CHAPTER 8

Frequency Allocation Plan

INTERNATIONAL TELECOMMUNICATION UNION

CCIR

INTERNATIONAL
RADIO CONSULTATIVE
COMMITTEE

RECOMMENDATIONS AND REPORTS OF THE CCIR, 1986

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

XVIth PLENARY ASSEMBLY
DUBROVNIK, 1986

VOLUME IX – PART 1

FIXED SERVICE USING RADIO-RELAY SYSTEMS

Geneva, 1986

XXV

FIXED SERVICE USING RADIO-RELAY SYSTEMS

STUDY GROUP 9

Terms of reference:

To study questions relating to line-of-sight and trans-horizon radio-relay systems operating via terrestrial stations at frequencies above about 30 MHz.

1982-1986-1990 *Chairman:* J. VERRÉE (France)
Vice-Chairmen: M. MUROTANI (Japan)
H. WILLENBERG (Germany (Federal Republic of))

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP 9

Under its terms of reference, Study Group 9 studies questions relating to the terrestrial fixed service using line-of-sight and trans-horizon radio-relay systems in the troposphere and excluding the ionosphere.

Radio-relay systems lend themselves to the transmission of a wide range of signals in many frequency bands and have been employed for several decades to equip telecommunication networks world-wide. To ensure that radio-relay systems fit smoothly into the networks, Study Group 9 collaborates closely with the various CCIR and CCITT Study Groups concerned.

These include in particular the following Study Groups, for which Study Group 9 has appointed Special Rapporteurs:

– CCIR Study Group 5, concerning the propagation data required;
– CCITT Study Group XVIII, concerning the characteristics of digital networks.

Line-of-sight radio-relay systems use low emission powers, receivers of relatively low sensitivity and extremely directional antennas. This makes it possible to share frequencies with other microwave systems used by various services, by limiting the powers used by the different services and coordinating geographical locations.

Several services, chiefly space services, are concerned.

The most important of these is the fixed-satellite service which generally shares the frequencies used by radio-relay systems. Specific studies on sharing conditions and arrangements have been conducted for several years in close cooperation with CCIR Study Group 4 in a Joint Working Party. It is on these studies that the relevant provisions of the Radio Regulations are based.

The other examples of frequency sharing concern the broadcasting-satellite service, the mobile-satellite service in certain bands, the Earth exploration-satellite and space research services and the terrestrial VHF and UHF mobile and broadcasting services. Such sharing may impose various restrictions on radio-relay systems which have to be defined in agreement with Study Group 9. The implications of such restrictions, which could result in unacceptable constraints for the development of radio-relay systems, have to be studied with some care.

A considerable degree of standardization has been achieved for analogue radio-relay systems, which are covered by many Recommendations. It might be considered that studies on these systems have been completed and no more are necessary. However, more and more studies are required to keep up with technological development in digital techniques, the use of high frequencies and frequency sharing with other services.

Study Group 9 has therefore been particularly active during the 1982-1986 study period, which also included the necessary work for the Conference Preparatory Meeting for WARC ORB-85 (June-July, 1984) and the First Session of the World Administrative Radio Conference on the Use of the Geostationary-Satellite Orbit and the Planning of the Space Services Utilizing It (WARC ORB-85) (August-September, 1985).

The Interim Meeting and Final Meeting of Study Group 9 were held in Geneva from 30 April to 16 May, 1984 and 30 September to 15 October, 1985 respectively.

XXVI

Over 200 contributions were submitted for these two meetings by administrations (representing a 25% increase in relation to the previous period) on the basis of which some 190 documents drawn up during the meetings were approved.

As in the past, this substantial workload was distributed among five Working Groups dealing with the following main items:

- performance objectives and effects of propagation on the design and operation of radio-relay systems;
- radio-frequency channel arrangements and spectrum utilization;
- baseband and intermediate frequency interconnection;
- maintenance;
- radio-relay systems for special applications;
- frequency sharing with other services.

The above classification is used for the arrangement of the sections of Study Group 9 texts in Volume IX; in this introduction the problems covered by the Study Group are considered in the same order.

1. Performance objectives and propagation effects

The main task facing Study Group 9 was the study of the most recent proposals put forward by CCITT Study Group XVIII relating to the performance of digital systems. In particular, account was taken of the distinction made in an ISDN between "high grade performance" systems, "medium grade performance" systems and "local grade performance" systems (between the subscriber and the local exchange).

For "high grade performance", Recommendation 594 and Report 930 were expanded. New Recommendation 634 was drawn up for real links in which the percentages of time are proportional to the length (for $L \geq 280$ km) and a residual bit error ratio was defined to prevent the accumulation of residual errors on digital sections from causing additional degraded minutes.

New Report 1052 considers the error performance and availability of "medium grade" systems in an ISDN.

New Report 1053 studies the case of "local grade" systems in an ISDN, and gives in an annex a proposed new Recommendation; the values of percentage of time that it contains are to be studied during the next period.

Study Group 9 prepared several notes for CCITT Study Group XVIII in order to establish the close coordination required for further studies on the performance of digital systems (see Annex I).

New Report 1054 deals with interference caused by terrain scattering when two radio hops cross each other and the terrain at the intersection is visible from both the transmitter of one of the hops and the receiver of the other. The described mechanism, which may also be of use for studying coordination between a terrestrial transmitter and a receiving earth station, requires more detailed consideration.

The effects of propagation on the design and operation of line-of-sight radio-relay systems were studied by Interim Working Party (IWP) 9/4, set up in 1981 by Decision 55 and chaired by Mr. McCormick (Canada). The revised version of Report 784 contains much information of use in the planning of radio-relay systems, and in particular digital systems. Since Interim Working Party 9/4 had successfully completed its task, it was disbanded and Decision 55 was deleted by the 1984 Interim Meeting. Mr. McCormick and all those who participated actively in the Interim Working Party's studies again deserve congratulations for their excellent work.

A Study Group 9 note to Study Group 5 draws attention to the worst-month statistics, a concept widely used for the definition of performance objectives for radio-relay systems (see Annex I).

The wording of Recommendation 557 was clarified as regards availability objectives for digital systems. In the revised version of Report 445, an improved formula to define availability was adopted and much antiquated statistical information, no longer of any value, was deleted.

New Study Programme 7G/9 covers the performance of digital trans-horizon systems.

2. Radio-frequency channel arrangements and spectrum utilization

The study of radio-channel arrangements for digital systems has been the main item on the agenda for several years.

Work is focused on two possibilities:

- either re-use of the channel arrangements recommended for analogue systems, which allows the coexistence of analogue and digital systems on the same artery and at the nodal points, and thereby facilitates gradual digitization of networks; or
- new channel arrangements designed specifically for digital transmission which are possibly not compatible with existing channel arrangements.

XXVII

These two possibilities have been successfully investigated and several outstanding problems were solved during the 1982-1986 study period.

New Recommendation 635 relates to high bit rate (90, 140 or 200 Mbit/s) systems in the 4 GHz band using frequencies selected in a homogeneous pattern with a basic spacing of 10 MHz. Report 935 was deleted, and the information retained was incorporated in Report 934 (Radio-frequency channel arrangements for high and medium-high capacity digital radio-relay systems operating in the frequency bands below about 10 GHz), which has six Annexes.

Recommendation 383 (1800 channel systems operating in the lower 6 GHz band) now applies to 140 Mbit/s digital systems following the same channel arrangement.

