction that only one satellite is required to determine a user's position.

4.4 *Hybrid systems*

Combinations of the four basic techniques can be used to provide either radionavigation or radiolocation systems.

Such combinations, particularly of angle measurement and distance measurement, often lead to a reduction in the number of satellites required but the greater complexity of the angle measuring technique usually offsets this advantage.

5. Summary and conclusions

5.1 The distance measuring technique is used operationally in a geodetic survey system and experimentally for the location of ships and aircraft. The survey system demonstrates that the technique can achieve high accuracy when coherently transmitted frequencies below 500 MHz are used to correct for ionospheric retardation. The experiments have demonstrated that ranging precision better than a few microseconds can be achieved under average ionospheric conditions. The technique can be used in system configurations for either radiolocation or radionavigation, in some configurations there is no need for transmissions from the mobile vehicle. A variety of narrow-band and wideband modulation methods can be used. Narrow bandwidths can provide accuracy sufficient for some applications, making it possible to share channels and some elements of vehicle-borne equipment with a communication service. Wide-bandwidth techniques can provide shorter acquisition time and protection against interference, usually with greater accuracy. The choice of frequency lies between 100 and 2000 MHz with the optimum between 400 and 700 MHz. Further tests are needed to measure the effect of spatial and temporal variations of the ionosphere on position-fix accuracy at VHF frequencies. Experiments are needed at frequencies near 1500 MHz to measure position-fix accuracies achievable with aircraft and marine equipment that is operationally and economically suitable.

5.2 Rate of change of distance is used in an operational system that provides a high accuracy navigation service for ships; the ships do not require a transmission facility. The technique is limited to orbit heights below approximately 2000 km, a comparatively large number of satellites is required if service is to be available to a user at frequent intervals. The satellites may be simple and low-powered but must have highly stable transmission frequencies. The time required for a fix determination is of the order of minutes and thus the technique is not attractive for use by aircraft. The choice of frequencies is between 100 and 1000 MHz. An operational system, using two coherently transmitted frequencies below 400 MHz, has demonstrated that errors due to ionospheric retardation can be corrected.

5.3 Measurement of angle at the user craft provides a means of radionavigation which does not require a user craft transmission facility. The elevation of two or more satellites is measured by receiving their radio transmissions on a highly directive antenna referenced to local vertical. The method of fix determination is familiar to navigators. Equipment is bulky and expensive making the technique unattractive for aircraft and some ships; however, the equipment may also be used with the Sun and possibly the Moon.

Frequencies in the range of 10 to 300 GHz are technically suitable. Measurement of angle at the satellite can provide a radiolocation service. Signals transmitted from the user are received at the satellite and the angle of arrival is measured by antennae that form an interferometer. The technique is applicable to ships and to aircraft. It has the advantage that a single satellite can provide a position-fix. The measurement technique and the satellite equipment are complex. The satellite attitude must be known to high accuracy, making it doubtful that a system of useful accuracy could be implemented with present day technology; however, the use of calibration references on the Earth's surface is possible. The complexity of the technique has made it less attractive than that of distance measurement. It has been studied extensively but not tested in orbit. Experiments will need to be undertaken to determine the accuracies that are achievable.

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REPORT 394-1 *

FEASIBILITY OF FREQUENCY SHARING BETWEEN THE RADIODETERMINATION-SATELLITE SERVICE AND THE TERRESTRIAL SERVICES

(Question 17/8)

(1966 – 1970)

1. Introduction

This Report refers to Question 17/8, § 5, i.e. " is the sharing of frequencies with other systems feasible, and if so, with what other systems and under what conditions? " The question is treated in general terms and partially based on information regarding radiodetermination-satellite systems contained in Report 216-2.

* This Report was adopted unanimously.

2. Four potential situations for interference are identified

- — interference from terrestrial stations to an airborne or shipborne receiving station in the radiodetermination-satellite service;
- — interference from terrestrial stations to the satellite-borne receiving station in the radiodetermination-satellite service;
- — interference to terrestrial stations resulting from transmissions from space stations in the radiodetermination-satellite service;
- — interference to terrestrial stations from airborne or shipborne stations using the radiodetermination-satellite service.

3. Frequency-sharing considerations

Since experience with radiodetermination satellites is limited, it is generally inappropriate to determine the feasibility of sharing such systems with other services. This decision would also depend upon whether the radiodetermination-satellite system contemplated is either a passive (only satellite transmitting) or an active (satellite and earth stations both transmitting) system. Meaningful calculations regarding signal levels and interference protection ratios in a shared environment cannot be made unless all major parameters are known precisely for all radiodetermination-satellite systems envisaged. These would include the type of satellite orbit, as well as power, antenna radiation pattern, mode of emission, transmitter/receiver characteristics, etc. In addition, the frequency bands that might be made available to the radiodetermination services would likely be shared with existing radionavigation terrestrial services in an environment of many different systems exhibiting various emission characteristics and powers. Where permitted by the Table of Frequency Allocations, satellite communications' capability for air traffic control might also be incorporated with the radiodetermination function on the same frequency channel.

The interference susceptibility of an actual system is a major factor in determining the feasibility of sharing. This susceptibility is likely to vary, both with the type of system and with the nature of the interfering signal.

Once these characteristics are known, appropriate propagation curves may be used to calculate signal levels with reasonable accuracy and thus determine the feasibility of shared use.

Without precise knowledge of these characteristics, the feasibility of sharing cannot be reasonably determined. An analysis of the interference potential will have to be made on an individual system basis considering the following:

- — frequency band to be shared,
- — noise temperature of the receiver,
- — bandwidth,
- — modulation modes,
- — antenna characteristics,
- — the effect of interference caused by several simultaneous transmissions,
- — minimum level of desired signal at receiver input,
- — permissible level of undesired signal at receiver input,
- — percentage of time interference may be tolerated,
- — transmission loss along the undesired signal propagation path,
- — transmission loss along the desired signal propagation path.

It is assumed that, initially, sharing of the radionavigation function of the radiodetermination-satellite service will probably be in the frequency bands now allocated to the radionavigation service. Presently used long-distance radionavigation ground-reference aids using radio-frequency energy include: Omega, Dectra, Decca, Loran (A and C) and Consol. Because of the low frequencies used by these aids, it is unlikely that radiodetermination-satellites would share the same bands. Doppler airborne radar is a self-contained aid and operates in a band that might also be useful for radiodetermination-satellite systems and therefore would be considered in a shared environment. It is conceivable that sharing might also be contemplated in other bands, which include stations radiating appreciable energy, such as high-powered radars. Bands occupied by short-distance navigational aids such as VOR and DME might also be candidates for sharing, and some criteria regarding co-ordination distance would have to be developed, depending upon the radiodetermination-satellite system under consideration. It should be recognized that range rate systems may not be operated in a shared environment.

Special sophisticated modulation techniques may lead to other methods of simultaneous usage of frequency spectrum. The advances in technology for these techniques, such as " spread spectrum ", appear sufficiently encouraging to suggest further experimentation in this area.

4. Conclusions

In view of the above considerations, the feasibility of sharing frequencies for the radiodetermination-satellite service will have to be determined on a case-by-case basis after recognition and analysis of the technological parameters of both the satellite system, as well as the terrestrial system under consideration.

REPORT 504 *

TECHNICAL CHARACTERISTICS OF COMMUNICATION-SATELLITE SERVICE TO AIRCRAFT AND SHIPS

Propagation, antennae and noise as factors affecting the choice of frequency for telecommunications between an aircraft/ship and a satellite

(Study Programme 17A/8)

(1970)

1. Introduction

Conventional transmissions in the VHF and HF bands are currently used for two-way communications between an aircraft/ship and a land station. The VHF band gives a service basically limited to line-of-sight distances and is unaffected by ionospheric

* This Report was adopted unanimously.

disturbances. This line-of-sight limitation can be partially overcome by the use of high power transmission and forward scatter. Experience indicates that an extended range VHF system can provide communications out to about 900 km (500 nautical miles) for an aircraft operating at 12 000 m (40 000 feet) or above, this range reducing by about 90 km (50 nautical miles) for each 3000 m (10 000 feet) reduction in altitude.

HF communications are not subject to this line-of-sight limitation, but are very susceptible to ionospheric disturbances. Protracted periods occur when communications either are not possible or are possible only at the lowest frequencies in the band. In addition, the HF bands are highly congested and subject to interference, so that the capacity for expansion of HF communications is small, at least in certain parts of the world.

These limitations on existing services have led to consideration of the technical feasibility of communications between an aircraft/ship and a remote ground terminal using a satellite relay. Initial experiments between an aircraft and the ground were in fact conducted in the VHF band with the SYNCOM III satellite and subsequently repeated with the two U.S. NASA Applications Technology Satellites ATS-1 and ATS-3 now in orbit. Ship/shore telecommunications have also been conducted via the ATS satellites. It should be noted that these tests were not necessarily conducted under optimized conditions such as would be used in the future in a space telecommunications system especially established for aircraft/ships. For example, broadband rather than narrow-band techniques were used and the satellite antenna polarization was linear rather than circular. Plans have been made to perform experiments in the decimetric band (1540-1660 MHz) allocated to the aeronautical service. Transponders in the later ATS satellites will be employed.

This Report discusses in some detail the propagation, antenna and noise characteristics of the transmission path between satellite and aircraft in bands 8 and 9, taking account of the aeronautical/maritime environment. The aeronautical and maritime services are late-starters in the field of satellite communications and thus benefit from fundamental studies already made, and particular use is made of Report 205-2 in this contribution. It should be noted that the selection of frequency bands will depend upon other factors including:

— the current usage of the bands,

— the need for protection of existing users of the allocated bands,

— the type of equipment which can be installed, or is already installed, on board aircraft and ships,

— the needs of operators.

Further considerations would be entailed if aircraft/ship radionavigation and/or radiolocation facilities were required in addition to a communication service. For example, account might also have to be taken of the effects of the ionosphere and of the troposphere on the phase of the radiated signals.

This Report is not intended to specify or design an operational link, but rather to provide some of the technical data for aeronautical and/or maritime satellite systems.

The effects of propagation and noise on the choice of frequency for satellite relays between ground stations have already been summarized in Report 205-2. Much of this summary is relevant to aeronautical or maritime satellites, but a number of differences arise. In both cases, ground terminals can be large and highly developed, cooled receivers can be used, satellites can be autotracked with narrow beam antennae and the incoming signals can be readily tracked in frequency when Doppler shifts make this necessary. However, the provision of aerodynamically acceptable tracking antennae on high performance aircraft presents a major problem. Further, a basic philosophy in aviation is to keep elaboration and complexity in airborne equipment to a minimum to improve reliability. Antenna stabilization and tracking problems would also occur in the maritime case, particularly in the case of small ships.

The cases for world-wide aeronautical/maritime-satellite services have not yet been established. If a satellite service covering specific regions (e.g. North Atlantic) is required, attitude stabilized satellites must be used with, if possible, directional antenna systems, providing coverage principally over the region to be served.

2. Allocated frequency bands

At the Extraordinary Administrative Radio Conference (Space), Geneva, 1963, agreement was reached on the frequency bands which may be used for aeronautical satellite services. These bands had previously been allocated for aeronautical use and the new Regulations adopted in 1963 permit them to be used also for systems employing space techniques.

Two VHF bands are allocated on a primary basis to the aeronautical mobile service and are currently in use for this service. In addition to the exclusive aeronautical mobile bands, there are some allocations to the radionavigation satellite service which would be available also for the exchange of communications of aeronautical and maritime mobile services. These bands are between 1500 and 6000 MHz.

3. Propagation

3.1 *Free-space attenuation*

Free-space conditions apply beyond the ionosphere and the power loss is then solely due to the divergence of the radiation. As shown in Report 205-2, the power loss of a link is a function of frequency, distance and the characteristics of the antennae at each end of the transmission link.

If an antenna can be provided on an aircraft or ship with a given effective area regardless of the frequency used, the received power available at the antenna will depend only on the e.i.r.p. of the satellite and the distance between the satellite and the aircraft or ship.

As the frequency increases, however, the beamwidth of the antenna decreases. Use of higher frequencies, therefore, raises greater problems in acquiring and tracking the satellite. Alternatively, if these problems cannot be solved, it may be necessary to increase the beamwidth of the antenna by reducing its effective area, thereby increasing the e.i.r.p. of the satellite needed at these higher frequencies.

3.2 *Tropospheric attenuation*

The upper end of the usable radio-frequency spectrum will be determined by the absorption caused by precipitation, clouds and gases in the atmosphere, although such absorption will not normally occur at the operational heights of aircraft. It will be necessary for systems to be viable for aircraft at all heights and so an upper frequency between 10 GHz and 20 GHz, as indicated in Report 205-2, is required to provide reliability under the worst conditions.

3.3 *Ionospheric attenuation*

The lower limit of the usable radio-frequency spectrum will be determined by ionospheric reflection and absorption which, in general, increase with decreasing frequency. For equatorial and temperate regions a lower frequency limit of about 70 MHz will assure penetration of the ionosphere without significant attenuation.

In addition to the diurnal and seasonal variations which occur in the ionosphere there are sporadic variations arising from variations in solar activity. These sporadic variations have the greatest effect in the auroral zones and must be allowed for in planning a service for a region which overlaps these zones.

In particular in these zones noticeable absorption can occur due to polar cap and auroral events; these two phenomena occur at random intervals, last for different periods of time and their effects are a function of the locations of the terminals and the elevation angle of the path. Therefore, for most effective system design these phenomena should be treated statistically, bearing in mind that the correlation times for auroral absorption are of the order of hours and for polar cap absorption are of the order of days.

Table I shows the southern limit of the northern auroral zone as a function of longitude. At some longitudes the auroral zone covers regions of the earth where an observer is within line-of-sight of a geostationary satellite.

TABLE I

Northern auroral zone

Longitude	Zone boundary (N-latitude) (degrees)	Northern limit of the principal North Atlantic flying zone (degrees)
45° E	80	
15° E	70	
15° W	65	58
30° W	62	62
45° W	60	62
60° W	58	58
90° W	57	
120° W	60	
150° W	70	

The values given in Table I are for broad guidance only. In most sectors there is a solar cycle change in position averaging about 3°, the zone being furthest south in solar maximum years. This boundary also changes with season and solar activity.

For aircraft or ship satellite links, with satellites in geostationary orbit, the shadow of the auroral absorbing zone will be displaced to the North by a maximum of 7° for angles of elevation of 5° and by a maximum of 3° for angles of elevation of 20°.

3.3.1 *Auroral absorption*

Auroral absorption is believed to be due to an enhancement of electron density in the lower ionosphere by the entry of energetic electrons following a solar disturbance and is one such sporadic source of attenuation. Auroral absorption tends to maximize in the morning hours [1,2]. Events are relatively short-lived, lasting up to a maximum of five or six hours, but with an average duration of about 30 minutes [3,4]. Measurements have been made at 30 MHz [4] at 65 MHz [5] and at 81·5 MHz [6] but little information is available at higher frequencies. Assuming that the absorption is inversely proportional to the square of the frequency, calculations based on 6000 hours of Kiruna riometer data [7] yielded the equivalent absorption at 127 MHz as shown in Table II. Thus, the effect appears to be of minor importance at VHF and will rapidly become negligible at higher frequencies. Moon-bounce experiments at 440 MHz yielded no measurable absorption [8].

TABLE II

Auroral absorption at 127 MHz (Kiruna) (dB)

Percentage of the time	Angle of elevation	
	20°	5°
0·1	0·6	1·0
1·0	0·4	0·6
2·0	0·3	0·5
5·0	0·25	0·4

Note.—Kiruna is just inside the auroral zone at sunspot maximum.

3.3.2 *Polar cap absorption*

A second source of sporadic attenuation is polar cap absorption (PCA) [9] which occurs on relatively rare occasions, with an onset some hours following a solar flare. The absorption is long-lasting and is detectable over the sunlit polar cap area north of about 60° N geomagnetic latitude [10, 11]. Polar cap absorption occurs most usually during the peak of the sunspot cycle when there may be 10-12 events per year. Such an event may last up to a few days. This is in contrast to auroral absorption, which is frequently quite localized, with variations in periods of minutes. The absorption is due to bombardment of the upper atmosphere by relatively low energy (approx. 150 MeV) solar protons which are focused by the Earth's magnetic field to the auroral zones.

The absorption is produced by ionization at heights greater than about 30 km and because of the high frequency of collision between electrons and neutral molecules at heights between 30 km and 90 km, this additional ionization results in considerable attenuation principally in the HF and lower VHF range.

Table III is an estimate [7] of the number of hours per year of detectable polar cap absorption at 30 MHz during the last solar cycle based on the years for which evidence is available.

TABLE III

Incidence of polar cap absorption

Year	1952–1953	1956	1957	1958	1959	1960	1961	1962	1963
Hours of polar cap absorption	0	400	750	700	600	650	210	0	140

On the basis of 30 MHz data collected in 1958 an estimate has been made [7] of the equivalent absorption at 127 MHz (Table IV). Again, the bulk of recorded data is at 30 MHz. Extrapolation to higher frequencies is difficult because only absorption generated above 55 km obeys the inverse square law. Some measurements over an 18 month test period made at 104 MHz using a meteor scatter link showed a loss greater than 30 dB for a single period of 7 hours. This loss has been attributed to exceptionally intense polar cap absorption [12, 13].

TABLE IV

Estimated polar cap absorption at 127 MHz (Kiruna) (dB)

Percentage of the total time	Angle of elevation	
	20°	5°
1·0	5 to 10	8 to 16
2·0	4 to 7	6 to 11
5·0	1·5 to 2	2·5 to 3·2
10·0	0·5	0·8

It must also be emphasized that, in Table IV, the correct interpretation of 1 % of the time is not 1 minute per 100 minutes but rather 1 hour per 100 hours or even 10 hours per 42 days. In fact, it is not exceptional for a major event to last for three days.

It is important that in the allocation of adequate system margins, the incidence of auroral absorption and polar cap absorption events should be considered. It is noted that for frequencies above 500 MHz, polar cap absorption would not be greater than 1 or 2 dB at the worst.

A model for polar cap absorption for analysis of its effect on communication systems in the VHF bands has been made. This model is based on the maximum value of polar cap absorption expected, which occurs during the daylight hours on the first day of its occurrence. The absorption decreases to small values at night, and increases to about half of the maximum value during the daylight hours of the second day. This repeats on the third day, when the maximum value is about one fourth of that of the first day. The above estimates are based on measured values during a polar cap absorption [10] with the maximum value for the first day being 1·2 dB for vertical incidence at 136 MHz. This value was derived by scaling the maximum value 30 dB polar cap absorption measured at 30 MHz [15] according to an inverse frequency squared law. The values for oblique incidence were obtained using the following equation:

$$A_0 = A\, k \sec Z,$$

where A = absorption at vertical incidence (dB),

A_0 = absorption at an elevation angle (90°–Z) (dB),

Z = zenith angle,

k = correction factor.

The correction factor, used to take into account the curvature of the ionosphere, ranges from 1·0 to 1·2. In computing the model, a value for k of 1·0 was used for $Z = 80°$ (10° elevation angle). Fig. 1 shows the absorption as a function of time following a major polar cap absorption event. The model is based upon the simplification that all the absorption involved decreases with the inverse square of frequency. This tends to over-emphasize the fall off of absorption with frequency. It is also based upon experience with only a single exceptionally large polar cap absorption event.

The distribution obtained from it (Fig. 2), however, is expected to be representative of the effect of polar cap absorption on satellite signals that pass through parts of the ionosphere affected by polar cap absorption events at the indicated elevation angles [31]. The numbers obtained from this figure are comparable to those in Table IV. When data become available, the model should be replaced with actual measured values of polar cap absorption. There is an urgent need for more experimental data over a range of frequencies.

3.4 *Scintillation*

Scintillations (analogous to the " twinkling " of stars) occur when radio waves pass through the ionosphere. They are caused by irregularities in electron density and the consequent variations of refractive index.

The magnitude of the effect will depend on the length of the path through the ionosphere, i.e., the angle of elevation of the satellite. Again, since it is an ionospheric effect, it will vary diurnally and seasonally, also sporadically with solar activity. The diurnal effect is particularly marked at middle latitudes with increases in scintillation amplitude occurring around the midnight hours, of up to 4 or 5 times the normal daylight values.

Scintillations are variations in both amplitude and phase; the former variations must be allowed for in evaluating the power budget or reliability of a system, the latter may be a restraint on the choice of a method of modulation.

A limited amount of data is available on the magnitude of amplitude scintillation, almost entirely in the VHF band. It has been established that the magnitude of the amplitude scintillations (ratio of the deviation of the power to the mean power) decreases inversely as the square of the frequency for frequencies above about 100 MHz, up to 400 MHz [14]. For frequencies below about 100 MHz, the dependence on frequency is not yet well established.

The dependence of amplitude scintillations on latitude and frequency has been established by several workers [14]. At mid-latitudes and frequencies of about 136 MHz, peak-to-peak fades in excess of 6 dB occur about 1% of the time. At high latitudes (greater than about 60°) and the same frequencies, peak-to-peak fades in excess of 20 dB are commonly observed and, when the ray path is parallel to the Earth's magnetic field, these peak-to-peak fades may exceed 50 dB. Simultaneous observations at Resolute Bay (latitude 74° N) and Ottawa (latitude 45° N), made at frequencies near 230 MHz [14], indicated the following peak-to-peak fades:

Ottawa: in excess of 2 dB for less than 1% of the time,

Resolute Bay: in excess of 10 dB for about 80% of the time,
in excess of 20 dB for about 4% of the time.

A large group of meaningful scintillation data was extracted from recordings of the INTELSAT I [18] and INTELSAT II telemetry signals at 136 MHz, taken by the U.S. Air Force Cambridge Research Laboratories, at Hamilton, Massachusetts (latitude 42° N), and analyzed by the Communications Satellite Corporation. About 10% of 2280 hours of observation of INTELSAT I during 1965 yielded data showing amplitude scintillations. In these experiments the angle of elevation of the satellite was 25°. The data showed that the depth of fade did not exceed 3 dB for more than 0·1% of the total observation time; 90% of these fades exceeding 3 dB lasted less than 25 s. There were 56 fades exceeding 6 dB with an estimated median duration of about 5 s. However, at higher latitudes, considerably longer periods of scintillation have been observed.

Further measurements were made with INTELSAT II (F-3) during 1967 at an elevation angle of about 13°. Fig. 3 shows amplitude distribution for both the INTELSAT I measurements in 1965 and the entire INTELSAT II observation period of May 1967 through February 1968. The 1965 data show less scintillation than 1967, possibly due to lower sunspot numbers (20 in 1965 as compared with 100 in 1967) and higher elevation angles. The data for the duration of 3 dB and 6 dB fades are not significantly different for 1965 and 1967 data (Fig. 4).

World-wide surveys of satellite signals have shown the existence of an often sharply defined zone of enhanced scintillation at auroral and sub-auroral latitudes [19, 20]. Fluctuations in the signal strength greater than 20 dB have been recorded on trans-auroral zone signals at 136 MHz [15]. Severe scintillation may be expected on such signals at frequencies up to at least 400 MHz near solar maximum. At frequencies below about 200 MHz severe scintillation may be expected, on the average, for from a few minutes to over 1 hour per day [15].

There is a severe lack of quantitative information on scintillation effects as a function of the path geometry, particularly at low elevation angles. Present indications are that for systems designed for aeronautical and/or maritime services at VHF for regions including part of an auroral zone, ionospheric scintillation fading must be taken into account in order to assure adequate system margins, remembering that at high latitudes these scintillations may be particularly severe.

Scintillation may also occur as a result of tropospheric effects.

3.5 *Tropospheric ducting*

When meteorological conditions are such that a layer exists in the atmosphere in which the refraction index increases rapidly with height, radiation, originating in the layer at low angles of elevation, may be trapped and guided around the curved surface of the Earth. Under these conditions, abnormally good point-to-point ground communications are obtained at VHF, UHF and at microwave frequencies. This ducting also gives rise to severe interference from remotely sited co-channel stations.

A communication-satellite system may be severely affected under conditions of strong ducting, when transmissions from satellites at low angles of elevation may suffer complete refraction and never reach a receiver on the ground. However, in practice, it is believed that the angles of elevation of an operational aeronautical or maritime satellite system would be sufficiently large for this effect not to occur frequently.

3.6 *Multipath*

Signals travelling between aircraft/ships and satellites may travel by more than one path, the alternate paths being reflected. In such links the reflecting surface will usually be sea-water. The combination of both the direct and reflected signals may cause serious variation of the levels of received signal. Frequency dependence of this phenomenon is closely associated with the nature of the reflecting surface (ocean waves), as well as various other factors that are involved in the reflection, such as whether they are specular or diffuse. A theoretical discussion and experimental data on aircraft multipath effects are contained in Report 505.

3.7 *Other propagation factors*

3.7.1 *Faraday rotation*

Faraday rotation of the plane of polarization of a wave transmitted through the ionosphere is a consequence of the interaction of the Earth's magnetic field and the motion of the electrons in the ionosphere when excited by the transmitted wave. There are two distinct propagation velocities for the components of the polarized wave, one normal to and the other along the direction of the magnetic field component.

A linearly polarized wave, in passing through the ionosphere, undergoes a progressive rotation in the plane of polarization. The magnitude of the polarization rotation is dependent upon the total electron content over the propagation path; and changes as the electron content changes diurnally and with solar activity. Maximum rotation occurs during the day [27]. The total polarization rotation is proportional to the strength of the Earth's magnetic field, resolved along the direction of propagation. These propagation characteristics have the effect of causing fading between linearly polarized antennae. The total rotation experienced by the linearly polarized wave is inversely proportional to frequency [28].

The maximum change in polarization angle observed at VHF will be of the order of 2 or 3 complete rotations. Data made available by the United States of America (Fig. 5) were obtained from signals received on 136 MHz using the SYNCOM II satellite.

The avoidance of fading between linearly polarized antennae due to Faraday rotation, particularly at the lower frequencies, would require polarization tracking at the receive end of the link, a technique generally considered impractical for links between satellite and mobile stations. Therefore a circularly polarized antenna must be used on at least one end of the satellite-to-mobile link. A link between a linearly polarized and a circularly polarized antenna would produce a constant 3 dB loss compared to an ideal link with matched polarizations (e.g. circular-to-circular). Perfect circular polarization is usually not achievable in practical antenna designs so that on actual links some signal fluctuation will be observed due to Faraday rotation, the amplitude of which will be dependent upon the axial ratio (degree of polarization ellipticity) of the antennae.

Also to be taken into account when computing the effect of multipath from reflection at the Earth's surface is the fact that the axial ratio of an incident elliptically polarized wave may be increased or decreased upon reflection (particularly at small angles) since Faraday rotation varies the orientation of the principal polarization axis of the incident wave. This results from the difference in reflection coefficient to be expected between vertical and horizontal components in most multipath situations.

The effects of Faraday rotation on wideband signals can be of significance to system performance. When observed on a linearly polarized antenna the differential rotation effects cannot be corrected by reorientation of the antenna axis. On circularly polarized antennae, the effect is to introduce differential phase shifts of signal components across the band. Thus the effects of Faraday rotation for signal components separated in frequency may be expected to be subject to frequency and phase selective distortion. The total Faraday rotation observed with signals at 136 MHz indicates that this effect will not impose a serious limitation on the RF bandwidth of a narrow-band VHF satellite system.

3.7.2 *Dispersion*

Dispersion refers to the non-linear dependence of phase velocity with frequency in a transmission medium. The ionosphere is such a medium. The principal effects of dispersion are those produced on modulated signals. Transmission through the ionosphere results in signal distortion with a corresponding decrease in effective signal-to-noise ratio. In the lower VHF range it may be necessary to limit the design of systems to relatively narrow transmission bandwidths if this type of selective distortion is to be avoided [29].

4. Noise

4.1 *Introduction*

A major factor in the choice of an optimum frequency band is the distribution of background radio noise. This noise arises by radiation from :

— natural terrestrial and extra-terrestrial sources;

— the absorbing atmosphere around the Earth;

— electrical equipment.

For an aeronautical satellite system, particular attention must be paid to the airborne terminal with its high density of electrical and electronic equipment.

For a maritime satellite system attention will have to be given to the suppression of shipborne electrical equipment.

4.2 *Extra-terrestrial noise*

There are four sources of extra-terrestrial noise contributing to noise observed at an earth station or an aircraft or ship terminal. These are:

— background cosmic radiation amounting to 3 degrees K;

— galactic radiation, which is a maximum from the centre of the galaxy. Report 205-2, Fig. 6, shows that the noise decreases rapidly with increase of frequency;

— point sources within the galaxy (radio stars). These are of very small angular width and would contribute insignificantly to the overall noise when using beamwidths which are practicable from airborne antennae;

— the Sun, which has an equivalent noise temperature varying from about 10^6 degrees K in the VHF band to about 10^4 degrees K at 10 GHz (quiet Sun). There is a large variation over the sunspot cycle, e.g. from $2{\cdot}3 \times 10^4$ degrees K to $9{\cdot}0 \times 10^4$ degrees K at 4 GHz. Again, a small angle is subtended at the Earth (approximately 0·5°), even so there will be increases in apparent sky temperature if the Sun lies within the beam of the antenna (about 60 degrees K for an antenna beam 20° wide at 1 GHz). (In the case of a disturbed Sun, the antenna temperature contribution from this source may be about 100 times as much for a very small percentage of time.)

4.3 *Natural terrestrial noise*

For reception at an earth station or aircraft or ship terminal, atmospheric absorption may also add to the observed noise. Report 205-2, Fig. 6, shows how the total atmospheric sky temperature due to atmospheric absorption varies as a function of angle of elevation.

For reception at the spacecraft, and when the Earth lies wholly within the antenna beam of the satellite, a background noise temperature of about 290 degrees K will be observed at all frequencies for which the ionosphere and the troposphere are completely transparent.

Natural terrestrial noise is also produced by lightning discharges in thunderstorms. The level of this noise is very dependent on geographical location and season and is expected to be significantly greater than galactic noise at a frequency of about 100 MHz above a major storm area. This noise would therefore need to be taken into account in planning, if a VHF system were to be adopted.

If aircraft antennae can be designed with a wide beam to satisfy the required satellite viewing angles and with low side-lobes and a high front-to-back ratio, the contribution of earth's radiation to system noise temperature could be less than 10 degrees K [25].

4.4 *Man-made noise*

Man-made noise arises in a variety of ways, motor-vehicle ignition, electric motors, switch gear, corona on high-tension lines, etc. and is obviously greatest in densely populated and industrial areas.

The equivalent temperature of this noise decreases rapidly with frequency [24]. To the observer in space, the Earth has a small number of " hot " areas with noise temperatures above the background of up to 180 degrees K at 100 MHz and decreasing rapidly with increasing frequency to less than 1 degree K at 1 GHz. The angles subtended at a satellite by these " hot spots " are very small and so the extra noise produced will be negligible. The angles subtended at an aircraft may be quite large, but should only contribute to aircraft receiver noise through antenna side-lobes or when satellites are being observed at low angles of elevation.

However, when considering satellite/aircraft and satellite/ship links, the noise environment becomes much more important especially as such noise may enter the receiving system via other paths than through the antenna. Little information is available on aircraft or shipboard noise over the region of the radio-frequency spectrum of interest but such noise will certainly decrease with increasing frequency.

5. Antenna considerations for aircraft and ships

5.1 *Antenna stabilization and tracking considerations for shipborne terminals*

In the case of ships, high gain antennae with adequate stabilization and automatic tracking are technically feasible but costly. To meet the needs of the maximum number of potential users, a maritime system should ideally be designed to operate with unstabilized antennae capable of being fitted to small craft and preferably requiring only manual alignment at infrequent intervals (re-alignment for changes of course could fairly readily be achieved automatically). The system should operate at or above a performance level specified for values of roll which may typically be in the region of $\pm 20°$ and angles of pitch of $\pm 10°$. Assuming these to be the worst case operating conditions, the maximum achievable signal level would be obtained, in principle, by using an antenna having half-power beamwidths of about 40° and 20° in two orthogonal planes. The realizable gain of such an antenna at the half power point would be in the region of 12 dB.

For a fixed beamwidth shipborne antenna, the effective path loss between ship and satellite increases with frequency at the rate of 6 dB per octave (Report 205-2, § 2.2), thus favouring the choice of the lowest possible operating frequency. The lower limit is determined largely by considerations listed in §§ 3 and 4. In addition, the size and weight of an antenna having 12 dB gain will at some point become significant as the frequency is reduced. The lower limit indicated by these diverse considerations is expected to lie broadly in the region of 100-200 MHz.

Due to the frequency dependence of effective path loss between antennae of fixed beamwidth as noted above, the received signal would fall for example by about 22 dB in changing from 125 MHz to 1600 MHz. As a result, the output power required from a shipborne transmitter, all other things being equal, would increase by 22 dB. This is the result of the fact that for fixed beamwidth antennae, the antenna size will be reduced with increasing frequency. However, with a shipborne antenna gain of 12 dB, speech communications via a geostationary satellite having an earth coverage beam should be readily achievable at frequencies up to the order of 2000 MHz. At the upper end of this band the transmit power required should not exceed the order of several hundred watts. This required transmit power would be reduced for systems using satellite antenna beamwidths of less than earth coverage. For example, a satellite antenna gain of 19 dB at 1600 MHz would result in a transmit required power of the order of 100 watts. It should be noted that the antenna beamwidth and the frequency selected will affect the satellite transmitter power requirement in much the same manner as it affects the shipborne transmitter power requirement. The upper limit on frequency practicable for use in small ships will be somewhere in the region which can be broadly described as the upper end of band 9 and lower end of band 10.

It would be advantageous to make use of circular polarization to:

— circumvent the effects of Faraday rotation due to the ionosphere;

— avoid the need for rotating the plane of polarization as the vessel manoeuvres.

5.2 *Aircraft antenna considerations for satellite links*

It is usual to consider circular polarization for a satellite-to-aircraft link for the two reasons of § 5.1 above. Moreover, there is the need to reduce the fading effects of sea reflection at angles of elevation above the Brewster angle since it is difficult to design an antenna for an aircraft that would completely reject the reflected ray.

An aircraft flying within the region illuminated by the satellite may receive the incoming signal at any angle of elevation from the horizon to the zenith and at any azimuthal heading. For example, if a geostationary satellite were to be employed at 30° W longitude, the elevation angles to the satellite at aircraft locations along the principal routes of the North Atlantic would be roughly between 20° and 35°. Other routes, particularly those in the South Pacific, would require coverage at elevation angles near the zenith. For this reason, the aircraft antenna should have good coverage for most of the upper hemisphere. A single fixed beam antenna providing this type of coverage would be limited in gain to approximately 3 dB. However, it is to be noted that low polarization axial ratios cannot be practically achieved over a hemisphere with such an antenna.

Most of the VHF tests conducted with the ATS satellites involved the use of two types of dual beam aircraft antennae. In one type, coverage is divided between high and low elevation angles, each beam providing essentially uniform azimuthal coverage. The other type employs separate antennae located on each side of the aircraft in the wing body fairing. Although linearly polarized, this antenna provides good suppression of multipath signals due to its location. Its main limitation is the lack of coverage in the fore and aft directions.

In the 1600 MHz band there is a need to consider more directive antennae in order to offset at least in part the increased path loss in this band as discussed in § 5.1. Properly designed directive antennae will have the additional merit of providing greater protection from multipath signals.

In this band, there are three principal possibilities to assure hemispherical coverage:

— to have a hemispherical beam which implies that the gain is limited to 3 dB and the difficulty of achieving circular polarization is compounded by the path loss problem;

— to have two or more separate antennae each of which would cover a different segment of the hemisphere;

— to further reduce beamwidth and steer the beam by electronic means.

An electronically steered antenna has been built in France to cover directions to one side of an aircraft. It provides a peak gain of 12·5 dB at 1600 MHz and by selection of beam positions assures a gain in excess of 10 dB over half of the hemisphere except for low elevation angles fore and aft. The polarization ellipticity ratio of this antenna is better than 5 dB, also the difference between the gains in the direct and reflected paths is of the order of 8 dB at an elevation of 10°; this figure increases rapidly with increase in elevation (see Fig. 6).

Such an antenna can be mounted in suppressed radomes in aircraft. Mounting studies have been made for Boeing 707 and 747 and Concorde.

6. Summary and conclusions

Considerations of tropospheric and ionospheric attenuation indicate that an aeronautical or maritime satellite service which does not involve propagation across an auroral zone could operate in a frequency band lying between about 70 MHz at the lower end and between 10 and 20 GHz at the upper end. At the lower frequencies ionospheric effects will be a dominant influence on the determination of required system power margins.

The degrading effects of scintillation are statistical in nature and do not necessarily demand full excess power margins in order to produce a viable system.

Considerations of background noise generally indicate that, within the band determined above, minimum noise temperatures should be achievable in the UHF bands for the link satellite-to-aircraft or ship. The choice of frequency for the link aircraft/ship-to-satellite is not very dependent on noise considerations.

Assuming that aircraft and ships use antennae of constant effective areas (apertures) regardless of frequency, it would appear, on the basis of current knowledge of propagation and noise, that higher frequencies would be preferable to VHF frequencies for the satellite-to-aircraft/ship links of an aeronautical/maritime communication satellite system. Based on this assumption the use of higher frequencies could present practical antenna steering and installation difficulties. However, studies and developments are under way to solve such problems.

Finally, there are other considerations which must be taken into account, such as airborne and shipborne antenna design, satellite power per channel, geographical location of the area to be served, modulation techniques, and the satellite orbits used. Some of these considerations will in turn be affected by the type of traffic carried by the system, e.g. voice or data.

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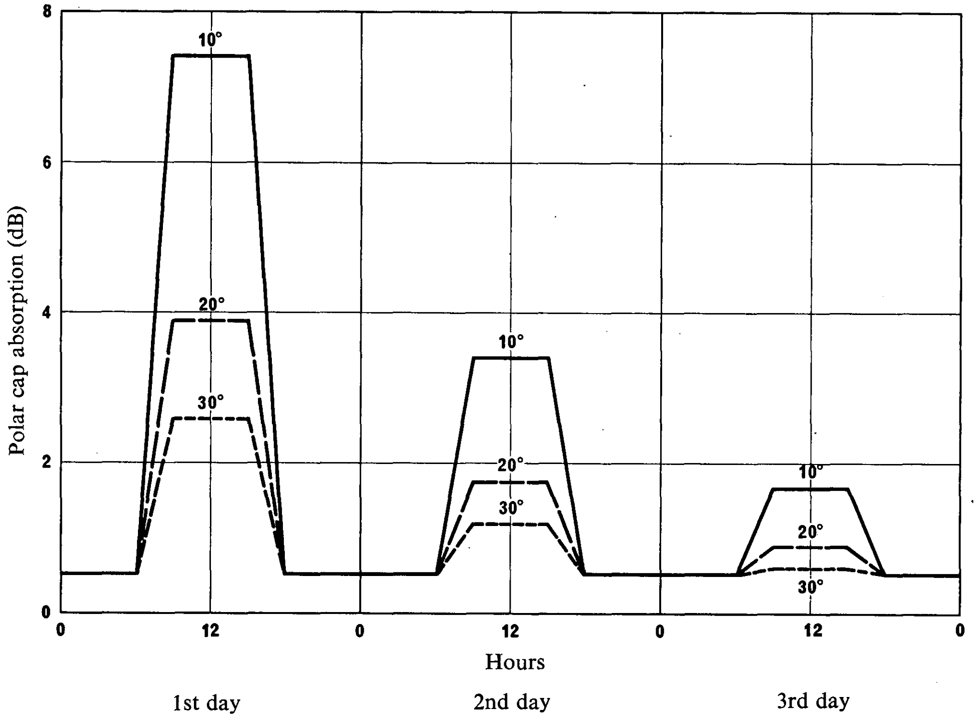

FIGURE 1

Model of polar cap absorption, following a major flare

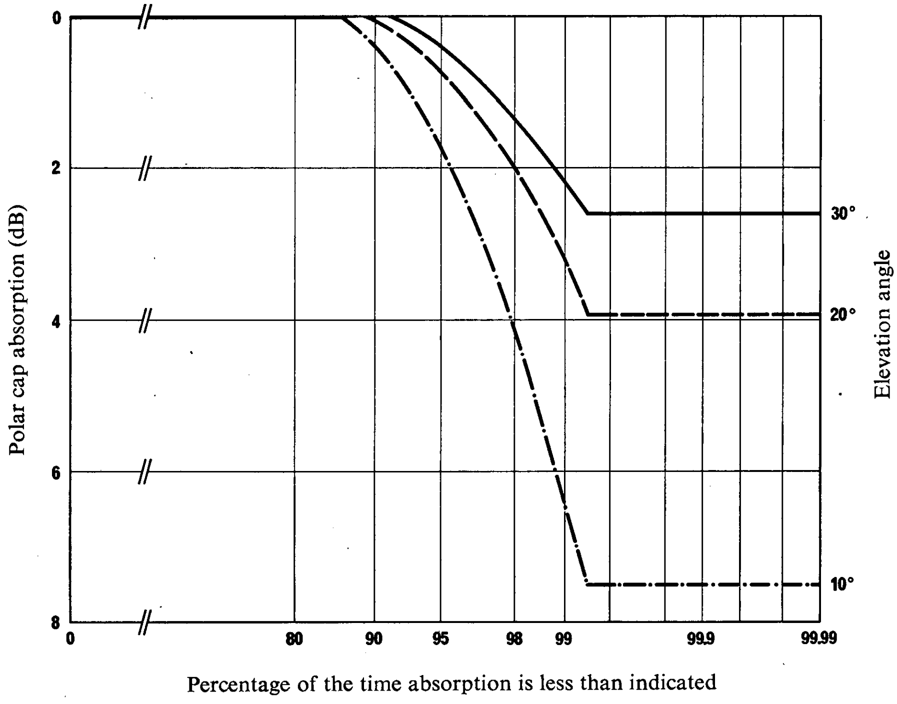

FIGURE 2

Polar cap absorption during maximum of sunspot cycle.
Polar cap absorption event frequency is taken as one per month.
Elevation angle is a parameter.