New Report 1055 deals with medium and small capacity digital radio-relay systems below 12 GHz and supplements Report 934 on large and medium capacity systems. Recommendations 385 (7 GHz band) and 386 (8 GHz band) contain an appropriate reference to the new Report.

In the 11 GHz band, the channel arrangement in Recommendation 387 can now also be used for 140 Mbit/s digital systems under the arrangements given in new § 9 and Annex II, as well as the channel arrangements described in Report 782 which has been revised and simplified.

In the 15 GHz band, new Recommendation 636 for low and medium capacity systems was expanded to cover both systems planned with a basic channel spacing of 14/28 MHz and those planned on the basis of a preferred spacing of 2.5 MHz or multiples thereof. The text was approved by virtue of a compromise reached with some difficulty.

The revised wording of § 5 of Recommendation 595 (17.7-19.7 GHz) clarifies the conditions for planning low capacity digital systems.

A further difficult compromise resulted in the adoption of new Recommendation 637 concerning the 23 GHz band for channels whose central frequencies are selected in a uniform reference pattern with a preferred interval of 3.5 MHz or 2.5 MHz. Application of this Recommendation may give rise to several variants described in the new version of Report 936, which relates to use of the frequency bands between about 18 GHz and 40 GHz and provides considerable information for a wide range of applications of such systems, in particular in local networks.

It can be seen that the new Recommendations provide flexible channel arrangements, with central frequencies selected in uniform reference patterns with a fixed basic spacing. This constitutes a completely different approach for digital systems from the strict channel arrangements recommended for analogue systems.

For analogue systems, new Report 1056 deals with radio-relay systems using vestigial-sideband amplitude modulation (AM/VSB) for the transmission of multiple television signals, for instance for remote distribution purposes. These systems, in use for many years, have never before been covered by a CCIR text. The available information relates to systems operating at 12 GHz or 13 GHz and in the 6 GHz band, and supplements the data on AM/SSB telephone systems at 6 GHz given in Report 781.

In respect of the radio-frequency characteristics of systems, Report 378 was considerably expanded to incorporate the most recent information on multi-state digital modulation systems which provide very efficient use of the spectrum. These modulation methods are the subject of new Study Programme 35A/9.

Report 376 sets out new data on frequency diversity techniques applied to digital radio-relay systems.

Report 937 on spurious emissions of radio-relay systems was also expanded, although further study is required.

Several Reports in this section have grown extremely large and probably contain outdated or factual information of dubious value. It would certainly be advisable to consider these texts during the next study period with a view to simplifying and clarifying their content and make them more directly usable.

3. Baseband and intermediate frequency interconnection

The baseband interconnection of analogue radio-relay systems for telephony, defined in Recommendation 380, was redefined for 600 and 960 channel systems (Table I and Note 1).

Report 786 relating to the simultaneous transmission of analogue and digital signals over analogue radio-relay systems, was expanded to include information on the use of amplitude modulation single sideband (SSB) systems and on the transmission of digital signals and multiplexed-analogue-component (MAC) television signals.

XXVIII

The choice of intermediate frequencies for high capacity digital systems is analysed in greater depth in the new version of Report 788, the conclusion is that for obvious practical reasons the frequencies of 70 or 140 MHz recommended for analogue systems should generally be used.

4. Maintenance

In Report 787 on the supervision and protection of digital systems, the method and characteristics used for supervision are considered in greater depth.

In addition to the progress made in the studies on digital performance objectives, Report 613 on bit-error measurement was improved with the definition of a measurement algorithm and the introduction of the idea of cyclical code error detection.

Study Group 9 considered that cooperation with the IEC on measurement methods for radio-relay systems should be continued, in view of the development of digital techniques; Opinion 50 was thus confirmed.

5. Radio-relay systems for special applications

These are mainly simple systems usually used in rural areas and of particular interest to the developing countries.

The main innovation lies in the preparation of new Report 1057 on point-to-multipoint systems utilizing time-division multiple access techniques (P-MP, TDMA), examples of which are given in Table I for the frequencies between 1.5 GHz and 26 GHz.

Reports 379 and 940 were consequently simplified; Report 379 now deals exclusively with low-capacity analogue or digital point-to-point systems used for rural telephone routes, and has a new Annex III containing an example of use of the 1.5 GHz band for such systems.

For subscriber connections, revised Report 380 looks at performance objectives for local networks in rural areas, and raises the question of less stringent standards for "local grade" ISDN systems that can be applied for reasons of economy to long systems in areas with low subscriber densities. The attention of CCITT Study Group XVIII has been drawn to this problem.

6. Frequency sharing with other services

6.1 *General*

Study Group 9 has kept abreast of the sharing studies undertaken in various fields by other Study Groups.

For the Earth exploration-satellite and space research services, Report 942 (passive sensors in the 18.6-18.8 GHz band) was updated and a note to Study Group 2 drawn up concerning Reports 987 (space research in the 2 GHz shared band) and 685 (deep-space research) (see Annex I).

A comment was submitted to Study Group 8 in respect of sharing with the maritime mobile-satellite service at 1.6 GHz (Report 917).

Study Programme 17B/9 relating to sharing with the broadcasting-satellite service was updated in the light of the outstanding problems at 12 GHz and the new problem of high-definition television raised by the WARC ORB-85.

Question 30/9 on sharing with the mobile service and the terrestrial broadcasting service in the VHF and UHF bands was also updated and Study Group 9 participated in the establishment of the Joint Interim Working Party (JIWP) for preparation of the Region 3 Conference scheduled for 1988.

Study Group 9 has also made arrangements for participation in the JIWP for CCIR inter-sessional studies with a view to the Second Session (1988) of the WARC ORB Conference which is referred to in Decision 73.

6.2 *Sharing with the fixed-satellite service*

As regards sharing with the fixed-satellite service, new Recommendation 675 on interference to digital radio-relay systems serves to supplement Recommendation 558 on interference to digital systems by satellites, which includes a new § 1.3 and new Note 2 pointing out the relationship with interference caused by other FSS networks (Recommendation 523). The interference criteria for digital radio-relay systems are discussed in the revised version of Report 877.

An important new problem, i.e. the conditions for frequency sharing between fixed service and fixed-satellite service systems for bidirectional frequency use was studied. New Report 1005 deals with this problem, which is covered in new Study Programme 17F/9.

New Report 1006 considers the protection of feeder links to broadcasting satellites at around 18 GHz and concludes that the present radio-relay system e.i.r.p. limits (Recommendation 406 and Article 27 of the Radio Regulations) are adequate.

XXIX

With regard to coordination, the new version of Report 382 takes account of the latest available propagation data and provides various sets of curves according to frequency. An Appendix to the Report puts forward an alternative method for determining propagation along the great circle, which will have to be studied in more depth during the next study period.

A note from Study Groups 4 and 9 to Study Group 5 sets out the propagation data which will have to be developed to enable progress to be made in the study of these complex problems (see Annex I).

Administrations are requested to compare the results produced by applying the various methods in Report 382 and in Appendix 28 to the Radio Regulations, to which no amendments are proposed at this stage.

Various additions were made to Reports 448, 388 and 792.

7. Terminology

The new version of Recommendation 592 clarifies the various types of communication and the terminology relating to radio-frequency channel arrangements of radio-relay systems. It comes at the beginning of the texts of Volume IX.

Study Group 9 has transmitted to the CMV its proposals concerning the abbreviations commonly used by the Study Group for inclusion in the Annex to Recommendation 666.