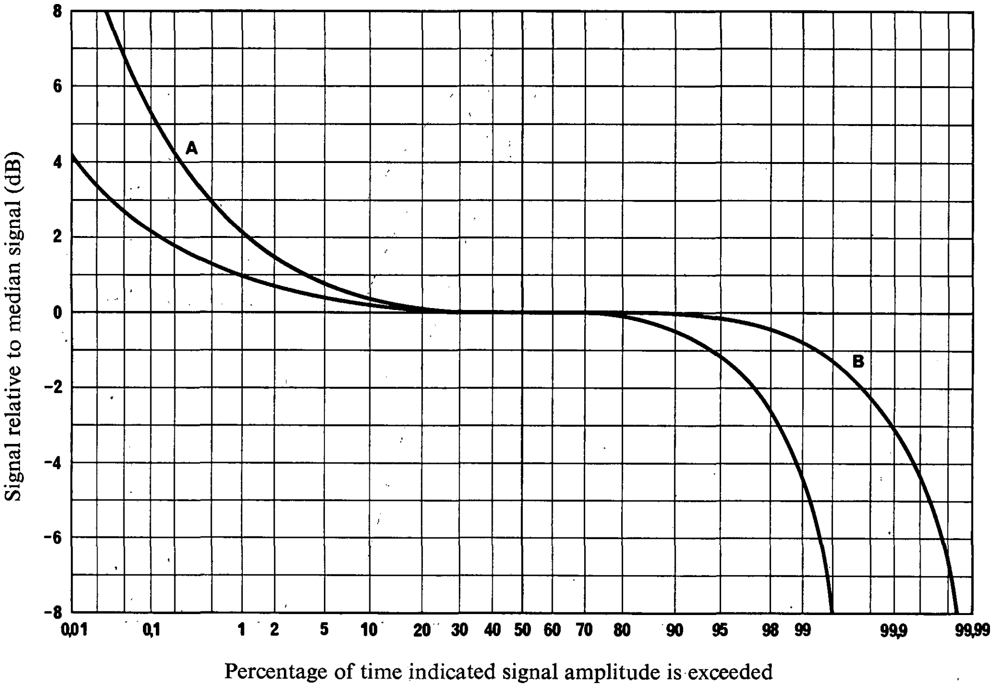

FIGURE 3

Ionospheric scintillation of INTELSAT I and II VHF signals

A: INTELSAT II (F-3) 4050 hours of data (11 May 1967 to 17 February 1968)

B: INTELSAT I (Early Bird) 2280 hours of data (5 May to 9 August 1965)

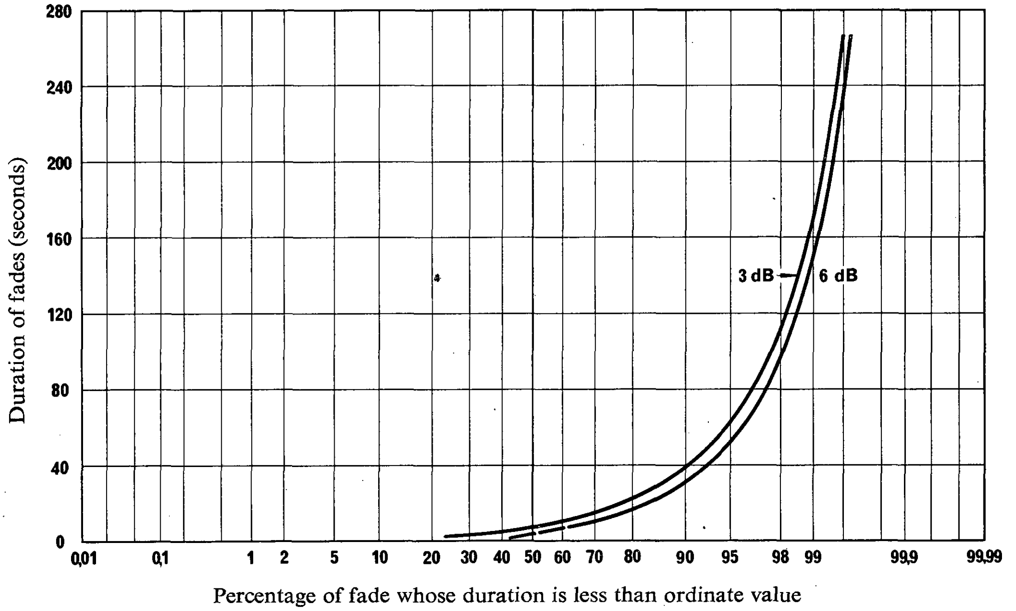

FIGURE 4

Distribution of duration of 3 dB and 6 dB fades due to ionospheric scintillation of INTELSAT II-F3

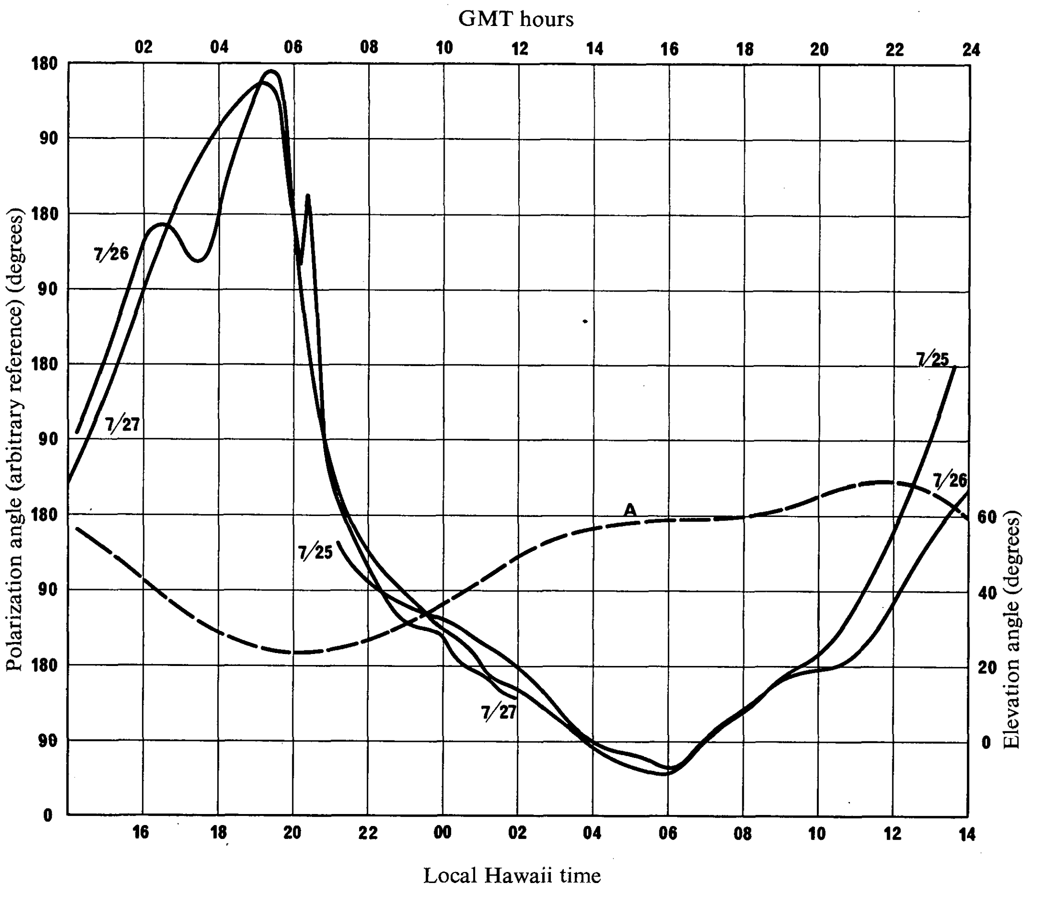

FIGURE 5

Polarization angle from SYNCOM II

A: Elevation angle

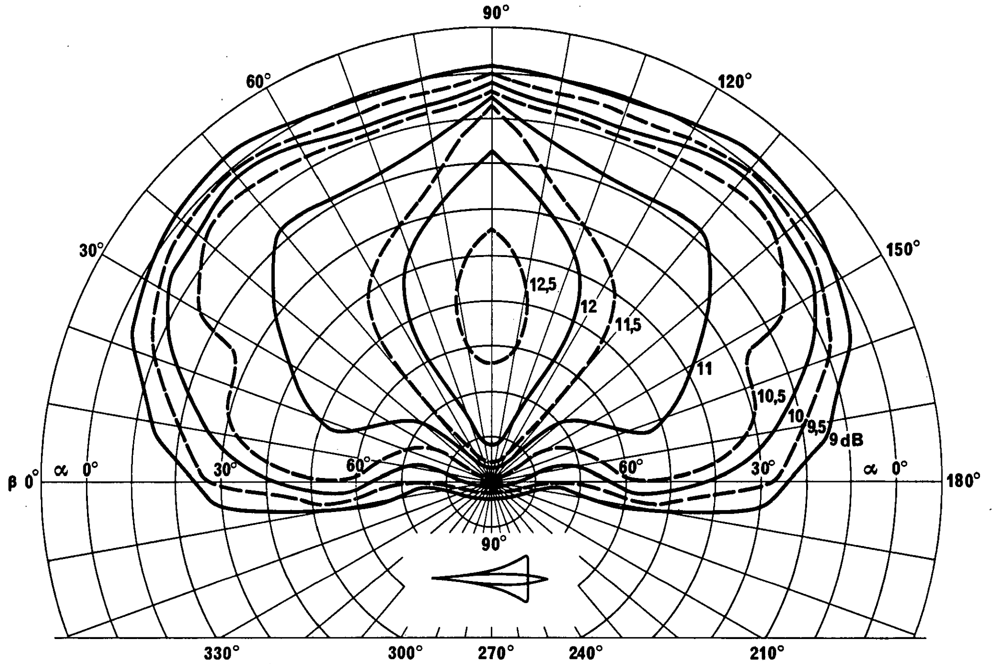

FIGURE 6

Starboard antenna coverage

α: Elevation β: bearing

Frequency 1600 MHz

REPORT 505 *

TECHNICAL CHARACTERISTICS OF COMMUNICATION-SATELLITE SERVICE TO AIRCRAFT AND SHIPS

Multipath effects in an aircraft-to-satellite communication link

(Study Programme 17A/8)

(1970)

1. Introduction

Study Programme 17A/8 calls for studies on the preferred frequencies and technical characteristics for satellite-to-aircraft links. One factor which will need to be considered is the effect of multipath propagation.

This Report treats most of those aspects of multipath propagation of particular concern to radiocommunication. Further studies will be required to assess those factors (for example, relative time delay) which are of greater concern in designing radiodetermination systems [13].

Interference between electromagnetic waves arriving at an aircraft directly from a satellite and those arriving by reflection from the surface of the Earth give rise to variations in signal strength as the aircraft receiving antenna moves through the interference field. (Transmission from the aircraft similarly gives rise to fading at the satellite antenna.)

Apart from the variations in signal strength the two-path transmission link leads to distortion of the modulation because all intelligence is received twice within a small period of time.

The consequences of these multipath effects on system design are considered in subsequent sections of this document.

2. Radio-frequency interference

2.1 *Geometry of the link*

For angles of elevation above a few degrees, the geometry of specular reflection is such that it is a good approximation to consider the surface of the Earth as flat and the wave fronts from the satellite as plane. Table I gives the vertical separation (to a close approximation) between the planes of interference maxima, due to the superposition of the direct and indirect waves, as a function of the elevation of the satellite. For angles below 30° this separation is approximately inversely proportional to the angle of elevation.

* This Report was adopted unanimously.

At angles of elevation below a few degrees and for aircraft altitudes above about 10 000 m (30 000 ft), the effect of the curvature of the Earth is to produce a significant defocusing of the reflected radiation and, in addition, atmospheric refraction becomes significant. The effect of the defocusing is equivalent to a reduction of the terrestrial reflection coefficient ρ. The divergence factor V, by which the reflection coefficient must be reduced is shown in Fig. 1, for aircraft at two altitudes, as a function of the elevation of the satellite.

TABLE I

Elevation of satellite (degrees)	Separation between maxima (wavelengths)
2	14·4
4	7·2
8	3·6
15	1·8
30	1·0
60	0·6
90	0·5

2.2 *Reflection coefficients*

Figs. 2, 3 and 4 show the theoretical reflection coefficients for vertically and horizontally polarized waves incident on flat, smooth land, sea and ice. The most important operational situation to consider with regard to multipath fading is probably over-sea flight and so sea reflection properties are considered in the greatest detail in the following sub-sections.

2.2.1 *Reflection from the surface of the sea*

The electromagnetic field above the surface of the sea may be considered as being the resultant of three vectors arising from: the direct wave, the coherently reflected wave, the phase and amplitude of which are determined by the geometry and the roughness of the sea and finally, an incoherently reflected (scattered) wave, with random phase and a Rayleigh distribution of amplitude [1].

An expression has been derived [2] for the magnitude of the coherently reflected wave in terms of the r.m.s. sea wave-height, h, and angle of elevation of the satellite at the point of reflection (Ψ), assuming that the first Fresnel zone contains a large number of scatterers.

This expression has been used to construct the nomogram shown in Fig. 6 from which may be determined the peak-to-peak fade depth due to coherent reflection for any combination of surface roughness factor (SRF) and smooth-sea reflection coefficient. The nomogram shown in Fig. 5 may be used to determine the surface roughness factor. It may be readily determined that for Sea State 5 and satellites at angles of elevation above 20°, coherent reflection at 120 MHz should be of negligible proportions. At 1600 MHz coherent reflection should be negligible for satellites at angles of elevation above about 6° at Sea State 3.

The incoherently reflected signal has the effect of producing fluctuations on the signal resulting from the interference of the direct and coherently reflected waves. These fluctuations may be expressed as a standard deviation on this resultant signal. Measurements of this standard deviation at a maximum of the interference field using small angles of elevation (less than 5°) have been made at a frequency in band 10 [1]. The experimental results are very scattered, but the trend is for an increase in standard deviation from 0 to about 0·3 times the signal which would be reflected from a smooth sea as the surface-roughness factor increases from 0 to about 120×10^{-3}. For greater surface-roughness factors the standard deviation decreases slightly. Fig. 7 shows the peak-to-peak (3σ) fluctuations as a function of surface roughness for various values of the smooth-sea reflection coefficient assuming that the experimental results can be extrapolated to other frequencies and elevation angles. Thus peak-to-peak fluctuations of the order of 8 dB would occur at 120 MHz for Sea State 5 and angles of elevation above about 10° for horizontally polarized waves. At 1600 MHz and Sea State 5 the same order of fluctuations would occur for angles of elevation above about 1°.

The change of phase of a coherently reflected wave for a perfectly smooth sea is different for horizontally and vertically polarized radiation. This results in a change of band of circularly polarized waves reflected at angles well above the Brewster angle due to the phase reversal on reflection of the vertically polarized component.

In the plane of incidence, depolarization in the coherent reflection from a rough surface is a second-order effect [2], so this band reversal applies even for rough seas provided that the first Fresnel zone contains a large number of scatterers, a valid assumption in the aircraft case.

2.2.2 *Reflection from ice*

The reflection coefficients for ice shown in Fig. 4 are based on the electrical properties of a *névé*, i.e. a surface consisting of snow which gradually changes with depth to compact snow and finally to ice. Such a surface is found in Greenland and the Antarctic ice cap. Measurements of dielectric properties of *névé* have been made in Antarctica [3] and are valid up to temperatures around −15° C and approximately correct up to a few degrees below freezing point. At round 0° C the polycrystalline ice begins to thaw and the dielectric constant changes rapidly from 4 to 78. Hence rapid changes in reflection coefficient are to be expected where the surface temperature approaches 0° C. The Brewster angle is about 40° for a *névé* and since a geostationary satellite is always viewed from lower angles of elevation over such surfaces, reflected circularly polarized waves have a large component of the original band of polarization.

2.2.3 *Reflection from land*

The reflection coefficients shown in Fig. 2 are based on the electrical properties of " average " ground and assume a perfectly plane surface. For angles of elevation above 10°, the reflection coefficients are lower than the corresponding coefficients over a sea surface, much lower in the case of vertical polarization. Below 10° values are, in general, higher than the corresponding values for smooth sea. It is probable however that coherent reflection coefficients are considerably lower than shown in Fig. 2 because of the non-smooth nature of most land surfaces.

2.3 *Fading and fluctuation magnitude over sea*

The peak-to-peak magnitude of the fading and the magnitude of the signal fluctuations may be obtained from the foregoing data provided that the radiation pattern of the aircraft antenna is known. If the antenna gain in the direction of the satellite is *p* dB greater than the gain in the direction of the incoming reflected wave then the smooth-sea reflection coefficient of Fig. 6 is modified accordingly. Knowledge of the surface roughness factor then enables the peak-to-peak fading magnitude to be obtained. Also of importance to the system engineer is the absolute depth of a fade below the signal which would be received in the absence of coherent multipath reflections; such depths of fading are also obtained from Fig. 6.

An aircraft descending or climbing will experience mean peak-to-peak variations of signals as indicated from Fig. 6.

The effect of incoherent reflection will be to produce fluctuations in the mean peak-to-peak variations, the order of magnitude is given in Fig. 7 in terms of the smooth-sea reflection coefficient. For a non-isotropic aircraft antenna the smooth-sea reflection coefficient must be modified by the antenna discrimination factor, *p*.

For an aircraft in level flight the angle of elevation of the satellite will change very slowly, but it will be seen from Table I that for angles of elevation greater than about 15°, successive maxima of the interference pattern are separated in altitude by two wavelengths or less. At 120 MHz, this separation will be 5 m which is much less than the ability of a transport aircraft to maintain height and so, even in nominally level flight, the full peak-to-peak variations occur.

2.4 *Use of circular polarization*

Due to the reversal in sense of circularly polarized radiation on reflection from a surface at angles of elevation greater than the Brewster angle, circularly polarized satellite and aircraft antennae may be used to reduce multipath fading. Calculations have been made [4] of the depth of fading over a smooth sea for a number of configurations of aircraft and satellite antennae. The general conclusion is that, provided an aircraft antenna can maintain good circularity over the hemisphere of interest, coherent fading will be reduced to small proportions for angles of elevation of the satellite above about 10°. Incoherent fluctuations will also probably be reduced significantly by the use of circular polarization.

Over ice, circular polarization gives no help in reducing the depth of fading for a geostationary satellite. Vertically polarized emissions would appear to be the least subject to fading under these conditions.

2.5 *Fading spectrum*

In satellite relay systems, the relative importance of different fading rates will depend upon the characteristics of the system and the types of signal carried.

In nominally level flight over the sea, with a satellite at an elevation of about 5°, coherent fading cycles with durations of tens of seconds may be expected at 120 MHz; these durations will be of the order of seconds at 1600 MHz. For an aircraft descending at about 300 m/min (1000 ft/min) with a satellite at an elevation of about 60°, fading rates will average 5 and 50 times per second for 120 MHz and 1600 MHz respectively.

For reflection from land or ice, changes in the mean height of the terrain of about 30 m per km would produce a coherent fading rate of about one per second for a typical subsonic cruising speed at 120 MHz if the altitude of the aircraft could be absolutely maintained.

The spectrum of incoherent fading over sea depends on the rate of change of scatterer distribution within the illuminated zone. This illuminated zone extends over many kilometres as seen from an aircraft. The rate of change will be governed by the size of the zone (i.e. by elevation of the satellite and altitude of the aircraft), the aircraft speed and the spectrum of the surface waves. For a high-flying aircraft it is a reasonable assumption that the motion of the sea surface will produce the most significant change in scatterer distribution. Thus it would be expected that the incoherent fading spectrum will contain frequencies up to the order of 1 Hz but that most spectral energy will be concentrated in the region of 0·05 to 0·3 Hz as in the non-aeronautical case [5].

2.6 *Comparison of sea reflection in bands 8 and 9*

The most obvious choice of frequency for an aeronautical satellite system would appear to be either band 8 (about 120 MHz) or band 9 (about 1600 MHz). It is therefore pertinent to compare sea reflection effects at these two frequencies. The comparison may be summarized as follows :

— the reflection coefficient for a smooth sea is slightly less at band 9 than at band 8 for angles of elevation greater than 3°;

— coherent reflection reduces much more rapidly in band 9 with increasing height of sea waves for a satellite at a given elevation;

— for a given angle of elevation and sea state, incoherent reflection is greater in band 9;

— divergence, being a purely geometrical effect, is not dependent on frequency;

— antenna discrimination will be much better in band 9, if, as the frequency increases, the physical aperture of the aircraft antenna is kept constant (all other factors being equal, the physical aperture must be maintained, to preserve a sufficiently high signal-to-noise ratio in band 9);

— the fading spectrum in band 9 would probably be similar to that in band 8 for incoherent fading. When coherent fading dominates, satellite elevations would usually be below about 10°, when interference maxima are becoming more widely separated. The order of magnitude difference between the wavelengths at the two frequencies will result in an order of magnitude difference in the frequency of fading during climb and descent. For a given ability in maintaining the altitude of the aircraft the band 8 fading frequency will be at least significantly higher than that in band 9, and may be as much as ten times the band 9 value.

3. Modulation interference

Modulation interference arises from the differences in the length of the paths, and hence the propagation times, between the direct and reflected waves received at the aircraft. Any measures taken to reduce radio-frequency interference such as antenna discrimination or the use of circular polarization will equally reduce modulation interference.

When coherent reflection cannot be eliminated, for example when operating over ice at low angles of elevation, the only resort is to ensure that the system of modulation used is minimally liable to errors or garbling due to the presence of the time-delayed signal. A data link system employing frequency-shift keying would obviously require some form of error detection and correction with a consequent loss of channel capacity.

Any proposed system of modulation will need to be examined for its error liability having regard to the magnitude of the difference in propagation time; this will be a function of the altitude of the aircraft and of its position with respect to the sub-satellite point. The difference in propagation times for aircraft at heights up to 33 000 m (100 000 ft) has been determined [6, 7]. The longest possible difference in propagation time occurs when the aircraft is immediately beneath the satellite; for an aircraft height of 17 000 m (50 000 ft) the difference is then 100 μs. When the direct path from satellite-to-aircraft is tangential to the Earth the difference will be zero. Taking as an example the North Atlantic civil air routes, for a geostationary satellite at longitude 30° W the difference in propagation time for aircraft between 8000 m (25 000 ft) and 17 000 m (50 000 ft) will be between 20 and 60 μs.

Modulation systems which give a measure of protection against multipath effects have been both devised and tested [8, 11].

4. Experimental studies

4.1 *ATS-1 and ATS-3 satellite experiments*

Some experimental data at VHF using the ATS-1 and ATS-3 satellites have been obtained using airborne receivers. These data were obtained over a range of elevation angles and for a largely unknown range of sea states and thus could not be compared with the theoretical predictions.

The peak-to-peak fades obtained were of the order of 3 to 9 dB [9].

4.2 *NIMBUS II satellite experiments*

The United States Federal Aviation Administration has conducted flights over ocean areas in order to obtain data on the effects of VHF (136·95 MHz) multipath signals received from the NIMBUS II satellite. The antenna on the NIMBUS II satellite was linearly polarized. However, at certain elevation angles, the presence of the solar paddles caused the linearly radiated signals to have right-hand circular components. The tests were made using two separate antennae on board the same aircraft, with the capability of switching between the two antennae during the course of the tests. One antenna was a standard VHF aircraft blade (vertically polarized). The other was an antenna (referred to as a " Satcom " antenna) expressly designed for satellite reception and intended to be circularly polarized. Examination of antenna pattern data taken on a 1/10 scale model of the Lockheed C-5A with a model of this satellite antenna indicates it to be primarily vertically polarized at low elevation angles (Table II).

The Satcom antenna is a two-mode device using crossed dipoles for the high angles and a vertical stub and horizontal stub, combined in phase quadrature, for low angles. Figs. 8, 9 and 10 illustrate the comparison of the results of the fading effects obtained with both antennae for elevation of 0 to 10 degrees, 10 to 19 degrees, and also for elevation angles of 20 degrees and above. Fig. 11 shows the comparison of the fading statistics for the Satcom antenna " Zenith Mode " and the vertical blade. The fade depths recorded on the over-

TABLE II

Axial ratio of aircraft " Satcom " antenna (dB)

Elevation angle (degrees)	Maximum	Minimum	Mean
0	19	3	13·7
10	18	1	10·2
20	9	2	5·4
30	6	0	3·0

ocean flights ranged from 0 to 10 dB. The average fade depth for both the Satcom and the linearly polarized aircraft antennae varied primarily as a function of the azimuth and elevation angles. The data showed a more marked multipath degradation for the Satcom antenna below 10° elevation angles than for the blade antenna. Conversely, there was a more marked improvement in multipath rejection above 20° elevation angles for the circularly polarized antenna than for the linearly polarized antenna.

4.2.1 *Discussion of results*

When using a Satcom antenna, the results of the tests (for all elevation angles) indicated that for 98 per cent of the data samples, fade depth was less than 8 dB. The average fade depth measured was 4 dB and the maximum was 10 dB. On the other hand, at higher elevation angles, the effects of multipath fading were less severe, and an example of the data obtained at 20° and greater angles is as follows:

Percentage of samples where the *fade depth was lower than:*

(%)	(dB)
72	2
90	4
98	6
100	8

4.3 *Additional studies*

Some empirical data on the effects of multipath in the frequency band 225-400 MHz is now becoming available. Experiments [2] have been conducted using circularly polarized satellite transmissions. The results of these tests were generally in agreement with those taken from NIMBUS II even at low elevation angles (10° to 15°). It is thus premature to make a comparison between the various bands and their relationship to the multipath fading problem. Frequency dependence is closely associated with the nature of the reflecting surface (ocean waves), as well as the countless assumptions that have to be made regarding the reflections, such as whether they are specular or diffuse, etc. Because of these problems associated with the rapidly changing quality of ocean waves, only a series of controlled tests in several frequency bands would provide positive guidance. There are plans to launch an experimental satellite containing a UHF transponder for tests with aircraft; this should provide much of the required information.

It should be noted that the aircraft antenna directivity can play a very important role in the reduction of multipath effects. Generally, the greater the antenna directivity and the better the side-lobe suppression, the less susceptibility it will have to multipath fades.

Experimental results in the 225-400 MHz band obtained from a cliff-top site have shown good agreement with theoretical predictions over the limited range of elevation angles and sea states experienced.

5. Conclusions

Under certain conditions of frequency, polarization, aircraft antenna pattern, satellite angle of elevation and texture of the reflecting surface, multipath propagation will adversely effect the operation of an aeronautical communication-satellite link.

When linear polarization is used and little discrimination by the aircraft antenna against the reflected radiation is possible then coherent reflection will cause wave interference. This will usually be more significant in band 8 than in band 9 because a given surface roughness results in reduction of coherent reflection as frequency increases. In fact a quite moderate sea state will reduce coherent reflection in the UHF aeronautical band to negligible proportions except at angles of elevation of a few degrees. At these latter angles the defocusing of the reflected radiation due to the curvature of the Earth will reduce the interference to an insignificant amount. For example, at Sea State 3, coherent reflection will be reduced by 50% or more at angles of elevation 3° at 1600 MHz. The corresponding angle of elevation at 120 MHz is about 40°. Basic data on expected sea states in specific locations are available [12].

The use of circular polarization with antennae of good axial ratio at each end of the link will provide considerable protection against coherent reflection at angles well above the Brewster angle and, in the case of sea reflection, could give significant protection down to an angle of elevation about 5° at 120 MHz. However, for reflection from a *névé*, circular polarization will give little help to a geostationary satellite system.

Antenna discrimination against the reflected wave will provide additional reductions in coherent reflection. Such discrimination will be more practicable in band 9 than in band 8. In fact, in band 9, such discrimination may well be inherent in the system.

Incoherent reflection leading to random signal fluctuations will be more significant in band 9 than in band 8. The use of circular polarization and antenna discrimination will reduce these fluctuations, which otherwise could cause peak-to-peak variations of the order of 7 to 8 dB, in band 8 as well as in band 9.

Multipath propagation will also lead to errors in a data transmission system and if the measures noted above cannot be used, some care must be exercised in deciding the modulation technique to be used.

Because of the many parameters involved, experimental confirmation of theoretical predictions is difficult to obtain. A very limited controlled experiment from the top of a cliff has given results which are in good agreement with theoretical predictions at a single frequency in the 225-400 MHz band.

Tests using aircraft at VHF have produced fading depths which are not inconsistent with the theoretical studies having regard to the imprecise knowledge of sea state and aircraft attitude.

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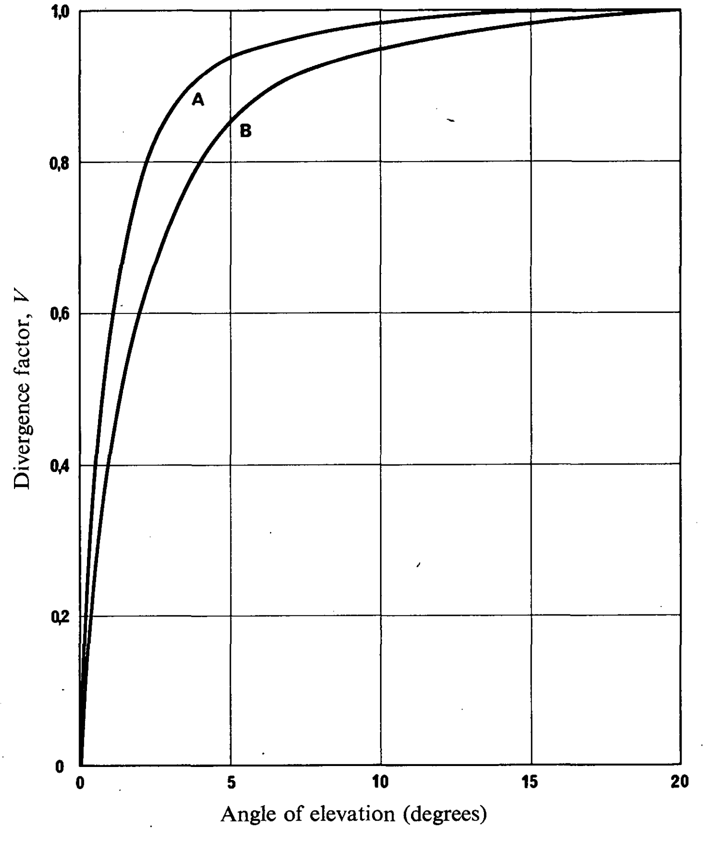

FIGURE 1

Divergence factor as a function of angle of elevation

Curve A: height 3300 m Curve B: height 10 000 m

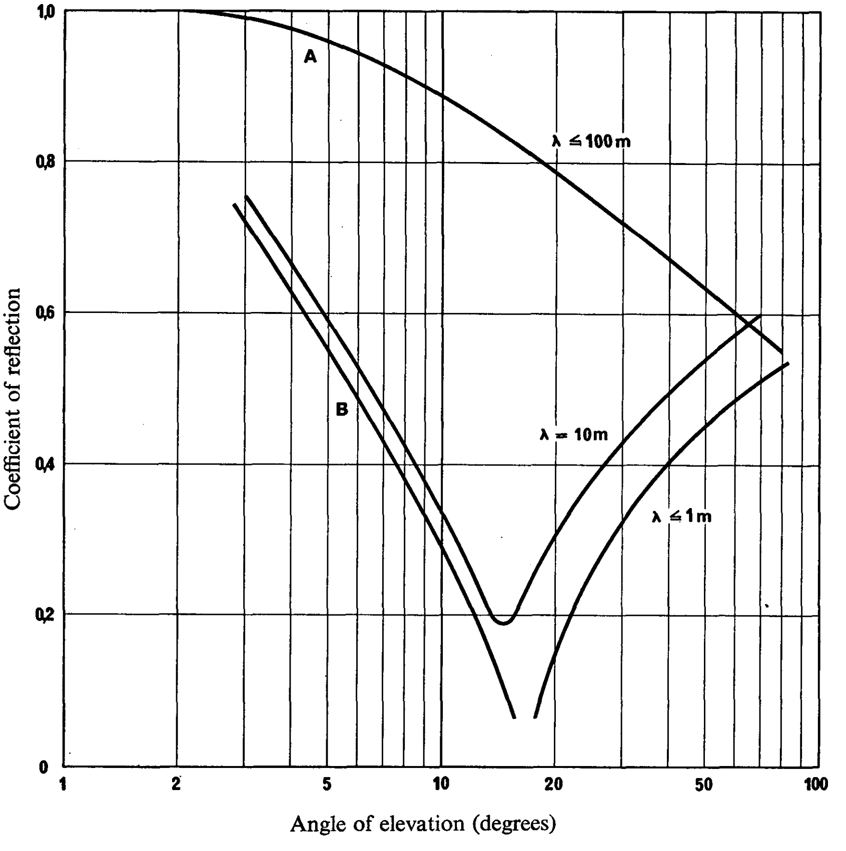

FIGURE 2

Coefficient of reflection for plane average ground as a function of the angle of elevation

Curve A: horizontal polarization Curve B: vertical polarization

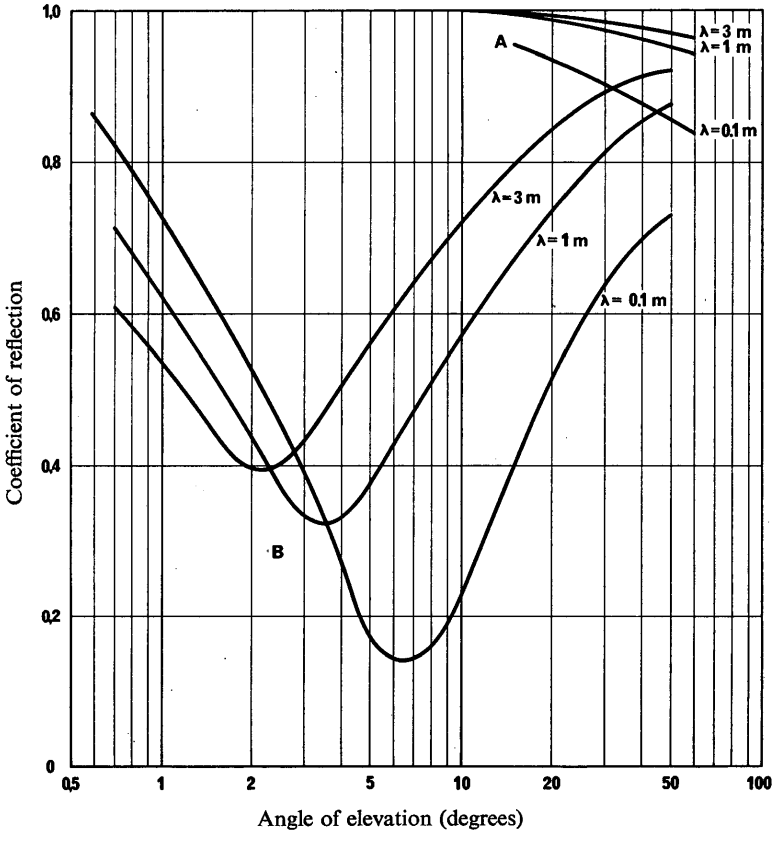

FIGURE 3

Coefficient of reflection of smooth plane sea as a function of the angle of elevation

Curve A: horizontal polarization Curve B: vertical polarization

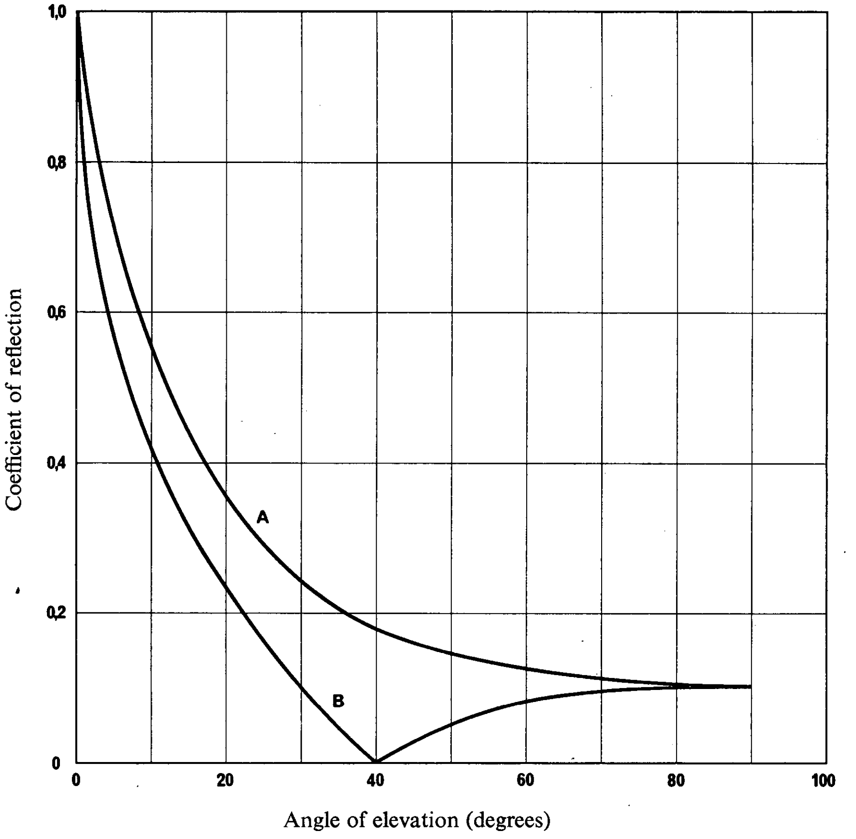

FIGURE 4

Coefficient of reflection of an ice cap (névé) as a function of the angle of elevation

Curve A: horizontal polarization Curve B: vertical polarization

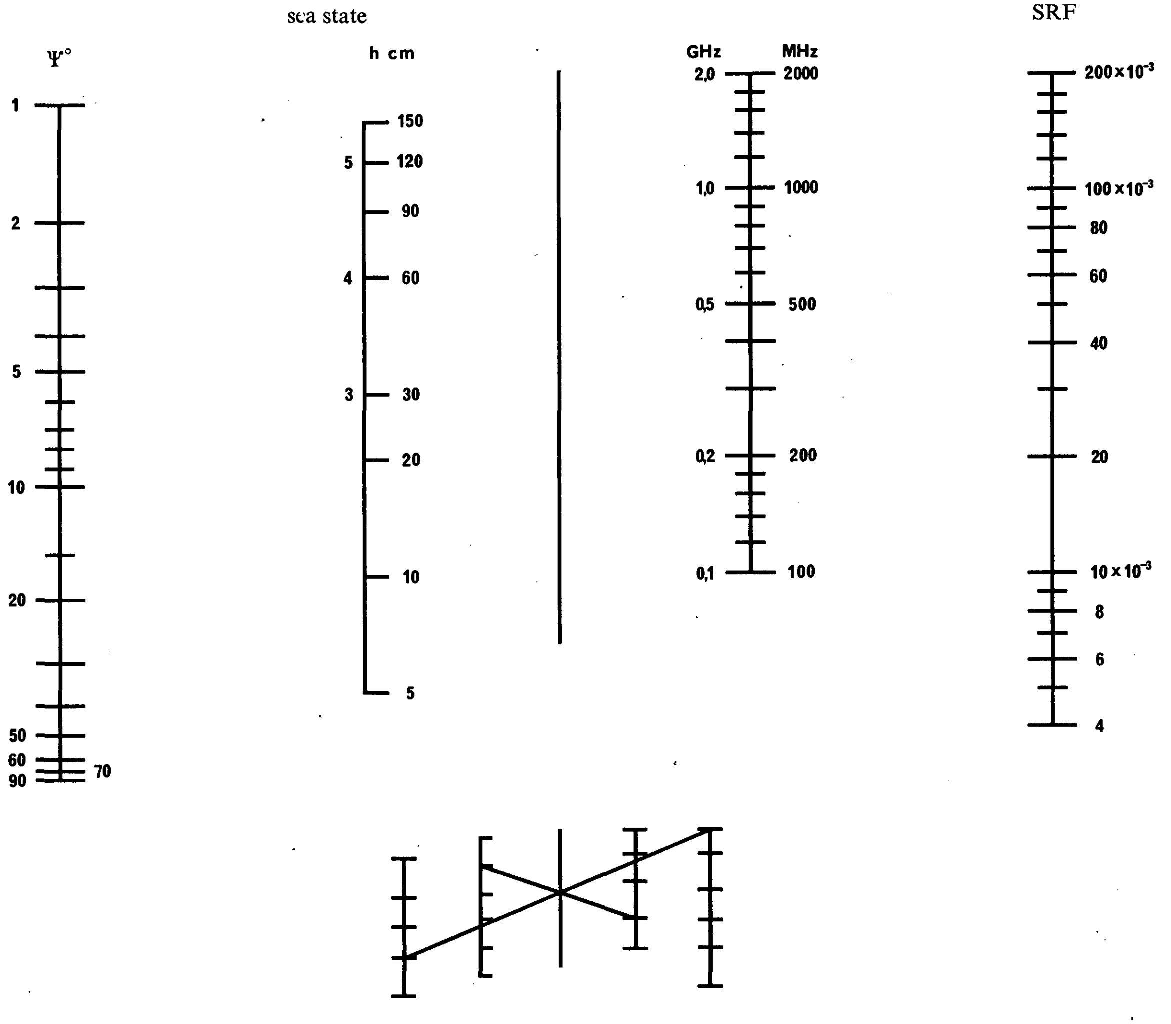

FIGURE 5

Surface roughness factor nomogram

$$SRF = \frac{hf}{c} \sin \Psi$$

SRF = surface roughness factor
c = velocity of propagation
h = r.m.s. sea-wave height
f = frequency
Ψ = angle of elevation