8. Reorganization of Questions and Study Programmes

Studies on analogue systems can be considered to have been completed except for special cases and will not be continued, given the change-over to digital techniques.

Questions 2/9 and 4/9 and associated Study Programmes 2A/9, 2B/9, 2C/9 and 4A/9, as well as Study Programmes 5A/9, 5B/9, 5C/9, 7B/9 and 7C/9 have therefore been deleted. Question 3/9 has been incorporated in the revised version of Question 1/9 and Study Programme 3A/9 has been deleted. Study Programme 1A/9 has been retained, but in an amended form focusing on analogue systems with high spectrum efficiency (e.g. amplitude modulation).

Question 12/9 with its six Study Programmes relating to digital systems has been deleted in favour of five new Questions and one Study Programme. Study Programmes 12B/9, 12C/9, 12E/9, 12F/9, 12H/9 and 12J/9 have become, subject to a number of editorial amendments, respectively, Questions 33/9, 34/9, 35/9, Study Programme 35A/9 and Questions 36/9 and 37/9.

This reorganization, mainly of form, results in a new structure of Questions and Study Programmes geared to the current orientation of Study Group 9 activities.

Several modifications have been made to Questions 5/9, 7/9, 9/9, 16/9, 25/9, 27/9 and 30/9.

The only completely new texts are Study Programme 7G/9 on digital trans-horizon systems, Study Programme 34A/9 on multi-state digital modulations, Study Programme 17E/9 on the criteria for sharing between radio-relay transmitters and receiving space stations in the fixed-satellite service (which deals with a problem studied from the very beginning and covered by Recommendation 406 and Report 790) and Study Programme 17F/9 on sharing criteria for bidirectional use of frequencies by the fixed-satellite service.

9. Programme of work for the next study period

On the basis of the following analysis and of discussions that have been held, it is possible to identify the main areas of activity to which Study Group 9 will have to give priority during the next study period.

The areas of work are as follows:

- preparation of Recommendations on error ratio objectives for digital radio-relay systems in the medium and local grade portion of an ISDN connection and the distribution of the availability objectives applicable to the three grades (high, medium and local), investigating whether these objectives should be divided into propagation objectives and maintenance objectives (see Table II);
- analysis of the situation resulting from the wide variety of radio channel arrangements which may be used for digital systems, in particular in the same frequency band (see Table III);
- study of modulation methods offering highly efficient use of the spectrum for digital (multi-state digital modulations – Study Programme 34A/9) and analogue (revised version of Study Programme 1A/9) operation;
- limitation of spurious emissions and definition of frequency tolerances applicable to digital systems (Question 19/9);
- characteristics for the interconnection, supervision and protection of digital systems (Questions 36/9 and 37/9);
- development of point-to-multipoint systems using TDMA techniques (Study Programme 27A/9);

XXX

- definition of allowable performance and availability objectives for special networks other than those in the ISDN and applicable to telephone radio-relay systems in bands 8 and 9 used in local networks in rural areas (see Annex II to Report 380);
- frequency sharing with the fixed-satellite service for bidirectional use of frequencies (Study Programme 17F/9) and improvement of coordination methods (see Table IVa);
- development of studies on sharing with services other than the fixed-satellite service (see Table IVb), taking into account the requirements of future conferences, in particular the WARC ORB(2).

The attached tables illustrate these areas. Where no Recommendation exists, reference is made to the relevant Questions and Reports. Table I shows the position as regards the Recommendations on analogue systems.

Also, Study Group 9 should consider new Question 38/9 based on the proposals of the Plan Committee for Latin America (Paramaribo, 1985) for a study of the applicability of cellular-type mobile radiocommunication systems for use as fixed systems in rural areas.

10. Conclusion

Clearly the work conducted by Study Group 9 during the 1982-1986 study period has been extremely fruitful; the latest progress in digital radio-relay techniques and in frequency sharing with other services was considered and the texts for submission to the XVIth Plenary Assembly were finalized.

Study Group 9 drew up five new Recommendations and eight new Reports and radically amended five existing Reports on subjects important to the development of digital systems. The structure of the Questions and Study Programmes was altered to the current pattern of work. The Study Group also made arrangements to participate in the preparation of future Conferences, especially the WARC ORB(2).

The order in which the texts are arranged in Volume IX – similar to that adopted in the previous edition – was chosen so that the texts are presented as logically and clearly as possible. It should facilitate the use of Volume IX, in particular by those who are not familiar with the work of the CCIR.

The particularly heavy workload was handled thanks to the help of the various participants who took an active part in the work, and the services of the ITU which succeeded in producing the vast amount of necessary documents in time.

Special mention should be made of the Chairmen of the Working Groups and Sub-Groups, as well as the members of the Drafting Group who successfully performed an extremely difficult task.

The Chairman wishes once again to extend his thanks to everyone involved and to express his very special gratitude to Messrs. H. Willenberg and M. Murotani, Vice-Chairmen, for their extremely efficient assistance, without which he would have been unable to accomplish his duties.

ANNEX I

TEXTS OF THE FINAL MEETING OF STUDY GROUP 9 TO BE KEPT FOR THE NEXT STUDY PERIOD

Notes to:

- CCITT Study Group XVIII:

  Doc. 9/365: CCITT Recommendations G.821 and G.921
  Doc. 9/383: High-grade real digital links
  Doc. 9/399: Performance objectives for rural local networks

- CCIR Study Group 5:

  Doc. 9/398(Rev.1): Worst-month statistics
  Doc. 4/388(9/392) + Corr.1: Interference and coordination distance statistics

- CCIR Study Group 2:

  Doc. 9/396: Reports 981 and 685: Space research at 2 GHz and in deep space

- CCIR Study Group 8:

  Doc. 9/342: Sharing with the maritime mobile-satellite service at 1.6 GHz

TABLE I – *Characteristics of radio-relay systems specified in CCIR Recommendations (analogue systems)*

	Frequency band	Maximum number of telephone channels: 1	6	12	24	60	120	300	600	900/960	1200/1260	1800	2700	Television	Trans-horizon
	Bands 8 and 9														388
Occupied bandwidth	2 GHz:														
Number of radio-frequency channels	Bandwidth 200 MHz					◄		283		►					
Centre frequencies and radio-frequency channel arrangements	Bandwidth 400 MHz								◄	382		►		382	
	4 GHz								◄	382		►		382	
Polarization arrangements	6 GHz								383		384	383	384	383, 384	
	7 GHz					◄	385	►							
	8 GHz							386		386				386	
	11 GHz								◄	387		►		387	
	13 GHz									497				497	
Interconnection at:															
audio frequencies				◄				268					►		
baseband frequencies					◄			380					►		
intermediate frequencies					◄					403				►	
video frequencies														270	
Hypothetical reference circuit				◄	391	► ◄				392			►	567 (CMTT)	396
Allowable noise power in the hypothetical reference circuit				◄				393					►	555	397
Noise in the radio portions of real circuits				◄				395					►		593
Allowable values of interference from the fixed-satellite service				◄				357					►		
Availability objectives for a hypothetical reference circuit							◄			557			►		
Frequency deviation				◄				404					►	276	404
Pre-emphasis and de-emphasis characteristics					◄			275					►	405	275
Line regulating and other pilots					◄					381, 401					►
Signalling and service channels						◄				400					►
Stand-by arrangements						◄				444				►	
Auxiliary radio-relay systems						◄				389				►	
Residues of signals outside the baseband						◄			381				►	463	381
Maintenance measurement in actual traffic					◄				398				►		
Measurements of noise using a continuous uniform spectrum						◄			399				►		