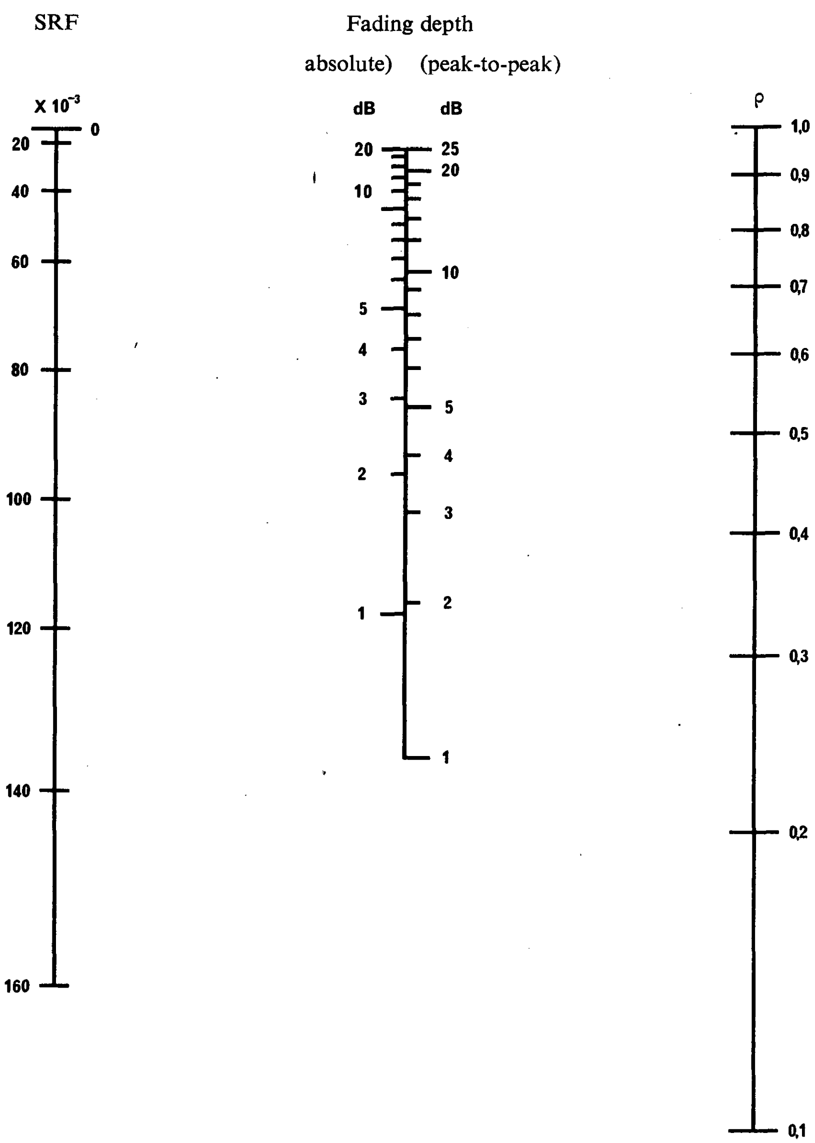

FIGURE 6

Multipath fading nomogram

SRF = surface roughness factor
ρ = smooth-sea reflection coefficient

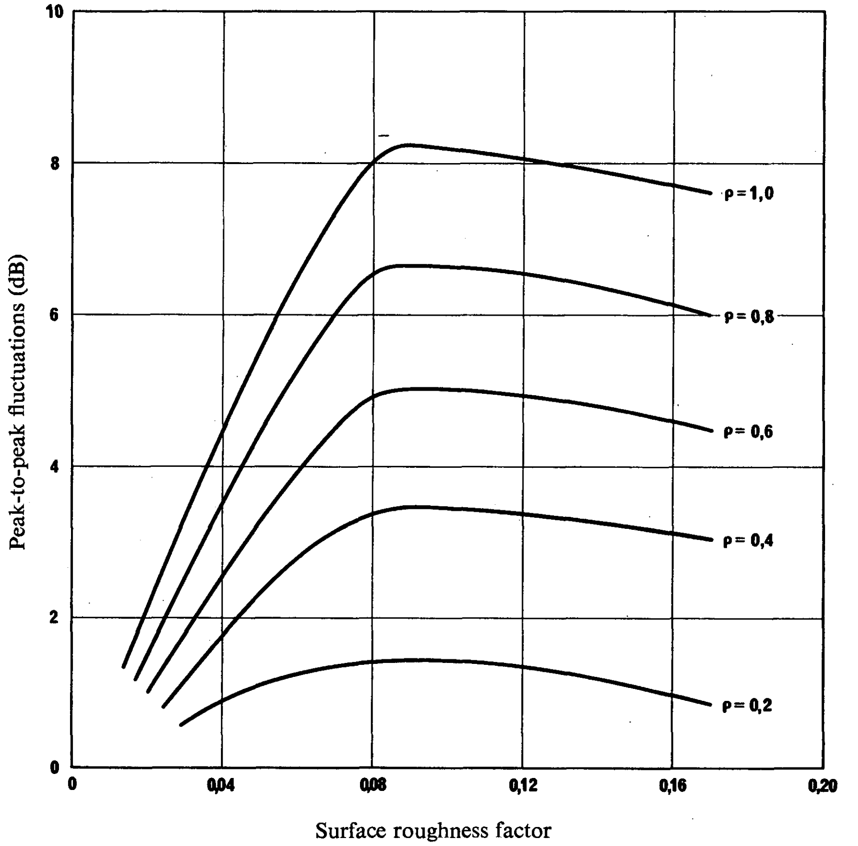

FIGURE 7

Peak-to-peak fluctuation as a function of surface roughness

Surface roughness factor: $\frac{h}{\lambda} \sin \Psi$

λ: wavelength (cm)

h: r.m.s. surface wave-height (cm)

Ψ: satellite elevation angle

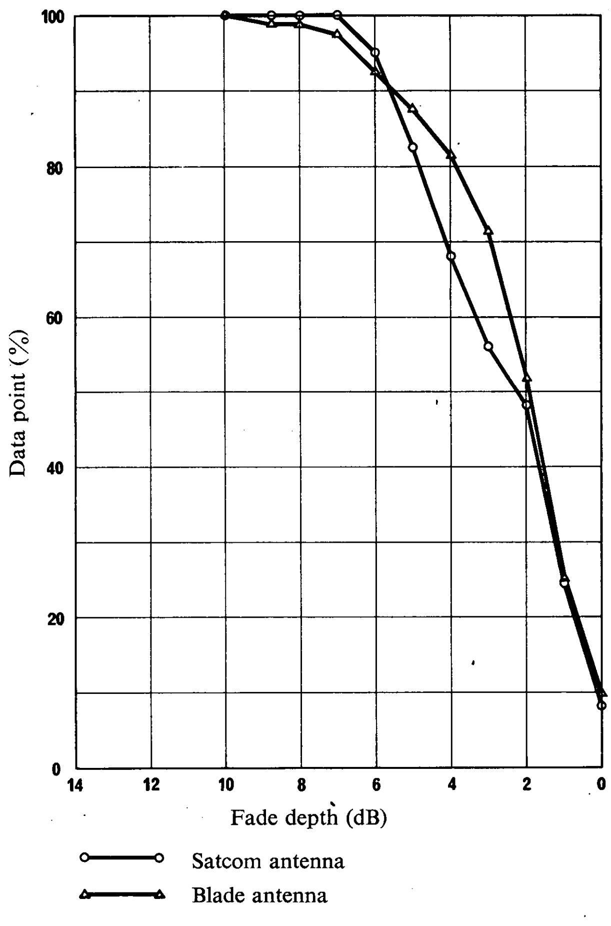

FIGURE 8

Percentage of data points that do not exceed the abscissa value for elevation angles between 0 and 9 degrees of the Satcom antenna horizon mode

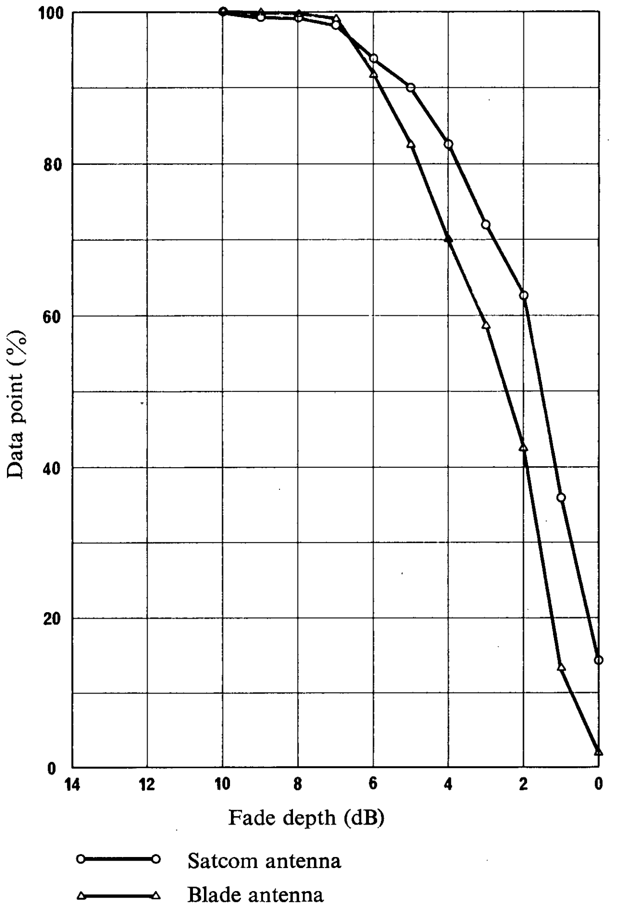

FIGURE 9

Percentage of data points that do not exceed the abscissa value for elevation angles between 10 and 19 degrees of the Satcom antenna horizon mode

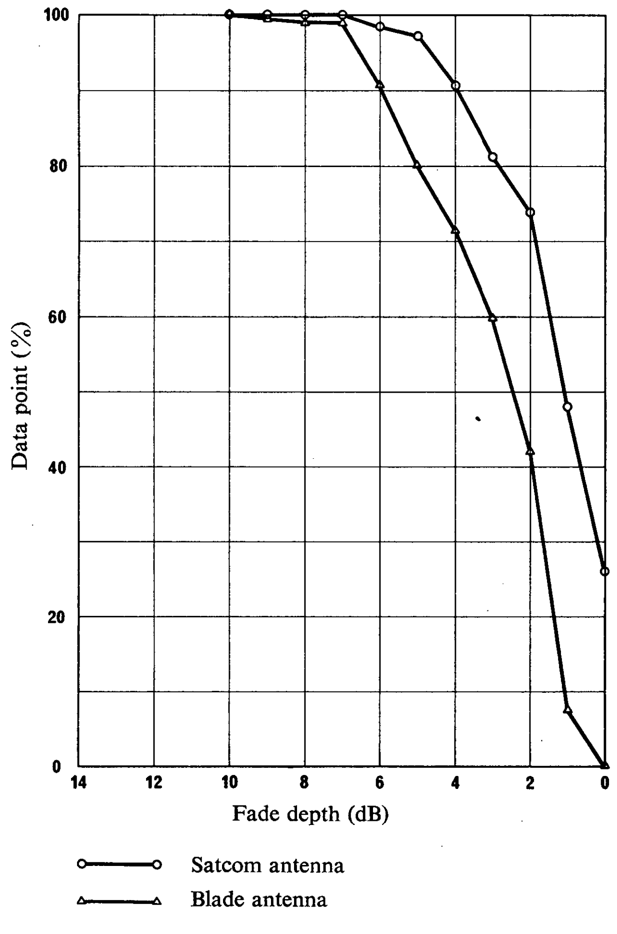

FIGURE 10

Percentage of data points that do not exceed the abscissa value for elevation angles 20 degrees and greater of the Satcom antenna horizon mode

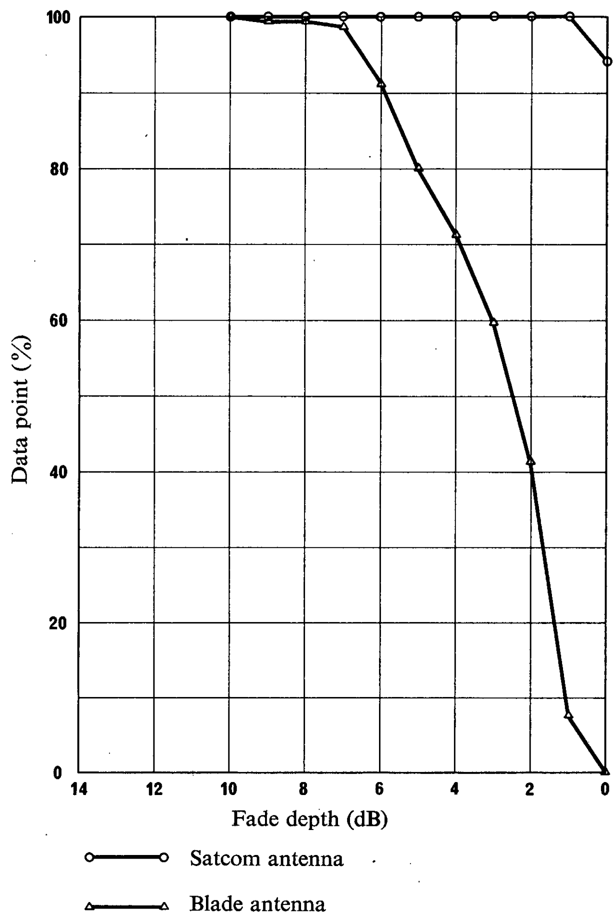

FIGURE 11

Percentage of data points that do not exceed the abscissa value for all elevation angles of the Satcom antenna zenith mode

REPORT 506 *

TECHNICAL CHARACTERISTICS OF COMMUNICATION-SATELLITE SERVICES TO AIRCRAFT AND SHIPS

Satellite orbits for systems providing communication and radiodetermination for stations in the mobile service

(Study Programme 17A/8)

(1970)

1. Introduction

Study Programme 17A/8 calls for studies on the preferred types of orbits to provide links for communication and radiodetermination in the aeronautical and maritime-mobile services.

Report 206-2 discusses the choice of orbit for communication satellites serving fixed earth stations. Much of that discussion is also relevant to stations providing communication and radiolocation for the mobile services, but additional factors arise in the mobile services which may influence the choice of orbit, thus:

— the mobile station must be small, robust and simple to operate and maintain;

— an antenna system for an aircraft station will be physically limited by aerodynamic considerations;

— the angle of elevation of the satellite may have a more significant effect on link performance, owing to unique propagation factors for such services, viz. the behaviour of the troposphere for satellite-to-ship links at the lower frequencies which may be involved. Such factors as reflection of signals at the surface of the Earth and the characteristics of practicable aircraft antennae have also to be taken into account, especially for the aeronautical-mobile service;

— service will be required to large geographical areas, not to specific locations thus suggesting that particular attention be given to high altitude orbits especially the synchronous altitude. Ultimately, truly global coverage may be required, including the polar regions; however, economics suggest that the total number of satellites should be minimized;

— except on routes carrying high densities of traffic, service interruptions lasting a few minutes at satellite hand-over may not be objectionable, it might therefore be feasible to operate a system using a series of non-geostationary satellites without requiring the duplication of land-station antennae;

— it might be desirable to use the same satellites for a joint communication and radiodetermination service, and the requirements of the latter could produce the more stringent limitations on the choice of orbit;

* This Report was adopted unanimously.

— any orbital configuration chosen to provide a continuous radiodetermination service which demands simultaneous coverage of both a ground station and the mobile station would automatically provide the necessary coverage for a communications service;

— the long propagation time of high-altitude satellites is not likely to introduce any significant limitations on operation;

— the requirements for radiodetermination may include the necessity for mutual area coverage by more than one satellite. The relative spacing and location of such satellites has an important influence on the accuracy of position determination.

In the light of these differences the factors governing the choice between several possible types of orbit are reviewed here from the viewpoint of the mobile service, both for limited geographical coverage and for global coverage.

2. Orbits for satellite communication systems

2.1 *Orbital configurations for limited geographical coverage*

2.1.1 The geostationary satellite orbit has obvious advantages because it offers large areas of coverage and thus gives a continuous service to a given region by the use of a single satellite. However other direct orbits would be essential if polar coverage were needed, either instead of, or in addition to, geostationary satellites. The main alternatives to the geostationary satellite orbit are:

— highly elliptical orbits at an inclination of about 63°;

— circular polar orbits;

— inclined synchronous orbits (either circular or elliptical).

2.1.2 *Geostationary satellite orbit*

A single geostationary satellite will serve an extensive area, as shown in Fig. 1*a* (see also Report 205-2). Coverage would be somewhat reduced if it were necessary to operate simultaneously to two geostationary satellites well separated in longitude, as might arise if radiocommunication and radiodetermination functions were combined in the same system (see Fig. 1*b*). Even for a single geostationary satellite, the angle of elevation of the satellite will be low for stations in high latitudes and there will be no service near the poles.

2.1.3 *Highly elliptical inclined orbits*

2.1.3.1 A satellite in a highly elliptical orbit has a relatively low velocity near apogee and if this is matched to the Earth's rotational velocity the satellite will appear almost stationary over a particular geographical area for a substantial part of its orbital period. If the period is synchronous or sub-synchronous, this effect will recur at the same longitude on successive days, but in general the precession of the line of apsides will slowly change the latitude at which apogee occurs. However, at a particular inclination *(i)* for which $5 \cos^2 i = 1$ approximately (which will be represented in this Report by the round figure of 63°), there is no precession of the perigee; if the apogee is at, or near, latitude 63° N or 63° S, this will result in a combination of some of the advantages of the geostationary orbit with good polar coverage.

2.1.3.1.1 Four satellites in elliptical 12-hour orbits inclined at 63° with apogee at 63° N and an altitude of apogee of about 40 000 km, all following the same earth track at intervals of 6 hours, could provide continuous coverage to northern latitudes as shown in Fig. 2*a*.

2.1.3.1.2 Two satellites in similar elliptical orbits, following the same earth track, one 6 hours later than the other, could provide a reduced continuous northern latitude coverage as shown in Fig. 2*b*.

The minimum coverage obtainable with these systems is shown in Table I. A combination of the two-satellite system described in § 2.1.3.1.2 with one stationary satellite would provide good coverage of the Atlantic or Pacific Oceans, with extensive additional coverage of the Arctic Ocean. The southern polar regions could, of course, be served in an analogous way, given two further satellites in an appropriate elliptical orbit.

2.1.3.2 Extensive coverage can be obtained from satellites in elliptical orbits inclined at 63° with apogees at lower latitudes, or with shorter periods but polar coverage is best when the apogee is at a latitude of 63° and although coverage would be greater the longer the period, it would probably be undesirable to adopt orbits with apogees higher than that of a 12-hour period satellite, that is about 40 000 km. Such satellites however will not give as good coverage at low latitudes as is provided by a smaller number of geostationary satellites.

TABLE I

Minimum polar coverage using 12-hour elliptical orbits inclined at 63°

Angle of elevation of satellite (degrees)	Latitude above which the stated angle of elevation is always exceeded (degrees)	
	System of four satellites, as described in § 2.1.3.1.1	System of two satellites, as described in § 2.1.3.1.2
20	36	63
15	29·5	57·5
10	23·5	52·5
5	17·5	47·5

2.1.3.3 In fact, however, if a number of satellites were placed in orbits inclined at 63°, to follow initially the same earth track, then the effects of lunisolar gravitational forces would be to change the inclination and height of perigee of each satellite differently. In addition, these perturbing forces would also cause precession of the perigee. Thus, the tracks on the ground would slowly cease to coincide and gaps in the coverage area would arise. Further studies would be required, in order that the initial orbits could be chosen so that the requirements for orbit corrections would be minimized.

2.1.4 *Circular polar orbits*

A considerable number of satellites in circular polar orbits would generally be needed to give continuous service to limited areas, often as many as would be needed to provide complete global coverage. An exceptional case however is that of the polar regions, where a small number of satellites give good coverage. For example, three satellites in circular 24-hour polar orbits following a common earth track at equal intervals of time would provide the three zones of coverage shown in Fig. 3, if used with one pair of eight-hour active arcs, and one pair of four-hour active arcs, as illustrated. Some extension of coverage would be obtained if fully flexible satellite activation were used. The coverage of various similar systems is summarized in Table II.

TABLE II

Minimum polar coverage using satellites equally spaced in a single earth track with circular polar orbits

Angle of elevation of satellite (degrees)	Latitude above which the stated angle of elevation is always exceeded (degrees)			
	Period: 24 hours		Period: 12 hours	
	Number of satellites			
	3	6	6	8
20	89	59	—	50·4
15	84	54	72	42·3
10	79	49	53·4	34·6
5	74	44	40·2	27·1

2.1.5 *Inclined synchronous orbit*

2.1.5.1 A satellite in a 24-hour circular orbit inclined at 30° spends eight hours each day north of latitude 14° N, and eight hours a day south of latitude 14° S. A group of three such satellites, following the same figure-of-eight earth tract at 8-hourly intervals, would cover a rather smaller span in longitude at the equator than would a geostationary satellite, but would give substantially higher angles of elevation and a wider longitudinal span at high latitudes, and would extend coverage to the poles, see Fig. 4*a*. Even better coverage at high latitudes could be obtained, at some cost in equatorial coverage, either by increasing the number of satellites in a group (and so reducing the length of the active arc) or by increasing the inclination of the orbits. Fig. 4*b* shows the coverage provided by four satellites in orbits inclined at 45°.

2.1.5.2 A group of satellites in 24-hour inclined circular orbits could clearly be used to extend the coverage of a geostationary satellite northwards and southwards, but they might also be used alone to serve an area like the Atlantic Ocean, in systems for which the special qualities of geostationary satellites (e.g. for radiodetermination) were not important. Some small improvement in equatorial coverage could be obtained by activating the inclined synchronous satellites during the intermediate arcs of their orbits, that is, during transit from the northern to southern active arc and vice versa.

2.1.5.3 The pole of an inclined synchronous orbit will precess approximately 6° per year about an axis between the terrestrial polar axis and the pole of the ecliptic. This slow precession will probably not be serious within the expected lifetime of a satellite provided that the coverages from successive satellites overlap sufficiently; the major component, a common precession about the Earth's axis of the nodes of all satellites of a group, could be offset simply by making their common nodal period slightly less than one sidereal day, but the remaining differential effects between satellites might alter the coverage pattern by a few degrees during the satellite lifetime.

2.2 *Orbital configurations for global coverage*

2.2.1 *Geostationary satellite orbit*

2.2.1.1 A few geostationary satellites located at regular intervals of longitude could serve most of the world, leaving only the high latitudes uncovered. Table III shows the relationship between latitude and minimum angle of elevation for up to six equally-spaced geostationary satellites. Coverage of two out of twelve equally-spaced satellites is virtually the same as for one out of six.

TABLE III

Coverage obtained with geostationary satellites at equal intervals of longitude

Angle of elevation of satellite (degrees)	Latitude below which the stated angle of elevation is always exceeded (degrees)			
	Number of satellites			
	3	4	5	6
20	19	48	54	57
15	38	56	61	63
10	51	63	67	68
5	62	71	73	74

2.2.1.2 By careful selection of the positions of geostationary satellites, it may be possible to provide coverage of important areas somewhat beyond the limits shown in Table III, at the cost of worsening the coverage in other areas where it is less important. If truly global coverage is required, satellites in other orbits must be used, either in addition to, or instead of, geostationary satellites. The choice for such other orbits will probably lie among highly-elliptical orbits inclined at 63°, polar circular orbits and inclined synchronous orbits.

2.2.2 *Highly-elliptical orbits inclined at 63°*

2.2.2.1 Fig. 2*a* shows the coverage that can be obtained in the northern hemisphere with four suitably deployed satellites in 12-hour orbits inclined at 63° with their apogees at 63° N. If a second system were added, to serve the southern hemisphere, global coverage would be obtained, except for two relatively small areas in the tropics. These gaps could be closed by four more satellites in 12-hour orbits inclined at 63°, with the apogee in the equatorial plane, following the same earth track at intervals of 6 hours. However, continuous global coverage could be obtained, using fewer satellites, if elliptical-orbit satellites were merely used to add polar coverage to the coverage provided by a system of geostationary satellites. The most suitable combination for any specific system would depend on the minimum acceptable angle of elevation of the satellite and on the extent to which geostationary satellite coverage was desirable. Several possible arrangements are listed in Table IV. Fig. 5 shows how the coverage areas of the components of these systems might be disposed.

TABLE IV

Some arrangements of stationary and 12-hour highly-elliptical orbits inclined at 63° for continuous global coverage

System	Number of satellites in indicated orbits (¹)					Minimum angle of elevation of satellite (degrees)
	Geostationary	Elliptical with apogee at stated latitude			Total	
		63° N	0°	63° S		
A	3	2	—	2	7	9
B	4	2	—	2	8	14
C	2	4	—	4	10	15
D	3	4	—	4	11	22
E	4	4	—	4	12	33
F	—	4	4	4	12	7

(¹) In all these arrangements, the elliptical-orbit satellites serving either hemisphere follow the same earth track, but the time intervals vary from case to case. In Systems A and B the two satellites are 6 hours apart. In Systems C, D and E the four satellites are at intervals of 6 hours. The arrangement for System F is given in § 3.2.1. In all combinations the optimum longitudinal relationship between the earth tracks of elliptical-orbit satellites and the location of geostationary satellites must be maintained.

2.2.3 *Circular polar orbits*

Complete global coverage may also be provided using satellites in circular polar orbits, alone or in combination with geostationary satellites. Table V shows a few of many possible arrangements, the minimum angles of elevation being shown for a simple system of active arcs and coverage zones. Higher minimum angles of elevation would be obtained if fully flexible satellite activation and utilization were used.

It should be noted that truly polar synchronous orbits (90° inclination) do not necessarily provide the most favourable combination with stationary satellites; near-polar inclinations may give a better combination of coverage and elevation angle.

TABLE V

Some arrangements of satellites in geostationary and circular polar orbits for continuous global coverage

System	Number of geostationary satellites	Satellites in circular polar orbits				Total number of satellites	Minimum angle of elevation of satellite (degrees)
		Period (hours)	Number of groups	Number of satellites per group	Longitude relationship between groups (degrees)		
A	—	24	3	3	120	9	3
B	—	12	2	6	90	12	15
C	—	24	3	4	120	12	11
D	—	24	4	3	90	12	7
E	3	24	3	3	120	12	18
F	4	24	2	3	180	10	16
G	3	12	1	6	—	9	9·5
H	4	12	1	6	—	10	12
J	4	12	1	8	—	12	18·5

Note. — All the satellites in a polar-orbit group are assumed to follow the same earth track at equal intervals, transits of the ascending node being synchronized. Earth track of polar-orbit satellites must be related in longitude, to the location of geostationary satellites (where used), so as to give optimum coverage.

2.2.4 *Inclined synchronous orbits*

Three or four groups of three or four satellites in inclined circular 24-hour orbits could also provide global coverage, each group serving an area as shown in Figs. 4*a* and 4*b*. Table VI shows the minimum angle of elevation, world-wide, that could be obtained with typical systems of this kind.

TABLE VI

Global coverage with inclined synchronous satellites

System	Number of satellites per group	Number of groups	Total number of satellites	Inclination of orbits (degrees)	Minimum angle of elevation of satellite (degrees)
A	3	3	9	36	9
B	4	3	12	32	13
C	3	4	12	55	15
D	4	4	16	50	25

2.3 *Other system considerations*

2.3.1 *Doppler carrier-frequency shift*

Doppler frequency-shift will arise due to the relative motions of the land station, satellite and mobile station.

The total shift in an operational system will be dependent on the system design, e.g. the shift on the land station-to-satellite link could conceivably be readily compensated, leaving a significant contribution only from the mobile station-to-satellite link. In the design of systems provision should be made for Doppler shifts appropriate to aircraft speeds of at least Mach 3.

2.3.2 *Satellite failure*

Communication-satellite design has been developing towards a stage at which sufficient redundancy in sub-systems will ensure gradual rather than sudden failures. However, it may not prove cost effective even if feasible to provide satellite designs which would give complete protection from catastrophic failure. If a spare satellite is not already available in orbit, such a failure will cause loss of coverage. The loss of coverage will be extensive in some systems, especially those depending largely or wholly on geostationary satellites, but may be relatively limited in others where considerable overlapping of visibility areas occurs. To provide a sufficiently reliable service, it may be necessary to put spare satellites into orbit although it would not always be necessary to provide a spare satellite for each satellite in service, since for circular orbits a spare satellite could be moved quickly to any station in its orbital plane without heavy use of propellant fuel. However, some systems vary considerably as to the number of orbital planes used, and consequently the number of spare satellites that would be needed. All geostationary satellites are in the same orbital plane. In general, non-stationary satellites providing polar coverage will all be in different orbital planes, but there are exceptions; among the systems considered in §§ 2 and 3, for example, those using six or nine satellites in 24-hour circular orbits (polar or inclined synchronous) use only three orbital planes.

2.3.3 *Location of land stations*

The number of land stations would normally be kept to a minimum although this will be conditioned by operational requirements, and their number could vary according to the extent of the areas to be covered by the system and the acceptability or otherwise of interruptions to service at satellite hand-over. There will usually be a wide choice of locations for land stations for high altitude satellites, but some difficulty may be experienced in finding suitable sites for serving parts of the Pacific Ocean and the southern polar regions using 12-hour circular orbits.

2.3.4 *Radiation environment*

Orbits for which satellites must spend appreciable time at low altitudes will present the most severe exposure to the Van Allen radiation belts. This will result in greater required shielding on the satellite and lower power efficiencies for solar power systems.

2.3.5 *Steering of antennae at mobile stations*

If directive antennae are used at mobile stations, movement of the vehicle will create a satellite-tracking problem even if the satellite is in geostationary orbit. Difficulties in tracking will be greater for a moving satellite.

Satellite acquisition, a further problem for directive antennae, will be aggravated when a system of moving satellites is used.

2.3.6 *Radio-frequency utilization*

Systems may not be equally economical in the use made of the radio-frequency spectrum. In particular, when more than one satellite is visible simultaneously from a mobile station with low antenna directivity, it may be necessary to assign different carrier frequencies for the satellite-to-mobile station link for each satellite, to prevent interference. Geostationary satellite systems would make least demands on the radio-frequency spectrum.

3. Orbits for radiodetermination satellite systems

The selection of orbits for satellite systems used to obtain position (and velocity) information by radiodetermination involves consideration of factors in addition to coverage areas which dominate the choice for communication systems. Each radiodetermination technique concept involves a geometric system in which range or angle measurements (or some variation of these parameters or their derivatives) are made from the satellite(s) to the user vehicle. These geometries affect position determination accuracies and impose practical limitations on satellite orbit requirements.

System concepts requiring only one satellite for making a position determination (angle or angle plus range measurements) have the fewest orbit limitations and essentially fall in line with the requirements of communication systems. However, these satellites require extremely precise attitude determination and control and are far more complex than communication relay type satellites.

The measurement of ranges or range differencies is a method of obtaining accurate and continuous position and velocity determinations through the utilization of relatively simple radio-relay type satellites. Appropriate systems could include both radionavigation and radiolocation functions. The minimum satellite network required for position determination is two satellites. Range measurements are made between a mobile craft and each satellite. If the craft's altitude is known, its location can be determined by trilateration, in this case the intersection of the three spheres determined by the altitude and the distances from the two satellites. High accuracy can be achieved with such a system except for regions within approximately $\pm 5°$ of the latitude of the great circle in the plane of the two satellites, provided that the satellites are spaced sufficiently far apart. This system can be expanded on an evolutionary basis so that for example six satellites would provide global position determination capability with the exception of the polar regions and a narrow belt about the equator [8]. If the mobile craft transponds, the range measurements can be made directly by a ground station which sends a ranging signal on a round trip from ground station to the satellite to the mobile craft and back [1]. Velocity data can be derived from Doppler measurements on the carrier.

A mobile craft fitted only with a receiver can also determine its position with a network of two satellites making passive one-way range measurements, provided it has an accurate clock available. The clock could be calibrated periodically at known locations using the satellite ranging signals. The addition of a third satellite within the field of view would remove this dependence upon time. The mobile craft then measures the range differences between the vehicle and pairs of satellites for a " hyperbolic " fix. The addition of a fourth satellite with good geometry permits the non-transponding mobile craft to measure position, altitude, velocity, and time. The passive user's measurements could be digitized and transmitted back to a ground station for traffic surveillance.

One system design concept for non-transponding users has one stationary satellite and three others in elliptical inclined orbits with a 24-hour period [7]. The combination of ellipticity (approximately 0·3) and inclination (approximately 30°) is chosen so that the ground trace of the satellite is a circle about its mean position on the equator. The coverage of such a network is indicated in Fig. 6. It should be noted that the effect of the earth's equatorial bulge is to produce an orbit degradation, the correction of which would require the expenditure of more fuel than is required for the maintenance of the orbit of a geostationary satellite.

Several useful synchronous orbits which can provide varying degrees of position and velocity information have been discussed. In all of these cases, the orbits are equally suitable to provide a communications service as well. Therefore, such systems would provide satellite redundancy for communications and varying levels of redundancy for radiodetermination services. The selection of optimum orbits will depend upon both detailed definition of user requirements and economic implications [5, 6].

The area coverage networks could be conveniently expanded to a world-wide network using synchronous satellites. A number of useful networks have been studied. Complete pole-to-pole coverage can be provided by a system of eighteen satellites. A traffic surveillance world-wide network of ten satellites has been considered with six in stationary and four in inclined orbits. For radionavigation applications utilizing range difference measurements, a network providing coverage over the continental United States, Europe and the Atlantic Ocean employs eight stationary satellites and two satellites in elliptical ($e = 0{\cdot}35$), inclined (52°) 12-hour orbits with apogee in the northern hemisphere.

For world-wide coverage, orbits other than the synchronous orbits could be used. Orbits below synchronous altitude would permit reduced boost velocity, but coverage would not be continuous until the entire network is orbited. For periods below approximately six hours, the number of satellites required for continuous coverage becomes prohibitively large.

Low altitude orbits are required for satellite radiodetermination systems relying upon the Doppler principle. World-wide coverage is obtained with a small number of satellites in polar orbits. However, the coverage is intermittent with lapses of minutes to hours between fixes. Such systems would be useful for many marine purposes but have limited utility for aviation.

In summary, it can be said that when the utility of a world-wide network has been established and requirements are firm, a selection of one of many possible orbit sets can be readily determined.

For global coverage the number of satellites required could be between six and eighteen depending upon the radiodetermination technique selected, the importance of the areas to be covered, the cost considerations, and system performance requirements [8].

4. Conclusions

4.1 Geostationary orbits have substantial advantages over other types of orbit if the coverage provided at the required minimum angle of elevation is adequate, since:

— fewer satellites and land stations are needed;

— a single orbital plane is used, which simplifies the provision of spare satellites in orbit;

— Doppler shift is least;

— problems of antenna tracking and acquisition in the mobile stations are least;

— continuous service can be introduced in a given region with the use of a single satellite.

It is probable that radiodetermination facilities can be combined with a communication system with minimum complexity if geostationary satellites are used.

A system for combined communication and radiodetermination can be based upon six geostationary satellites. This would provide coverage over a large part of the Earth's surface.

4.2 Satellites in non-geostationary orbits will have to be used, alone or in combination with geostationary satellites if the area to be served cannot be covered adequately by geostationary satellites alone. Several types of non-geostationary orbit have been considered, namely:

— highly-elliptical 12-hour orbits at an inclination of about 63°;

— circular polar orbits with 12-hour and 24-hour periods;

— inclined synchronous orbits.

No one type is obviously the best in all circumstances. Further consideration deserves to be given to the possible use of systems not limited to the provision of fixed geographical coverage.

4.3 Further studies are necessary to determine the relative efficiency of use of the spectrum for systems using the various orbit configurations.