XXXII

TABLE II – *Hypothetical reference digital paths – Performance and availability objectives*

		Section of an ISDN			Special applications other than ISDN
		High grade	Medium grade	Local grade	
Hypothetical reference digital paths (HRDP)		Recommendation 556	Question 33/9 (Report 1052)	Question 33/9 (Report 1053)	Questions 9/9, 10/9 (Report 380)
Performance objectives	For an HRDP	Recommendation 594 (Report 930)	Question 33/9 (Report 1052)	Question 33/9 (Report 1053)	Questions 9/9, 10/9 (Report 380)
	For a real radio-relay link	Recommendation 634 (Report 930)			
Availability objectives	For an HRDP	Recommendation 557 (Report 445)	Question 5/9 (Report 1052)	Question 5/9 (Report 1053)	Questions 9/9, 10/9 (Report 380)
	For a real radio-relay link	Question 5/9 (Report 445)			

XXXIII

TABLE III – *Radio-frequency channel arrangement for digital radio-relay systems*

Band	High capacity	Medium capacity	Low capacity
Below 2 GHz		Recommendation 283	Question 9/9 (Report 379)
2 GHz		Recommendations 283, 382 (Reports 933, 934)	Recommendation 283 (Report 933)
4 GHz	Recommendation 635 (Report 934)	Recommendation 382 (Report 934)	
6 GHz (lower)	Recommendation 383 (Report 934)	Question 35/9 (Report 934)	
6 GHz (upper)	Recommendation 384		
7 GHz		Question 35/9 (Report 1055)	Question 35/9 (Report 1055)
8 GHz		Question 35/9 (Reports 934, 1055)	Question 35/9 (Report 1055)
11 GHz	Recommendation 387 (Report 782)	Recommendation 387	Recommendation 387
13 GHz		Recommendation 497	
15 GHz		Recommendation 636 (Report 607)	Recommendation 636 (Report 607)
19 GHz	Recommendation 595 (Report 936)		
23 GHz	Recommendation 637 (Report 936)		
Approximately 18 to 40 GHz	Question 35/9 (Report 936)		

Note 1. – Report 607 also gives information for the 10, 12 and 14 GHz bands.

Note 2. – Report 936 also gives information for analogue systems.

Rec. 283-4

SECTION 9B: RADIO-FREQUENCY CHANNEL ARRANGEMENTS AND SPECTRUM UTILIZATION
9B1: RADIO-FREQUENCY CHANNEL ARRANGEMENTS

Recommendations and Reports

RECOMMENDATION 283-4*

RADIO-FREQUENCY CHANNEL ARRANGEMENT FOR ANALOGUE RADIO-RELAY SYSTEMS WITH A CAPACITY OF 60, 120, 300 AND UP TO 960** TELEPHONE CHANNELS OR LOW AND MEDIUM CAPACITY DIGITAL SYSTEMS OF EQUIVALENT RF BANDWIDTH OPERATING IN THE 2 GHz BAND

(Questions 1/9 and 12/9, Geneva, 1982)

(1959-1966-1970-1978-1982)

The CCIR,

CONSIDERING

(a) that it is sometimes desirable to be able to interconnect radio-relay systems of 60, 120, 300 and up to 960** telephone channel capacity, or low and medium capacity digital systems of equivalent bandwidth, on international circuits using radio frequencies in the 2 GHz band;

(b) that, in a frequency band 200 MHz wide, it may be desirable to interconnect up to six go and six return radio-frequency channels;

(c) that economy may be achieved, if at least three go and three return channels can be interconnected between systems each of which uses a common transmit-receive antenna;

(d) that for systems up to 300 telephony channels many interfering effects can be substantially reduced by a carefully planned arrangement of the radio frequencies in radio-relay systems employing several radio-frequency channels;

(e) that for systems up to 300 telephony channels it may sometimes be desirable to interleave additional radio-frequency channels between those of the main pattern;

(f) that it is desirable for the values of the mid-frequencies of the radio-frequency channels to be the same for 60, 120, 300 and up to 960 channel telephony systems, as well as for digital systems;

(g) that the spacing between the mid-frequencies of the radio-frequency channels should be such that the systems can work with the maximum frequency deviation given in Recommendation 404 for systems up to 600 telephone channels, while for 960 telephone channel systems a lower frequency deviation should be used in order to improve the spectrum utilization,

UNANIMOUSLY RECOMMENDS

1. that the preferred radio-frequency channel arrangement for up to six go and six return channels, each accommodating 60, 120, 300 or a maximum of 960** telephone channels or digital systems of equivalent RF bandwidth, and operating within the frequency bands listed under § 6, should be as shown in Fig. 1, which is derived as follows:

Let f_0 be the frequency of the centre of a 200 MHz band of frequencies occupied (MHz);

f_n be the centre frequency of one radio-frequency channel in the lower half of this band (MHz);

f'_n be the centre frequency of one radio-frequency channel in the upper half of this band (MHz);

then the frequencies in MHz of individual channels are expressed by the following relationships:

lower half of band: $f_n = f_0 - 108.5 + 14\,n$,

upper half of band: $f'_n = f_0 + 10.5 + 14\,n$,

where

$n = 1, 2, 3, 4, 5$ or 6;

* This Recommendation applies only to line-of-sight and near line-of-sight radio-relay systems.

** The provision of this Recommendation for 960 channels applies only in the frequency band 2500 to 2700 MHz.

Rec. 283-4

2. that, in a section over which the international connection is arranged, all the go channels should be in one half of the band, and all the return channels should be in the other half of the band;

3. that for adjacent radio-frequency channels in the same half of the band, different polarizations should preferably be used alternately;*

4. that, when common transmit-receive antennas are used and three radio-frequency channels are accommodated on a single antenna, it is preferable that the channel frequencies be selected by either making $n = 1, 3$ and 5 in both halves of the band or making $n = 2, 4$ and 6 in both halves of the band;

5. that, when additional radio-frequency channels, interleaved between those of the main patterns, are required, the values of the centre frequencies of these radio-frequency channels should be 7 MHz above those of the corresponding main channel frequencies;**

6. that the centre frequencies should preferably be those shown below:

f_0 = 1808 MHz for the band 1700 to 1900 MHz;
f_0 = 2000 MHz for the band 1900 to 2100 MHz;
f_0 = 2203 MHz for the band 2100 to 2300 MHz (see Note 3);
f_0 = 2586 MHz for the band 2500 to 2700 MHz***.

Other centre frequencies may be used by agreement between the administrations concerned.

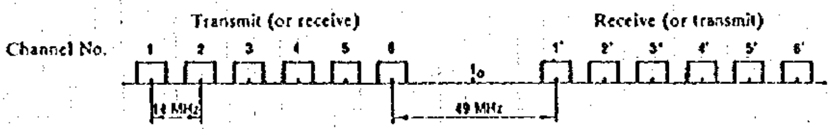


FIGURE 1 – *Radio-frequency channel arrangement for international connection of radio-relay systems operating in the 2 GHz band*

Note 1. – When the frequency band 1900 to 2300 MHz or 1700 to 2100 MHz is used for large capacity radio-relay systems and a 60, a 120 or a 300 channel system is used on the same route, the possibility of introducing mutual interference is greatly reduced if separate antennas are used for the two systems.