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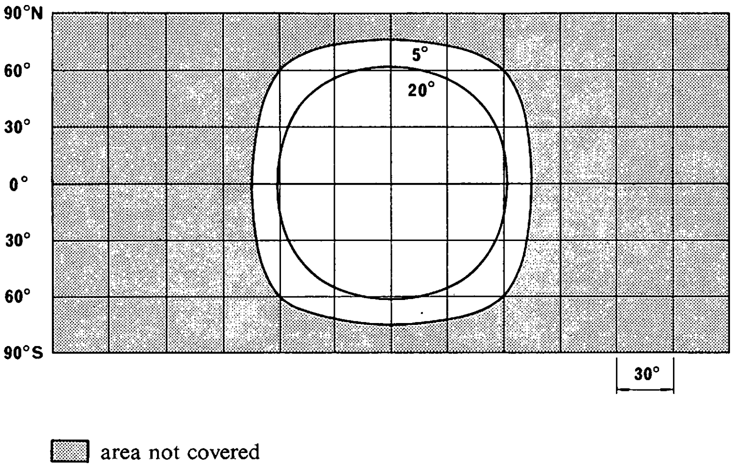


FIGURE 1*a*

Angle of elevation for a single satellite

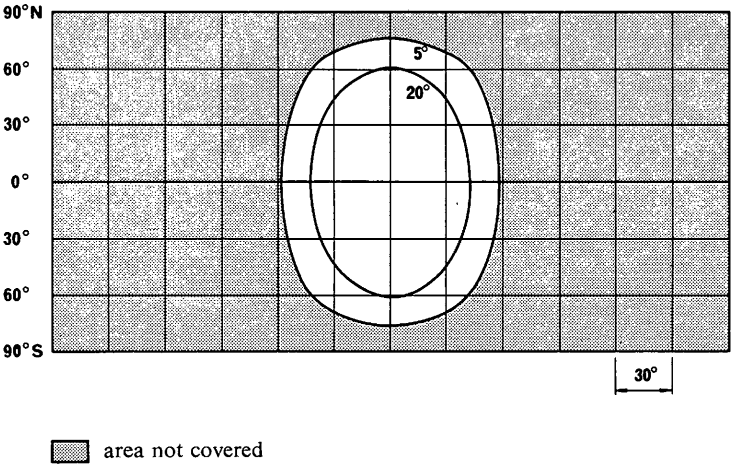
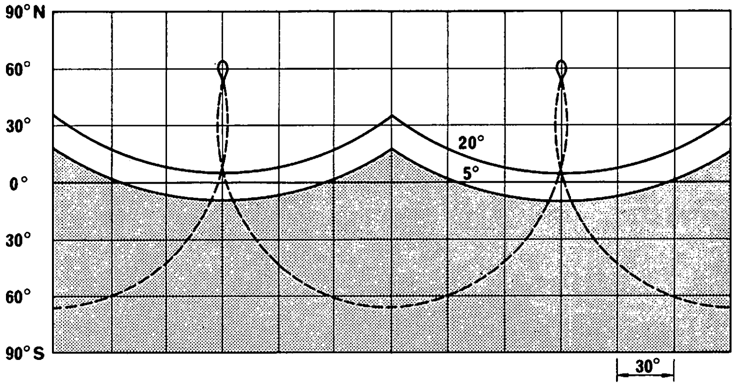


FIGURE 1*b*

Angle of elevation for the more distant of two satellites, separated in longitude by 30°

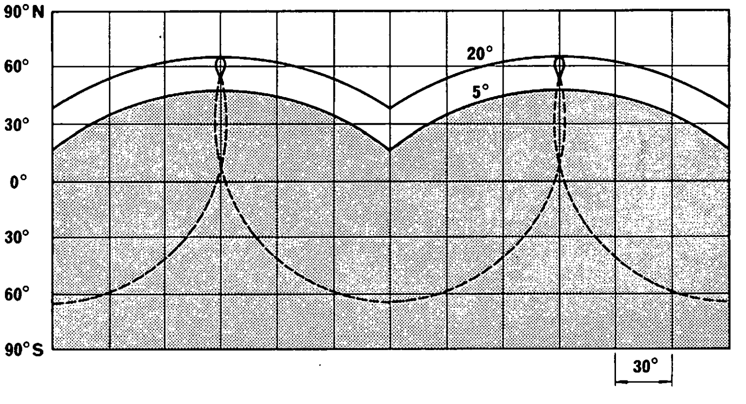


area not covered continuously

FIGURE 2*a*

Continuous coverage available with satellites in 12-hour highly elliptical orbits inclined at 63°, with apogee at 63° N, showing minimum angles of elevation

Four satellites at six-hour intervals around a common Earth track



area not covered continuously

FIGURE 2*b*

Continuous coverage available with satellites in 12-hour highly elliptical orbits inclined at 63°, with apogee at 63° N, showing minimum angles of elevation

Two satellites, one six hours behind the other in the same Earth track

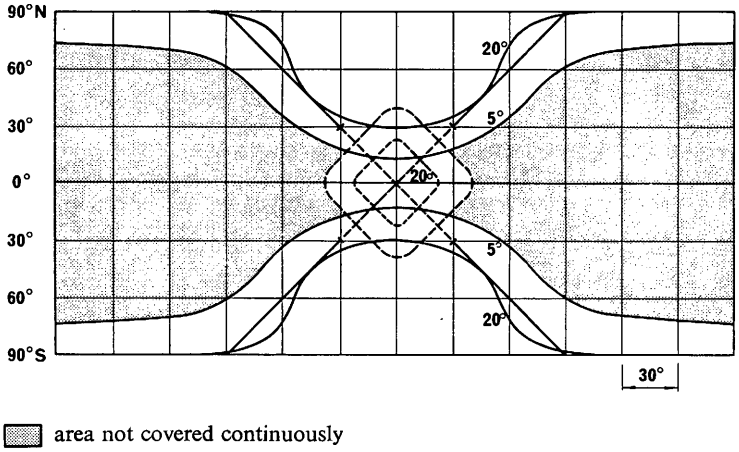


FIGURE 3

Continuous coverage available in three zones of coverage with three satellites in 24-hour circular polar orbits, with a common Earth track, showing the minimum angles of elevation and the active arcs

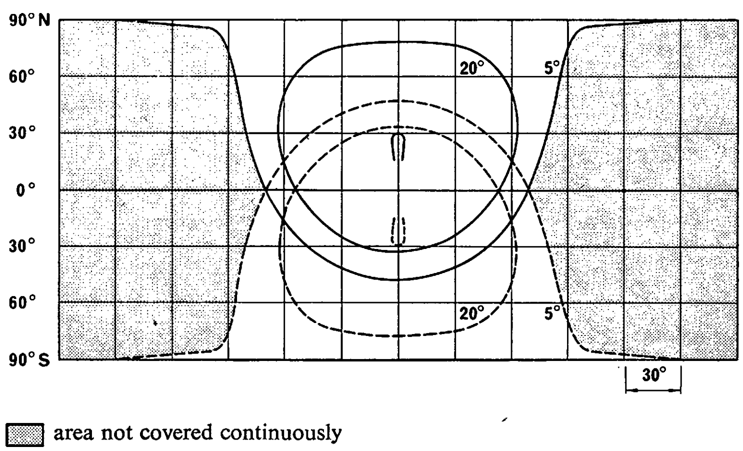


FIGURE 4*a*

Continuous coverage obtainable with satellites in inclined 24-hour circular orbits with a common Earth track, showing minimum angles of elevation

Three satellites at eight-hour intervals around the Earth track, orbits inclined at 30°, the active arcs are four hours before and after the most northerly and southerly passages

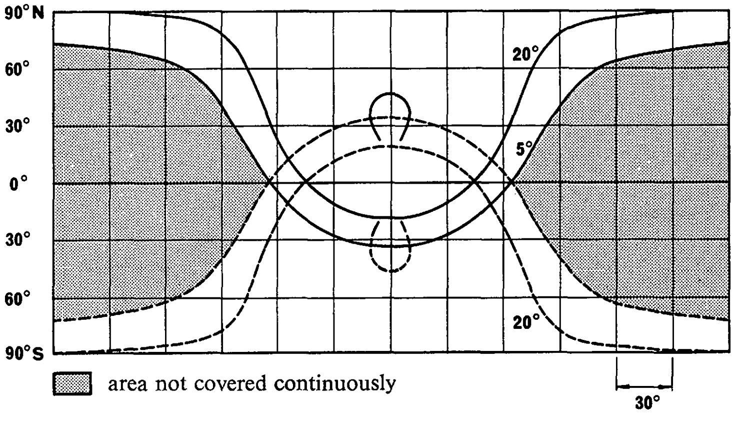


FIGURE 4*b*

Continuous coverage obtainable with satellites in inclined 24-hour circular orbits with a common Earth track, showing minimum angles of elevation

Four satellites at six-hour intervals around the Earth track, the orbits inclined at 45°, the active arcs are three hours before and after the most northerly and southerly excursions

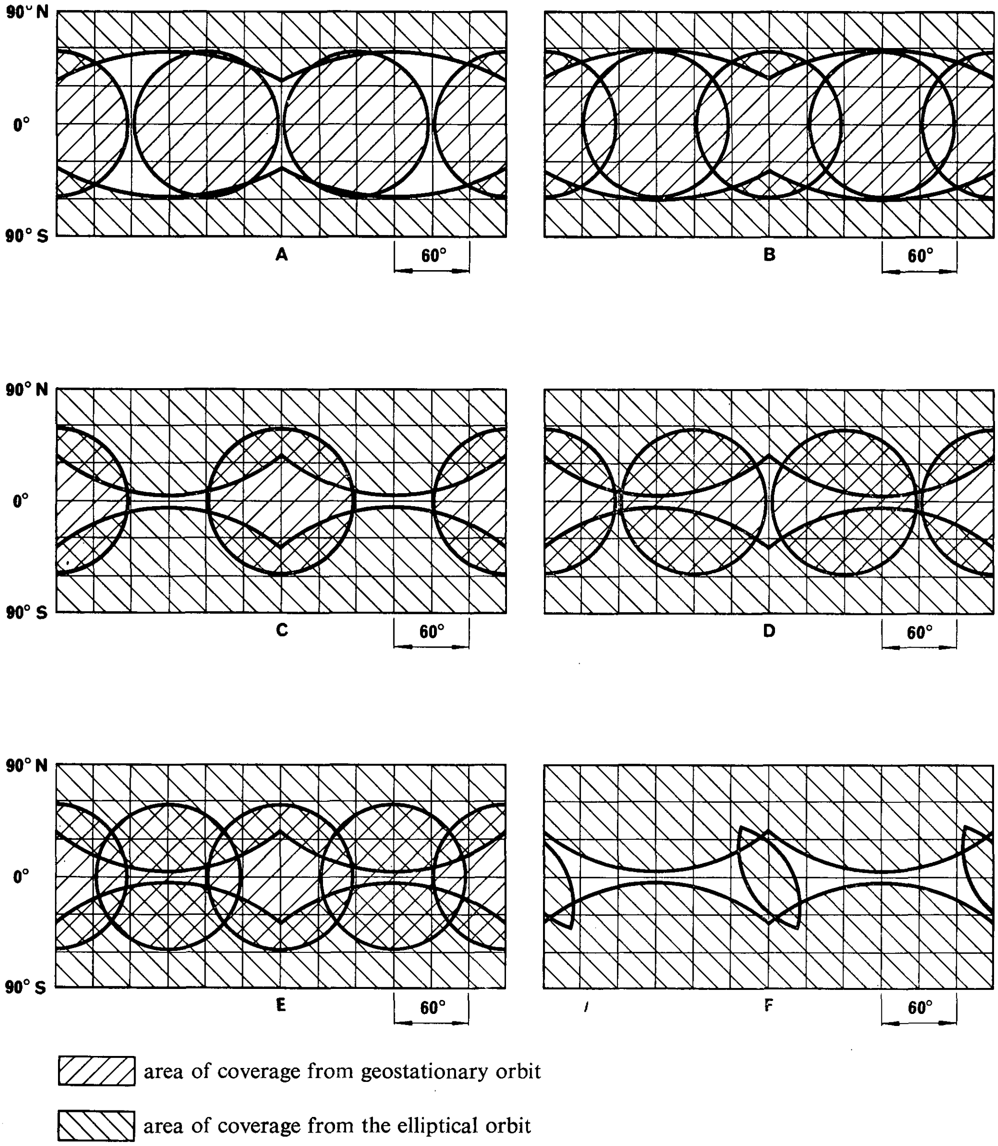
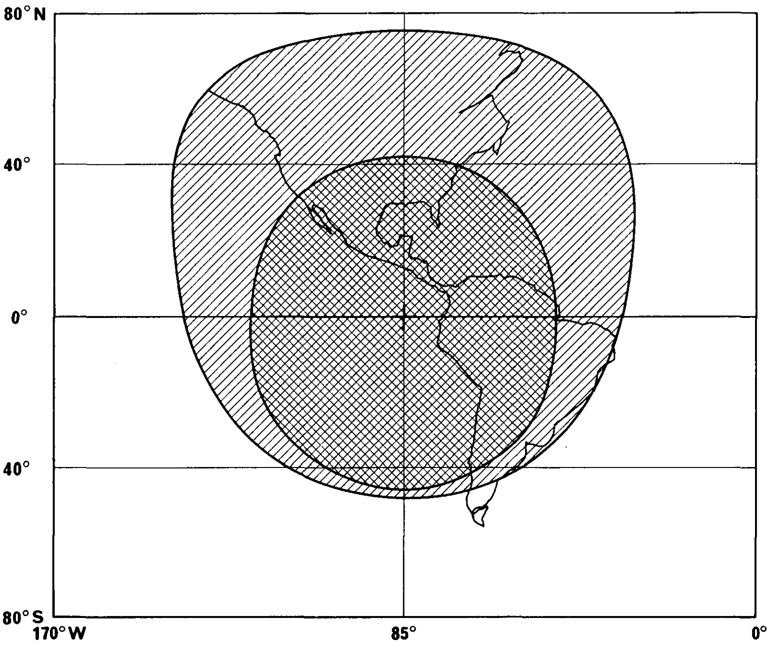


FIGURE 5

Areas of coverage for several sub-systems of the communication-satellite systems described in Table IV, showing the areas where the angle of elevation is never less than 20°



Accurate position, altitude, velocity, time and rate of climb information always available

Accurate position, time and velocity information always available

FIGURE 6

Coverage of four satellites " Y " constellation

REPORT 507 *

TECHNICAL CHARACTERISTICS OF SYSTEMS PROVIDING COMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR AIRCRAFT AND/OR SHIPS

Technical feasibility of systems employing space communication techniques jointly for communication and radiodetermination purposes

(Study Programme 17A/8)

(1970)

1. Introduction

In partial response to Study Programme 17A/8, this Report describes several methods of employing a satellite jointly for communication and radiodetermination purposes. The use of a single system with frequency sharing for both satellite communication and satellite radiodetermination applications provides several economic benefits. First, there are potential savings in the cost of the space segment, since fewer satellites are required if the system is shared. Second, a considerable reduction in user equipment costs may be achieved through the use of a common antenna and, in some cases, receiver, for both the communication and radiodetermination functions. In addition, there is an overall reduction in weight, both in the satellite and user equipment brought about through the shared use of equipment. The use of a single system could also result in more economical use of the frequency spectrum.

The technology required for the joint use of the same satellite for communication and radiodetermination has already been demonstrated in experiments with the United States ATS-1 and ATS-3 Applications Technology Satellites [1]. The techniques employed in these experiments, and other techniques that have been proposed, are described in this document along with satellite design and system considerations.

2. General system characteristics

The use of communication and radiodetermination signals through the same satellite repeater or transponder implies that the signals are located in the same frequency band. In general, a radiodetermination signal can be designed to occupy a bandwidth comparable to a voice or data signal, and can require less satellite equivalent isotropic radiated power (e.i.r.p.) than a voice signal. The bandwidth of a radiodetermination signal is a function of the accuracy of position determination (the better the required accuracy, the larger the bandwidth). The accuracy of position determination and speed of acquisition of the radiodetermination signal by the receiver are both functions of the satellite e.i.r.p., since they both increase with increasing signal-to-noise ratio. Furthermore, a longer access time allowance increases the accuracy of position determination because of the longer integration times possible.

* This Report was adopted unanimously.

The satellite repeater or transponder for relaying the voice, data and radiodetermination signals can provide a single wideband channel or separate channels with individual gain control or level limiting. The latter method can create difficult filter design requirements in the repeater. On the other hand, this approach has the advantage that the share of the total available transmitter power allotted to each carrier can be individually controlled. Consequently, the correct balance of satellite e.i.r.p. for the voice, data, and radiodetermination carriers can be obtained. *

Because of Doppler effects, plus transmit and receive carrier frequency instabilities that are inherent to any system, the required repeater bandwidth for a voice channel can range from about 15 to 50 kHz. For a data channel of 1200 to 2400 bits per second, a repeater bandwidth of 10 to 50 kHz can be expected. For high accuracy radiodetermination (0·01 to 0·1 km), repeater bandwidths as high as 2 MHz or more and/or high signal-to-noise ratios may be required.

3. Narrow-band satellite techniques

Several narrow-band satellite techniques have been proposed for radiodetermination applications. One suggested method [5] is based on the use of phase difference measurements made on several tones which modulate the carrier. The phase delay of each tone is measured either by the user or by a ground terminal.

Narrow-band satellite communication and radiodetermination techniques have been tested experimentally using the United States ATS-1 and ATS-3 Applications Technology Satellites. The VHF repeaters of the satellites used for these tests employed an up-link frequency of 149·22 MHz and a down-link frequency of 135·6 MHz. While the techniques may be used in other radio-frequency bands, one of the objectives of the experiments has been to determine the usefulness of a VHF communication repeater for radiodetermination purposes.

In the radiodetermination experiments, a tone-code ranging signal is used consisting of a 0·4 second transmission of a 2·4414 kHz tone followed immediately by a 30-bit digital address code transmission lasting approximately 12 milliseconds [1]. The address code is formed by transmitting an audio cycle for a digital " one " and suppressing a cycle for a " zero ". Alternatively, phase shift keying could be used for the code. The bandwidth of the modulating signal is within the 2·5 kHz audio bandwidth commonly used for mobile communication, except during the 12-millisecond code transmission when components up to 4 kHz are present. The signal repetition rate can be established at the option of the system designer.

The ATS-1 and ATS-3 experiments have employed both aircraft and ships for communication and radiodetermination test purposes. During these tests, the standard deviation of the range measurements from the two satellites to the mobile terminals has measured less than three microseconds for 95% of the time; however, the absolute range measurements may have been subject to bias errors due to ionospheric retardation [6].

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* It is also possible to combine voice, data or radiodetermination signals on a single frequency-multiplexed carrier, or else to time-multiplex these signals.

Plans have been made to perform experiments in the frequency band 1540—1660 MHz currently allocated to the aeronautical mobile service to evaluate the feasibility of this frequency band for joint space communication and radiodetermination purposes with mobile users. The later Applications Technology Satellites will be employed for these tests.

4. Wideband satellite techniques

Wideband techniques have been studied [2, 3] that employ spread spectrum multiple access modulation techniques, where pseudo-random sequences are used to spread the spectrum of the information. A satellite system which uses a simple limiting repeater, with all of the signals simultaneously occupying the full bandwidth of the repeater, might require bandwidths ranging from one to two per cent and operate in the 100 MHz to 5 GHz frequency range.

The radiodetermination signal might be generated in two ways. In the first way a ground terminal would transmit a repetitive pseudo-random sequence which would be relayed via a satellite hard-limiting repeater to the user being addressed, and detected with a matched filter. The user would then retransmit to the satellite the same pseudo-random sequence after a known time delay from the detection time. The ground station would detect the retransmitted signal in the same manner as the user equipment. The total two-way range may then be determined from the total time delay. Since the ranging error is inversely proportional to the bandwidth, the spread spectrum method, which utilizes the total bandwidth of the system, can provide an accuracy fully equivalent to a CW tone ranging system.

A second method of system operation is to employ several satellites which emit pseudo-random sequences in time synchronism. The users in the system must have the capability of detecting the pseudo-random sequence from each of the satellites and make time difference measurements to determine the difference in the ranges to the satellites.

The communication in each method can also be performed by using a pseudo-random sequence to spread the spectrum of digitized voice or data. Each of the users has access to the satellite simultaneously with each signal occupying the total bandwidth of the repeater. Addressing is accomplished by the assignment of a unique pseudo-random sequence for each of the users. Information transmitted to a user via the satellite is detected with a matched filter technique.

Wideband spread spectrum techniques have the advantage of simultaneous access to the system by all the users, as well as narrow-band interference rejection. However, these techniques have the disadvantage that the user's signal-to-noise ratio generally decreases with the number of simultaneous users. Additionally, at VHF, spread spectrum techniques may present difficulties at high latitudes due to the effect of large-scale ionospheric irregularities which produce fading [7].

5. Multiplexing techniques

Techniques to combine voice, data and radiodetermination signals have been studied in France [4]. If time-division multiplexing is employed, the combination can be achieved most readily if the voice signals are transmitted in binary digital form. This can result in a more economical use of the spectrum, increased efficiency in the satellite repeater and the possibility of using a single receiver in the vehicle to receive all the desired signals. Multiplexing also permits interrogation and data signals to be sent simultaneously to all the mobile terminals and this may lead to improved efficiency in an operational system. Moreover, if the signals are multiplexed and transmitted at rates of the order of several tens of kilobits per second, high precision radiodetermination may be achieved.

Frequency-division multiplexing can also be employed to combine the signals. In this case, the data and radiodetermination signals can be transmitted as modulated sub-carriers simultaneously with analogue voice signals. Upon reception, the combined signals can be separated by appropriate bandpass filtering.

6. Conclusions

6.1 Radiodetermination by means of signals transmitted from earth satellites can be accomplished through the use of either narrow-band or wideband techniques.

6.2 Experiments employing satellite communication repeaters in the VHF band have demonstrated that radiodetermination techniques can use a communication channel. Channel occupancy times of the order of 0·4 second have been demonstrated with ATS-1 and ATS-3.

6.3 The bandwidth of a radiodetermination signal is a function of the accuracy of position determination (the better the required accuracy, the larger the bandwidth). The accuracy of position determination and speed of acquisition of the radiodetermination signal by the receiver are both functions of the satellite e.i.r.p., since they both increase with increasing signal-to-noise ratio. Furthermore, a longer access time allowance increases the accuracy of position determination because of the longer integration times possible.

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REPORT 508 *

TECHNICAL CHARACTERISTICS OF SYSTEMS PROVIDING COMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR AIRCRAFT AND/OR SHIPS

Factors affecting the choice of performance objectives in the maritime mobile communication-satellite service

(Question 17/8, Study Programme 17A/8)

(1970)

Study Programme 17A/8, in calling for the study of the technical characteristics of communication-satellite links in a maritime-mobile satellite service, recognizes that a need exists for more reliable communication between land stations and distant ships. To determine the technical characteristics of such a communication-satellite system it is desirable to reach prior agreement on the performance objectives. This Report considers some of the factors to be taken into account in determining the performance objectives for telephony used for public correspondence (i.e. for private or business calls extended over the public telephone network).

There are at present no performance objectives recommended by the C.C.I.R. for the long-distance maritime service on which the objectives for a communication-satellite service might be based.

The present long range services use band 7 (HF) and it is felt that the performance objectives for a satellite system should represent an improvement over the performance actually obtained with the present methods. Such an improvement could be represented for example by the standard described as " good commercial quality " for the fixed service in band 7. This standard is defined in Recommendation 339-2 as an audio-frequency signal-to-noise ratio of 33 dB achieved for 90% of the time. In accordance with the normal practice used in telephone communications, it would be preferable that the objective be specified as a psophometrically weighted figure, in which case the quoted 33 dB would become approximately 35 dB.

This last figure may now be compared with the objectives given in Recommendation 353-2 for intercontinental satellite circuits providing point-to-point services. According to this Recommendation the permissible mean noise power in any hour should not exceed 10 000 pW0p. For a signal level equal to that of the mean speech level in an active channel of an international circuit the corresponding mean signal-to-weighted noise ratio at the end of a hypothetical reference circuit is in this case approximately 40 dB.

The maritime-mobile service, however, will have only a relatively short connection in the ship to the telephone instrument and it is therefore reasonable that the communication-satellite link itself need not meet such a high standard of performance as one which forms part of a long intercontinental connection.

Before a firm decision on an objective can be taken it is necessary also to take account of the performance which can be achieved in practice. It is the satellite-to-ship link of the circuit for which it will be most difficult to achieve a high standard of performance. For example the combined effects of link loss and noise temperature may be some 40 dB worse than that for a typical communication-satellite link used for point-to-point services.

* This Report was adopted unanimously.

The main factors which will determine the signal-to-noise ratio for this link are the satellite e.i.r.p. available, the frequency, the gain of the ship's antenna, the noise figure of the ship's receiver, the modulation method employed and any special techniques such as speech processing. Due to the problems of the design of the ship's antenna in various frequency bands it is clear that the need for low cost, high reliability and ease of maintenance will set a limit to the antenna gain and therefore to the overall performance. If frequency modulation is used the satellite e.i.r.p. required will not be very sensitive to changes in the required channel signal-to-noise ratio provided sufficient bandwidth is available.

A further point to be considered is that the high acoustic noise environment in some vessels may prevent full advantage being taken of a high quality circuit.

It may well be that the effects of various constraints (including the economic ones) could result in early systems being designed to a standard below that which is considered suitable as a long-term objective. However, it would appear that, for circuits which are to be extended over a public telephone network for public correspondence, the final objective for the weighted signal-to-noise ratio to be met for at least 90% of the time should lie somewhere in the range 30 to 35 dB, or, assuming speech processing techniques are used, have a subjective quality which is equivalent to this. The equivalent objective for circuits not to be extended over a public telephone network, e.g. operator-to-operator circuits, has not been considered in this Report but clearly a lower standard may be acceptable in this case.

Further studies are required which take into account factors such as those above to determine the signal-to-noise ratios likely to be achievable and that these be considered when deciding what the design objectives should be.

The completion of the studies referred to should be treated as a matter of urgency since the frequency spectrum requirements of the maritime-mobile communication-satellite service will depend among other things on the technical design parameters which will themselves depend on the performance objectives.

REPORT 509 *

SIGNAL QUALITY AND MODULATION TECHNIQUES FOR RADIOCOMMUNICATION SATELLITE SERVICES FOR AIRCRAFT AND SHIPS

(Question 17/8)

(1970)

1. Introduction

This Report discusses signal quality specifications and the power efficiency characteristics of various voice and digital data modulation techniques for radiocommunication services by space techniques for aircraft and ships. It can be shown that if a system is designed to accommodate voice links, sufficient power would be available in that system to accomplish data transfer at rates of about 3 kilobits/second.

* This Report was adopted unanimously.

2. Voice modulation

A variety of modulation techniques (e.g., angle modulation—narrow-band frequency modulation (NBFM), wideband frequency modulation (WBFM); amplitude-modulation—single-sideband (SSB), double-sideband suppressed carrier (DSB-SC), etc.) and baseband voice processing techniques (baseband truncation, pre-emphasis, peak-clipping, vocoding, etc.) may be employed to implement communication links via satellite relay. The quality of a voice communications channel is frequently related to the signal-to-noise ratio (SNR) at the output of the voice demodulator. Several reasons discourage the use of SNR for this purpose. First, it must be characterized in terms of the baseband bandwidth (truncation), the shape of the noise background spectrum (pre-emphasis) and the amount of clipping (peak-to-r.m.s.) employed. Second, the standard frequency modulation improvement equation applies strictly to sine wave modulation and is valid only if heavy clipping (peak-to-r.m.s. ratio of 3 dB) is used. Third, the use of Carson's rule to determine the required intermediate frequency bandwidth is accurate only for a noise-like baseband modulating signal. No comparable expression for the bandwidth occupied by a voice signal has been developed.

The Articulation Index (AI) of a speech circuit indicates the effective proportion of an ideal voice channel (with respect to intelligibility) which that circuit will provide under the given signal and noise conditions [1]. In this technique the audio-band is non-linearly divided into 20 bands, each of which provides an equal contribution to the intelligibility of speech. This contribution is independent of what happens in the other segments. A signal-to-noise ratio of 30 dB must be provided in each of the bands, if an AI of 1·0 is to be achieved. Because voice power varies as a function of frequency, the effect of a given level of noise in each band will also vary. Therefore, they are weighted accordingly.

The relationship between Articulation Index (AI) and the radio-frequency signal-to-noise density at the receiver (C/N_0) is a convenient method for comparing the power efficiency of the modulation techniques. The AI of a speech circuit gives an unambiguous representation of the system's intelligibility and can be measured directly, thus facilitating the absolute comparison of various schemes. An example of the unique relationship between AI and Rhyme Word Air Traffic Control (ATC) Message intelligibility scores obtained by a specific test crew using a specific language and word list is illustrated in Fig. 1 [2]. The Rhyme Word scores are representative of inexperienced users, while the ATC Message scores are typical of air carrier pilots and air traffic controllers. An environment with no background noise is assumed in both cases. Personnel using an aeronautical mobile voice link in oceanic areas are quite experienced and the ATC Message curve typifies this type of operation. This may or may not be the case over land areas where less experienced pilots may use the air traffic system. It is expected that a similar relationship for maritime communications may be represented by a curve between those of ATC Messages and Rhyme Words.

2.1 *Voice quality*

The basic goal of a voice communications service for aeronautical and maritime traffic and operational control is to convey an adequate level of message intelligibility with very high reliability. A high level of intelligibility is advantageous because it may eliminate the need for message repeats and permits a higher word rate to be conveyed. However, its disadvantages include greater system costs associated with higher radiated power levels and a possible degradation of performance during below-threshold signal conditions. Thus, it is extremely important to determine accurately the minimum required signal quality for each type of service. In addition, because communication is a statistical process, the quality of the system should be specified for more than one design point. The intelligibility provided most of the time (e.g. 95%) and near worst case (e.g. 99·9%) conditions are two figures which have significant importance. High quality communications (>95% intelligibility) should be provided for the former and operation should be above the threshold of intelligibility under the latter conditions.

2.2 *Analogue voice modulation techniques*

An analysis of various analogue voice modulation techniques indicates that the two primary candidates for efficient and practical application to communications relay via satellite are narrow-band frequency modulation (NBFM) and single-sideband (SSB). Both have the potential for providing the aforementioned voice quality at reasonable expenditures of satellite power. Other factors, such as aircraft or ship equipment complexity, reliability and cost, will probably bear heavily on the choice of modulation scheme.

The design parameters of an FM voice communications system which has been optimized to operate above receiver threshold and provide an AI of 0·6 with the minimum total signal power is as follows:

— direct carrier NBFM;

— no pre-emphasis;

— clipping such that the peak-to-r.m.s. ratio of the modulating wave form is 6 dB;

— radio-frequency bandwidth of 10 kHz;

— use of phase-locked demodulator with threshold extension.

A reduction of the baseband signal to 2 kHz bandwidth and use of a 5 kHz radio-frequency bandwidth improves the intelligibility slightly for the condition of very weak signal levels; however, the upper band of AI achievable will be less than that achievable by wider base bandwidth systems. Correspondingly, an increase of radio-frequency bandwidth to 18 kHz lowers performance under marginal signal conditions but yields a higher level of AI when exceeding receiver threshold. The phase-locked demodulator is slightly more complex than the conventional frequency-modulation discriminator; however, a significant advantage of 4 dB in threshold level is obtained. In the near future, the phase-locked demodulator will require a very small additional investment. For a frequency-modulation system, power levels in the satellite must be such that the system operates above the receiver threshold most (e.g. >95%) of the time.

At lower AI's (<0·5), the FRENA (*Fre*quency a*n*d *A*mplitude) technique [3], which transmits an infinitely clipped SSB signal and a low frequency replica of the voice signal's amplitude variations, is more power efficient than NBFM; however, it cannot achieve the high AI's that are possible with NBFM or SSB. The transmitted spectrum occupies a radio-frequency bandwidth of 3 kHz.

An SSB system designed to provide the highest AI for any given signal power would have the following parameters:

— 6 dB per octave pre-emphasis above 800 Hz in baseband;

— 5 kHz baseband truncation;

— radio-frequency clipping with a peak-to-r.m.s. ratio of 6 dB.

Reducing the base bandwidth would require additional power in order to produce any given AI. For SSB operation, it is noted that clipping of the radio-frequency signal introduces significantly less distortion than clipping of the baseband signal.

2.3 *Comparison of analogue modulation technique performance*

The relation between articulation index and signal-to-noise density at the receiver is shown in Fig. 2 for various modulation techniques. For example, for the condition of a peak power limited satellite and a signal-to-noise density of 46 dB-Hz, it is noted that SSB yields an AI of 0·45 and 8 kHz and 18 kHz bandwidth frequency-modulation yield 0·55. This C/N_0 is the threshold value for an 8 kHz system and is 3 dB below threshold point of an 18 kHz system. A signal-to-noise density of 49 dB-Hz yields AI's of 0·55, 0·60 and 0·85 respectively, and is at or above threshold in each of these frequency-modulation systems.

The results shown are based upon a theoretical analysis of data generated by tests with the English language.

In addition to voice quality and satellite radiated power requirements other factors must be considered before selecting the modulation technique. Some of these factors are: current user equipment, spectrum requirements, effects of oscillator instabilities and Doppler shifts, system reliability and costs.

2.4 *Comparison of digital voice transmissions by delta modulation and phase shift keying techniques* [4, 5]

The transmissions of voice by digital techniques could employ phase shift keying (PSK) and matched filters with an 8 kHz sampling rate and 16 levels. This would require a data rate of 32 kilobits/second and a bandwidth of 64 kHz. An error rate of better than 10^{-3} would probably be required which necessitates a predetection signal-to-noise ratio (SNR) of 7 dB and a carrier-to-noise density ratio of 55 dB-Hz in the 64 kHz bandwidth. This would provide a signal-to-noise ratio of 28 dB in the 300 to 3000 Hz post detection bandwidth.

A delta modulation system with double integration could also be employed. This technique is more power efficient than PSK with an 8 kHz sampling rate at data rates less than 60 kilobits/second and higher error rates would be acceptable. Delta modulation with an 18 kilobits/second data rate would require a predetection signal-to-noise ratio in the 36 kHz bandwidth of –1 dB for an error rate of 10^{-1}. The required carrier-to-noise density ratio would then be 45 dB-Hz. The post detection signal-to-noise ratio provided in the 300 to 3000 Hz bandwidth would be 22 dB. This technique can utilize available integrated circuits which would reduce the size and weight of the modulator/demodulator.

It is to be noted that:

— at the data rate of 25 kilobits/second and with an infinite signal-to-noise ratio, delta modulation provides a post detection SNR which is 8 dB better than PSK;

— delta modulation has the advantage of tolerating higher rates of transmission error than PSK, thus, for the same data rate, the carrier-to-noise density can be reduced.

3. Digital data modulation techniques

The implementation of a digital data link provides an efficient means for the transfer of position reports, maintenance data, and other record messages [6, 7, 8]. The use of this link would off-load a significant amount of communications time from the normal voice links.

3.1 *Compatibility with voice channel*

In order to minimize the overall aeronautical/maritime satellite service costs and to provide a maximum of operational flexibility, it is desirable that the basic system be capable of interchanging either digital data or voice modes in a typical voice channel and that common hardware be utilized.

3.2 *The human-machine interface problem*

Alphanumeric digital communication, such as via direct printing radio telegraph, can convey information to humans at nearly the same rate as voice, but through a much narrower bandwidth. Conversely a much higher rate of information may be contained in the same bandwidth.

Machines, such as digital data systems, cannot always interpret these human language alphanumeric messages. For this reason, it becomes necessary for the operator to translate his message into machine language or for this to be done after reception. Various coding (or "canned message") systems have been proposed with the objective of originating the human's message in machine language as all or part of a relatively short binary number. These systems range from the use of a simple pushbutton for each possible message to sequentially coded techniques capable of providing a high degree of message flexibility with a corresponding degree of compression.

These sequential techniques generate binary numbers in which the meanings of digits depend on their location in the number, according to the format of the selected message. Any stored data such as the transmitting craft's identity and any pertinent instrument data can be entered automatically, so only the human information need be entered manually, in the code and sequence appropriate to the message format. The element of message information associated with any given key is changed in a manner depending on the sequential order in which the keys are actuated. Keyboards exist which facilitate this entry by providing for sequential change of key designations. These changes may be accomplished by projection by a key-tape transport mechanism or by any other suitable means.

3.3 *Link capacity and quality*

The relationship between data rate and data quality may be adjusted in order to take maximum advantage of the specific link signal strength for particular applications. A nominal bit error probability of one in 10^5 bits may be used as a design goal for a typical application [9]. Error correction codes may be employed if higher data quality is desired for a particular data service.

It is anticipated that the total data load to be relayed from mobile craft to ground based terminals may be significantly larger than the reverse path. It is also important to note that the technical and economic constraints which limit the selection of equipment for the relatively few earth terminals are much less severe than those limiting the implementation in the great number of mobile craft.

3.4 *Digital data modulation techniques*

The most efficient of the angle modulation techniques is coherent detection of direct carrier phase shift keying (bi-phase PSK); however, this approach requires relatively complex AFC tracking because there is no strong radio-frequency carrier signal. In order to maintain coherent reception, either a " times-two loop " or an " in-phase quadrature loop " is required, and resynchronization must be accomplished if modulation is not continuous. Some carrier power can be transmitted continuously if the modulation index is reduced. This reduces the link efficiency by about 1·7 dB, but would alleviate the AFC tracking problem.

The use of differentially coherent PSK also alleviates the problems associated with coherent synchronization; however, it is about 0·6 dB less efficient than bi-phase PSK when compared at a bit error rate of 10^{-5}.

The subcarrier PSK (PSK/PM) technique provides a radio-frequency carrier signal component which can be continuously tracked by all users. However, this method requires twice the bandwidth of the previously described techniques and the link efficiency is about 1·7 dB below that of coherent PSK.

The use of direct carrier frequency shift keying (FSK) would permit data to be time division multiplexed with FM voice and would enable common modulator/demodulator equipment to be utilized. However, this technique is 2·6 dB less efficient than bi-phase PSK. Predetection IF bandwidths on the order of the bit rate can be employed because of the unique nature of the FSK spectrum [10].

The use of subcarrier FSK (FSK/PM) would reduce the time required for initial acquisition and would provide continuous synchronization. This technique requires twice the spectrum of PSK and two demodulators in the receiver.

A comparison of the characteristics of candidate digital data modulation techniques is given in Table I. In addition to spectrum and power efficiency, other factors must also be considered before selecting the modulation technique. Some of these are: current user equipment, compatibility with voice equipment, propagation effects, and system costs.

TABLE I

Comparison of data modulation techniques

Characteristics	Digital data modulation techniques					
	Coherent detection PSK (bi-phase)	Differentially coherent PSK	PSK with carrier	Subcarrier PSK/PM	FSK (PCM/FM)	Subcarrier FSK/PM
Communications efficiency: Required C/N_0 for 600 bits/s with b.e.p. = 10^{-5} (dB-Hz)	38·0	38·6	39·7	39·7	40·6	42·3
Data capacity: Max. data rate for b.e.p. = 10^{-5} and C/N_0 = 45 dB-Hz (bits/s)	3000	2600	2100	2100	1700	1100
Relative amount of spectrum occupied by transmitted signal	2 Hz/bit/s	2 Hz/bit/s	2 Hz/bit/s	4 Hz/bit/s	2 Hz/bit/s	4 Hz/bit/s
Equipment complexity: Transmitter Receiver	Minimum Significant	Slight Significant	Minimum Moderate	Slight Moderate	Minimum Minimum	Slight Slight

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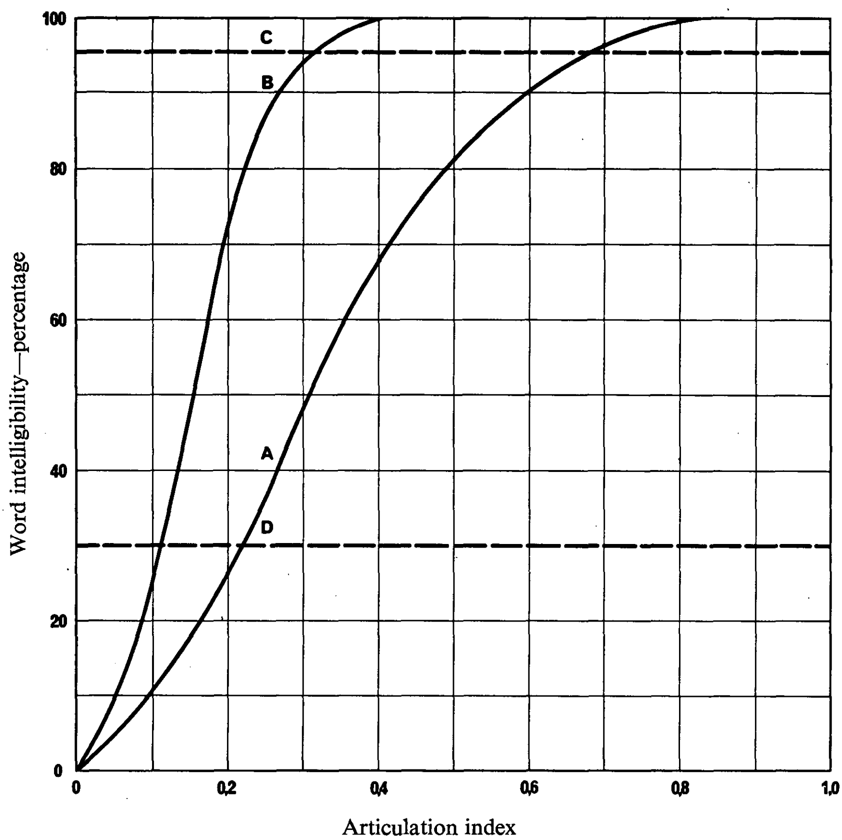

FIGURE 1

Percentage intelligibility as a function of articulation index

A: Modified rhyme tests
B: ATC message tests
C: Usual conditions (>95% of time)
D: Near worst case conditions (>99·9% of time)

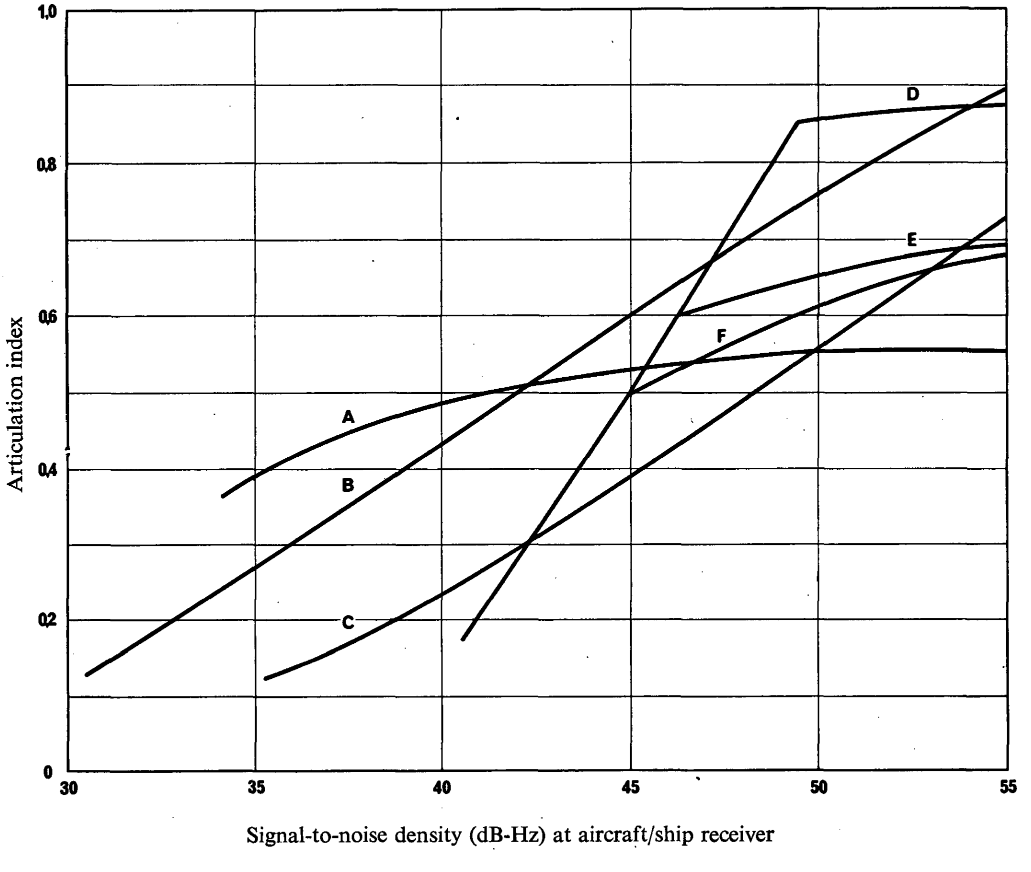

FIGURE 2

Comparison of optimized voice modulation techniques

A: FRENA
B: 5 kHz SSB-mean RF power
C: 5 kHz SSB-peak RF power
D: FM (18 kHz)
E: FM (10 kHz)
F: FM (8 kHz)

REPORT 510 *

THE EFFECTS OF CARRIER TO INTERMODULATION RATIO UPON RADIO-FREQUENCY CHANNEL SELECTION AND SATELLITE TRANSPONDER DESIGN FOR AERONAUTICAL AND MARITIME SERVICES

(Study Programme 17A/8)

(1970)

1. Introduction

This Report discusses the interrelation of channel spacing and carrier to intermodulation (*C/I*) requirements upon the design of channelized spacecraft transponders providing aeronautical and maritime communications services. If a non-linear transmitter follows the receiver, intermodulation products will be introduced which may affect system performance. Several alternative solutions are discussed.

2. Intermodulation products caused by transponder non-linearities

The direct current to radio-frequency power conversion efficiency of transponders, a significant factor in the overall spacecraft requirements, is highest when the final amplifier is operating in saturation. This limits the system to angle modulation schemes and inherently creates intermodulation products when a multiple number of signals are handled by the transponder. If the system is to perform within the constraint of a specified level of *C/I* such as 16 dB, then it is necessary that the channel spacing be controlled or the transponder be operated in the quasi-linear region.

2.1 *Controlled channel spacing*

If a hard-limiting transponder is used and the channels are equally spaced, the *C/I* for each signal will be 9 to 10 dB because odd order intermodulation products (i.e. the 3rd, 5th, 7th, etc.) will fall on the utilized signal channels. To alleviate this problem, controlled spacing frequency plans can be used. Babcock spacing [1] will prevent third order products from falling in the used signal channels and will increase the *C/I* ratio to greater than 20 dB. Another controlled spacing frequency plan for a four-channel system could utilize a spacing ratio of 3/4/5. With this plan the signals are free of both 3rd and 5th order products and the *C/I* ratio is approximately 30 dB.