Note 2. – In systems for up to 300 telephony channels, operational difficulties may be experienced along a route, due to over-reach and similar problems. In such cases, additional frequencies, spaced 3.5 MHz from the allocations given above, are available for use as stagger frequencies.

Note 3. – In certain countries, particularly in Region 2, it may be preferable to have the frequencies in MHz of individual channels as expressed by the following relationships:

lower half of band: $f_n = f_0 - 94.5 + 14\,n,$
upper half of band: $f'_n = f_0 - 3.5 + 14\,n,$

where

$n = 1, 2, 3, 4, 5$ or 6.

Interleaved channels should be 7 MHz below those of the corresponding main channels.

---

* The same polarization for adjacent channels can also be used for low capacity digital systems.

** In systems for 960 telephone channels in the band 2500 to 2700 MHz, or digital systems of equivalent RF bandwidth, it may not be practicable to use interleaved frequencies, because of the wide bandwidth occupied by the modulated carrier.

*** Attention is drawn to the fact that the lowest main channel frequency is below 2500 MHz and that in accordance with Article 8 of the Radio Regulations, all emissions are prohibited in the band 2690-2700 MHz except in the countries mentioned in Nos. 767 and 769 and for equipment in operation by 1 January 1985.

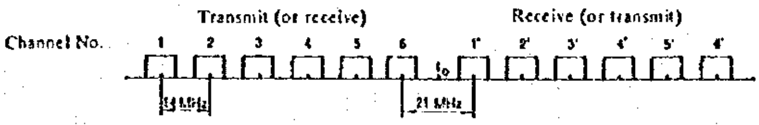


FIGURE 2 – *Radio-frequency channel arrangement referred to in Note 3*

Note 4. – When using a 960* telephone channel system, in accordance with this Recommendation, the following preferred values should be used:
– r.m.s. deviation per channel: 140 kHz,
– frequency of continuity pilot: 4715 kHz,
– r.m.s. deviation for the continuity pilot: 100 kHz.

REPORT 933

RADIO-FREQUENCY CHANNEL ARRANGEMENT FOR ANALOGUE RADIO-RELAY SYSTEMS WITH A CAPACITY UP TO 300 TELEPHONE-TYPE CHANNELS OR DIGITAL SYSTEMS OF EQUIVALENT RF BANDWIDTH OPERATING IN THE 2.3 TO 2.5 GHz BAND**

(Questions 1/9 and 12/9, Geneva, 1982)

(1982)

1. Introduction

Radio-frequency channel arrangements for systems with a capacity of up to 300 FDM-FM telephone channels or digital systems of equivalent radio-frequency bandwidths operating in the bands 1.7 to 2.3, and 2.5 to 2.7 GHz are given in Recommendation 283.

This Report presents a radio-frequency channel arrangement in the radio-frequency band 2.3 to 2.5 GHz, a band which has been allocated by the WARC-79 to the fixed service. This radio-frequency band could be used for various applications such as trunk connections in rural areas, medium-capacity radio circuits etc.

2. Frequency-band utilization

Independent of its application, it has been found useful to have only one basic radio-frequency channel arrangement. This would allow the application of radio-relay systems of various capacities, within a certain area, minimizing the risk of mutual, harmful interference.

3. Frequency pattern

3.1 The radio-frequency channel arrangement for the above radio-relay systems is based on an adjacent-channel spacing of 1 MHz, and is derived as follows:

Let f_0 be the reference frequency (in MHz) of the frequency pattern;

f_n be the centre frequency (in MHz) of one radio-frequency channel in the lower half of the band;

f'_n be the centre frequency (in MHz) of one radio-frequency channel in the upper half of the band;

then the centre frequencies of the individual channels can be expressed by the following relationships:

lower half of the band: $f_n = f_0 - 87 + n,$

upper half of the band: $f'_n = f_0 + 7 + n,$

where

$n = 1, 2, 3, \ldots, 80$

---

* The provision of this Recommendation for 960 channels applies only in the frequency band 2500 to 2700 MHz.

** This radio-frequency channel arrangement applies only to line-of-sight and near line-of-sight radio-relay systems.

Rep. 933

This is illustrated in Fig. 1.

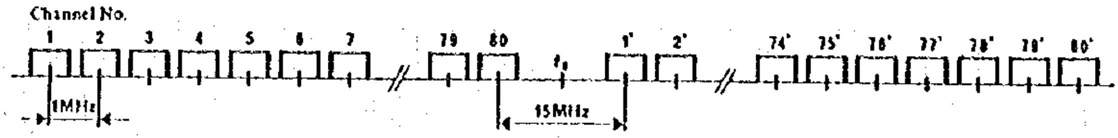


FIGURE 1 — *Radio-frequency channel arrangement for up to 300 telephone channels radio-relay systems operating in the 2.3 to 2.5 GHz band*

3.2 The reference frequency should preferably be f_0 = 2394 MHz.

3.3 In a section over which an international or rural connection is arranged, as well as in a network node, all the go channels should be in one half of the radio-frequency band, and all the return channels in the other half.

3.4 The preferred adjacent co-polar channel separations for various channel capacities are listed in Table I.

TABLE I

Channel capacity	RF channel separation (MHz)	n =
12 FDM	1	1, 2, 3, 4, ...
24 FDM	2	1, 3, 5, 7, ...
60 FDM	4	1, 5, 9, 13, ...
120 FDM	14	1, 15, 29, 43, ...
300 FDM	28	1, 29, 57
24 PCM	2	1, 3, 5, 7, ...
30 PCM	2	1, 3, 5, 7, ...
48 PCM	4	1, 5, 9, 13, ...
60 PCM	4	1, 5, 9, 13, ...

3.5 When, for example, either at a nodal point or within an artery (using cross-polar discrimination), and for capacities of 24 telephone channels or more, additional radio-frequency channels are required, the channel numbers should be as follows:

24 telephone channels n = 2, 4, 6, 8, ... ($n \leq 80$)
60 telephone channels n = 3, 7, 11, 15, ... ($n \leq 79$)
120 telephone channels n = 8, 22, 36, 50, ... ($n \leq 78$)
300 telephone channels n = 15, 43, 71.

Note 1. — The band 2400 to 2500 MHz (centre frequency 2450 MHz) is designated for industrial, scientific and medical (ISM) applications. Radio services operating within this band must accept harmful interference which may be caused by these applications.

Note 2. — For capacities of 60 telephone channels or more, additional frequencies with channel number:

n = 2, 4, 6, 8, etc. for 60 telephone channels
n = 5, 12, 19, 26, etc. for 120 telephone channels
n = 8, 22, 36, 50, etc. for 300 telephone channels

are available for use as offset frequencies. These frequencies may be of help to reduce interference along a route due to over-reach, or to reduce the requirements for the antenna discrimination in a network node.

Note 3. — Further studies are required to evaluate interference problems caused by intermodulation products between different systems working on the same route.