Both the Babcock and 3/4/5 techniques require that a relatively large bandwidth be divided into many channels. The specific channels to be used by the satellite system are then selected from this group. Table I gives examples of the required channel assignments for 4- and 6-channel systems if this technique were employed. Computer programmes have been developed which facilitate the determination of other channel spacings which are free of 3rd and 5th order intermodulation products [2].

* This Report was adopted unanimously.

It should be noted that intermodulation products will still fall on unused channels. In the case of a 6-channel Babcock spaced system the C/I ratio of channels 6, 7, 10, 12 and 14 is 13 dB. If close frequency separation between satellite up- and down-links is used, such as the 6 MHz suggested in ARINC characteristic No. 566, then it is difficult to filter out the intermodulation products falling within the satellite receiver's passband [3]. Therefore selective spacing of even a four-channel system may not permit the use of a hard-limited transponder if the up- and down-links are closely spaced.

TABLE I

Channel assignments for Babcock and 3/4/5 frequency spacing plans

Frequency plan	Number of adjacent channels	Channels used in the system	Spectrum efficiency	C/I
Babcock 4 signals	7	1, 2, 5, 7	57%	20 dB
Babcock 6 signals	18	1, 2, 5, 11, 13, 18	33%	20 dB
3/4/5, 4 signals	13	1, 4, 8, 13	31%	30 dB

Fig. 1 (curves B and D) shows the bandwidth required by Babcock type spacing and equal channel spacing, respectively. The increased bandwidth required by Babcock type spacing must be accommodated by the satellite transponder, thereby requiring broader bandwidth front end and power amplifier designs. At first glance, Babcock spacing may seem an inefficient use of spectrum. However, the unused channels could possibly be used by other satellites or for terrestrial communications.

It has been suggested that a VHF communication-satellite system could operate on channels of 50 kHz spacing, but interleaved between the present 50 kHz spaced channels of the terrestrial aeronautical mobile service. This would imply that the aeronautical service channels would be spaced at 25 kHz. A prohibition of the use of alternate channels essentially doubles the maximum bandwidth spread of channels as shown in Fig. 1 (curves A and C).

2.2 *Quasi-linear transponder*

The generation of intermodulation products can be reduced in equally spaced channel systems by operating the transponder in a low efficiency non-saturation mode. A linear transistor amplifier will have a C/I ratio of greater than 30 dB, but will have an efficiency of only about 30% versus 89% for the limiting type amplifier. An optimized system would utilize a quasi-linear transponder which gives a C/I ratio of greater than 16 dB for equally spaced signals but which reduces the efficiency by approximately 0·4 dB for transistor transponders. A 2 dB or 5 dB efficiency reduction would be required for 4 or 8 channel systems, respectively, if travelling wave tube amplifiers (TWTA) were necessary.

2.3 *Power conversion efficiency*

The ratio of effective radio-frequency output power per channel to the direct-current power required from the satellite power sub-system is a function of different variables, in particular: channels to be accommodated, the frequency band of operation, the type of frequency channel assignment, and the type of final stage power amplifier to be used. For the case of transistor operation, the efficiency takes into account the basic collector efficiency and losses associated with the driver, back-off to reduce intermodulation interference for multi-channel operation (quasi-linear operation), DC-DC conversion, intermodulation products and 1 dB for channel limiter variations, ageing and temperature variance.

The efficiency reached by the transistorized VHF equipment of the ATS-3 satellite (1967) was 67% (single channel operation), a value which is very close to the theoretical limit. The efficiency of transistorized UHF equipment is presently still far from the theoretical limit. The efficiency reached by the travelling wave tube UHF equipment of the ATS-5 satellite (1969) was 25% (single channel operation). In a manner similar to VHF experience it may be expected that in the near future, as improved transistors become available, that transistorized UHF amplifier performance will also approach the theoretical limit.

It is seen from Fig. 2 that the use of Babcock channel separations significantly increases transponder efficiency for more than two-channel operation by eliminating interfering third-order harmonics.

3. Conclusions

Babcock spacing of the channels enables the use of a hard-limiting transponder only if sufficient frequency separation between the up- and down-links is provided and the intermodulation products falling on the unused channels do not affect other systems. A TWTA handling more than four UHF channels will require about 3 dB less direct-current power if hard limiting is allowed.

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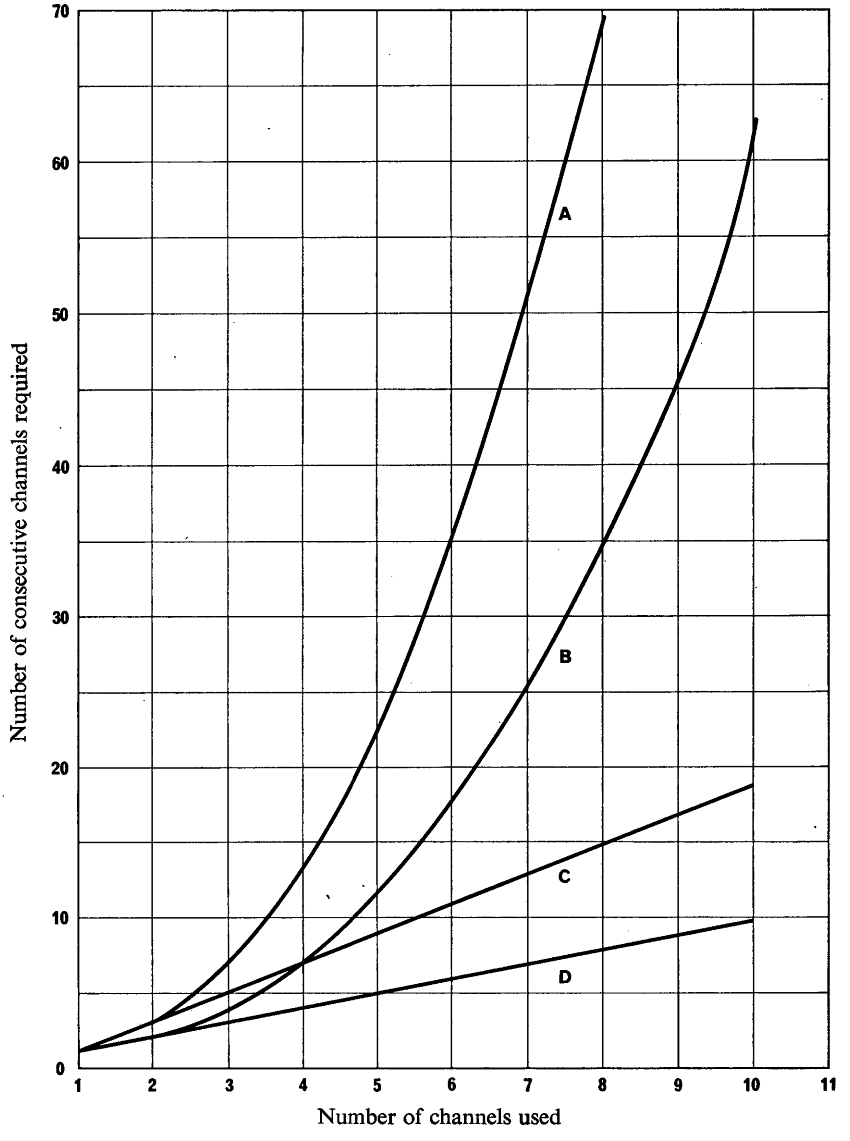

FIGURE 1

Bandwidth requirements for various channel spacing regimes

A: Babcock—Alternate channel restriction
B: Basic Babcock spacing
C: Equal spacing—Alternate channel restriction
D: Equal spacing

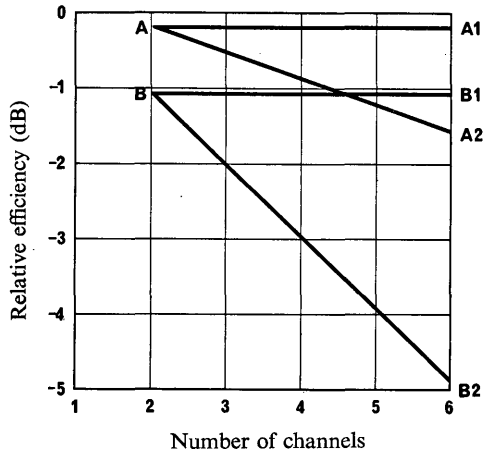

FIGURE 2

Relative power conversion efficiency for selected transponder types and channel spacing schemes (C/I ⩾16 dB)

A: Transistor transponder
A1: Babcock spacing
A2: Equal spacing
B: Travelling wave tube amplifier
B1: Babcock spacing
B2: Equal spacing

REPORT 511 *

FEASIBILITY FOR STATIONS IN THE AERONAUTICAL AND MARITIME-MOBILE SERVICES TO SHARE THE SAME FREQUENCY BANDS WHEN USING SPACE COMMUNICATION TECHNIQUES

Preliminary operational and economic considerations

(Study Programme 17A/8)

(1970)

1. Introduction

The future communication and radiodetermination requirements for aeronautical and maritime-mobile services are likely to be similar in certain respects. Because of these similarities, they may be able to share the same communication and radiodetermination systems and the same radio-frequency bands. Such system and spectrum sharing may offer both economic and operational advantages as well as providing for more efficient use of the radio-frequency spectrum [1]. Economic benefits can accrue by establishing either a common system or two separate systems by means of a single launch vehicle and spacecraft. Operational advantages can be realized through a joint communication system for search and rescue purposes and for distress purposes subject to the necessary agreements between the aeronautical and maritime-mobile services. If the operational requirements of the two services can be met in the same radio-frequency band, more efficient use of the radio-frequency spectrum may be realized.

2. Requirements

Sharing arrangements between the aeronautical and maritime-mobile services must take into account the differences in requirements for communication services needed by each. Aircraft, because of their higher speeds and closely controlled traffic patterns, have significant portions of their communications directly related to the safety and regularity of flight and traffic control. These types of communication are primarily radiotelephone and have an urgency attached to timely and frequent reports. Long range ship communications are primarily in support of ship operations and are primarily of record (telegraphic) types. While in general, communication requirements are less urgent than those of aircraft, some types of ship traffic such as environmental observations require timely transmission. Both aircraft and ships have common needs for distress and search and rescue communications. Position determining accuracy requirements for ships and for the air traffic control system may be of the same order, but the ATC system would generally require individual position determinations at much more frequent intervals than ships do because of the much higher speed of aircraft.

* This Report was adopted unanimously.

3. Frequency band considerations

For a world-wide system, technical factors limit consideration of communication-satellite systems to frequencies between about 70 MHz and 10 GHz [2]. Within this range, frequencies in the bands 118-136, 1540-1660, 4200-4400 and 5000-5250 MHz are allocated for aviation use; certain frequencies in the band 156-174 MHz are allocated for ships' use with limited aircraft use permitted. There is question as to what time in the future frequencies much above 1660 MHz will be operationally and economically feasible for use generally by the aeronautical and maritime-mobile services. Although there would appear to be technical advantages if a frequency allocation in the region 400 to 500 MHz were available, consideration is being given at this time only to VHF (118-136, 156-174 MHz) and UHF (1540-1660 MHz). The 118-136 MHz band is heavily used for conventional air/ground communication purposes on a world-wide basis. Certain frequencies within band 156-174 MHz are extensively used for maritime communications in some areas. The band 1540-1660 MHz is at the present time relatively uncongested.

4. Sharing possibilities

Three sharing possibilities between aircraft and ships are:

— sharing the same system utilizing the same frequency band and common channels;

— sharing the same system utilizing the same frequency bands and common channels for common needs (distress, search and rescue, radiodetermination, and public correspondence) and exclusive channels for unique needs (air traffic control, Notice to Mariners and Notice to Airmen);

— sharing the same system utilizing the same or different frequency band but each service having exclusive channels.

Some of the detailed considerations of the possibilities follow.

4.1 *Use of common channels*

If a sufficient number of discrete frequencies is available within a given frequency band to provide a multiple access system, then it would be feasible to use common channels by aircraft and ships. However, this arrangement would be operationally acceptable only if either there were enough channels in the system to assure immediate availability of a channel to meet operational requirements or a system of pre-emption were to be provided. It has been noted, however, that on transoceanic routes, aircraft requirements tend to peak at certain times [3]. Thus a system designed to handle the peak high priority telecommunication requirements (ATC, etc.) would have capacity available for other purposes during non-peak periods.

Joint operational use of the same band will necessitate an international understanding or arrangement among those organizations concerned with such matters; for example, I.T.U., I.C.A.O., and I.M.C.O.

4.2 *Common channels for common needs*

Such a system would retain the feature of the one described in § 4.1 but common channels would only be provided for common needs. The unique requirements of each service would be satisfied by exclusive channels.

In the aeronautical VHF band (118-136 MHz), studies have indicated that if some constraints can be accepted, a properly designed satellite system could be interleaved between the existing 50 kHz channelling scheme for conventional air/ground communications (see Report 512). On a technical basis, ship stations also could be accommodated on the interleaved channels because the technical restraints are less severe. Such use would be subject to the necessary agreement between the aeronautical and maritime-mobile services. However, because of the present and projected operational requirements by aviation for both conventional and satellite-relay communications, there is some doubt that the additional channel requirement imposed by ships could be satisfied in this band.

It may be difficult to earmark a number of international maritime-mobile channels within the band 156-162 MHz together with an equal number of channels in the band 162-174 MHz to provide for the needs of the maritime service for space communication techniques. There is doubt that enough spectrum space could be found between 156 and 174 MHz to provide for the requirements of both the aeronautical and maritime uses because of present and projected maritime requirements. Extensive use of frequencies throughout these bands by the land-mobile services is a further complicating factor.

A system design usable by both aircraft and ships within the band 1540-1660 MHz would provide the necessary common and discrete channels for each. However, further studies and tests are required in this regard.

4.3 *Exclusive channel assignments*

This alternative would provide exclusive frequencies for aviation and exclusive frequencies for maritime services. Such an arrangement assumes no common channels and availability of the necessary number of frequencies to independently support both the aircraft and ship needs within the same or different frequency band. Of the three possibilities considered this makes the least effective use of the spectrum.

5. Conclusions

5.1 Considerable additional work is necessary in cooperation with I.C.A.O. and I.M.C.O. to develop the technical, economic and operational data required for an assessment of the feasibility and desirability of the various frequency sharing arrangements for stations in the aeronautical and maritime-mobile services when using space techniques.

5.2 On the basis of information available it appears that the most effective system could be one which utilizes a common satellite, common frequency bands and common channels for common needs, and which provides for exclusive channels for ships and aircraft for unique needs. Concurrently, sharing between ships and aircraft of the exclusive channels of the other should be permitted on a basis of operational experience, validation of requirement and development of agreement between the aeronautical and maritime-mobile services. Factors of economics will have major significance in any system to be implemented. The primary consideration of the system design should be that of meeting the operational needs.

5.3 Allocations in the UHF band, particularly above 1 GHz, should be made in such a way as to provide maximum flexibility and to permit either separate or joint use by the aeronautical and maritime-mobile services as may be required.

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REPORT 512 *

FEASIBILITY OF SYSTEMS EMPLOYING SPACE COMMUNICATION TECHNIQUES FOR AIRCRAFT TO SHARE THE SAME FREQUENCY BAND BY INTERLEAVING WITH THE CONVENTIONAL VHF TERRESTRIAL AERONAUTICAL SERVICE

(Study Programme 17A/8)

(1970)

1. Introduction

The feasibility of communication-satellite service for aircraft to share the same frequency bands with land stations in the aeronautical-mobile service should be examined from the point of view of having the least effect to and from existing or proposed operations and with the aim of securing the efficient use of the radio-frequency spectrum. The prospects for systems employing both conventional and space techniques for communications with aircraft to use the same frequency band are limited by two characteristics which differ from the fixed services. These are the variable geometry of the transmission paths and the differences of antenna directivity. In order to determine the effect of one system upon the other, it is necessary to consider the technical characteristics of both systems. At the present time in the conventional aeronautical service, these characteristics are well known only for the VHF band.

Therefore, only that band is considered herein. A great deal depends upon the nature of the yet undefined operational requirements which any satellite-relayed communications system will have to meet. Once these requirements are made known, technical decisions can be made about the choice of system. Co-channel operations on existing channels may possibly be accomplished with sophisticated modulation techniques or by using time sharing systems, but these techniques are not treated in this Report. It does consider one mode of sharing which has been suggested and studied in some detail [1, 2]. In considering a full Earth-coverage system, a possible solution may be to use the technique of channel interleaving. Specifically, channel interleaving in the VHF aeronautical-mobile service would require the establishment of additional communication channels for systems using space techniques on frequencies spaced 25 kHz from existing 50 kHz channels now in use for the terrestrial aeronautical-mobile service. Proposals have been made to establish systems using space techniques for operational evaluation utilizing 25 kHz interleaved channels.

The United States Federal Aviation Administration conducted some operational tests to determine if interference might be caused by ATS-1 satellite transmission on 135·6 MHz. Those aeronautical stations on co-channel assignments and a number of other monitoring stations especially implemented for these tests were unable to detect any signal from the satellite, indicating that there would be no interference to the land station. As to be expected, when aircraft were within line-of-sight of a conventional aeronautical station transmitting on a co-channel assignment they experienced disruptive interference to reception of satellite signals.

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* This Report was adopted unanimously.

2. Channel interleaving

The effects of interleaving are mainly influenced by the selectivity of the receivers, the power and modulation modes of the transmitters, and the geographical separation of the stations. This Report relates to the possibility of using interleaved frequency-modulation channels spaced 25 kHz from existing amplitude-modulation channels (allotted on a 50 kHz basis). Sharing between these services involves eight potential types of interference paths, as shown in Table I. The characteristics of stations in the conventional services have been identified by the International Civil Aviation Organization (I.C.A.O.). Experimental results with the ATS satellites suggest appropriate characteristics for stations using space techniques in these bands. Table II lists the characteristics assumed in this Report.

TABLE I

Potential interference paths

Transmitter	Receiver			
	Land station	A/C	A/C(s)	Satellite
Land Station	—	D	U	U
A/C	D	—	U	U
A/C(s)	U	U	—	D
Satellite	U	U	D	—

Land station —Conventional aeronautical VHF land station
A/C —Aircraft using normal mode VHF
A/C(s) —Aircraft using satellite mode VHF
Satellite —Aeronautical satellite
D —Desired signal path
U —Undesired signal path

TABLE II

Assumed station characteristics

	Conventional mode		Satellite mode	
	Land station	Aircraft	Satellite station	Aircraft
E.i.r.p.	15 dBW	14 dBW	24 dBW	25 dBW
Modulation	6A3	6A3	15F3	15F3
Receiver bandwidth (nominal)	30 kHz	30 kHz	20 kHz	20 kHz
Receiver flux-density	—120 dBW/m²	—109 dBW/m²	—137 dBW/m²(1)	—138 dBW/²(1)
Receiver aircraft altitude	—	13 716 m (45 000 ft)	—	13 716 m (45 000 ft)

(1) At 90° elevation angle.

3. Laboratory tests

The United States Federal Aviation Administration has conducted some preliminary measurements aimed at determining maximum level of unwanted signal that would degrade communications speech intelligibility [2]. Talker-listener intelligibility for voice communications was determined by means of a machine which simulates voice signals (Speech Communication Index Meter). The signal-to-interference ratio was determined with relation to frequency channel spacing, bandwidth and modulation type. The results of the measurements do not take into account antenna directional characteristics or the effects of varying satellite elevation angles.

The nominal " 30 kHz " test receiver had a selectivity of 34 kHz at 6 dB bandwidth and 69 kHz at 60 dB bandwidth. This closely relates to the characteristics of aircraft receiver in current use by commercial aviation. The nominal " 20 kHz " test receiver had a bandwidth of 24 kHz at 6 dB and 60 kHz at 60 dB. It should be noted that aircraft in the satellite mode may utilize receivers that have a somewhat narrower bandwidth than the receiver used in these tests. A conventional discriminator was used in the frequency-modulation receiver and a sharp threshold of Articulation Index (AI) can be noted in Fig. 1 in the co-channel curve at a protection ratio of 10 to 12 dB. Figs. 1 and 2 indicate the levels of AI which resulted in the presence of interfering signals at 50 kHz, 25 kHz and on co-channel to the desired signal [4]. Although experienced air traffic controllers were able to copy routine ATC messages at a relatively low speech AI, additional tests using single rhyme words (considered to be the most difficult to copy) indicated that an AI of 0·85 approaches 100% intelligibility under what could be considered the most difficult situation. It would appear that, from a practical point of view, an AI of somewhat less may be acceptable and that satisfactory communication is possible with lower indexes. Arbitrary AI figures of 0·3, 0·5 and 0·85 were chosen for the purpose of this analysis and none should necessarily be construed as being a standard, since further studies will be required to verify these preliminary tests. The United States of America is currently conducting such additional studies and may be prepared to submit further data when such work has been completed.

4. Analysis

The use of experimental data derived from these measurements suggests that interference to and from land stations in the terrestrial-aeronautical mobile service may be analyzed by considering the co-existence of an interleaved 25 kHz satellite system. This Report assumes a frequency stability that is perfect and does not treat the effects of transmitter or receiver frequency drift. These factors would have a contributing effect on the discrimination against the undesired signal in the receivers under consideration. Additional studies are required to investigate this matter. Because of the greater transmitter powers and greater receiver sensitivities used by the existing VHF extended range (ER) service, adjacent channel sharing would be more difficult to achieve. From a practical point of view, one could avoid the selection of interleaved channels that are adjacent to ER channels; and, therefore, only the sharing with the conventional VHF service was considered. The interference situations that follow are based on the existence of only a single source of interfering signal. Studies indicate that the cumulative effects of a multiple number of interfering stations might require an additional margin of protection above the levels indicated below [1, 3]. For a single source, the various interference situations may be identified in accordance with the following:

	Articulation index 0·3	0·5	0·85

4.1 TO: *Aircraft using satellite*

4.1.1 FROM: *Land station in the conventional aeronautical-mobile service*

	0·3	0·5	0·85
Desired signal at aircraft	−138 dBW/m²	−138 dBW/m²	−138 dBW/m²
Required protection wanted/unwanted *D/U* (BW 20 kHz)	−41 dB	−35 dB	−31 dB
Maximum tolerable undesired signal	−97 dBW/m²	−103 dBW/m²	−107 dBW/m²
Minimum geographical separation to maintain required protection	116 km	232 km	350 km

4.1.2 FROM: *Aircraft in conventional aeronautical-mobile service*

	0·3	0·5	0·85
Desired signal at aircraft receiving satellite	−138 dBW/m²	−138 dBW/m²	−138 dBW/m²
Required protection *D/U* (BW 20 kHz)	−41 dB	−35 dB	−31 dB
Maximum tolerable unwanted signal	−97 dBW/m²	−103 dBW/m²	−107 dBW/m²
Minimum geographical separation to maintain required protection	104 km	206 km	320 km

4.2 TO: *Satellite-borne receiver*

4.2.1 FROM: *Aircraft in conventional aeronautical-mobile service*

	0·3	0·5	0·85
Wanted signal at satellite receiver	−137 dBW/m²	−137 dBW/m²	−137 dBW/m²
Required protection *D/U* (BW 20 kHz)	−41 dB	−35 dB	−31 dB
Maximum tolerable unwanted signal	−96 dBW/m²	−102 dBW/m²	−106 dBW/m²
Unwanted signal at satellite from aircraft in conventional mode	−148 dBW/m²	−148 dBW/m²	−148 dBW/m²
Protection margin	52 dB	46 dB	42 dB

4.2.2 FROM: *Land stations in conventional aeronautical-mobile service*

	0·3	0·5	0·85
Wanted signal at satellite receiver	−137 dBW/m²	−137 dBW/m²	−137 dBW/m²
Required protection *D/U* (BW 20 kHz)	−41 dB	−35 dB	−31 dB
Maximum tolerable unwanted signal	−96 dBW/m²	−102 dBW/m²	−106 dBW/m²
Unwanted signal at satellite from conventional land station	−147 dBW/m²	−147 dBW/m²	−147 dBW/m²
Protection margin	51 dB	45 dB	41 dB

	Articulation index 0·3	0·5	0·85
4.3 TO: *Land stations in conventional aeronautical-mobile service*			
4.3.1 FROM: *Satellite-borne transmitters*			
Wanted signal at land station	−120 dBW/m²	−120 dBW/m²	−120 dBW/m²
Required protection *D/U* (BW 30 kHz)	−23 dB	−16 dB	−7 dB
Maximum tolerable unwanted signal	−97 dBW/m²	−104 dBW/m²	−113 dBW/m²
Unwanted signal	−138 dBW/m²	−138 dBW/m²	−138 dBW/m²
Protection margin at land station	41 dB	34 dB	25 dB
4.3.2 FROM: *Aircraft transmitting to satellite*			
Wanted signal at land station	−120 dBW/m²	−120 dBW/m²	−120 dBW/m²
Required protection *D/U* (BW 30 kHz)	−23 dB	−16 dB	−7 dB
Maximum tolerable unwanted signal	−97 dBW/m²	−104 dBW/m²	−113 dBW/m²
Unwanted signal near radio horizon	−99 dBW/m²	−99 dBW/m²	−99 dBW/m²
Minimum geographical separation to maintain required protection	356 km	*	*
Protection deficiency at land station near radio horizon	—	5 dB *	14 dB *
4.4 TO: *Aircraft in conventional aeronautical-mobile service*			
4.4.1 FROM: *Aircraft transmitting to satellite*			
Minimum wanted signal at aircraft in conventional service	−109 dBW/m²	−109 dBW/m²	−109 dBW/m²
Required protection *D/U* (BW 30 kHz)	−23 dB	−16 dB	−7 dB
Maximum tolerable unwanted signal	−86 dBW/m²	−93 dBW/m²	−102 dBW/m²
Minimum geographical separation to maintain required protection	100 km	224 km	631 km
4.4.2 FROM: *Satellite-borne transmitters*			
Wanted signal at aircraft in conventional service	−109 dBW/m²	−109 dBW/m²	−109 dBW/m²
Required protection *D/U* (BW 30 kHz)	−23 dB	−16 dB	−7 dB
Maximum tolerable unwanted signal	−86 dBW/m²	−93 dBW/m²	−102 dBW/m²
Unwanted signal from satellite	−138 dBW/m²	−138 dBW/m²	−138 dBW/m²
Protection margin for aircraft	52 dB	45 dB	36 dB

* This indicates that geographical separations somewhat greater than the average radio horizon distance would be required to provide adequate protection.

5. Conclusions

The results of experiments and studies which were aimed at determining the relative tolerance to interference using frequency-modulation and amplitude-modulation channels spaced 25 kHz apart can be useful in determining whether a conventional aeronautical service can co-exist with a satellite relayed aeronautical communications system such as the one assumed. An examination of the various interference possibilities indicates that the critical interference path is the one between two aircraft; one operating in the conventional mode, and the other in the satellite mode. The selection of the desired value of Articulation Index will determine the geographical separation required between stations. If an Articulation Index of 0·5 is assumed, a separation of the order of 224 km protects the aircraft in the conventional mode from the interference transmissions from the aircraft transmitting to the satellite. If this minimum separation is maintained between the two aircraft, it also amply protects the aircraft in the satellite mode (which requires a separation of the order of 206 km from the aircraft in the conventional mode). The recommended separation should also satisfy the separation required between the conventional land station and the aircraft in the satellite mode which should be no less than the radio horizon (approximately 484 km at 45 000 ft (13 700 m)).

It follows, then, that by imposing the constraint that aircraft in the satellite mode do not transmit within 224 km of aircraft in the conventional mode, a certain additional separation will automatically be added to the land station. This distance will usually be the limit of the communication service area (as much as an additional 300 km) for the aircraft in the conventional mode. If this land station is near the coast, the aircraft in the satellite mode must maintain a theoretical maximum separation (based on this study) of approximately 524 kilometres from the coast. An interleaved VHF satellite relayed communication system for aircraft would have to be confined to ocean areas while maintaining such separations from land areas where conventional VHF is in use.

The effects of frequency drift and offset carrier operation of conventional equipment were not considered in this Report, nor has this Report considered the operational difficulties of channel interleaving which might arise from the operation of extended-range VHF systems or of air-to-air relay systems.

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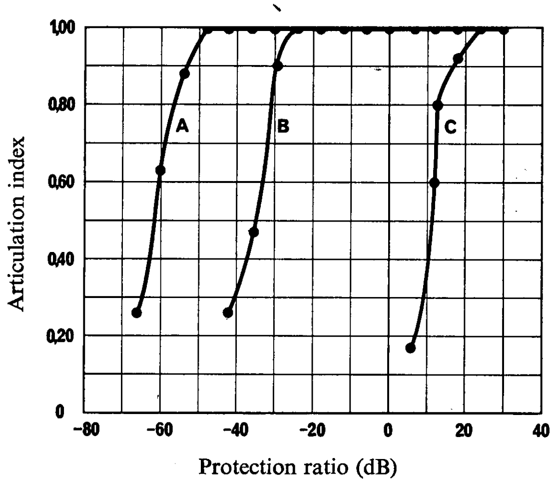

FIGURE 1

Articulation index as a function of protection ratio

Desired: frequency modulation
Undesired: amplitude modulation } 20 kHz intermediate frequency bandwidth

A: 50 kHz separation
B: 25 kHz separation
C: co-channel

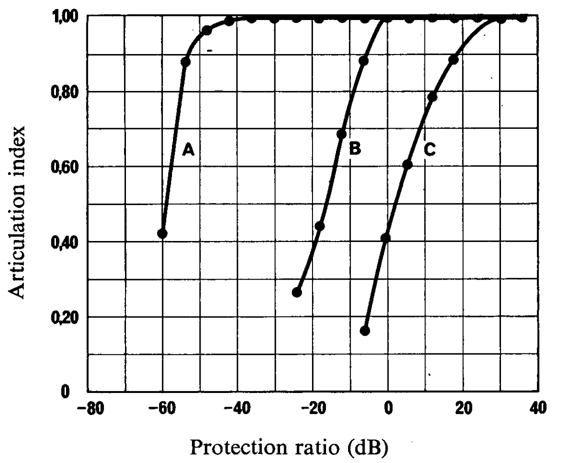

FIGURE 2

Articulation index as a function of protection ratio

Desired: amplitude modulation
Undesired: frequency modulation } 30 kHz intermediate frequency bandwidth

A: 50 kHz separation
B: 25 kHz separation
C: co-channel

REPORT 513 *

TECHNICAL CHARACTERISTICS OF SYSTEMS PROVIDING COMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR AIRCRAFT AND/OR SHIPS

Technical feasibility of systems employing space-communication techniques jointly for communication and radiodetermination purposes in the VHF mobile-communication bands

(Study Programme 17A/8)

(1970)

1. Introduction

This Report discusses some of the technical considerations affecting the feasibility of using the VHF aeronautical and maritime-mobile communication bands jointly for communication and radiodetermination purposes using space techniques.

Recent experiments with the United States ATS-1 and ATS-3 Applications Technology Satellites have demonstrated the feasibility of using satellites to relay 135·6 MHz voice and data communications between aircraft and ground stations. These same satellites have been used to demonstrate the feasibility of radio position determination of ships and fixed stations at 135·6 MHz employing distance measuring techniques.

Several studies discussed in this Report have recommended the use of special narrow-band satellite ranging signals suitable for use within the bandwidth and power limitations of a communication-satellite voice channel. These methods are summarized in the next section to illustrate the application of distance measuring techniques to the VHF mobile-communication bands.

2. Radiodetermination techniques

The VHF mobile-communication bands are currently divided into 50 kHz channels. Civil aircraft use double-sideband amplitude-modulation, while in the maritime band frequency modulation is employed. Satellite communication experiments at 135·6 MHz have employed narrow-band frequency modulation in order to reduce the satellite power requirements. In the future, the existing 50 kHz channels may eventually be split into 25 kHz spaced channels. Therefore, it appears wise to design any planned radiodetermination signals to occupy less than 25 kHz bandwidth if compatibility with future communication channels is to be assured. On the other hand, there may be technical advantages in the use of a number of contiguous or non-contiguous 25 kHz channels as a single radiodetermination channel.

* This Report was adopted unanimously.

2.1 *CW sidetone ranging*

One method of providing a radiodetermination signal suitable for use with a voice signal is to transmit a sinusoidal tone which modulates the carrier with the same type and depth of modulation employed for voice transmission. In theory, tones up to 12·5 kHz can be used within a 25 kHz channel, assuming that in the case of angle modulation the modulation index is reduced until only the first-order sidebands are significant. In practice, considerations of frequency stability and other factors may reduce the maximum tone frequency as much as 50%. Measurement of the phase shift between a transmitted interrogation signal and received reply signal provides information on the distance from the satellite to the user vehicle. Ambiguity encountered in the measurement may be removed by transmitting lower frequency tones or by interrupting the tone in some known fashion. The radiodetermination signal may be either time-shared with the voice transmission, or else it may be frequency-multiplexed, using appropriate filtering techniques to separate the two signals.

2.2 *Shift keyed ranging*

Frequency-shift keyed or phase-shift keyed signals can also be used to provide a radiodetermination function suitable for use with a voice transmission. In this case, the time delay between a binary sequence transmitted to a vehicle and the same sequence received from the vehicle provides information on the distance from the satellite to the vehicle. Frequency shifts of less than 12·5 kHz ensure that the radiodetermination signal spectrum will not exceed the 25 kHz bandwidth of a single satellite voice channel.

3. Radiodetermination accuracies

Two operational satellite systems already in existence have demonstrated the feasibility of using satellites transmitting in the VHF and lower-UHF regions of the spectrum to provide position information. These systems include the U.S.A. Doppler navigation satellite system [2, 3, 4, 6] and the geodetic SECOR satellite system [5]. In addition, a series of ranging experiments conducted by the United States has provided further data on the accuracy of satellite ranging in the aeronautical mobile communication band [1].

3.1 *Doppler navigation satellite system—operational results*

The United States has implemented an operational navigation satellite system in which Doppler shift measurements are made of stable carrier frequencies at 150 and 400 MHz to determine the location of the observer [2, 3, 4, 6]. The system uses two coherently related carrier frequencies to permit the elimination of ionospheric refraction effect. Based upon several years of operational experience, the navigation accuracy achieved by ships has generally been better than half a kilometre, limited primarily by the ability to measure the ship's velocity accurately. For stationary observers, accuracies of the order of 100 metres have generally been achieved for a single satellite pass.

3.2 *Geodetic SECOR satellite system—operational results*

Geodetic SECOR is an operational satellite system used for the geodetic surveying of stations on the Earth [5]. The SECOR satellites are in medium altitude orbit, above the region of the ionosphere where most of the refraction effect occurs. Like the U.S. Doppler navigation satellite system, SECOR employs two coherent frequencies (224·5 and 449 MHz) to eliminate first-order ionospheric retardation error, while providing very high accuracy range information. In this system, four sidetones modulate each carrier signal. SECOR has consistently demonstrated position-fix accuracies of better than 15 metres for fixed stations.

3.3 *ATS-1* and *ATS-3 ranging experiments at 135·6 MHz*

The United States has been conducting ranging and position determination experiments with the ATS-1 and ATS-3 Applications Technology Satellites using frequencies of 149·22 MHz for the up-link and 135·6 MHz for the down-link [1]. In these experiments, the ranging signal consists of a 2·4414 kHz tone which frequency-modulates the carrier. Measurement of the phase of the received tone with respect to the transmitted one provides information on the distance between the satellite and the user transponder. Phase measurement ambiguity is resolved by modulating the tone with a binary sequence which is correlated against the received signal. These experiments have deminstrated a measurement precision of better than a few microseconds under average ionospheric conditions, using a ranging signal that occupies the bandwidth of a single voice channel.

3.4 *Real-time ionospheric corrections*

The very high accuracy position determination capability achieved with the geodetic SECOR and Doppler navigation satellite systems is evidence that the coherent frequency technique is successful in eliminating most of the ionospheric retardation error. In a multi-channel communication-satellite system used also for radiodetermination, the two-frequency technique can be applied within the bandwidth limitations of the satellite repeater to correct the first-order ionospheric retardation. The technique can be applied by ranging either simultaneously or sequentially on two channels and observing the range difference for the ranging signals transmitted at the two carrier frequencies. Each of the two ranging signals can be designed to fit within a voice channel as discussed in § 2. Calculations indicate that the two-frequency technique applied on two channels 0·5 MHz apart will yield first-order ionospheric corrections with an accuracy of the order of a kilometre [7].

4. Conclusions

4.1 Radiodetermination techniques that can use a voice channel have already been demonstrated experimentally in the VHF aeronautical mobile communication band with the ATS-1 and ATS-3 Applications Technology Satellites.

4.2 Carrier frequencies as low as 224·5 and 150 MHz are in use on an operational basis and have proved successful in providing very high accuracy position determination of fixed stations with the SECOR satellite system, and of ships with the United States Doppler navigation satellite system.

4.3 The use of two-carrier frequencies for satellite radiodetermination at VHF and lower-UHF regions of the spectrum has proven successful in removing most of the position error caused by the ionosphere.

4.4 Two-carrier frequency ranging can be applied to achieve accurate radiodetermination. Extrapolation of experimental results together with theoretical studies leads to the conclusion that similar techniques may be applied in the VHF mobile communication bands in order to reduce ionospheric error. The ranging signals can be designed to be accommodated within two spaced voice channels.

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REPORT 514 *

TECHNICAL CHARACTERISTICS OF SYSTEMS PROVIDING COMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR AIRCRAFT AND/OR SHIPS

Some factors affecting planning and designing a satellite system to be used in the maritime-mobile service

(Question 17/8 and Study Programme 17A/8)

(1970)

1. Introduction

1.1 This Report refers to the list of requirements for maritime satellites (radiocommunication and radiodetermination) adopted by the VIIth Assembly of the Inter-Governmental Maritime Consultative Organization (I.M.C.O.). This list presents the preliminary position of I.M.C.O. and is attached as Annex I to this Report.

1.2 In planning and designing a satellite system meeting the operational requirements of I.M.C.O., the particular conditions of shipping should be taken into account and, for this purpose, close cooperation is needed between experts in space techniques, on the one hand, and shipping experts, on the other.

2. Basic design characteristics

As safety aspects play an important part in the operational requirements of I.M.C.O., the system should as far as practicable be capable of being used by ships regardless of size, which operate on routes where a satellite system can improve their safety. This might embrace more than 100 000 ships in the system. Therefore, the ship-borne equipment should be kept as simple and as inexpensive as possible. In particular, stabilized platforms and expensive steerable antennae should, as far as practicable, be avoided on board ships.

* This Report was adopted unanimously.

3. Services required

3.1 *Communication*

3.1.1 *Distress*

For the application of the system in cases of distress, including search and rescue actions, information will be needed of how many emergencies are to be expected at the same time in the area covered by any satellite in order to determine how many channels via the satellite may be involved simultaneously in the handling of these distress cases.

3.1.2 *Safety*

Another important task for meeting the operational requirements of I.M.C.O. will be to determine the number of communication channels via satellites for all communications dealing with the safety of shipping other than for distress cases, e.g. urgency and safety messages, including medical assistance, position reporting, meteorological, hydrographic and oceanographic information, etc.

3.1.3 *Public correspondence*

Long-range public correspondence for the maritime-mobile service is at present handled by terrestrial high-frequency communications. Apart from the question as to whether, when, and to what extent these communications may be carried out via satellites, it is clear from the operational, and possibly from the economic point of view, that calling of the ships by coast stations, or vice versa, may be better carried out by satellite communications.

Terrestrial maritime high-frequency communication service, as opposed to a satellite system, necessitates the use of several calling frequencies in different parts of the band to establish communication at any given time, and between any given place.

Further study is needed regarding long-range public correspondence traffic to determine how many channels via satellite would be needed, and what performance objectives may be required if and when this type of traffic is to be passed via satellites (see also Report 508).

3.1.4 *Common information required*

For all the communication purposes mentioned above, a knowledge of the number of ships operating at the same time in important shipping areas and the magnitude of the communication traffic they now generate and are expected to generate in the future will be essential.

Additionally, the information rate, the time duration per communication, the tolerable waiting time for a free channel and the number of channels available at any given time are parameters which have to be taken into account when considering the various items of the operational requirements.

3.2 *Radiodetermination* (see also Reports 216-2 and 515)

3.2.1 *General*

As for the position-fixing capability of the system, it must be decided whether or not preference should be given to

— on-board position fixing, or

— interrogation methods.

An interrogation method might well offer certain advantages to ships, since it may require less expensive ship-borne equipment, and will be particularly suitable for combination with a position-reporting system, and for joint transmission to the ship of the position information together with environmental, meteorological and oceanographic information.

3.2.2 *Accuracy*

When considering the position-fixing performance of the system, the accuracy required will need special attention. In particular, it will be necessary to distinguish between the absolute accuracy of a position (in geographic coordinates) and the relative accuracy (obtainable between ships operating in the same area).

Outside coastal approach areas, an absolute accuracy of the order of ± 1 to 3 nautical miles (with a probability of 95%) may be considered satisfactory for normal merchant shipping.

The relative accuracy, however, to be required for collision warning application of the system would need to be much higher than the absolute accuracy. The cost of a system for collision avoidance using satellite techniques in converging areas may be prohibitive and it may be more practicable to use other means for such purposes.

4. Frequency problems

4.1 *Frequency bands* (see also Reports 504 and 511)

The frequencies being mainly considered as technically appropriate for such a system are at present VHF (parts of band 8) and UHF (parts of band 9).