RECOMMENDATION 382-4 *

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR RADIO-RELAY SYSTEMS FOR TELEVISION AND TELEPHONY FOR 600 TO 1800 TELEPHONE CHANNELS, OR THE EQUIVALENT, OPERATING IN THE 2 AND 4 GHz BANDS OR FOR MEDIUM-CAPACITY DIGITAL RADIO-RELAY SYSTEMS OPERATING IN THE 4 GHz BAND

(Questions 1/9 and 35/9)

(1956-1959-1963-1966-1970-1982-1986)

The CCIR,

CONSIDERING

(a) that it is sometimes desirable to be able to interconnect radio-relay systems on international circuits at radio frequencies in the 2 and 4 GHz bands;

(b) that, in a frequency band 400 MHz wide, it may be desirable to interconnect up to six go and six return radio-frequency channels;

(c) that economy may be achieved if at least three go and three return channels can be interconnected between systems each of which uses common transmit-receive antennas;

(d) that many interfering effects can be substantially reduced by a carefully planned arrangement of the radio frequencies in radio-relay systems employing several radio-frequency channels;

(e) that it may sometimes be desirable to interleave additional radio-frequency channels between those of the main pattern;

(f) that the use of bit rates of 2 × 34 Mbit/s or 2 × 45 Mbit/s is possible in the 4 GHz band,

UNANIMOUSLY RECOMMENDS

1. that the preferred radio-frequency channel arrangement for up to six go and six return channels, each accommodating 600 to 1800 telephone channels, or the equivalent, and operating at frequencies in the 2 and 4 GHz bands, should be as shown in Fig. 3 and should be derived as follows:

Let f_0 be the frequency of the centre of the band of frequencies occupied (MHz);

f_n be the centre frequency of one radio-frequency channel in the lower half of the band (MHz);

f'_n be the centre frequency of one radio-frequency channel in the upper half of the band (MHz);

then the frequencies in MHz of individual channels are expressed by the following relationships:

lower half of band: $f_n = f_0 - 208 + 29\,n$,

upper half of band: $f'_n = f_0 + 5 + 29\,n$,

where

$n = 1, 2, 3, 4, 5$ or 6;

2. that in a section over which the international connection is arranged all the go channels should be in one half of the band, and all the return channels should be in the other half of the band;

3. that for adjacent radio-frequency channels in the same half of the band, different polarizations should preferably be used alternately; i.e. the odd numbered channels in both directions of transmission on a given section should use H(V) polarization, and the even numbered channels should use V(H) polarization, as shown in Fig. 1 below:

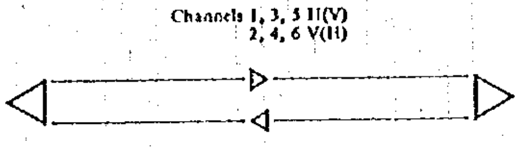


FIGURE 1

* This Recommendation applies only to line-of-sight and near line-of-sight radio-relay systems.

Rec. 382-4

Note. – When antennas for double polarization are used, the arrangement of channels shown in Fig. 2 may be used by agreement between administrations:

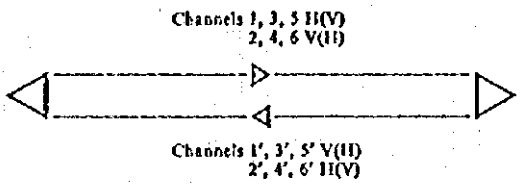


FIGURE 2

4. that, when common transmit-receive antennas are used, and not more than three radio-frequency channels are accommodated on a single antenna, it is preferred that the channel frequencies be selected by either making $n = 1, 3$ and 5 in both halves of the band or making $n = 2, 4$ and 6 in both halves of the band;

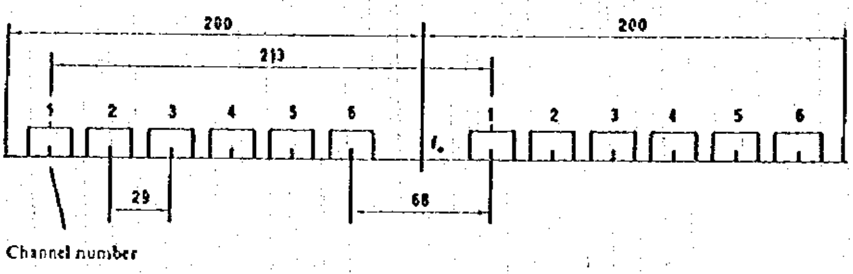


FIGURE 3 – *Radio-frequency channel arrangement for radio-relay systems with capacities from 600 to 1800 telephone channels, or the equivalent, operating in the 2 and 4 GHz bands, for use in international connections*

5. that when additional radio-frequency channels, interleaved between those of the main pattern, are required, the values of the centre frequencies of these radio-frequency channels should be 14.5 MHz below those of the corresponding main channel frequencies*;

6. that to minimize interference within a system, the centre frequency f_0 should preferably be as given below:

in the 2 GHz band, f_0 = 1903 or 2101 MHz (see Note 1);

in the 4 GHz band, f_0 = 4003.5 MHz,

Other centre frequencies may be used by agreement between the administrations concerned**

7. that due regard be taken of the fact that in some countries, mostly in a large part of Region 2 and in certain other areas, another radio-frequency channel arrangement for 4 GHz systems is used. A description of this radio-frequency channel arrangement is given in Annex 1. Attention is drawn to the problem of interconnection.

---

* In analogue radio-relay systems for 1800 telephone channels, or the equivalent, and in radio-relay systems with digital modulation using a bit rate of 2 × 34 Mbit/s or 2 × 45 Mbit/s, it may not be practicable to use interleaved frequencies, because of the wide bandwidth occupied by the modulated carrier.

** Interference due to certain harmonics of the shift frequency, which may fall near radio-frequency channel frequencies f_n (MHz) in radio-frequency repeaters, or may fall near (f_n ± 70 MHz) in repeaters using an intermediate frequency of 70 MHz, may in certain cases be serious. Such interference may be reduced by choosing a suitable value for f_0, such as those given in § 6.

Rec. 382-4

8. that if a digital transmission at 2 × 34 Mbit/s or 2 × 45 Mbit/s is established in the existing 4 GHz arrangement, there exist modulation systems which ensure compatibility on the same artery between digital and analogue radio-frequency circuits with up to 1260 analogue telephone channels, provided that the analogue and digital radio-frequency circuits are cross-polarized.

Note 1. – In certain countries, particularly in Region 2, it may be preferable to use as centre frequency:

f_0 = 1932 MHz instead of 1903 MHz, and

f_0 = 2086.5 MHz instead of 2101 MHz.

Note 2. – In the U.S.S.R., a radio-frequency channel arrangement conforming to the scheme in Fig. 1 of Recommendation 497 is used in the frequency band 3700 to 4200 MHz and for systems with a capacity of 1800 telephone channels or the equivalent. The reference frequency f_0 is then 3947.5 MHz.

Note 3. – In the People's Republic of China, the frequency band from 3400 to 4200 MHz has been divided into two groups each with a frequency band 400 MHz wide. The radio-frequency channel arrangement is identical to that shown in Fig. 3 of this Recommendation, where f_0 = 3592.0 MHz and 4003.5 MHz, respectively.

ANNEX 1

DESCRIPTION OF THE RADIO-FREQUENCY CHANNEL ARRANGEMENT REFERRED TO IN § 7

1. The radio-frequency channel arrangement for a band 500 MHz wide and for up to six go and six return channels (Group 1) and an interleaved pattern of six go and six return channels (Group 2), each accommodating up to 1260 telephone channels or the equivalent, or up to 2 × 45 Mbit/s, operating in the 4 GHz band, is as shown in Fig. 4 and is derived as follows:

Let f_r be the frequency of the lower edge of the band of frequencies occupied (MHz);

f_n be the centre frequency of one radio-frequency channel in the go (return) channel of the band (MHz);

f'_n be the centre frequency of one radio-frequency channel in the return (go) channel of the band (MHz);

then the frequencies in MHz of individual channels are expressed by the following relationships:

Group 1

go (return) channel, $f_n = f_r - 50 + 80\,n$,

return (go) channel, $f'_n = f_r - 10 + 80\,n$,

where

n = 1, 2, 3, 4, 5 and 6.