In choosing the frequency band, due consideration must be given to whether and to what extent the establishing and maintaining of a stable communication link via satellite will be affected by:

— the motion of the ship due to all causes,

— environmental meteorological conditions,

— propagation conditions on the radio path.

4.2 *Frequency sharing* (see also Reports 394-1, 507, 511 and 513)

Special attention should be given to the problems and/or advantages of frequency sharing with other satellite or terrestrial services and mutual interference between satellite and terrestrial communications of the mobile services operating on the same or on adjacent channels.

Note. — The Director, C.C.I.R., is requested to draw the attention of the Inter-Governmental Maritime Consultative Organization (I.M.C.O.) to this Report.

ANNEX

INTER-GOVERNMENTAL MARITIME CONSULTATIVE ORGANIZATION (I.M.C.O.)
LIST OF REQUIREMENTS FOR MARITIME SATELLITES

(Radiocommunication and Radiodetermination)

The following operational requirements of interest to shipping appear to be important enough to be considered by Administrations in their preparations for the I.T.U. Space

Conference, with a view to the possible provision of frequencies for space relay techniques to serve the maritime-mobile services.

The importance of these requirements are classified as follows:

A: important B: desirable C: possible

A 1. Handling of *distress cases* including search and rescue control communications, also position determination by the land-based station of the mobile craft in distress and of *search and rescue* units involved. In special cases, communication between search-and-rescue centres.

A 2. *Distribution* of *urgency and safety messages* including *medical assistance.*

A 3. Interrogation of the land-based station by mobile craft station for *obtaining position information* possibly followed by environmental meteorological and oceanographic information,
or
regular interrogation of the mobile craft station at appropriate intervals of time by the land-based station and transmission of position information etc. to the mobile craft.

B 4. Automation of the *position-reporting* system based on a position information as mentioned in § 3. The present repeated individual reporting actions of mobile craft could then be abolished.

A 5. Distribution of *meteorological, hydrographic* and *oceanographic* information (reports, forecasts and warnings) for mobile craft.

A 6. *Collection* of meteorological, hydrographic and oceanographic *observations* of mobile craft and ocean data stations.

B 7. *Traffic control* including collision warnings, especially in converging areas, subject to the radiodetermination system providing sufficient relative accuracy (see § 3).

A 8. Individual meteorological and oceanographic guidance of mobile craft by the land-based station *(weather routing).*

A 9. *Selective calling* of ships by coast stations for introducing public correspondence through terrestrial communications.

A-B 10. *Public correspondence* (including operational business between ships and their companies). In this context it has to be studied whether and to what extent radiocommunications at present performed on high-frequency and medium-frequency bands could be replaced by such via satellites.

B 11. *Data transmission* (e.g. use of ground-based computers).

B-C 12. *Television* for medical, operational and entertainment purposes.

REPORT 515 *

TECHNICAL CHARACTERISTICS OF SYSTEMS PROVIDING COMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR AIRCRAFT AND/OR SHIPS

The use of geostationary satellites for radiodetermination by distance measuring techniques

(Study Programme 17A/8)

(1970)

1. Introduction

The location of ships and aircraft may be determined by measuring the propagation time of a radio signal from the satellite to the user and return. The propagation time can then be converted to a range measurement by relating it to the known propagation velocity of the radio signals. The principles of various positioning techniques including distance measurements are discussed in Report 216-2. The distance measurement technique has gained attention because of its particular usefulness with geostationary satellites. There is considerable flexibility afforded in the design of an actual system and a number of different systems have been proposed using this technique. The characteristics for some of these systems are summarized in the Annexes. None have actually been implemented, although some experimentation and technical development is under way.

The selection of a preferred system is dictated by:

— the characteristics of the vehicle (aircraft or ships);

— accuracy with which location is needed;

— associated communications requirements;

— frequency with which location measurements must be repeated for each vehicle;

— speed with which fix must be made;

— state of technological development;

— the cost to the individual user;

— the cost of the terrestrial and space segments.

A number of these parameters affect the choice of the operating frequency. The VHF and UHF bands appear to be technically suitable for links between satellite and the mobile vehicles. The VHF band has the economic merit that the maritime and aeronautical equipment used for the satellite service can, if specifically designed, be used also for the terrestrial mobile service. On the other hand, the UHF band holds the greatest accuracy potential in the range measurements.

* This Report was adopted unanimously.

2. Principles of system operation

Range measurement radiodetermination satellite systems can be characterized as single range, multiple range, or range difference systems. These systems generally require *a priori* knowledge of the user's altitude, although several of the concepts can be extended to provide altitude information.

2.1 *Single-range measurements*

A single satellite is sufficient to locate a user along a line of position if altitude is already known. In operation, a fixed earth station transmits a coded interrogation signal that is relayed to the user by the satellite. A transponder in the user vehicle is designed to recognize its own preassigned address upon receipt of the interrogation signal. The retransmitted signal is relayed by the satellite to the earth station, where the elapsed time between interrogation and reply signals is measured. If the position of the satellite is known the elapsed time gives the distance from the user to the satellite, the locus of which is a sphere. This sphere intersects the Earth's geoid, corresponding to the user's altitude, in a circular line of position. Annex I describes a radiolocation system for the North Atlantic region based on the single satellite ranging principle.

2.2 *Multiple-range measurements*

The single satellite ranging principle can be extended to additional satellites. Range measurements made from two geostationary satellites are sufficient to locate a user if altitude is known. In this case the two distances measured from the satellites to the user determine two spheres that intersect in a circle. The intersection of this circle with the Earth's geoid at the user's altitude determines two positions—one in the northern and one in the southern hemisphere. *A priori* information on the general location of the user will determine his position without ambiguity. Annexes II, III, IV and V describe four radiolocation satellite systems based on the two-satellite ranging principle.

A system of three satellites provides the additional range information needed to determine the user's altitude, and the user's position can then be located at the intersection of three spheres whose centres are the three satellites. Annex VI illustrates a method of employing satellites to determine a user's altitude.

2.3 *Range-difference measurement*

An alternative method of determining position is based on the principle of measuring the differences in distances between several satellites and a vehicle. Each range-difference measurement locates the user on a hyperbolic surface. Two independent range-difference measurements, obtained with three satellites, produce two hyperboloids which intersect the Earth at two points, one of which is the user's position.

In a typical operating system, a fixed earth station transmits signals to the satellites. The user measures the differences between the arrival times of the several satellite signals and transmits this information to the earth station. A configuration might also be used in which signals transmitted by the user are relayed through two satellites and the time difference measurement made at the fixed earth station.

3. Sources of measurement error

3.1 *Tropospheric and ionospheric ranging errors and their correction*

A major limitation to the accuracy of radiodetermination by satellite results from refractive effects in the troposphere and ionosphere. Radio wave retardation due to the troposphere is independent of frequency. Tropospheric retardation at sea level, 100% humidity and zero elevation is 116 m [1]. It decreases with increasing elevation angle from an observer to a satellite, altitude and decreasing humidity.

Ionospheric retardation at frequencies near 1500 MHz is comparable to the tropospheric retardation. At VHF it is much larger because it varies inversely as the square of the frequency. Ionospheric effects may be reduced by exploiting their strong frequency dependence, either by using sufficiently high frequencies or by using two lower frequencies simultaneously and thereby generating a first-order ionospheric refraction correction.

During undisturbed daytime, sunspot maximum conditions, the one-way range bias due to retardation is as shown in Fig. 1. It is 3600 m at 0° elevation, 3200 m at 10° and 2400 m at 20°. It is expected that corrections based on predictions of electron content may reduce the bias to the order of 30% of the total bias.

If calibration stations are used as part of a radiodetermination system, corrections to less than 10% of the total range bias (less than 240 m at 20° elevation) might be achieved in the region surrounding a station assuming that the distances from the satellite to the calibrating stations are accurately known. Appropriately located stations would be equipped with repeaters like those used in mobile craft. The known range from the satellite would be subtracted from a calibration range measurement to derive an accurate range correction.

Unpredictable solar disturbances cause changes in the ionosphere that can increase range bias as much as 50% over the values shown in Fig. 1.

If a two-satellite radiolocation system is used without an applied correction, the effect of the disturbance will be an apparent systematic displacement of all the craft in a limited area. The relative position determinations of these craft would not be significantly affected.

More data is needed on the size of the area in which the information from a calibration station can be used, and therefore the number required in the area served. However, an estimate can be made on the basis of an extreme case [2], in that instance sunset occurred at the peak of the disturbance and the total electron content dropped by a factor of ten in one hour. It would have caused a change in total range bias from approximately 2700 to 270 m for an elevation angle of 20°. Assuming that the principal cause of the decay is related to sunset, the east-west gradient of electron density and hence range bias would have been over a distance approximating the distance the terminator moved over the Earth in one hour, or approximately 1000 km. Calibration stations at 1000 km intervals would probably have been sufficient to determine the range bias correction during that event.

3.2 *Multipath error*

Multipath error occurs when the ranging signal travels over two or more different paths, and is generally produced by reflections from the ocean or the Earth's surface [3]. For narrow bandwidth signals the desired direct signal and undesired multipath signals combine vectorially to produce a phase error or, equivalently, an error in measured propagation time delay. The greatest differences in propagation delay occur when the user is at high altitudes and the satellites are viewed at large elevation angles. The greatest multipath signal amplitudes occur when the user views the satellites at low elevation angles and the multipath signal appears specular. Several methods are available to reduce ranging errors caused by multipath. One technique takes advantage of the directional characteristics of high-gain user antennae by rejecting the multipath signals outside the main beam of the antenna since the antenna would normally be beamed away from the Earth. This technique is more readily implemented at the higher frequencies when, for a given gain, antenna apertures are smaller. At elevation angles above the Brewster's angle, circular polarization will also reduce multipath by discriminating against oppositely polarized multipath signals. As the aircraft moves through *the interference pattern,* the average of the errors due to multipath moves towards zero. It is therefore possible to reduce the multipath error by suitable averaging over several measurements or by filtering; it follows that satellite access time must be increased. This technique is most effective at high frequencies when used by high-speed aircraft. Other methods of multipath error reduction are based on the use of wideband radiodetermination signals or frequency diversity. In this case, an ensemble averaging effect is achieved due to the frequency dependence of the multipath signals.

3.3 *Other sources of error*

3.3.1 *Accuracy of satellite location*

Uncertainties in satellite position will introduce errors in the range measurements of the radiolocation system. Range and angle tracking systems at microwave frequencies (6 and 4 GHz) currently in use with operational geostationary satellites have a single-measurement accuracy (1σ) of the order of 0·015° in angle and 1000 m in range. Such measurements, taken over a sufficiently long period of time, may reduce the satellite position uncertainties to the order of 50 m in altitude and 0·0005° in latitude and longitude.

Using geostationary satellites, this magnitude of satellite position uncertainty would produce a range error contribution (1σ) to the radiodetermination system of the order of 100 m. An order of magnitude reduction in satellite position uncertainty should be achievable by improving the single measurement ranging accuracy from 1000 m to the order of 30 m.

3.3.2 *Uncertainty in vehicle altitude*

Barometric type altimeters capable of providing instrument accuracies of approximately 40 m absolute (2σ) are due in the future to be standard on new aircraft. This includes the mechanical errors of the altimeter instrument. External pressure datum errors and non-standard atmospheric temperature errors can also be significant when absolute altitude is required. U.S.A. Weather Bureau data show that, for one per cent of the year, pressure altitude variation for subsonic aircraft due to barometric pressure change can exceed 150 m and could range as high as 250 m for short periods of time. The variation will be greater for supersonic aircraft at their cruise altitude.

As an alternative method of measuring aircraft altitude, radar altimetry is available, but is not in general use because it requires knowledge of the ground elevation in order to obtain the altitude above mean sea level. The effect of aircraft absolute altitude error is small at low user-to-satellite elevation angles in radiodetermination systems in which altitude is used as an input to the solution for the user's latitude and longitude. In the North Atlantic region, for example, the positioning error component due to this uncertainty may be calculated by multiplying the altitude error by a factor between 0·36 and 0·70 corresponding to elevation angles between 20 and 35 degrees, respectively.

3.3.3 *Equipment induced errors*

Propagation delays incurred as the signal passes through ground, satellite and aircraft or ship equipment will also contribute to the position-fix error. This type of error is primarily the result of non-linear phase shifts, oscillator instabilities, and thermal noise, each of which is under the system designer's control. Ground station and satellite contributions can be made negligible with a minimum effect upon total system cost.

Theoretically, at VHF the highest baseband frequency would be limited to approximately 10 kHz, assuming 25 kHz channelling. In this case, a one degree error in phase measurement will result in a 42 m one-way distance ranging error. This is more than an order of magnitude smaller than the error caused by ionospheric refraction. Thus, the phase accuracy requirements could be relaxed to 100 m (2·5° at 10 kHz) with little effect upon the net position fix accuracy achievable at VHF.

Frequency constraints at UHF (1540-1660 MHz) are not as severe and satellite power requirements can be reduced by increasing the highest baseband frequency. However, if the ranging signals must have characteristics which permit them to be transmitted via the same channels used for voice, the radio-frequency bandwidth of the ranging signals would be limited accordingly.

3.3.4 *Geometric dilution*

The geometry inherent in satellite ranging systems is such that position-fix accuracy is a function of the location of the user craft relative to the sub-satellite points. Very near the equator errors in the measurement of range, aircraft altitude or satellite position will cause latitudinal position-fix errors one or two orders of magnitude larger than the original range measurement error, while longitudinal errors will be about equal to the original error. At the higher latitudes the latitudinal error approaches the range measurement error and the longitudinal error increases slightly.

3.3.5 *Estimates of position accuracy*

Estimates of position accuracy for VHF and UHF are contained in the Annexes.

4. Status of technology

4.1 *Satellite technology*

Technology has been sufficiently developed to permit implementation of the satellite portion of a radiodetermination system using distance measurement. A satellite of the order of 150 kg mass could provide the necessary sensitivity and power levels at synchronous orbit altitude. In any system using common satellites for both communication and radiodetermination functions, the ranging signal can be designed to employ the same bandwidth as a voice grade communications channel, but will generally require less power.

4.1.1 *Satellite antennae*

The maximum gain of satellite antennae in the VHF bands is limited by the physical size of the antenna, while in the UHF bands the limitation is the maximum area on the Earth which requires coverage. VHF (135·6 MHz) antennae with a gain of about 9 dB are in use on the ATS-1 and ATS-3 satellites; designs exist for increasing this gain by 3 to 6 dB on satellites of about 150 kg in mass. The ATS-5 satellite launched in the summer of 1969, has an antenna gain of about 15 dB in the UHF band (1600 MHz). This gain could also be increased by 3 to 6 dB with less than Earth coverage.

The satellite antenna should be circularly polarized.

4.1.2 *Satellite power*

Current technology used in geostationary satellites limits the available end-of-life DC power to the order of one watt per kilogram of total satellite mass. In typical designs, radio-frequency power levels of 50-60 watts at VHF and 25-30 watts at UHF are achievable for satellites of 150 kg mass. In general, a ranging signal will require up to an order of magnitude less power, depending upon the position-fix accuracy required, the user's antenna gain and the ranging technique employed.

4.2 *Aircraft terminals*

4.2.1 *Aircraft antenna*

The important parameters in the antenna design are gain, attainable patterns and the polarization. The gain or effective area should be large in the direction of the satellite and low in the direction of the Earth, to minimize the effects of multipath. Additional isolation from multipath effects can be obtained above the Brewster angle if the aircraft and satellite antennae are circularly polarized. Such considerations imply the use of a directive steerable antenna on the aircraft.

Aerodynamic drag, size and weight, together with installation problems, however, preclude the use of conventional high gain antennae in current commercial aircraft. The economic value of all usable space in such aircraft favours as small an antenna as possible. These factors and the high cost of an airborne antenna control system plus the doubtful reliability of electro-mechanical switching to provide an automatic or semi-automatic tracking capability favours the use of low gain antennae or electronically steered arrays that do not protrude from the aircraft surface.

4.2.2 *Aircraft receivers*

Maximum advantage is to be gained from the use of low-noise receivers when external noise is negligible in comparison to internal receiver noise. Transistor preamplifiers could be used up to 1000 MHz and tunnel diode or parametric amplifiers above. With this choice, receiver noise figures will be between 2 and 4 dB for frequencies up to 5000 MHz. Transistor amplifiers have the advantages of simplicity, reliability and low cost.

4.2.3 *Aircraft transmitters*

Air-cooled VHF aircraft transmitters capable of 500 watt minimum power output, using NBFM with a 5 minute on/5 minute off duty cycle are current state-of-the-art. They have been tested in the ATS satellite experimental programme. At 1·5 GHz transistor amplifiers of 20 watt power output have been developed.

4.3 *Ship terminal technology*

4.3.1 *Antenna*

The desirability of using antenna directivity to enhance signal strength, reduce multipath and provide protection in sharing, requires that the shipboard antenna have a reasonably high gain. However, economic factors suggest the undesirability of employing gains which require satellite tracking to overcome ship motion. Tests. conducted on the U.S.A. Applications Technology Satellite programme have demonstrated that a gain of the order of 10 dB is feasible within these constraints. Provided the radiodetermination system does not require simultaneous use of two satellites, such antennae are well within economic constraints, current technology and can be designed to survive the maritime environment.

4.3.2 *Power amplifier*

VHF transmitters in the power range 30-300 watt are available for the shipboard terminal.

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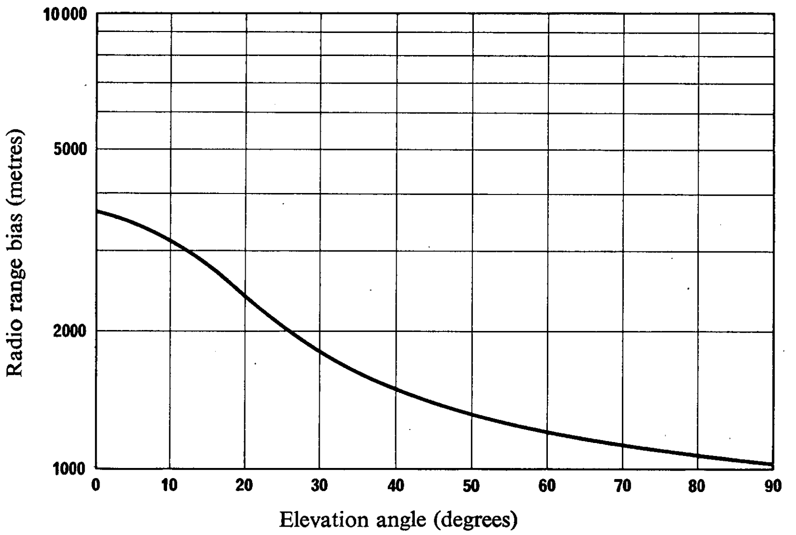

FIGURE 1

Uncorrected radio one-way range bias 130 MHz, daytime, sunspot maximum
($5{\cdot}4 \times 10^{17}$ electrons/m^2)

ANNEX I

A SINGLE SATELLITE LINE OF POSITION TECHNIQUE

Cross-track navigational accuracy of Doppler-equipped transatlantic aircraft can be greatly improved by augmenting the Doppler system with a satellite ranging system. A single range line of position from a synchronous satellite positioned over the mid-Atlantic provides the aircraft with an independent measure of its cross-track position. By periodically updating the Doppler system with ranging data, the normally increasing cross-track error can be reduced to a steady-state r.m.s. value, which depends on ranging accuracy and frequency of updating. The updating functions can be mechanized with a manual procedure or a fully automated system.

The principle depends on the use of a satellite-to-aircraft range measurement that defines a spherical surface of position. A second sphere is defined by the sum of the radius of the Earth and the aircraft altitude. The intersection of the two spherical surfaces results in a line of position, which, in the North Atlantic, is primarily in an east-west orientation. Considering the Doppler-measured along-track elapsed distance as a circular line of position centred at the previous waypoint, a position fix can be obtained by intersecting the two lines of position. The accuracy of this fix depends on the accuracy of the line of position measurements. The range line of position can be considered as an independent measure of the aircraft's cross-track position, and, if sufficiently accurate, the resulting Doppler/satellite fix can be used to update the Doppler system, thereby reducing the cumulative Doppler cross-track error.

The aircraft obtains the raw range signal with the satellite communications transceiver, as follows. At the beginning (or end) of a regularly scheduled position report, the aircraft transmits a few milliseconds of ranging signal to the satellite, which then returns the signal to the aircraft, where it is received and demodulated. Additional equipment then measures the round trip delay by comparing the phase of the received signal with that of the transmitted signal. The round trip delay is a function of satellite-to-aircraft range. The data are then adjusted for satellite/Earth relative motion, ionospheric delay, and equipment delay by using precomputed corrections and equipment calibrations. The resulting range delay determines the desired line of position which can be used to derive a Doppler/satellite fix.

Operations in the updating procedures can be grouped into three major functions: ranging, data processing, and control. The ranging function consists of the generation, transmission, reception, and delay determination of the ranging signal. The data processing function includes correction of the range data for satellite motion, ionospheric bias, and equipment delays, as well as Doppler/satellite range position determination and preparation of Doppler reset. There are two ways of mechanizing the update functions. The first approach is to perform the data processing and control manually, and the second is to fully automate these functions. In both mechanizations, the ranging function is automated in the interest of minimizing the satellite usage time.

The first step in designing the ranging system is selection of a suitable ranging concept. The concept must be compatible with planned aeronautical-satellite communications equipment and procedures. In addition, it must provide sufficient accuracy and have no significant ambiguities. Of the several concepts that have been proposed, a tone-burst technique operating in the VHF aeronautical band was selected.

The ranging system operates as follows. A VHF carrier is frequency modulated with a 1 kHz ranging tone, generated by an on-board reference, and transmitted to the satellite for a duration of 200 milliseconds. The returned signal is received about 50 to 70 milliseconds after the end of transmission, depending on the round trip range. After demodulation and cycle averaging, the phase of the received tone is measured relative to the phase of the reference tone.

This concept satisfies the necessary criteria. The frequency band of operation, mode of modulation, and bandwidth requirements (less than 15 kHz) are compatible with planned satellite-communications equipment. The 1 kHz tone supplies adequate ranging accuracy after compensation is made for ionospheric bias, and its inherent two-way range ambiguity of 81 nautical miles is automatically resolved by the Doppler-derived position fix. The technique is also compatible with operating procedures in that the tone burst can be added to the beginning or end of regularly scheduled position reports.

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ANNEX II

RADIODETERMINATION BY SATELLITES BY THE DISTANCE-MEASUREMENT TECHNIQUE

The Dioscures project

1. Introduction

The Dioscures system is a proposed world-wide integrated radiocommunication and radiodetermination system whose capacity can be progressively expanded to cope with the development of aeronautical and maritime transport. It is a permanently available system and its frequency bands have been selected in such a way that the performance characteristics of the system (transmission quality and accuracy of location) should prove satisfactory to users. The present document is limited to a discussion of the radiodetermination function of the system.

2. Principle of position-determination method

The system studied is based on the measurement of the distances between the moving craft (aircraft or ship) and two geostationary satellites (for example, a satellite S_1 situated at 10° W and another satellite S_2 situated at 60° W for coverage of the Atlantic). The position of a moving craft is generally determined on the initiative of a station on the ground, generally in accordance with a pre-set schedule. However, users are always able to ask for their positions at other times by using the radiocommunication system.

A measurement signal including the call sign of the moving craft is transmitted by the earth station in the band 5000-5250 MHz. Satellite S_1 amplifies this signal and retransmits it in the band 1540-1560 MHz in the common coverage zone of the two satellites. When the moving craft recognizes its call sign, it automatically retransmits the signal to the two satellites in the band 1640-1660 MHz. Satellites S_1 and S_2 each relay the signal to the ground in the band 5000-5250 MHz. By measuring the delay corresponding to the paths:

ground – satellite S_1 – moving craft – satellite S_1 – ground and

ground – satellite S_1 – moving craft – satellite S_2 – ground,

it is possible to deduce the distances between the satellite and the moving craft and thus locate the moving craft on two spheres centred on the satellites. By knowing the altitude of the moving craft, it is possible to pinpoint its position at the intersection of three spheres and the sense of the latitude is determined by the moving craft itself.

3. Application of the method

The distance measurement is based on the transmission of a 25 Hz digital signal:

— In the ground→moving craft direction, this signal sampled at a rate of 3·6 kilobauds is time-multiplexed with all the radiocommunication signals, i.e., three telephone channels coded and transmitted in digital form at a rate of 18 kilobauds each, one telex channel, two position-data transmission channels at 18 kilobauds and one synchronization channel at 18 kilobauds. This multiplex has a rate of 90 kilobauds.

— In the moving craft→ground direction, another 36 bauds multiplex is formed comprising the 25 Hz digital signal sampled at 9 kilobauds, a position-data transmission channel at 18 kilobauds and the synchronization at 9 kilobauds.

To obtain a distance measurement, the earth station transmits continuously a pseudo-random code with a period of 40 ms. All aircraft receive this code which synchronizes a clock in the moving craft which has a period of 40 ms. When it is interrogated, the aircraft retransmits a pseudo-random code with a period of 40 ms whose beginning and end are exactly in phase with the beginning and end of the code received.

The earth station measures the time difference between the beginning of a received code and the beginning of the transmitted code and evaluates the distance of the moving craft with respect to the two satellites. The accuracy of the distance determination depends on the short-term stability of the aircraft clock and the stability of the receiving clock on the ground.

The receiving clock of the aircraft is used again to synchronize the transmission clock to ensure strict synchronism of the transmitted and received signals. For a given signal-to-noise ratio, the phase jitter depends on the filtering function of the data clock.

The filtering necessitated by the primary synchronization corresponds to a noise band f of the order of 30 Hz ($f = 30$ Hz).

Thus the r.m.s. scintillation expressed as a fraction of the elementary duration of the digit for a signal-to-noise ratio (S/N) after demodulation is:

$$\sigma_\Phi = (0{\cdot}615/\sqrt{S/N}) \cdot \sqrt{2\pi f T}$$

At a rate of 36 kilobauds one obtains for signal-to-noise ratios of 3 and 10 dB corresponding to extreme S/N values:

$$\sigma_\Phi = 3{\cdot}8 \times 10^{-2}$$

$$\sigma_\Phi = 1{\cdot}41 \times 10^{-2}$$

This corresponds to a variable error of between 300 m (degraded link) and 115 m.

Similarly at 90 kilobauds one obtains for signal-to-noise ratios of 5 and 10 dB:

$$\sigma_\Phi = 1{\cdot}5 \times 10^{-2}$$

$$\sigma_\Phi = 0{\cdot}7 \times 10^{-2}$$

This corresponds to an error of between 50 m and 25 m.

4. Measurement cycle

The duration of a position-determination cycle is 1160 ms and is broken down as follows:

— transmission of the call sign to the moving craft;

— reply to the moving craft on the position determination carrier frequency with a message which enables the earth station to achieve full synchronization;

— transmission of the distance measurement code by the earth station and repetition of this code by the moving craft and the satellites.

At the same time the earth station, using another data-transmission channel and operating at a rate of 75 bauds, sends the interrogated moving craft its calculated position 5×1160 ms beforehand.

In addition the earth station, the satellite and the moving craft all use coherent repeaters so that the passbands of the latter can be minimized and Doppler information is available for use if a satellite fails.

The capacity of the system is 256 interrogations every five minutes but can be increased without any difficulty.

5. System performance

The performance of the position as regards position determination has been predicted by means of a mathematical model assuming the following sources of error:

— measurement equipment and repeaters (electronic errors);

— altitude measurements (or in the case of ships, misevaluation of the geoid);

— multipath effects;

— ionospheric propagation;

— inaccuracies as regards the position of the satellite.

These errors can be broken down into a systematic error (any value between 0 and M) and a Gaussian error defined by a standard deviation σ. The values corresponding to these errors are given in Tables I and II, respectively, for an aircraft and a ship. Figs 2 and 3 show the maximum diameter of the zone of the error in the position of the moving craft as a function of its latitude and longitude for the two cases considered above.

For certain types of users (cable-laying and hydrographic vessels, for example) arrangements could be made to provide a high-precision position determination service. The whole sequence of the identification, synchronization and measurement signals lasts 1160 ms but as the actual measurement operation only lasts 200 ms, it is possible to perform at least four measurements. Averaging out such a small number of measurements would not yield any appreciable improvement in the method. In the case of ships, however, it would be possible to carry out position determinations over two cycles (i.e., 2320 ms) and perform measurements for 1320 ms—this would make it possible to carry out about 30 measurements. As the main errors are Gaussian, the position-determination accuracy could thus be improved by a factor of 5 and an accuracy of at least 100 m could be obtained in 95% of cases.

TABLE I

Errors for aircraft

Type of error	Systematic error	Standard deviation of the Gaussian error
electronic	$M = 0$	$\sigma = 150$ m
altitude	$M = \pm 100$ m	$\sigma = 200$ m
ionospheric	$M = \frac{+ 5 \text{ m}}{\sin \beta_i}$	$\sigma = 0$
multipath	$M = \frac{\pm 50 \text{ m}}{\sin \beta_i}$	$\sigma = 0$
satellite { altitude	$M = 0$	$\sigma = 50$ m
satellite { longitude and latitude	$M = 0$	$\sigma = 100$ m

β_i = angle of elevation of satellite with respect to the moving craft.

TABLE II

Error for ships

Type of error	Systematic error	Standard deviation of the Gaussian error
electronic	$M = 0$	$\sigma = 150$ m
geodesic	$M = \pm 20$ m	$\sigma = 0$
ionospheric	$M = \frac{+5 \text{ m}}{\sin \beta_i}$	$\sigma = 0$
multipath	$M = 0$	$\sigma = 0$
position of satellite { altitude	$M = 0$	$\sigma = 50$ m
position of satellite { longitude and latitude	$M = 0$	$\sigma = 100$ m

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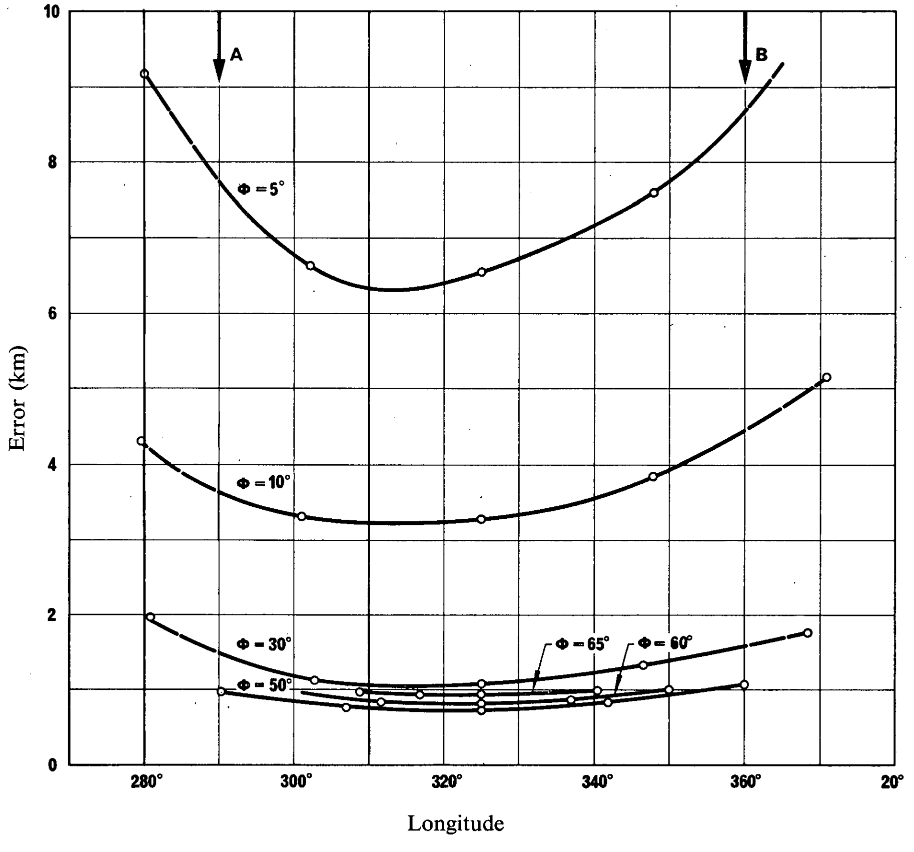

FIGURE 2

UHF (1540-1660 MHz, L band): errors in position of aircraft in 95% of cases

A, B: Dioscures limit

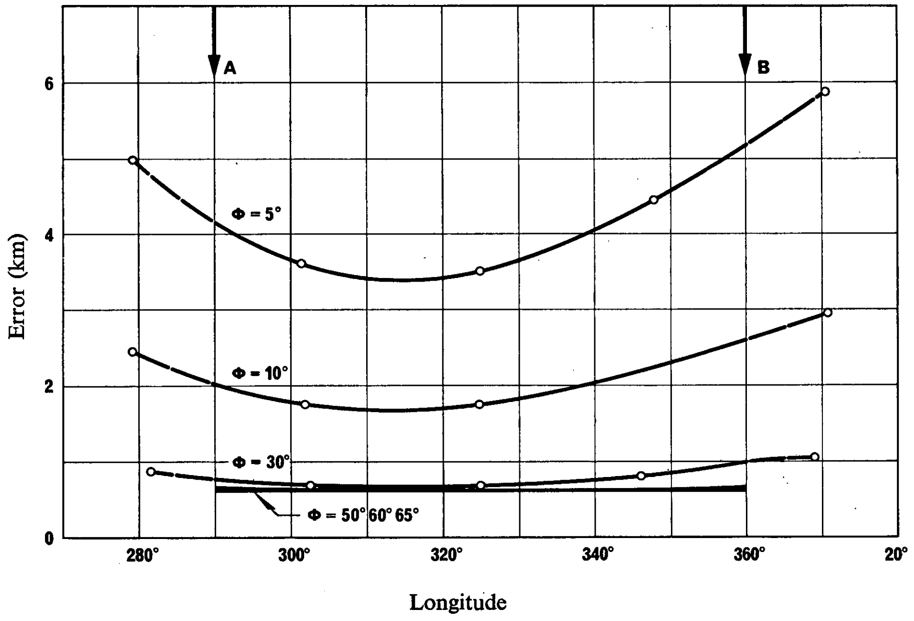

FIGURE 3

UHF (1540-1660 MHz, L band): errors in position of ship in 95% of cases

A, B: Dioscures limit

ANNEX III

THE RANGE PLUS RANGE SUM DISTANCE MEASURING TECHNIQUE [1]

1. Introduction

Direct range measurements to aircraft via synchronous satellites coupled with a data relay of aircraft altitude can provide sufficient information to a ground based air traffic control centre for accurate and reliable independent traffic surveillance over whole ocean areas. This technique requires two satellites; however, this penalty is somewhat offset by the communications redundancy inherent in a multiple satellite system.

The particular aircraft location is defined by the intersection of three spheres, two of which are centred at the satellites with radii corresponding to the respective measured satellite-to-aircraft ranges and a third which is the geoid through the aircraft altitude. The minimum system implementation would utilize two antenna terminals, each directed to separate satellites, at a single ground site. Only one terminal is required to transmit at a given time; however, both are required to receive. The aircraft needs only a single receiver/transmitter and a single antenna provided that the beamwidth is large enough to encompass both satellites. The aircraft and satellite equipment are relatively simple because all of the processing functions are performed at the ground station.

2. Ranging signals

A comparison of ranging signal modulation techniques (including CW sidetone, pseudo-noise coded digital CW, pulse, and compressed pulse) in terms of power and bandwidth efficiency, position fix rate capacity and compatibility with satellite and aircraft equipment indicates that for a fix-time limited system (i.e., bandwidth constrained) the CW sidetone ranging is most appropriate for this application.

The power and bandwidth required is dependent upon the fix time per ranging measurement. Since the maximum speed of the supersonic transports is about 1800 knots, (3330 km/h), the goal of a maximum distance of 75 nautical miles (139 km) between fixes requires surveillance of each SST every 150 seconds. For the subsonic jets, the required fix rate would be once every 450 seconds. For example, in 1975, the maximum number of aircraft in flight over the Atlantic is expected to be about 150, including SST's. In this case, SST's would be serviced three times as often as the subsonic jets, resulting in a total allowable single position fix time of 2·2 seconds.

A practical baseband signal design incorporates modulation of the lower sidetones (as subcarriers) on the second highest tone. Ranging signal acquisition consists of sequentially acquiring the RF carrier, then the two highest sidetones simultaneously, and finally the lower tones simultaneously. This three-step process should consume no more than about one-half the total fix time. When system oscillator instabilities and Doppler rates are considered, it is acquisition time which dictates radio-frequency carrier and sidetone loop bandwidths. Accuracy, in terms of phase errors, then dictates required signal-to-noise ratios in the respective loops. When the distribution of radio-frequency power in the carrier and individual sidetones is optimized, the total received radio-frequency signal-to-noise density required can be determined as a function of accuracy, bandwidth and receiver acquisition time. For example, for a required accuracy of 0·1 nautical miles (thermal noise only) and a position fix time of 2·2 seconds, increasing the radio-frequency signal bandwidth from 20 kHz to 40 kHz saves less than 1·3 dB in total ranging signal power. Increasing bandwidth from 40 kHz to 100 kHz saves only 0·4 dB. Because the ranging powers are much less than that for a voice channel, it may be concluded that narrow-band ranging signals are quite appropriate for aircraft surveillance. The ground terminal can always be transmitting, with all aircraft frequency tracking the radio-frequency carrier component of the signal. Sub-carrier PSK may be used for a 32-bit address at 100 bits/s, time shared with sidetones. Upon recognition, a 32-bit signature is transmitted by the aircraft, followed by a 15-bit altitude message, and then the (relayed) ranging signals.

3. Performance

The satellite power required for the satellite-to-aircraft link is a factor influencing the overall system implementation. The accuracy versus signal-to-noise density is depicted in Fig. 4 for VHF (130 MHz). The ordinate is the latitudinal position-fix error which will result during a sunspot maximum day with an ionospheric disturbance which increases the total electron content in a vertical column to 8×10^{17}. This is an extremely unusual condition [2]. The utilization of calibration stations is expected to reduce the bias error to within 10% in the regions near the stations and could be expected to reduce the error to 25%, midway between the stations. The correction to 25% has been assumed for this figure.

4. Summary

The following aircraft surveillance requirements may be accommodated by a two-satellite ranging technique:

— surveillance independent of pilot/crew action of 150 to 200 jet aircraft (including 50-75 SST's) per communications data channel;

— position-fix accuracies of ± 2 nautical miles or less and a maximum distance travelled between fixes of 75 nautical miles (139 km) of flight. Five nautical miles was determined to be adequate to support a 60 nautical miles (111 km) lateral separation standard at the mean-time-between-collisions of 1 per 10^8 flights;

— utilization of system/signal designs at VHF which are compatible with aircraft and satellite communications equipment and frequency assignment plans. In particular, it was assumed desirable to minimize the required radio-frequency bandwidth per surveillance channel to 25 kHz as a design goal because this is equivalent to the bandwidth required for an optimized voice communications channel.

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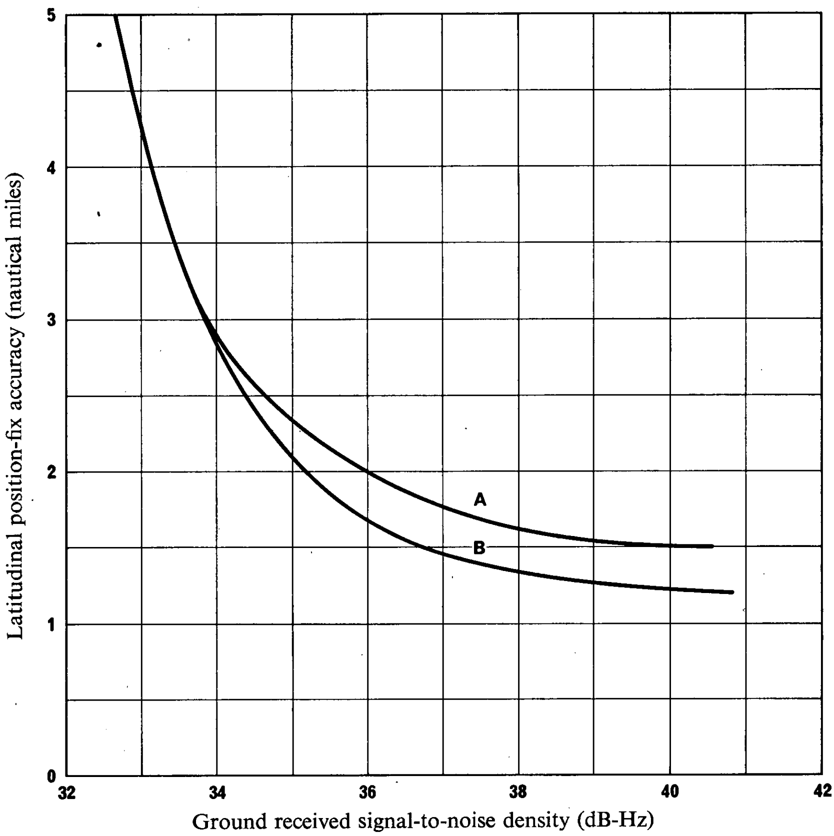

FIGURE 4

Performance of VHF ranging

Conditions: CW sidetone of 20 kHz bandwidth in a 25 kHz channel
Ionosphere: vertical electron content 8×10^{17} electrons/m^2
Multipath: 100 m + 100/sin β
Satellite position accuracy: 100 m
Aircraft altitude accuracy: 50 m
Equipment errors: 100 m
Ionospheric correction to 25% of bias error

A: 20° latitude
B: 65° latitude

ANNEX IV

THE TONE CODE RANGING TECHNIQUE

The " tone code " ranging technique impresses a time marker on the radio-frequency carrier. This technique has been tested by using the VHF transponders on the Applications Technology Satellites, ATS-1 and ATS-3, by using the following characteristics:

— useful accuracy can be achieved within the modulation and radio-frequency bandwidths of present day mobile communications;

— the technique can be used with wide bandwidth for high accuracy;

— it requires only one channel for range measurement, receiving and transmitting in the simplex mode if desired without need for an antenna diplexer;

— the time required for a range measurement is a fraction of a second so that it can time share a communication channel with little additional time usage of the channel;

— it can be implemented by the addition of an inexpensive solid state responder unit attached to a communications receiver-transmitter;

— it can, but need not, employ digital or digitized voice transmissions to provide synchronizing of the user responder, thereby further increasing the efficiency of channel usage;

— there are no " lane " ambiguities in the range measurements;

— user identification is simple and is confirmed in the returned signal.

The tone code interrogation signal is a short audio-frequency tone transmission followed by a digital address code in which audio cycles are inhibited for zeros, transmitted for ones. Alternatively, phase shift keying could be used.

Each user of the system is assigned a unique digital address code. When the user's fix is to be determined, as scheduled by a ground terminal computer, the tone burst followed by his address code is transmitted by the ground station to only one of a pair of synchronous satellites, the " interrogating satellite ", that repeats it. All of the users receive the satellite transmission, but the transponder of the one user that is addressed recognizes the address code automatically, and after a precise delay, retransmits the tone code to both satellites. Each satellite repeats the signal. The ground terminal observes the time from the first repetition by the interrogating satellite to the times of the user's returns by each of the two satellites. With these measurements, it can determine the ranges from the two known positions of the satellites to the user and hence the user's position, assuming altitude is known. A convenient frequency for the tone code transmitted from the ground station is

2·4414 kHz, derived by binary division from an accurate 10·0 MHz oscillator. The frequency is within the audio passband of aircraft voice communications. It is transmitted by frequency modulation, or any other modulation capable of transmitting a phase coherent audio tone. The tone duration used in the current tests is 1024 cycles and the code 30 bits, so that the tone-code duration is 0·43 seconds.

The user receives the tone cycles from the satellite on its communication receiver. All of the tone cycles received from the satellite, even though they may be interrogations from other aircraft, are applied to a phase matching circuit. A locally generated tone of the same frequency is also applied to the phase matcher, which adjusts the phase of the locally generated tone so that it corresponds to the phase of the received tone. The local tone is generated at the same frequency as the ground terminal tone within an accuracy of one part in 10^6 or better, an accuracy achievable from a moderately priced oscillator.

The phase matcher averages over the 1024 received cycles in establishing the timing of the locally generated phase. The averaging process improves the timing precision by the square root of the number of cycles averaged. At threshold signal-to-noise ratio for a narrow-band FM receiver, the phase of the zero crossings of the locally generated tone is matched within approximately 1·0 microsecond to the phase of the received tone zero crossings.

The locally generated tone is used to generate clock pulses that clock the received interrogation signal into an address code recognizer that consists of a shift register with summing circuits pre-wired to correspond to the digital address code of the user. Digital pulses timed from the received tone zero crossings are clocked into the address code recognizer. When the sequence of pulses representing the user's address code is clocked into the recognizer, it produces a single output clock pulse that opens a gate to interrupt the locally generated pulses that are clocking the shift register. The duration of the interruption is precisely controlled by a pulse counter. During the interval in which the clock pulses are interrupted, the user's transmitter is activated and the antenna is switched from the receiver to the transmitter. When the switching is completed, the locally generated 2·4414 kHz tone is transmitted until the end of the precisely measured interval. Clock pulses are then reapplied to the shift register and the address code is clocked out to key the audio tone to the transmitter and return the address code, followed by the user's altitude, back through the satellite to the ground station. Introduction of the delay while the antenna is switched eliminates the need for a diplexer in the user equipment. It also enables reception and transmission to occur on the same frequency.

There are separate receivers at the ground terminal for the two satellites. If the transmissions from the satellites are on the same frequency, they may be distinguished at the ground terminal by directive antennae. Each receiver output is applied to an address code recognizer similar to that in the user equipment. Prior to the interrogation of an individual user, the taps of the summing circuit are switched to correspond to the code of the user to be addressed. When the address code is received from a satellite, a single output clock pulse occurs at the output of the summing circuit.

The first return from the interrogating satellite produces a time reference pulse which is followed by the second return from the interrogating satellite and the single return from the other satellite. The time interval between the reference pulse and the following returns are separately measured, and from these measurements the ranges from the satellites to the users are determined.

The time intervals are introduced into a computer. A moderately sized computer can determine an explicit solution for the user's location within a fraction of a second.

The following is a description of experiments made to test this technique.

Range measurements were made to a buoy moored in deep water near Bermuda, to a DC-6B aircraft in flight off the coast of New Jersey and over the U.S.A. Mid-West, to a KC-135 jet aircraft at high altitude over the North Atlantic, to a ship in the Gulf of Mexico, to a small panel truck in upstate New York and to transponders at various ground-based locations.

Tone-code interrogations were usually made through ATS-3. In some of the tests the transponder responses were relayed back to the ground terminal by both ATS-1 and ATS-3; position-fixes were computed for many of these dual responses. In the tests when the transponder was within the coverage area of only one satellite a line-of-position was computed.

Several hundred range measurements were made to the buoy during an eleven-day period. A random sample of the measurements was used to compute the latitude at which the line-of-position crossed the buoy's longitude. All such samples were within 4 km of the buoy's position. Better accuracy was achieved at night. The computations included ionospheric retardation correction based on a model derived from published data.

Position-fixes were computed for the DC-6B aircraft as it was airborne over the Mid-West, including a flight over Lake Michigan. A sample of position-fix determinations was compared with VORTAC fixes; all were in agreement within 6 km. There was no significant multipath error for the Lake Michigan flight.

Two flights of the DC-6B were tracked by a precision radar. A systematic disagreement of from zero to several miles was observed between the satellite and radar determinations of latitude. The cause has not been identified. Such systematic disagreement has not been observed with other ground references.

During some interrogation periods nearly 100% responses were received, during others there was a lower response ratio. The variable performance was due to unfavourable antenna patterns and multipath propagation.

The test results met or exceeded the expected performance of a narrow bandwidth tone code ranging technique and the tests have provided useful data on the ranging and position-fix accuracies that can be achieved in the VHF aeronautical mobile frequency band.

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ANNEX V

THE SPEED, POSITION AND TRACK (SPOT) TECHNIQUE

SPOT (speed, position and track) is a proposed synchronous satellite ranging system which utilizes phase difference measurements of angle modulated CW signals. It can provide precise position determinations of aircraft and marine vessels in both a traffic surveillance and self-navigation mode. Other applicable services, such as search and rescue and two-way data and voice communications, can readily be incorporated on the same satellites.

The SPOT system is comprised of ground control stations where CW signals at UHF (1540-1660 MHz), modulated with two or more tones and a data link, are generated and transmitted to satellites, and return signals are processed for traffic control and synchronization purposes; a network of satellites in 24-hour orbits which relays radio-frequency signals from the ground stations to a field of users and vice versa; and the " user " instrumentation where the navigation tones are processed for a position fix, and/or transponded and relayed to the ground stations for the traffic surveillance function.

Results of error analyses indicate the feasibility of achieving position-fix accuracies of 0·2 km over transoceanic distances and approximately an order of magnitude improvement over relative distances of a few hundred kilometres. Performance is related to the sophistication and cost of the user equipments.

Design configurations have been studied for a North Atlantic system employing satellites with low-noise, hard-limiting receivers and modest transmitter power requirements (20 watts average) for a traffic surveillance, passive navigation, or a combined system.

For traffic surveillance in the North Atlantic, the space segment can have two synchronous equatorial satellites located approximately at 20° and 70° West longitude. The ground control centre can be located on the east coast of the United States or the west coast of Europe convenient to international air traffic terminals. The operational sequence of the system is as follows:

— the ground control centre transmits a CW signal at UHF (1540-1660 MHz) to satellite A. This carrier is modulated with two tones, for example, a high tone of 8 kHz and a low tone of 500 Hz. In addition, binary phase shift-keying is employed on the low tone to serve as a digital data channel. The data channel also functions as a command link by instructing each user when to return the ranging signal. The ground control centre data processing and control equipment (in accordance with a predetermined role call schedule) selects a particular user for a surveillance check by transmitting his unique address code;

— satellite A, after frequency shifting, relays the radio-frequency signal to the field where it is continuously available to every user;

— when a particular user receives his address code via the data channel, his transmitter is turned on automatically for a brief period (1-2 seconds) and he transponds the received signal, adding his address code, altitude and other pertinent status data back to satellites A and B;

— both satellites then relay their respective return signals to the ground control centre after frequency shifting;

— the ground control centre compares the phases of the returned tones to the reference tones to obtain the range data which identifies the user's position. The satellite ephemerides are assumed to be known by the ground control centre.

The system configuration for the passive user mode closely resembles the forward link of the surveillance mode. The ground control centre transmits tone modulated carriers to the two satellites. At specific time intervals, the data channel conveys ephemeris data on the satellites and other general navigation advisories. The satellites, after frequency translation, relay their respective signals to the user field. The users continuously receive signals from both satellites. When making a position fix, the radio-frequency carriers are demodulated and the tones are extracted to be compared with a local reference oscillator in synchronism with the ground control centre tone generator. The data link provides updated information on the satellite ephemerides to complete the data inputs required by the user to compute his position. The typical method of operation is visualized as follows. Prior to departure from a terminal or a known geodetic reference, the user calibrates or sets his phase meters at zero. During his trip the zero crossings of phase are automatically recorded, thus providing lane identity at all times. For a precision position fix, the phase angles are read to the required accuracy. The user reference oscillator drift or instabilities will introduce errors. However, off-the-shelf, temperature-controlled crystal oscillators are reported to yield frequency stabilities of the order of 5×10^{-11} for periods up to 24 hours. For 1·85 km accuracy, an aircraft would not require recalibration of such an oscillator while en route. For marine users who may be on the high seas for periods of many days or weeks, however, a daily recalibration of the phase meter or local reference oscillator could be accomplished through the use of the surveillance mode, particularly during those daily periods when air traffic densities are low.

Ambiguities resulting from the repetition of phase-angle measurements at every tone cycle are resolved by adding tones of lower frequency until the equivalent range of the lowest tone is sufficiently long for non-ambiguous position fixes. If it is assumed that phase can be measured to 5°, a high tone of 8 kHz provides a range precision of 0·517 km, sufficient to meet a requirement of 1·85 km position-fix accuracy in the user's navigational (horizontal) plane. This tone has a lane width of 37·7 km thus requiring the lower tone to have a range precision within this limit to assure that the correct tone lane is identified during the position-determination process. Practical equipment considerations, however, limit the high-to-low tone ratio to approximately 16, indicating a low tone of 500 Hz. This tone provides a non-ambiguous lane width of 603 km and can be resolved well within the fine tone requirements. As a growth feature, additional tones can be added, such as a 64 kHz tone to provide 0·185 km position-fix accuracies, by the ground control centre without requiring any modifications to the satellite and user equipment, except for the special user who wants to take advantage of the higher precision.

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ANNEX VI

AN INTEGRATED NAVIGATION AND TRAFFIC CONTROL SATELLITE SYSTEM

1. Introduction

This proposed system would use multiple satellites transmitting ranging signals accurately time-synchronized. If the user knows his own altitude and obtains signals from three properly located satellites, he has sufficient information to determine his position. If he also wishes to determine altitude, he needs to measure the range difference between four appropriately located satellites. Continuous coverage of the heavily travelled North Atlantic routes can be obtained using four satellites in 24-hour synchronous orbits. Should one of these four fail, altitude and rate of climb information is lost, but position and velocity information is still available. Failure of two of the four satellites causes a degradation of position accuracy to the order of several miles at the end of a transatlantic flight. Thus, the system provides considerable in-orbit redundancy. World-wide coverage (including altitude measurement) can be obtained with 12 to 18 satellites, the number of satellites depending on system design goals. Users obtain navigation data by measuring range differences between satellite pairs. In addition, data links to the satellites are provided for automatic relay of digital data between aircraft and a traffic control centre. The navigation data received at the traffic control centre from aircraft are processed by a ground-based computer with no airborne computations required. Traffic-control instructions in digital form can then be sent to the aircraft from the traffic-control centre via the satellite link. All transmissions are in the 1540-1660 MHz band.

2. System capabilities

The capabilities of this system include:

World-wide or area coverage

— all weather,

— near continuous.

Single-fix position and velocity accuracy of the world-wide system

— position CEP: 18 m absolute,

— velocity: 0·06 m/s,

— altitude accuracy: 39·2 m absolute,

— rate of climb accuracy: 0·12 m/s,

— world-wide time standard: better than 0·1 μs accuracy.

The system is in effect a satellite-based extension of previously known hyperbolic navigation concepts such as LORAN, OMEGA or DECCA. An alternate technique possible with this system is for a user to measure four one-way range measurements against his own (relatively inaccurate) crystal oscillator. He then has sufficient data to solve for his position, altitude and accurate time. Similarly, the user who wants to measure velocity and rate of climb measures either the range rate difference from the Doppler of each of these signals or the four inaccurate range rates.

The system makes use of a ground-station network to track the satellites. The number of ground stations needed ranges from 3 to 11, depending upon the satellite constellation and the design requirements. Only range difference information is measured by the tracking stations and, consequently, the antennae required are small and can be fixed. The simplicity of tracking antennae and measurements required leads to low overall ground station cost for the navigation network.

The tracking stations send their data to a master ground station via a transponder on the satellites. The transponder also relays traffic control data as described in another section.

The master ground station uses the tracking data to compute ephemeris and satellite oscillator time correction. These are transmitted to the satellites (approximately every hour) by the master station, which may be co-located with a tracking site. Periodically (every three or four months) attitude control and station-keeping commands are transmitted to the satellites. There will be one to three master stations required, depending on the constellation chosen. Ground station to satellite contact can be lost for up to eight hours. Moderate degradation will occur in system accuracy after several hours of outage.

Bibliography

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QUESTIONS AND STUDY PROGRAMMES, RESOLUTIONS AND OPINIONS

(STUDY GROUP 8)

QUESTION 1/8 *

SIGNAL-TO-INTERFERENCE PROTECTION RATIOS AND MINIMUM FIELD STRENGTHS REQUIRED IN THE MOBILE SERVICES

The C.C.I.R., (1963)

CONSIDERING

(a) that full effect should be given to the studies which the Administrative Radio Conference, Geneva, 1959, in its Recommendation No. 3, invited the C.C.I.R. to continue for all services;

(b) that for certain kinds of mobile services, partial data relating to interference protection ratios and minimum field strengths required, exist in documents of some Conferences of the I.T.U., for example, in the Final Acts of the International Administrative Aeronautical Radio Conference, Geneva, 1948-1949 and of the Special Regional Conference, Geneva, 1960;

(c) that such documents, however, do not constitute a complete and consistent set of data relating to all kinds of mobile services operating in all frequency ranges, particularly with respect to VHF-UHF mobile services;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the signal-to-interference protection ratios which define the threshold of harmful interference for the several mobile services;

2. what are the signal-to-noise ratios and the minimum field strengths required for satisfactory reception of the different classes of emission in the several mobile services;

3. what are the appropriate fading allowances in the several mobile services?

Note 1. — The above studies should be continued simultaneously and with the same urgency.

Note 2. — Particular attention should be given to those studies which will assist the further refinement of the technical standards used by the International Frequency Registration Board.

Note 3. — The above-mentioned studies should be carried on permanently and recommendations and possible revisions be published as soon as practicable.

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* This Question replaces Question 1/XIII of former Study Group XIII and is identical with that text.

STUDY PROGRAMME 3A/8 *

SELECTIVE-CALLING SYSTEMS FOR USE IN THE INTERNATIONAL MARITIME MOBILE SERVICES

The C.C.I.R., (1959 – 1963 – 1966)

CONSIDERING

(a) that Recommendation 257-1 does not give a full reply to Question 3/XIII;

(b) that the essential technical characteristics of a selective-calling system to be agreed upon need further study, in accordance with Report 320-2;

(c) that it is desirable to standardize technical and operating characteristics;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. trials of selective-calling systems, with a view to coming to a decision on the type of system that should be adopted internationally;

2. consideration of the number of individual code combinations required and the principles to be adopted in their allocation;

3. determination of those technical and operating characteristics of the selective-calling system which require international standardization;

4. degree of immunity of the systems from false operation and degree of their response to wanted signals.

QUESTION 5-1/8 **

THE INTRODUCTION OF DIRECT-PRINTING TELEGRAPH EQUIPMENT IN THE MARITIME MOBILE SERVICE

The C.C.I.R., (1965 – 1966 – 1970)

CONSIDERING

(a) that there is a requirement for communication in the maritime mobile service by means of direct-printing telegraph techniques;

(b) that the same information may need to be transmitted simultaneously from one coast station to a number of ship stations;

* This Study Programme replaces Study Programme 3A/XIII of former Study Group XIII and is identical with that text.

** This Question replaces Question 5/XIII of former Study Group XIII.

(c) that ship stations may need to transmit messages and data to coast stations;

(d) that the modulation rates and the telegraph codes used in the telegraph equipment should conform to C.C.I.T.T. standards;

(e) that the use of an error-indicating, an error-indicating and correcting, or an error-correcting system for such circuits may be necessary and that the characteristics of such systems need to be agreed upon;

(f) that any special operating procedures necessary for such a service should be agreed upon;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what types of error-indicating, error-indicating and correcting, or error-correcting system should be recommended for use over the radio paths;
2. what is the maximum modulation rate that should be used over the radio paths *;
3. what types of modulation should be used over the radio paths *;
4. what overall quality of transmission (error rate or transmission efficiency factor) is required for this service;
5. what operational procedures should be recommended for such a service?

QUESTION 6/8 **

SELF-SUPPORTING ANTENNAE FOR USE ON BOARD SHIPS

The C.C.I.R., (1966)

CONSIDERING

(a) that conventional main wire-antennae, suspended between the masts of merchant vessels, impede cargo-handling operations;

(b) that repeated dismantling and re-rigging of main wire-antennae in harbours leads to increased wear and tear and consequently decreases the reliability of the antenna system;

(c) that the superstructure of modern ships makes it more and more difficult to install main wire-antennae of sufficient height and clearance;

(d) that, therefore, the use on board ships of self-supporting main antennae is increasing;

* See Recommendation 440-1 and Appendix 20B (Mar) to the Radio Regulations.

** This Question replaces Question 6/XIII of former Study Group XIII and is identical with that text.

(e) that for several years, efforts have been made to improve the radiation properties and the efficiency of self-supporting antennae, to meet the requirements of the minimum normal range of ship stations in the MF band (International Convention for the Safety of Life at Sea, London, 1960, Chapter IV, Regulation 9, § (*g*));

(f) that the table of metre-amperes, which appears in the aforementioned Convention and which gives an indication of the normal range obtainable with an installation including a conventional main wire-antenna, cannot be applied to self-supporting antennae;

(g) that experimental work has shown that, in the frequency band 405-535 kHz, self-supporting antennae have, in general, poorer radiation properties than conventional main wire-antennae;

(h) that properly constructed and installed self-supporting antennae, however, have better radiation properties in the 2 MHz bands and HF bands compared with conventional main wire-antennae;

(j) that it is important that antennae and transmitters be suitably matched;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what advice should be offered to the Inter-Governmental Maritime Consultative Organization by the C.C.I.R. on the additions to be made to the table of metre-amperes given in the International Convention for the Safety of Life at Sea, London, 1960, Chapter IV, Regulation 9, § (*g*), to include self-supporting antennae;

2. what practical methods should be used to assess the properties of self-supporting antennae installed on board a ship in regard to radiation under different conditions, e.g. ship's draught, humidity, precipitation, location and configuration of the antennae;

3. to what extent will it be possible to use the dimensions of the antenna and its height above the deepest load waterline in assessing compliance with the requirements of the said Convention?

STUDY PROGRAMME 6A-1/8 *

SELF-SUPPORTING ANTENNAE FOR USE ON BOARD SHIPS

Performance at 500 kHz

The C.C.I.R., (1970)

CONSIDERING

(a) that there are now radically different physical and electrical configurations of self-supporting antennae as compared to the 500 kHz antennae to which Chapter IV, Regulation 9, § (*g*), of the International Convention for the Safety of Life at Sea, London, 1960, was intended to apply **;

* This Study Programme replaces Study Programme 6A/XIII of former Study Group XIII.

** Other types of antenna such as slot antenna are being developed and these also may have to be considered at some future date.

STUDY PROGRAMME 6A-2/8*

SELF-SUPPORTING ANTENNAE FOR USE ON BOARD SHIPS

Performance at 500 kHz

(1970 - 1972)

The C.C.I.R.,

CONSIDERING

(a) that there are now radically different physical and electrical configurations of self-supporting antennae as compared to the 500 kHz antennae to which Chapter IV, Regulation 9, §*(g)*, of the International Convention for the Safety of Life at Sea (London, 1960) was intended to apply **;

(b) that to provide an adequate answer to Question 6/8, additional data are needed as to the design, installation and performance of self-supporting antennae so that a proposal might be made for modification of Regulation 9, § *(g)*, so as to be applicable to self-supporting antennae while ensuring that such installations will meet the minimum normal ranges specified for ship stations;

DECIDES that the following studies should be carried out:

data on performance of self-supporting antennae should be collected and communicated to the Director, C.C.I.R., and the Chairman, Study Group 8.

1. Description

1.1 Characteristics, dimensions and material of antennae as mounted on shipboard, e.g., overall height above deepest-load water-line, etc., including simple diagrammatic sketches where appropriate;

1.2 information pertaining to the base insulator, lead-in insulator and any other insulator in the antenna system including, if possible:

1.2.1 physical dimensions and description including sketches;

1.2.2 shunt capacitance of each insulator;

1.2.3 information concerning the materials used;

1.3 information concerning the antenna-loading coil (if any), including its location, dimensions and electrical characteristics;

1.4 gross tonnage of the ship (G.R.T.).

* This Study Programme was adopted by the Interim Meeting of Study Group 8, Geneva, 1972.

** Other types of antenna such as slot antenna are being developed and these also may have to be considered at some future date.

2. Performance measurements and data presentation

2.1 The following list contains the kinds of measurements that would be helpful to the C.C.I.R. Administrations are encouraged to submit their measurement data to the C.C.I.R. and to include as much of the information as may be available to them. It is recommended that tests be repeated at intervals on the same ship, when convenient, to determine the effects of different conditions on the measurements. §§ 2.1.1, 2.1.2, 2.1.3 and 2.1.4 are considered to be most essential;

2.1.1 overall height (in metres) of antenna above the load-water-line at the time of measurement;

2.1.2 overall height (in metres) of antenna above the deepest load-water-line;

2.1.3 current (in amperes) delivered to antenna system at point "A" of the drawing in the Annex by the transmitter with class of emission A0;

2.1.4 current (in amperes) at points "B" and "C" of the drawing in the Annex with class of emission A0. It is recognized that in some cases points "B" and "C" coincide;

2.1.5 field strength (in mV/m) measured over sea water at a distance of at least 3 nautical miles and adjusted to a reference value at 1 nautical mile in accordance with Recommendation 368-1 of the C.C.I.R., with class of emission A0;

2.1.6 effective height of the antenna (in metres) calculated from measured field strength; the current used to calculate the effective height to overall height should be that at the base of the radiating element;

2.1.7 the ratio of effective height to height above the actual load-water-line at the time of measurement (h_e/h_{LL});

2.1.8 antenna connecting systems, giving dimensions in metres of both radiating and non-radiating elements as indicated in the figure of the Annex;

2.1.9 dimensions (in metres) and description of antenna-loading devices;

2.1.10 capacitance (in pF) of the antenna system:

— transmitter disconnected;

— transmitter and radiating elements disconnected at point "B";

— transmitter and radiating elements disconnected at the base insulator (at point "C");

2.1.11 impedance (in ohms) of the antenna system as measured at point "A" of the drawing in the Annex;

2.1.12 radiation resistance of the antenna (in ohms), method of calculation to be specified;

2.1.13 resonant frequency of the antenna system (kHz);

2.1.14 test frequency (kHz);

2.1.15 efficiency of antenna (%) (ratio of radiated antenna power to total antenna power, see Chapter IV, Regulation 9, § *(g)* of the International Convention for the Safety of Life at Sea, London, 1960);

2.1.16 weather conditions on board ship at time of measurements (rain or dry);

2.1.17 condition of insulators as determined by visual inspection.

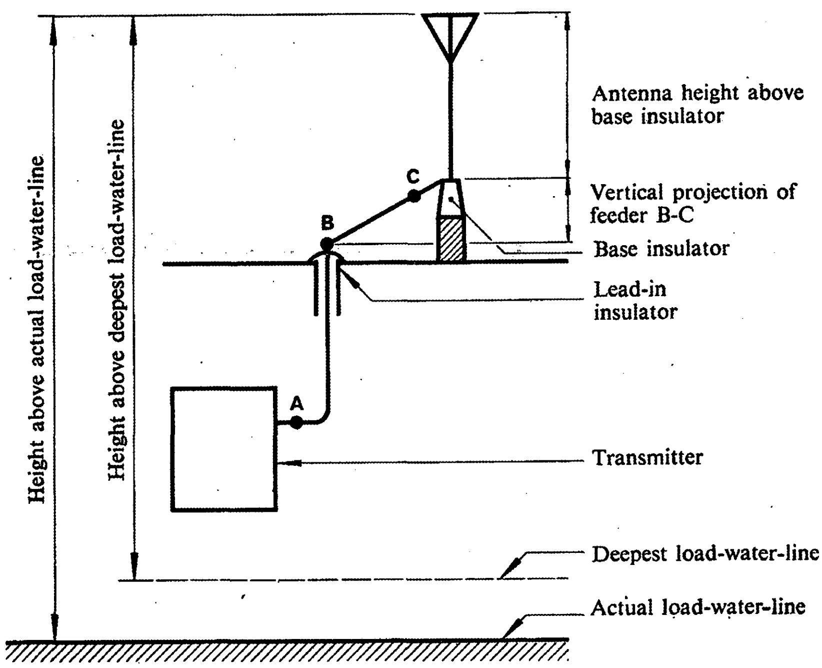
3. **Installation details**

3.1 The length for which a substantial component of the lead-in runs parallel closely to a massive metallic object and its average distance from that object;

3.2 special provisions for protection from adverse weather conditions, smoke, corrosion or vibration;

3.3 notations concerning effects of adverse weather, sea spray, smoke, vibration or corrosion on antenna, base insulator and loading device.

ANNEX



Diagrammatic representation of self-supporting antenna *(b)* that to provide an adequate answer to Question 6/8, additional data are needed as to the design, installation and performance of self-supporting antennae in order that a proposal might be made for modification of Regulation 9, § (*g*), so as to be applicable to self-supporting antennae while ensuring that such installations will meet the minimum normal ranges specified for ship stations;

UNANIMOUSLY DECIDES that the following studies should be carried out:

data on performance of self-supporting antennae should be collected and communicated to the Director, C.C.I.R., and the Chairman, Study Group 8.

1. Description

1.1 Characteristics, dimensions and material of antennae as mounted on shipboard, e.g., overall height above deepest-load waterline, etc., including simple diagrammatic sketches where appropriate;

1.2 information pertaining to the base insulator including, if possible:

1.2.1 physical dimensions and description including sketches;

1.2.2 shunt capacitance (total value if there is more than one insulator, or if the insulator is a part of a supporting assembly);

1.2.3 information concerning the materials used;

1.3 information concerning the antenna-loading coil (if any), including its location, dimensions and electrical characteristics;

1.4 dimensions of the ship.

2. Performance measurements and data presentation

2.1 The following list contains the kinds of measurements that would be helpful to the C.C.I.R. Administrations are encouraged to submit their measurement data to the C.C.I.R. and to include as much of the information as may be available to them. §§ 2.1.1, 2.1.2, 2.1.3, 2.1.4 and 2.1.5 are considered to be most essential;

2.1.1 overall height (in metres) of antenna above the load waterline at the time of measurement *;

2.1.2 current (in amperes) delivered to antenna system at point " A " of the drawing in the Annex by the transmitter with class of emission A0;

2.1.3 current (in amperes) at point " B " of the drawing in the Annex with class of emission A0;

2.1.5 field strength (in mV/m) measured over sea water at a distance of at least 3 nautical miles and adjusted to a reference value at 1 nautical mile in accordance with Recommendation 368-1 of the C.C.I.R., with class of emission A0;

* The height given should be the actual value at the time of measurement. The height above the deepest-load waterline, if different from the value at time of measurement, should also be noted.

2.1.6 effective height of the antenna (in metres) calculated from measured field strength; the current used to calculate the effective height should be that at the base of the radiating element;

2.1.7 shape factor of antenna (ratio of effective height to overall height of antenna above deepest-load waterline);

2.1.8 antenna connecting system including dimensions in metres;

2.1.9 height of antenna feed point above load waterline (in metres) *;

2.1.10 height (in metres) of the antenna structure above base insulator;

2.1.11 length (in metres) of radiating elements;

2.1.12 dimensions (in metres) and description of antenna-loading devices;

2.1.13 capacitance (in pF) of the antenna system:
— transmitter disconnected;
— transmitter and radiating elements disconnected;
— transmitter and radiating elements above the base insulator disconnected;

2.1.14 impedance (in ohms) of the antenna system as measured at point " A " of the drawing in the Annex;

2.1.15 radiation resistance of the antenna (in ohms), method of calculation to be specified;

2.1.16 resonant frequency of the antenna system (kHz);

2.1.17 test frequency (kHz);

2.1.18 efficiency of antenna (%) (ratio of radiated antenna power to total antenna power, see Chapter IV, Regulation 9, § (*g*) of the International Convention for the Safety of Life at Sea, London. 1960);

2.1.19 weather conditions on board ship at time of measurements (rain or dry).

3. Installation details, for example:

3.1 location on ship;

3.2 separation from nearby objects;

3.3 protection from adverse weather conditions, smoke, corrosion or vibration;

3.4 experience of effects of adverse weather, sea spray, smoke, vibration or corrosion on antenna, base insulator and loading device.

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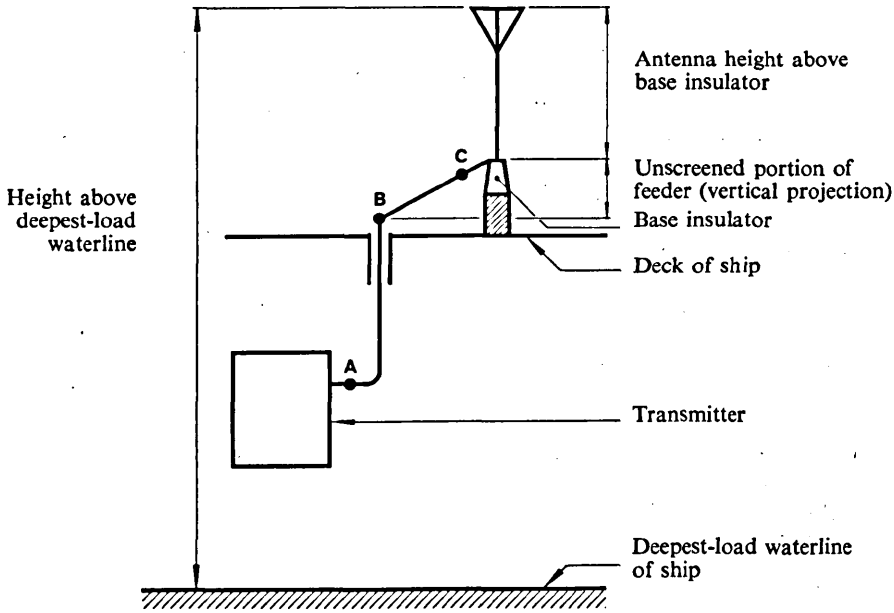
* The height given should be the actual value at the time of measurement. The height above the deepest-load waterline, if different from the value at time of measurement, should also be noted.

ANNEX



Diagrammatic representation of self-supporting antenna

QUESTION 7-1/8 *

CHARACTERISTICS OF EQUIPMENT AND PRINCIPLES GOVERNING THE ALLOCATION OF FREQUENCY CHANNELS IN THE LAND MOBILE SERVICES BETWEEN 25 AND 500 MHz

The C.C.I.R., (1956 – 1966 – 1970)

CONSIDERING

(a) that an interchange of information on the requirements of Administrations concerning the technical characteristics of equipment used in land mobile services between 25 and 500 MHz, would be advantageous in the development of those services;

(b) that an exchange of information among different countries concerning the practices applied to the assignment of channels and the experience gained in the operation of land mobile services between 25 and 500 MHz is of value in general;

(c) that a certain measure of agreement may be desirable on the characteristics of the land mobile equipment that are used in the border areas of neighbouring countries to minimize mutual interference;

(d) that a certain measure of agreement may also be desirable on the practices governing the allocation and use of channels in land mobile services between 25 and 500 MHz in border areas;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the technical requirements of Administrations concerning equipment used in land mobile services between 25 and 500 MHz that are of international importance in the development of such services, e.g. transmitter power, antenna characteristics, emission characteristics, frequency tolerance;

2. to what extent would it be desirable to standardize the performance characteristics of land mobile equipment between 25 and 500 MHz internationally;

3. what are the broad practices adopted by Administrations in the allocation of channels to the various kinds of user in the land mobile service between 25 and 500 MHz, e.g. channel separation, geographical spacing of stations in the same adjacent channels, frequency separation for duplex operation, degree of frequency sharing in a particular service area;

4. to what extent is it desirable to reach international agreement on the practices for the allocation of channels in the land mobile service between 25 and 500 MHz?

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* This Question replaces Question 7/XIII of former Study Group XIII.

STUDY PROGRAMME 7-1A/8 *

TECHNICAL CHARACTERISTICS OF LAND MOBILE EQUIPMENT BETWEEN 25 AND 500 MHz

The C.C.I.R., (1966)

CONSIDERING

(a) that Report 319-2 gives a partial answer to Question 7-1/8;

(b) that information contained in this Report will facilitate cooperation between Administrations in the technical operation of their services;

(c) that a degree of standardization is desirable, since the land mobile service connected to the national network may form part of an international connection, as stated in Recommendation 77-2;

(d) that it is desirable to determine equipment technical characteristics, to facilitate the planning of channel allocation in the land mobile bands;

(e) that it would therefore be desirable to reach agreement upon which are the essential technical characteristics for VHF and UHF radiotelephone equipment for use in the land mobile service, in order to expedite the international interchange of data on such equipment;

UNANIMOUSLY DECIDES that the following studies should be carried out:

determination of equipment characteristics (including methods of measurement) for the various land mobile services between 25 and 500 MHz which may be adopted by Administrations, in particular:

1. for frequency-modulation systems:

1.1 the maximum frequency deviation for various channel-frequency spacings;

1.2 pre-emphasis and de-emphasis characteristics;

2. for amplitude and frequency-modulation systems:

2.1 the maximum audio-frequency bandwidth;

2.2 frequency tolerances of transmitters;

2.3 typical and maximum output powers of base and mobile-station transmitters;

2.4 mean power limits of harmonic and other spurious emissions:

2.4.1 falling in any other land mobile channel,

2.4.2 falling within the bands of other radio services;

2.5 receiver characteristics, particularly:

— frequency stability,
— selectivity,
— radiation,
— intermodulation,
— choice of intermediate-frequency,
— sensitivity,
— audio-frequency response.

Note. — Study Programmes 7-1B/8, 7-1C/8 and 7-1D/8 should be borne in mind.

* This Study Programme replaces Study Programme 7A/XIII of former Study Group XIII and is identical with that text.

STUDY PROGRAMME 7-1B/8 *

MINIMUM CHANNEL-SEPARATION AND OPTIMUM SYSTEMS OF MODULATION FOR LAND MOBILE SERVICES BETWEEN 25 AND 500 MHz

The C.C.I.R., (1966)

CONSIDERING

(a) that Report 319-2 partly answers Question 7-1/8;

(b) that congestion in the VHF and UHF bands is a serious problem in many countries;

(c) that this is due to the rapid growth of the land mobile services;

(d) that in a number of countries many base stations are operated from within a limited geographical area;

(e) that the frequency tolerances given in Table I (Column 3) of Report 181-1 are now readily achievable with equipment used in the land mobile service;

(f) that in a number of countries impulse noise is at such a level as to cause serious degradation to communications range;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the minimum bandwidth necessary for various known modulation techniques, in particular for double-sideband amplitude-modulation, frequency-modulation and single-sideband emissions;

2. determination of the relative advantages and disadvantages of various types of modulation system as the occupied bandwidth approaches the minimum necessary for the transmission of intelligence, taking into account the necessary signal-to-noise ratio at the receiver input;

3. determination of the minimum channel-separation achievable between base station transmitters located within a limited geographical area or at a common site;

4. determination of the minimum frequency-separation between transmitters and receivers under conditions of duplex operation at the same site;

5. determination of the technical characteristics, criteria and techniques to achieve, in practice, the channel and frequency separations in §§ 3 and 4.

* This Study Programme replaces Study Programme 7B/XIII of former Study Group XIII and is identical with that text.

STUDY PROGRAMME 7-1C/8 *

INTERFERENCE DUE TO INTERMODULATION PRODUCTS IN THE LAND MOBILE SERVICES BETWEEN 25 AND 500 MHz

The C.C.I.R., (1966)

CONSIDERING

(a) that Report 319-2 only partly answers Question 7-1/8;

(b) that large numbers of base station transmitters and receivers may be operated within the same limited geographical area;

(c) that such transmitters may produce high-level intermodulation emissions, the odd orders of which fall within and on either side of a land mobile band, and these may fall on receive frequencies of land mobile stations;

(d) that channelling plans can be devised so as to minimize the effects of intermodulation products;

(e) that receivers may have spurious intermodulation responses as a result of two or more strong input signals;

(f) that external non-linearly conducting elements may produce intermodulation products from two or more signals;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. determination of the various causes of intermodulation products arising within transmitters, receivers and external non-linear elements, and the various techniques which may be used to minimize their production and reduce their effects, the method used being stated in each case;

2. determination of the maximum permissible mean power of intermodulation emissions for satisfactory operation in the land mobile services;

3. determination of the precautions that are required against the formation of intermodulation products in receivers and which are compatible with satisfactory operation of the land mobile services.

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* This Study Programme replaces Study Programme 7C/XIII of former Study Group XIII and is identical with that text.

STUDY PROGRAMME 7-1D/8

SYSTEMS FOR RADIOTELEPHONE NETWORKS FOR THE LAND MOBILE SERVICE WITH EXTREMELY ECONOMICAL FREQUENCY UTILIZATION

The C.C.I.R., (1970)

CONSIDERING

(a) that the number of radio stations in the land mobile service is increasing very rapidly;

(b) that the VHF and UHF bands are already overcrowded, and it may be necessary to use higher-frequency bands for the land mobile service;

(c) that for such higher frequencies, the coverage areas of each base station might be small;

(d) that by optimizing the size of base station coverage areas, better economy of the frequency spectrum might be achieved;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. for public and private systems, the optimum sizes of base station coverage, from the point of view of frequency spectrum economy and complexity of equipment;

2. the techniques appropriate to land mobile networks, including base stations with optimum coverage areas:

— for land mobile services for public use;

— for land mobile services for private use;

3. in what way should the following aspects be taken into consideration, in planning such systems:

3.1 frequency bands, including those higher than those used hitherto;

3.2 the topographical features;

3.3 the operational and technical problems when mobile stations move from one coverage area to a neighbouring area during a transmission or during a call;

3.4 the operational problem when, because of technical limitations, mobile stations have to remain in the same coverage area during a transmission.

QUESTION 8-1/8 *

MF AND HF LAND MOBILE SERVICES

Preferred technical characteristics of single-sideband equipment

The C.C.I.R., (1966 – 1970)

CONSIDERING

(a) that the final report of the Panel of Experts on the reduction of congestion in the HF spectrum has recommended the adoption of single-sideband techniques;

(b) that the necessary bandwidth of single-sideband emissions is less than that for other radiotelephone emissions;

(c) that there is an increasing need for economy in the use of spectrum space;

(d) that the use of single-sideband emissions in the maritime mobile service has been decided by the Maritime Conference, Geneva, 1967;

(e) that the International Civil Aviation Organization (I.C.A.O.) has adopted preferred technical characteristics for single-sideband equipment for the aeronautical mobile service;

(f) that the need for the use of single-sideband systems for the fixed services has been stressed (see Radio Regulation No. 465 and C.C.I.R. Recommendation 100-1);

(g) that sharing between the land mobile and other services exists in many frequency bands;

(h) that intercommunication between stations in the various mobile services may be necessary, particularly for search and rescue operations;

(j) that it is desirable for common, preferred technical characteristics to be adopted, as far as possible, for the maritime, aeronautical and land mobile services;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what basic requirements should be met for medium frequency and high frequency land mobile equipment, in particular the type of single-sideband emission, the sideband which should be used, and the channel separation;

2. what technical performance should be required of the transmitter—in particular, peak envelope power, frequency stability, modulation frequency response, levels of spurious emissions, level of carrier suppression, and restrictions on intermodulation products;

3. what technical performance should be required of the receiver—in particular, selectivity, sensitivity, audio-frequency response, frequency stability, blocking and intermodulation characteristics, and levels of spurious emissions;

4. what other special requirements are necessary for single-sideband equipment used in the medium frequency and high frequency land mobile service?