Group 2

go (return) channel, $f_n = f_r - 70 + 80\,(n - 6)$,

return (go) channel, $f'_n = f_r - 30 + 80\,(n - 6)$,

where

n = 7, 8, 9, 10, 11 and 12.

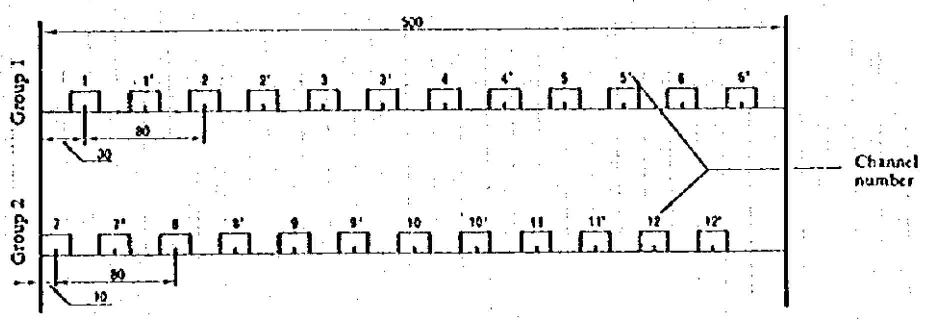


FIGURE 4 – *Radio-frequency channel arrangements described in Annex 1*
(All frequencies are in MHz)

2. In a section over which international connections are arranged, the go and return channels are in the same group and are adjacent channels in that group.

3. In any section, both the go and return channels of any one group are of one polarization.

4. In any section, the channels of each group are of different polarizations.

5. In general, the value of f_r is 3700 MHz.

Note. – Subject to agreement between administrations concerned, 1800 telephone channels may be accommodated on each radio-frequency channel using either Group 1 or Group 2 frequencies.

RECOMMENDATION 635

RADIO-FREQUENCY CHANNEL ARRANGEMENTS BASED ON A HOMOGENEOUS PATTERN FOR DIGITAL RADIO-RELAY SYSTEMS WITH A CAPACITY OF THE ORDER OF 90 Mbit/s, 140 Mbit/s OR 200 Mbit/s OPERATING IN THE 4 GHz BAND*

(Question 35/9 and Study Programme 35A/9)

(1986)

The CCIR,

CONSIDERING

(a) that high-capacity digital radio-relay systems of the order of 90 Mbit/s, 140 Mbit/s or 200 Mbit/s are required in the 4 GHz radio-frequency bands;

(b) that the lower band limits of the 4 GHz radio-frequency bands are not uniform and vary internationally from 3400 to 3800 MHz;

(c) that efficient use of bands of different width can be achieved by radio-frequency channel arrangements matched to the width of the band available;

(d) that a high degree of compatibility between RF channels of different arrangements can be achieved by selecting all channel centre frequencies from a uniform basic pattern;

(e) that the centre gaps of the individual channel arrangements and the guard spacing at the edges of the band can be chosen by non-occupancy of a suitable number of RF-channel positions in a homogeneous basic pattern;

(f) that the uniform basic pattern spacing should not be unjustifiably small (i.e. the number of RF-channel positions too high) nor so large as to jeopardize efficient use of the available spectrum;

(g) that the absolute frequencies of the basic pattern should be defined by a single reference frequency,

UNANIMOUSLY RECOMMENDS

1. that the preferred radio-frequency channel arrangement for high-capacity digital radio-relay systems in the order of 90 Mbit/s, 140 Mbit/s or 200 Mbit/s, operating in the 4 GHz band, should be selected from a homogeneous pattern with the following characteristics:

Centre frequencies f_n of the radio-frequency channels within the basic pattern

$$f_n = 4200 - 10\,m \quad \text{MHz} \qquad (1)$$

m: integral number depending on available frequency band: 1, 2, 3 ...

2. that all the go channels should be in one half of the band and all the return channels should be in the other half of the band;

3. that the channel spacing XS, the centre gap YS, the guard spaces Z_1S and Z_2S at the edges of the band and the antenna polarization should be agreed between the administrations concerned;

* General principles of RF channel arrangements for digital systems below 10 GHz are given in Report 934.

4. that the alternated or co-channel arrangement plan should be used, expamples of which are shown in Fig. 1.

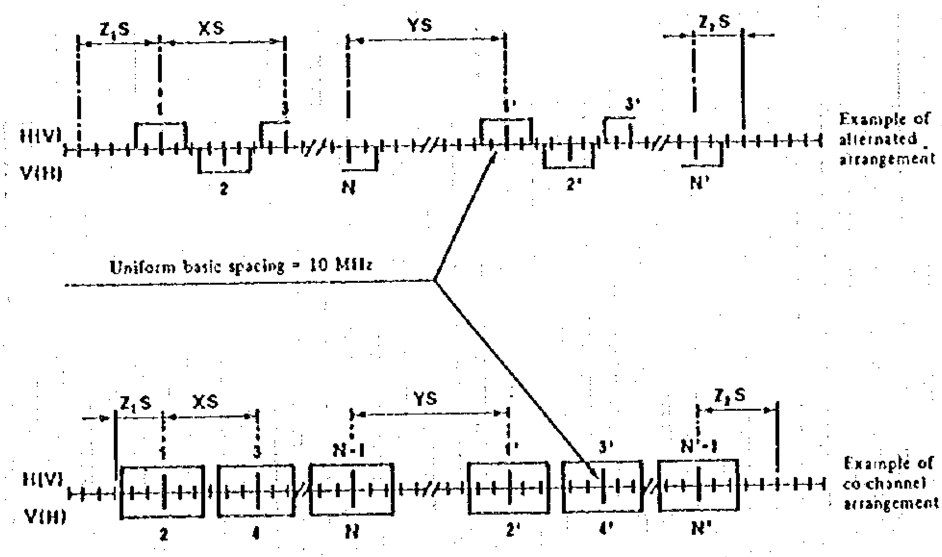


FIGURE 1 – *Examples of channel arrangements based on RECOMMENDS 1 and 2*

(For definitions of *X, Y, Z* and *S*, see Report 378)

REPORT 934-1

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR HIGH AND MEDIUM-HIGH CAPACITY DIGITAL RADIO-RELAY SYSTEMS OPERATING IN THE FREQUENCY BANDS BELOW ABOUT 10 GHz

(Question 35/9 and Study Programme 35A/9)

(1982-1986)

1. Introduction

The purpose of this Report is to present the basic criteria for the determination of preferred RF channel arrangements for digital systems operating in the frequency bands below about 10 GHz. By taking into account the different hierarchical levels and the fact that the transmission capacity per radio channel should be equal to, or a multiple of, one of these hierarchical levels. This Report considers, as medium-high and high-capacity systems the gross bit rates of 2 × 34 Mbit/s (70 Mbit/s), 2 × 45 Mbit/s (90 Mbit/s), 140 Mbit/s, and 200 Mbit/s.

A related text is Report 782 dealing specifically with the 11 GHz band.

The use of frequency bands below about 12 GHz (Question 35/9) for digital radio-relays may be envisaged in two ways:

– either by the re-use of the channel arrangements recommended for analogue radio-relays, which enables analogue and digital systems to co-exist on the same artery and at nodal points and, in particular, is consistent with gradual digitization;

– or by the formulation of new channel arrangements specifically designed for digital transmission, sacrificing, if need be, compatibility with existing channel arrangements.