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* This Question replaces Question 8/XIII of former Study Group XIII.

QUESTION 9-1/8 *

SELECTIVE-CALLING SYSTEM FOR FUTURE OPERATIONAL REQUIREMENTS OF THE MARITIME MOBILE SERVICE

The C.C.I.R., (1967 – 1970)

CONSIDERING

(a) that Recommendation 257-1 **, in answer to Question 3/XIII, meets the immediate operational requirements of certain Administrations;

(b) that future operational requirements may necessitate the development of different types of selective-calling systems;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the operational requirements for selective calling that may be necessary for future maritime communication systems;
2. what other information, in conjunction with the selective call, may be required for the operation of future maritime communication systems;
3. what are the requirements and particular services, which may necessitate the inclusion of error control in conjunction with digital selective calling, and what particular error-control means are most compatible with those requirements;
4. what are the best means for meeting the operational requirements bearing in mind the technical and economic factors and the need for frequency-spectrum conservation?

QUESTION 10-1/8 ***

REDUCTION OF FREQUENCY SEPARATION BETWEEN ADJACENT CHANNELS IN THE VHF (METRIC) MARITIME MOBILE BAND

The C.C.I.R., (1967 – 1970)

CONSIDERING

(a) that the use of the VHF (156-174 MHz) band by the maritime mobile service is increasing;

(b) that, as a result of decisions at the Maritime Conference, Geneva, 1967, additional channel allocations have been made;

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* This Question replaces Question 9/XIII of former Study Group XIII.

** See also the Report by the Special Meeting of Study Group XIII, Geneva, 1967.

*** This Question replaces Question 10/XIII of former Study Group XIII.

STUDY PROGRAMME 9-1A/8*

SELECTIVE-CALLING SYSTEMS FOR USE IN THE INTERNATIONAL MARITIME MOBILE SERVICES IN THE SHIP TO SHORE DIRECTION

(1972)

The C.C.I.R.,

CONSIDERING

(a) that there is severe congestion in many of the frequency bands used in the maritime mobile service, particularly the MF and HF radiotelephone ship to shore channels;

(b) that this congestion causes great difficulties for ships wishing to make calls to coast stations;

(c) that these difficulties would be relaxed if selective-calling techniques could be used in the ship to shore direction;

(d) that selective-calling techniques for the maritime mobile service are available in the shore to ship direction;

(e) that the ultimate selective-calling system in the shore to ship direction is under further study within the C.C.I.R.;

DECIDES that the following studies should be carried out:

1. what selective-calling system should be used in the ship to shore direction, bearing in mind the desirability of avoiding unnecessary multiplication of systems with regard to:

1.1 the different frequency bands in use;

1.2 the two different directions;

1.3 the different classes of emissions;

1.4 possible future automatic alarm system for distress, to be used in shore to ship and ship to shore as well as ship to ship directions.

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* This Study Programme was adopted by correspondence before the Interim Meeting of Study Group 8, Geneva, 1972.

(c) that this has reduced the frequency separation between adjacent channels to 25 kHz;

(d) that, as there is already in operation much equipment designed for 50 kHz channel separation, the reduction of frequency spacing between adjacent channels makes necessary the consideration of technical characteristics of equipment, and harmful interference;

(e) that, although certain technical characteristics are laid down in the Radio Regulations, there may be a need for more detailed international standards of equipment in the VHF maritime mobile service;

UNANIMOUSLY DECIDES that the following question should be studied:

1. in view of the reduction to 25 kHz frequency separation between adjacent channels:

1.1 what technical characteristics should be adopted for equipment used in the international VHF maritime radiotelephone service;

1.2 what will be the effects on the performance of the radiotelephone system;

2. what special measures, if any, need to be taken in addition to those contained in Resolution No. Mar 14 of the Radio Regulations to introduce the 25 kHz separation between adjacent channels with the minimum adverse effect on existing services?

QUESTION 11/8 *

IMPROVEMENTS IN THE PERFORMANCE OF RADIOTELEPHONE CIRCUITS IN THE MF AND HF MARITIME BANDS

The C.C.I.R., (1968)

CONSIDERING

(a) that there is a need to improve the quality of transmission of MF and HF maritime radiotelephone circuits;

(b) that the adoption of new compandor principles which have recently become available might offer the prospect of such an improvement;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the methods by which compandor techniques can be applied to maritime radiotelephone circuits in the MF and HF bands;

2. what improvement in performance is to be expected with these techniques;

3. what characteristics would need to be agreed if such a technique were adopted;

* This Question replaces Question 11/XIII of former Study Group XIII and is identical with that text.

4. what changes, if any, would need to be made to the tolerances of existing equipment, etc. to satisfactorily apply such techniques;

5. what measures should be taken to provide compatible operations between stations utilizing compandor principles and those fitted with conventional equipment only?

STUDY PROGRAMME 11A/8

IMPROVEMENTS IN THE PERFORMANCE OF RADIOTELEPHONE CIRCUITS IN THE MF AND HF MARITIME BANDS

Linked compressor and expander systems

The C.C.I.R., (1970)

CONSIDERING

that to provide an adequate answer to Question 11/8 additional data are required as to the performance of systems and methods of comparing systems proposed for the improvement of transmission performance in the MF and HF maritime bands, especially in the public correspondence service;

UNANIMOUSLY DECIDES that the following studies should be carried out:

1. the methods that should be used for the objective assessment of the quality of communications;

2. the effect of interference from other stations on the quality of communications when interference exists in:

2.1 the speech channel,

2.2 the control channel;

3. whether diversity reception should be applied, and whether there are any restrictions in its application and effectiveness;

4. the working procedures necessary for setting up two-way calls and broadcast calls;

5. the effectiveness of the system when used with various languages, especially those which depend greatly on consonant sounds for good intelligibility;

6. the advantage of the linked compressor and expander system compared with other systems for improvement, from the standpoints of efficiency, complexity and economy;

7. the effect on the quality of a conventional communication in a working channel when a linked compressor and expander system is used in an adjacent channel.

Note. — Data on the methods of testing and evaluating the transmission improvement of systems using the linked compressor and expander technique, and the results of tests, evaluations and comparisons of such systems should be collected by Administrations and forwarded to the Director, C.C.I.R., and the Chairman of Study Group 8.

QUESTION 12/8 *

RADIO-PAGING ** SYSTEMS

The C.C.I.R., (1968)

CONSIDERING

(a) that systems for paging by means of radio are in operation in a number of countries and that their use is extending;

(b) that as the areas of coverage are increased, the possibility of interference between different radio-paging systems, and between radio-paging systems on the one hand and other radiocommunication systems on the other hand is increased;

(c) that the various systems already in use, or proposed, are not necessarily compatible one with another;

(d) that system compatibility is necessary in the case of international operation;

(e) that for international operation it is desirable to agree on the parameters of the system;

(f) that it is essential to make the most efficient use of the available radio-frequency spectrum;

UNANIMOUSLY DECIDES that the following question should be studied:

1. from a technical point of view, what frequency bands are most suitable for radio-paging systems;

2. what overall quality of transmission (capacity, degree of immunity from false calls, successful call ratio, etc.) should be provided by radio-paging systems;

3. what are the technical characteristics of radio-paging systems on which international agreement is desirable;

4. what operational facilities need to be specified to permit international operation of radio-paging systems, and in what circumstances could they share frequencies with other radiocommunication systems?

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* This Question replaces Question 12/XIII of former Study Group XIII and is identical with that text,

** Radio paging—a one-way calling system without speech.

QUESTION 13/8

INFLUENCE OF THE DOPPLER EFFECT ON RADIOCOMMUNICATION IN THE AERONAUTICAL MOBILE SERVICE

The C.C.I.R., (1970)

CONSIDERING

(a) that in Annex 10 to the Convention on International Civil Aviation, Volume I, 2nd edition, § 4.11.1.5, basic frequency stabilities (emission and reception) are laid down for aeronautical mobile services using single-sideband modulation taking Doppler effects into consideration but without giving it much importance;

(b) that the text in question stemmed from discussions on the introduction of single-sideband techniques to the aeronautical mobile service during the I.C.A.O. COM/OPS Division Meeting, Montreal, 1966;

(c) that at that conference it was stated *inter alia* that:

— it was necessary to apply a frequency tolerance to on-board equipment to allow for the Doppler effect;

— it was possible to establish practical tentative values for the Doppler effect taking into account the frequency used and aircraft speed;

(d) that for the purposes of the aeronautical mobile service, it is therefore necessary clearly to establish the influence of the Doppler effect, particularly with respect to supersonic aircraft;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what is the influence of the Doppler effect on radiocommunication in the aeronautical mobile service, taking the following factors into account:

1.1 speed of the aircraft,

1.2 use of special techniques,

1.3 feasibility of practical evaluation of the Doppler effect, depending on frequency and relative speed,

1.4 importance and consequences of the permissible frequency tolerances in equipment on board, taking the Doppler effect into account.

Note. — The Director, C.C.I.R., is requested to bring this Question to the notice of I.C.A.O. and to make arrangements with that Organization for coordination with a view to exchanging the results of investigations and data.

QUESTION 13-1/8

INFLUENCE OF THE DOPPLER EFFECT ON RADIOCOMMUNICATION IN THE AERONAUTICAL MOBILE SERVICE

(1970 – 1972)

The C.C.I.R.,

CONSIDERING

(a) that in Annex 10 to the Convention on International Civil Aviation (Volume I, 2nd edition, § 4.11.1.5) basic frequency stabilities (emission and reception) are laid down for aeronautical mobile services using single-sideband modulation, taking Doppler effect into consideration, but without giving it much importance;

(b) that the text in question stemmed from discussions on the introduction of single-sideband techniques to the aeronautical mobile service during the I.C.A.O. COM/OPS Division Meeting (Montreal, 1966);

(c) that at that conference it was stated *inter alia* that:

— it was necessary to apply a frequency tolerance to on-board equipment to allow for the Doppler effect;

— it was possible to establish practical tentative values for the Doppler effect taking into account the frequency used and aircraft speed;

(d) that for the purposes of the aeronautical mobile service, it is therefore necessary clearly to establish the influence of the Doppler effect, particularly with respect to supersonic aircraft:

DECIDES that the following question should be studied:

1. what is the influence of the Doppler effect on HF single-sideband radiocommunication in the aeronautical mobile service;

2. what is the feasibility of a practical evaluation of this Doppler effect;

3. what are the permissible frequency tolerances when taking this Doppler effect into account;

4. is there a need to use special techniques which would reduce or eliminate adverse system and/or service effects arising from Doppler frequency shift?

Note. — The Director, C.C.I.R., is requested to bring this Question to the notice of I.C.A.O. and to make arrangements with that Organization for coordination with a view to exchanging the results of investigations and data.

QUESTION 14/8

DIRECT-PRINTING AND OTHER DATA SIGNALS USING VOICE-FREQUENCY TECHNIQUES ON VHF RADIOTELEPHONY CHANNELS IN THE MARITIME MOBILE SERVICE

The C.C.I.R., (1970)

CONSIDERING

(a) that provision is made in Appendix 18 of the Radio Regulations for radiotelephony in the international maritime mobile service in the frequency band 156-174 MHz;

(b) that the application of VHF radio techniques enables communication services to be made available to ships on coastal and inland waters with predictable reliability and coverage area;

(c) that in many such areas, the use of digital and analogue voice-frequency techniques now utilized over land circuits can be extended to ships by VHF radio using existing radio equipment;

(d) that there are developing requirements for reliable facilities enabling the exchange of direct-printed information, and of data and facsimile traffic between ships and subscribers ashore;

(e) that a number of Administrations have already introduced direct-printing techniques in the maritime mobile service;

(f) that the required shipborne equipment should not be unduly complex;

(g) that a VHF maritime radiotelephone channel may be suitable for direct printing and other data signals or that such a channel may be suitable for simultaneous transmission of radiotelephony and direct-printing or similar data signals;

(h) that preferably the radiotelephone traffic-handling capacity, and the service quality, of the available channels should not be unduly reduced by the introduction of direct-printing or other kinds of traffic;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what technical standards should be adopted in the use of voice-frequency techniques for direct-printing, data and facsimile transmissions in the international VHF maritime mobile service;

2. what are the comparative advantages of using the same or different channels for radiotelephony and the other kinds of traffic referred to in § 1 above;

3. what procedures, including choice of frequency channels, should be adopted for types of communication other than radiotelephony with duplex and simplex radio equipment?

QUESTION 15/8

USE OF RADIO-BEACON STATIONS FOR COMMUNICATIONS

The C.C.I.R., (1970)

CONSIDERING

(a) the widespread use of radio-beacons in the aeronautical and maritime radionavigation services;

(b) the trend towards the fitting of direct-printing telegraph equipment on board ships;

(c) the need for transmitting information to aircraft and ships relating to weather, ice and other environmental matters affecting their navigation and safety;

(d) that in some areas there are disadvantages in using the VHF bands because of the limited range or in using the HF bands because of ionospheric disturbances but that in the LF band and the lower MF band propagation characteristics are generally stable and therefore suitable for reliable communications over broad areas;

(e) that speech and telegraph emissions may be superimposed on the carrier of some radio-beacons without measurable degradation in the performance of direction finders;

(f) that frequency and equipment economies may be effected by the dual use of existing radio facilities;

(g) that the classes of emission A2 and A2H are used with some radio-beacons for identification purposes;

UNANIMOUSLY DECIDES that the following question should be studied:

1. what are the preferred types and technical characteristics of supplementary emissions that can be superimposed on the carrier of a radio-beacon in the LF or lower MF band without affecting its identification readability or the performance of direction finders fitted in ships and aircraft;

2. what are the preferred operational procedures that should be followed in the use of radio-beacons with both communication and navigation functions?

Note. — The Director, C.C.I.R., is requested to inform the International Civil Aviation Organization (I.C.A.O.) and the Inter-Governmental Maritime Consultative Organization (I.M.C.O.) of the adoption of this Question. The results of these studies, when completed, will be brought to the attention of these two Organizations.

QUESTION 16/8

SYSTEMS PROVIDING RADIOCOMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR AIRCRAFT AND/OR SHIPS

The C.C.I.R., (1970)

CONSIDERING

(a) that former Study Group IV, which had to study the technical characteristics arising from operational needs, has given its views in principle on various technical factors related to both the aeronautical and maritime mobile services via satellite, for example on choice of frequency bands, choice of orbit, frequency sharing, etc.;

(b) that Study Group 8, which is involved in the identification of the various operational functions required for the mobile services, has no appropriate Question or Study Programme on this subject;

(c) that the International Civil Aviation Organization (I.C.A.O.) has already commenced the study of the application of space communication techniques for aeronautical requirements, in particular at the meeting of the COM/OPS Division (Montreal, October 1966) and has instituted a specialized panel called " ASTRA ";

(d) that the Inter-Governmental Maritime Consultative Organization (I.M.C.O.) has presented to the I.T.U. a preliminary list of operational requirements on the subject of maritime satellites for radiocommunication and radiodetermination (see Annex to Report 514);

(e) that Report 514 comments on these preliminary operational requirements presented by I.M.C.O.;

(f) that for the World Administrative Radio Conference for Space Telecommunications, to be held in June 1971, a clear identification of the various operational functions required for the mobile services will be necessary;

UNANIMOUSLY DECIDES that the following question should be studied:

what are the various operational functions required for radiocommunication and/or radiodetermination systems using satellite techniques for aircraft and/or ships, when relevant factors, such as operational requirements, traffic distribution, system complexity and economic efficiency, are taken into account?

Note. — The Director, C.C.I.R., is requested to draw the attention of I.C.A.O. and I.M.C.O. to this Question and to invite them to cooperate in the study.

QUESTION 17/8 *

TECHNICAL CHARACTERISTICS OF SYSTEMS PROVIDING COMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR AIRCRAFT AND/OR SHIPS

The C.C.I.R., (1968 – 1970)

CONSIDERING

(a) that the conclusions of the 51st meeting of the Committee on the Peaceful Uses of Outer Space were approved by the General Assembly of the United Nations at its XXIInd Session, in particular as regards:

— approval of the report of the " Working Group on a navigation services satellite system ";

— continuation by I.C.A.O., I.M.C.O. and other specialized agencies of the studies undertaken on space techniques;

(b) that I.C.A.O. has already begun the study of the application of space communication techniques for aeronautical requirements, in particular at the meeting of the COM/OPS Division (Montreal, October 1966) and has instituted a specialized panel called " ASTRA ";

(c) that I.M.C.O. has also begun the study of space techniques for communications and navigation with respect to maritime requirements, in particular for the safety of life at sea;

(d) that in its Recommendation No. Aer 2, the Extraordinary Administrative Radio Conference, Geneva, 1966, for the preparation of a revised allotment plan for the aeronautical mobile (R) service, advocated that study be made of the use of space communication techniques in the aeronautical mobile (R) service;

(e) that, in its Recommendation No. Mar 3, the World Administrative Radio Conference, Geneva, 1967, to deal with matters relating to the maritime mobile service, invited the C.C.I.R. to study the technical aspects of space communication systems which offer the potential of fulfilling the maritime requirements with respect to the navigation of ships at sea;

(f) that a number of Administrations are already studying satellite systems for air traffic control and air navigation by satellites;

(g) that systems employing space communication techniques to perform a radiodetermination function may be an important means for the support of air traffic services and may contribute considerably to the fulfilment of various operational needs for the safety of life at sea, such as search and rescue, traffic separation guidance, collision warnings, etc;

* This Question replaces Question 19/IV of former Study Group IV.

(h) that the frequencies to be used by such systems employing space communication techniques should be the subject of international agreement, not only to facilitate the setting up of such systems, but to avoid interference to and from other satellite systems and stations of other services;

UNANIMOUSLY DECIDES that the following question should be studied with respect to aircraft and/or ships:

1. what are the preferred types and technical characteristics of the following systems:

1.1 radiocommunication-satellite systems;

1.2 radionavigation-satellite systems;

1.3 radiolocation-satellite systems;

2. what are the preferred frequency bands for such systems;

3. are combined systems for radionavigation and radiolocation purposes feasible and advantageous;

4. are combined systems for radiocommunication and radiodetermination purposes feasible and advantageous;

5. is the sharing of frequencies with other systems feasible, and if so, with what other systems and under what conditions?

STUDY PROGRAMME 17A/8 *

TECHNICAL CHARACTERISTICS OF SYSTEMS PROVIDING COMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR AIRCRAFT AND/OR SHIPS

The C.C.I.R., (1968 – 1970)

CONSIDERING

(a) that there is a need for more reliable long-distance communication between land stations and:

— aircraft,

— ships;

(b) that systems employing space communication techniques could be conceived so as to ensure a service of sufficient reliability;

* This Study Programme replaces Study Programme 19A/IV of former Study Group IV.

(c) that communication with aircraft and ships may be needed for the transmission of telephony or telegraphy (including data transmission, direct printing, facsimile) or both;

(d) that in the interest of conservation of the radio-frequency spectrum and to minimize the equipment which aircraft and ships carry, there might be overall merit in:

— using the same maritime-mobile frequency bands whether the ship is communicating with a land station directly or via a satellite;
— using the same aeronautical-mobile frequency bands whether the aircraft is communicating with a land station directly or via a satellite;
— establishing a joint aeronautical-mobile/maritime-mobile communication band;

(e) that the use of common satellites for mobile service to both aircraft and ships might well be advantageous, especially if the same order of frequency were to be suitable for both;

(f) that important advantages, including those of frequency economy, might arise from combined systems for both communication and radiodetermination;

UNANIMOUSLY DECIDES that the following studies should be carried out to establish:

1. the preferred types of orbit to provide:

1.1 communication via satellite between land stations in the aeronautical-mobile service and aircraft and between land stations in the maritime-mobile service and ships;

1.2 a radiodetermination service via satellites for aircraft and for ships;

2. the preferred frequencies and technical characteristics for:

2.1 satellite-aircraft links;

2.2 satellite-ship links;

2.3 satellite-land links;

3. the technical feasibility of developing and operating communication-satellite systems for both the aeronautical-mobile service and the maritime-mobile service in the same frequency bands;

4. the technical feasibility of developing and operating communication-satellite systems for the aeronautical and/or maritime mobile services in the same frequency bands as other space and/or terrestrial services;

5. the technical feasibility of developing and operating systems employing space communication techniques jointly for communication and radiodetermination purposes for aircraft and/or for ships.

Note. — The Director, C.C.I.R., is requested to draw the attention of the International Civil Aviation Organization, the Inter-Governmental Maritime Consultative Organization and through the Secretary-General of the I.T.U., the United Nations Committee on the Peaceful Uses of Outer Space, to the existence of this Study Programme and, in particular, to invite I.C.A.O. and I.M.C.O. cooperation in this study.

STUDY PROGRAMME 17B/8*

TECHNICAL AND ECONOMIC CHARACTERISTICS OF SYSTEMS PROVIDING RADIOCOMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR SHIPS IN DIFFERENT FREQUENCY BANDS

(1972)

The C.C.I.R.,

CONSIDERING

(a) that under Recommendation No. Spa2 - 6, the World Administrative Radio Conference for Space Telecommunications (Geneva, 1971) recommended "that the C.C.I.R. continue its studies to determine the optimum portions of the frequency spectrum and related sharing conditions to accommodate maritime mobile satellite service requirements, taking into consideration advances in space radiocommunication technology";

(b) that certain channels in two small bands near 160 MHz may be allocated to the maritime mobile satellite service, in addition to the bands between 1535 and 1660 MHz;

(c) that the band 406.0 to 406.1 MHz has also been allocated to the mobile satellite service for low power emergency position-indicating radio-beacon systems using space techniques;

(d) that additional data are required as to the adequacy, usefulness and economic viability of the above bands for the maritime mobile satellite service;

(e) that the use of a multiplicity of frequency bands in the maritime mobile satellite service may have adverse effects on the viability of the systems;

(f) that possible developments of maritime systems may be applicable to future aeronautical/maritime search and rescue services;

(g) that Study Programme 17C/8 has been approved to study the suitability of the VHF frequency allocations for safety and distress purposes;

DECIDES that the following studies should be undertaken:

1. the suitability of the frequencies allocated to the maritime mobile satellite service, especially for small ships and survival craft, in particular with regard to safety, distress and search and rescue;

2. the economic and operational consequences of multiple shipboard and satellite equipment.

Note. — The Director, C.C.I.R., is requested to draw the attention of I.M.C.O. and I.C.A.O. to this Study Programme and invite them to cooperate in the study.

* This Study Programme was approved during the Interim Meeting of Study Group 8, Geneva, 1972.

STUDY PROGRAMME 17C/8*

TECHNICAL CHARACTERISTICS OF SYSTEMS PROVIDING RADIOCOMMUNICATION AND/OR RADIODETERMINATION USING SATELLITE TECHNIQUES FOR SHIPS IN THE VHF BAND

(1972)

The C.C.I.R.,

CONSIDERING

(a) that in Resolution No. Spa2 - 5, the World Administrative Radio Conference for Space Telecommunications (Geneva, 1971) is of the opinion "that it is important for the maritime mobile satellite service to be able to use some narrow-band channels on an exclusive basis for safety and distress as soon as practicable";

(b) that certain narrow bands may be allocated between 157.3125–157.4125 MHz and between 161.9125–162.0125 MHz for this purpose, in accordance with No. 287A of the Radio Regulations and Resolution No. Spa2 - 5;

(c) that the World Administrative Radio Conference on maritime mobile telecommunications in 1974 is invited to decide if and to what extent the maritime mobile satellite service should be introduced in these bands on an exclusive basis and make any consequential changes in the Radio Regulations;

(d) that additional data are required on the adequacy and usefulness of these bands for safety and distress in the maritime mobile satellite service;

(e) that there may be interference problems with terrestrial services;

DECIDES that the following study should be undertaken:

the suitability of the above bands in the maritime mobile satellite service for distress and safety purposes.

Note. — The Director, C.C.I.R., is requested to draw the attention of I.M.C.O. and I.C.A.O. to this Study Programme and invite them to cooperate in the study.

* This Study Programme was approved during the Interim Meeting of Study Group 8, Geneva, 1972.

STUDY PROGRAMME 17D/8*

FREQUENCY SHARING BETWEEN THE RADIONAVIGATION SERVICE AND THE RADIONAVIGATION SATELLITE SERVICE ON THE ONE HAND AND THE FIXED-SATELLITE SERVICE ON THE OTHER HAND

(1972)

The C.C.I.R.,

CONSIDERING

(a) Recommendation No. Spa2 – 15 of the World Administrative Radio Conference for Space Telecommunications (Geneva, 1971);

(b) that frequency sharing between the radionavigation service and the fixed-satellite service (Earth-to-space) has been adopted in the frequency band 14.0 to 14.3 GHz and between the radionavigation satellite service and the fixed-satellite service (Earth-to-space) in the frequency band 14.3 to 14.4 GHz;

DECIDES that the following studies should be carried out:

the criteria for frequency sharing between the radionavigation service and the fixed-satellite service (Earth-to-space) in the frequency band 14.0 to 14.3 GHz and also between the radionavigation satellite service and the fixed-satellite service (Earth-to-space) in the frequency band 14.3 to 14.4 GHz.

* This Study Programme was adopted at the Interim Meeting of Study Group 8, Geneva, 1972.

QUESTION 18/8

INTERNAL COMMUNICATIONS ON BOARD SHIPS BY MEANS OF SMALL VHF PORTABLE RADIOTELEPHONE APPARATUS

The C.C.I.R., (1971)

CONSIDERING

a) that the World Administrative Radio Conference to deal with matters relating to the maritime mobile service (Geneva, 1967) has decided to reduce the channel spacing for international maritime mobile VHF radiotelephone services from 50 kHz to 25 kHz (RR *, Res. Mar 14);

b) that the use of Channels 15 and 17 for internal operational communications on board ships has been authorised (Appendix 18 of RR *, note *i)*);

c) that the use of Channel 16 (156·8 MHz) is restricted to calling and safety purposes (Appendix 18 of RR *);

d) that Channel 16 is used in some parts of Region 2 for distress calls;

e) that, in order to avoid harmful interference on Channel 16, the effective radiated power on Channels 15 and 17 has been restricted to 0·1 W (Appendix 18 of RR *, note *i)*);

f) that the use of small VHF portable radiotelephone apparatus for internal communications on board ships can be very useful in emergencies;

g) that some members of the Inter-Governmental Maritime Consultative Organization (I.M.C.O.) requested an increase in power to a value of 1 to 2 W for such apparatus on Channels 15 and 17;

h) that there is a considerable variation in the antenna efficiency factor of small VHF portable apparatus and that there is insufficient information based on systematic investigations available;

i) that this special problem of increase in power on Channels 15 and 17 will probably be discussed at the next World Administrative Radio Conference to deal with matters relating to the maritime mobile service, Geneva, 1974;

DECIDES that the following question should be studied:

What is the maximum effective radiated power permissible on Channels 15 and 17 for on-board communications by means of VHF portable apparatus which will not cause harmful interference on Channel 16, taking into account the environmental conditions on board ships and the average characteristics of these portable apparatus ?

* Radio Regulations, 1968 edition.

QUESTION 18-1/8

INTERNAL COMMUNICATIONS ON BOARD SHIPS BY MEANS OF PORTABLE RADIOTELEPHONE EQUIPMENT

(1971 – 1972)

The C.C.I.R.,

CONSIDERING

(a) that the World Administrative Radio Conference to deal with matters relating to the maritime mobile service (Geneva, 1967) decided to reduce the channel spacing for international maritime VHF radiotelephone services from 50 kHz to 25 kHz (Resolution Mar 14 of the Radio Regulations*);

(b) that the use of Channels 15 and 17 for internal operational communications on board ships has been authorized (Appendix 18, Note *(i)* of the Radio Regulations*);

(c) that the use of Channel 16 (156.8 MHz) is restricted to calling and safety purposes (Appendix 18 of the Radio Regulations*);

(d) that Channel 16 is used in some parts of Region 2 for distress calls;

(e) that in order to avoid harmful interference in Channel 16 (Appendix 18, Note *(i)* of the Radio Regulations*), the effective radiated power on Channels 15 and 17 has been restricted to 0.1 W for on board communication;

(f) that the Inter-Governmental Maritime Consultative Organization (I.M.C.O.), recognizing the benefits to the safety of life at sea resulting from the use of portable radio equipment for internal communications on board ships, is of the opinion that the existing provisions of the Radio Regulations are too restrictive;

(g) that some members of I.M.C.O. requested an increase in power to a value of 1 to 2 W;

(h) that I.M.C.O. has indicated an operational requirement, particularly for safety purposes, for VHF and UHF frequencies to be made available for world-wide use on board ships on the high seas, in territorial waters and in harbours;

(j) that the use of Channels 15 and 17 may be restricted by national regulations (Appendix 18, Note *(i)* of the Radio Regulations*);

(k) that there is considerable variation in the factors relating the output power to the effective radiated power of small portable radio equipment and that more information is required;

(l) that frequency bands other than VHF may also be suitable for on board communication;

* Radio Regulations 1968 edition.

DECIDES that the following question should be studied:

1. what frequency bands are suitable for portable radio equipment for on board communication and what powers are required for effective communication;

2. how many channels should be provided;

3. what is the maximum effective radiated power in the respective frequency bands which will not cause harmful interference to other users, taking into account the environmental conditions on board the ship and the average characteristics of the portable equipment used;

4. what is technically the maximum effective radiated power permissible on Channels 15 and 17 of the international maritime VHF radiotelephony band;

5. what precautions must be taken to ensure that no interference is caused to the fixed radio installation on the ship?

Note. — The Director, C.C.I.R., is requested to bring this Question to the attention of I.M.C.O.

QUESTION 19/8

EQUIVALENT POWERS OF DOUBLE-SIDEBAND AND SINGLE-SIDEBAND RADIOTELEPHONE EMISSIONS

(1972)

The C.C.I.R.,

CONSIDERING

(a) that the Safety of Life at Sea Convention (London, 1960) prescribes a minimum value for the power of radiotelephone transmitters required to be carried aboard vessels of 300 tons gross tonnage and over;

(b) that in the 2 MHz band using class of emission A3, this minimum power is specified as 15 W (unmodulated) carrier output;

(c) that this power is taken to be the power necessary to assure a capability of transmitting from ship to ship clearly perceptible signals by day and under normal conditions and circumstances over a range of 150 nautical miles;

(d) that clearly perceptible signals are assumed to be received when the r.m.s. value of the field strength produced at the receiver by the (unmodulated) carrier is at least 25 μV/m;

(e) that in the interest of more efficient spectrum utilization, the World Administrative Radio Conference for the Maritime Mobile Service (Geneva, 1967) decided upon the conversion of all emissions in the 2 MHz band to single-sideband (SSB) by 1 January 1982;

(f) that new SSB transmitters utilize classes of emission A3A, A3H and A3J;

(g) that the Safety Convention requires that transmitters use the class of emission assigned by the Radio Regulations for these frequencies;

(h) that all the references in the Safety Convention to power are made in terms of unmodulated carrier, which is not appropriate to the SSB emissions;

DECIDES that the following question should be studied:

1. what should the r.m.s. values of the field strength produced at the receiver by radiated test signals using classes of emission A3A, A3H and A3J be, to provide a "clearly perceptible signal" — equivalent to the 25 μV/m used in § *(d)* for the case of A3 emissions — and what should be the nature of each such test signal;

2. what peak envelope powers are necessary to achieve equivalence over a range of 150 nautical miles for classes of emission A3A, A3H and A3J under the conditions given in § *(c)*?

QUESTION 20/8

BLACK-AND-WHITE FACSIMILE TRANSMISSIONS OVER COMBINED TELEPHONE AND RADIO CIRCUITS IN THE MARITIME MOBILE SERVICE

(1972)

The C.C.I.R.,

CONSIDERING

(a) the growing interest in the use of black-and-white facsimile transmissions over radio circuits in the maritime mobile service;

(b) that great advantages can be obtained by standardization of the technical characteristics of the transmissions;

DECIDES that the following question should be studied:

1. what are the preferred characteristics for black-and-white facsimile transmissions to and from ships where combinations of landline telephone circuits and maritime radio circuits are involved;

2. what operational procedures should be recommended for such transmissions?

Note. — The Director, C.C.I.R., is requested to bring this Question to the attention of the C.C.I.T.T.

Note by the Director, C.C.I.R.

The C.C.I.T.T. proposed that the expressions "telephone circuits" and "landline telephone circuits" in the text of this Question should read "metallic circuits" in conformity with C.C.I.R. Recommendation 344-2 (Vol. III, p. 124).

STUDY PROGRAMME 21A/8*

DEFINITION OF INTERFERENCE AND UNITS OF MEASUREMENT

(1972)

The C.C.I.R.,

CONSIDERING

(a) that the World Administrative Radio Conference for Space Telecommunications (Geneva, 1971) in RECOMMENDS 2.12 of its Recommendation No. Spa2 - 15, requests that the C.C.I.R. study the terms "acceptable (or unacceptable) interference" and "harmful interference" with a view to formulating clear definitions appropriate to, *inter alia*, the aeronautical mobile, maritime mobile, land mobile and radiodetermination services (terrestrial and satellite);

(b) that the above-mentioned definitions are essential for the development of proper criteria for the sharing of radio frequencies between stations of the aeronautical mobile, maritime mobile, land mobile and radiodetermination services (terrestrial and satellite) on the one hand and stations of other services on the other hand;

DECIDES that the following studies should be carried out:

1. investigation of the meaning of the terms "acceptable (or unacceptable) interference" and "harmful interference" with respect to the aeronautical mobile, maritime mobile, land mobile and radiodetermination services (terrestrial and satellite);

2. investigation of the appropriate units in which such types of interference may be expressed, whether in terms of signal level, of percentages of time, and/or by other means as the case may be.

Note. — The Director, C.C.I.R., is requested to draw the attention of I.C.A.O. and I.M.C.O. to this Study Programme and invite them to cooperate in the study.

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* This Study Programme is based on Question 45/1 of Study Group 1.

QUESTION 22/8*

MOBILE RADIOCOMMUNICATION EQUIPMENT FOR RELIEF OPERATIONS

(1972)

The C.C.I.R.,

CONSIDERING

(a) Recommendation No. Spa2 – 13 of the World Administrative Radio Conference for Space Telecommunications, Geneva, 1971;

(b) that rapid and reliable telecommunications are essential for relief operations in the event of natural disasters, epidemics, famines and similar emergencies;

(c) that, through damage or from other causes, the normal telecommunications facilities in disaster areas are often inadequate for relief operations and cannot be restored or supplemented quickly through local resources;

(d) that C.C.I.R. Study Group 4 is carrying out studies concerning standard specifications and preferred frequencies for transportable earth stations for relief operations;

DECIDES that the following question should be studied:

what are the preferred characteristics and frequency bands for radiocommunication equipment in the mobile service to establish telecommunications for relief operations, taking into account that this equipment may be connected to a transportable earth station in the fixed satellite service?

* See also Questions 22/3, 22/4, and 20/9.

RESOLUTION 20-2

CHARACTERISTICS OF EQUIPMENT AND PRINCIPLES GOVERNING THE ALLOCATION OF FREQUENCY CHANNELS IN THE LAND MOBILE SERVICES BETWEEN 25 AND 500 MHz

(Question 7-1/8)

The C.C.I.R., (1959 – 1963 – 1966 – 1970)

CONSIDERING

(a) that land mobile services of various kinds are growing rapidly;

(b) that, in border areas, difficulties may arise between the services of different Administrations;

(c) that it would be advantageous if there were a sufficient measure of agreement, where necessary, between Administrations on the characteristics of equipment and on the principles adopted in the planning for land mobile services;

UNANIMOUSLY DECIDES

1. that Administrations should consult together as necessary to resolve any difficulties concerning their land mobile services and for the purpose of improving such services;

2. that those Administrations which are interested in the provision of common land mobile services should consult together and should advise the C.C.I.R. of any technical and operational problems that require international study;

3. that Administrations should continue to submit new data and to update previously submitted technical specifications of land mobile equipment and the relevant measuring methods used in their respective countries for submission to the Chairman, Study Group 8 and the Director, C.C.I.R., for circulation. The attention of Administrations is drawn to the methods of measurement currently being standardized by the International Electrotechnical Commission (see Opinion 42);

4. that Administrations should submit information on practices adopted for the allocation of channels between 25 and 500 MHz for land mobile services to the Chairman, Study Group 8 and the Director, C.C.I.R., for circulation;

5. that Administrations should submit details of the blocks of frequencies between 25 and 500 MHz allocated:

5.1 for transmissions from base stations, and

5.2 for reception at base stations;

6. that Administrations which have reached agreement with adjacent countries on the operation of land mobile services in border areas, should submit to the C.C.I.R. technical and operational details of the agreement to assist other Administrations with similar problems.

OPINION 24 *

FACSIMILE TRANSMISSION OF METEOROLOGICAL CHARTS FOR RECEPTION ON BOARD SHIPS

The C.C.I.R., (1966)

CONSIDERING

(a) that meteorological charts are being transmitted extensively over radio circuits;

(b) that the transmissions concerned are mainly intended for exchange of meteorological information in the fixed services;

(c) that, however, it is desirable to adopt a more uniform practice for facsimile transmissions of meteorological charts intended for ships;

(d) that Chapter V, Regulation 4*b* (ii), of the International Convention for the Safety of Life at Sea, London, 1960, requests contracting governments to encourage the transmission of suitable facsimile weather charts for ships;

(e) that there is a need for the reception on board ships of suitable meteorological charts;

(f) that an increasing number of ships is being fitted with equipment for receiving meteorological charts;

(g) that the World Meteorological Organization (W.M.O.), in collaboration with the C.C.I.T.T., has standardized the equipment used for international meteorological transmissions (see the following W.M.O. documentation: Recommendations 60 and 61 of the third session of the Commission for Synoptic Meteorology (C.S.M.) and § 7.15 of the report of the fourth session of C.S.M.);

(h) that the W.M.O. standards provide for various drum speeds and indices of cooperation; the choice, which depends on the type of charts transmitted, is left at present to the discretion of meteorological services;

(j) that certain characteristics, concerning meteorological facsimile transmissions by radio, are contained in Recommendation 343-1;

IS UNANIMOUSLY OF THE OPINION

1. that consideration should be given to the provision of facsimile transmission of meteorological charts specifically intended for reception on board ships (see Recommendation 16-IV of the W.M.O. Commission for Maritime Meteorology);

2. that the layout of such charts, the minimum size of letters, figures and symbols, and the thickness of lines, should be standardized throughout the world, to facilitate their interpretation by ships' personnel when using small size recording equipment;

3. that the appropriate signals for preliminary tuning should be transmitted for about 120 seconds prior to the commencement of facsimile transmission of meteorological charts intended for ships;

* This Opinion terminates the study of Question 274.

4. that direct frequency-modulation (F4) should be employed for the facsimile transmission of meteorological charts over radio circuits, with the following characteristics:

— Decametric waves (3 MHz — 30 MHz)
Centre frequency (corresponding to the assigned frequency) . . . . f_0
Frequency corresponding to black . . . . f_0 −400 Hz
Frequency corresponding to white . . . . f_0 +400 Hz

— Kilometric waves (30 kHz — 300 kHz)
Centre frequency (corresponding to the assigned frequency) . . . . f_0
Frequency corresponding to black . . . . f_0 −150 Hz
Frequency corresponding to white . . . . f_0 +150 Hz

5. that consideration should be given to the use of one standard drum speed and one standard index of cooperation in facsimile transmissions specifically intended for reception by ships;

6. that consideration should also be given to keeping to a minimum throughout the world the number of radio frequencies employed for facsimile transmissions intended for reception by ships;

7. that the Director, C.C.I.R., should bring this Opinion to the attention of the W.M.O. for consideration by that Organization.

OPINION 42

METHODS OF MEASUREMENT OF TECHNICAL CHARACTERISTICS OF EQUIPMENT FOR THE LAND MOBILE SERVICE BETWEEN 25 AND 500 MHz

The C.C.I.R., (1970)

CONSIDERING

(a) that it is desirable to interchange information on the requirements of Administrations concerning the technical characteristics of equipment used in land mobile services between 25 and 500 MHz;

(b) that to facilitate the exchange of such information it is desirable to reach agreement on the methods to be adopted for the measurement of the technical characteristics;

(c) that it is understood that the International Electrotechnical Commission (IEC) is studying methods of measurement;

IS UNANIMOUSLY OF THE OPINION

1. that the IEC should be invited to advise the C.C.I.R. of any proposals they have made (or have under consideration) for the methods of measurement of the technical characteristics of transmitters and receivers which could be applied to radio equipment used in land mobile services;

2. that the Director, C.C.I.R., should be invited to transmit this Opinion to the IEC.

Note. — Recommendation 478 indicates the technical characteristics considered of international importance.

OPINION 43

SELF-SUPPORTING ANTENNAE FOR USE ON BOARD SHIPS

Performance at 500 kHz

The C.C.I.R., (1970)

CONSIDERING

(a) that an increasing number of ships are equipped with self-supporting antennae;

(b) that C.C.I.R. has studied the problems concerning self-supporting antennae and has collected some data from measurements carried out by Administrations (see Report 502);

(c) that further study is necessary;

IS UNANIMOUSLY OF THE OPINION

1. that the information given in Report 502 demonstrates that the values in the table of metre-amperes in Chapter IV, Regulation 9(*g*) of the International Convention for Safety of Life at Sea (SOLAS), London 1960, are not applicable to self-supporting antennae, and that after additional information is received, the values given in the table should be modified;

2. that this Opinion together with Report 502 should be brought to the attention of the Inter-Governmental Maritime Consultative Organization by the Director of the C.C.I.R.

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