Rep. 934-1

The first alternative has been followed in the 4 GHz band (see Recommendation 382) for systems with a bit rate of 2 × 34 and 2 × 45 Mbit/s and in the upper 6 GHz band (see Recommendation 384) for systems with a bit ratio of the order of 140 Mbit/s. Further examples of the use of frequency bands, as proposed by some administrations, are presented in Annexes I, II, III, IV, V and VI.

2. System design considerations

The determination of channel arrangements is a complex subject which depends on the following interrelated factors:

- the digital modulation method;
- the parameters defining the RF channel disposition (X, Y, Z and S parameters as defined in Report 378);
- the behaviour of the propagation medium.

These factors are discussed in the sub-sections which follow. In addition, consideration is given to the problems of compatibility in situations where digital and analogue systems may need to co-exist; in particular the problems of compatibility with 1800, 2700 and 3600 channel FDM-FM systems.

2.1 *Modulation methods*

The main characteristics which determine the suitability of a modulation method for use in the frequency bands below 10 GHz are:

- tolerance to interference and distortions;
- the efficiency of use of the spectrum (see Report 662).

Modulation methods are described in Report 378.

2.2 *Efficiency considerations*

The definitions of efficiency and compatibility need to be further investigated from the point of view of implementing digital systems in the bands below 10 GHz noting that sharing between analogue and digital systems is not always a necessary requirement.

There can be various degrees of coexistence of analogue and digital transmission systems, depending on the present use of the frequency bands in the areas concerned. These matters are considered in Report 610.

2.3 *Channel disposition*

The channel disposition is completely defined when the frequencies and the polarizations associated with each channel are given. Such values are expressed by the parameters X, Y and Z, which are normalized with respect to the symbol rate S.

The values of X, Y and Z depend on the modulation method adopted and on the degree of bandwidth reduction of which the equipment concerned is intended to be capable, and also on the complex balance that has to be struck by the system designer between the various interferences that can arise and other sources of system degradations.

The values of the normalized parameters are given in the Annexes for each frequency plan presented.

2.4 *Effects of anomalous propagation*

Report 784 comprehensively discusses how anomalous propagation can cause distortion and reduced cross-polarization decoupling (XPD) in high-capacity digital systems. To counter distortion it may be necessary to use space diversity reception and/or adaptive equalization. Reduced XPD has significant implications for both co-frequency and interleaved channelling arrangements, but various measures are available for ensuring the necessary degree of decoupling, for example:

- use of antennas chosen and aligned for good on- and off-axis XPD;
- use of space diversity;
- use of adaptive cross-polar interference cancellation techniques.

The relative protection obtained from each of these, needs to be carefully assessed [Richman, 1983].

In an interleaved channel arrangement, the decoupling acts to supplement the adjacent-channel filter selectivity.

For large repeater spacings, e.g. over water, the use of multi-carrier transmission may mitigate in-band amplitude dispersion [Yoshida *et al.*, 1983]. In this system the original pulse stream is converted into several pulse streams with lower bit rate, and, after modulating several carriers, commonly amplified by a single radio repeater. By this method, it may be possible to give more flexibility to a radio-frequency channel arrangement, as well as to realize larger repeater spacings.

3. **Homogeneous frequency pattern**

The channel spacing for high and medium-high capacity digital radio-relay systems depends on many factors mentioned in § 1 and § 2.

In order to accommodate the non-uniform band limits (lower or upper) of the considered band, the concept of a homogeneous pattern is proposed with the following characteristics.

The centre frequency of one radio frequency channel is given by either:

$f_n = f_r - \Delta f \cdot m$ MHz for f_r above the frequency band or:

$f_n = f_r + \Delta f \cdot m$ MHz for f_r below the frequency band

where:

f_r: reference frequency,

Δf: pattern interval,

m: integral number depending on available frequency band.

In a frequency channel arrangement for digital radio-relay systems selected for a homogeneous pattern, the centre gap will be an integral multiple of the spacing of the basic pattern so that in the case of different limits of the allocated frequency band it is possible to move the centre gap.

The channel spacing for digital radio-relay systems depends on many factors, such as bit rate, modulation method, filtering, polarization discrimination and propagation effects. Consideration of the above factors leads to specific solutions. The flexibility offered by the use of a homogeneous frequency pattern can give rise to a variety of channel arrangements which may make the process of coordination more complicated.

An example of such a homogeneous pattern is given in Recommendation 635. Specific radio-frequency channel arrangements derived from Recommendation 635 are given in Fig. 2 of Annex II and Fig. 6a and 6b of Annex VI to this Report.

4. **Use of existing channel arrangements**

Many existing CCIR RF channel arrangements below 10 GHz make use of two typical cross-polarized adjacent channel spacings: 29 to 29.65 MHz and 40 MHz.

As summarized in Annex I, digital systems having bit rates of 2 × 34 or 2 × 45 Mbit/s can be used with 29 to 29.65 MHz cross-polarized adjacent channel spacing. Digital systems having a capacity of 140 Mbit/s can be used with 40 MHz cross-polarized adjacent channel spacing (e.g. Recommendation 384).

It is also possible to insert a bit rate of the order of 140 Mbit/s in a spacing of 29 or 29.65 MHz (see Recommendations 383 and 382), as a result of recent progress, both technical and technological, in the field of modulation and of signal processing techniques in microwave frequencies and in intermediate frequencies or baseband, namely:

- space diversity techniques (see Report 376, § 6);
- processing of the signal in IF or baseband (equalizer);
- improvement of the antenna XPD.

As an example, it is possible to achieve a similar spectrum utilization efficiency by the use of 200 Mbit/s 16-QAM modulation with values of *X*, *Y* and *Z* as shown in Fig. 6a of Annex VI (see also Table III of Annex I). Other, higher-order, modulations can also be advantageous for these applications.

A number of different modulation methods are suitable for this operation and allow a gradual introduction of digital systems into existing networks.

For example, 8-PSK at 70 Mbit/s or 16-QAM at 90 Mbit/s and 1800 channel FDM-FM systems can operate compatibly on the same route with adjacent channel spacing of 29 to 29.65 MHz with low and acceptable impairments on the analogue systems as well as with 16-QAM at 140 Mbit/s with adjacent channel spacing of 40 MHz.

Practical experience gained in the United States with 16-QAM at 90 Mbit/s digital and 1800 voice circuit FDM-FM analogue systems using the 6 GHz radio-frequency channel arrangement of Recommendation 383 is presented in Annex IV. The use of existing channel arrangements for the transmission of digital signals has been demonstrated in the United States in the 4 GHz band using the 20 MHz channel spacing described in Annex I to Recommendation 382. Not only does the 45 Mbit/s, 8-PSK signal coexist with the 1800 voice circuit FDM-FM system on the same route but it also re-uses slightly modified repeaters from the FDM-FM system for its transmission and the protection channel is jointly used for the FDM-FM and the digital signals. Digital regeneration is only required in the protection switching stations. Long haul performance requirements have been met using switching sections with up to five or more non-regenerative repeaters [Cooney and Harvey, 1982; Jaeger *et al.*, 1982].

5. **Use of new channel arrangements specifically designed for digital systems**

When either engineering new digital routes or a digital conversion programme for existing analogue radio-relay systems is being undertaken on a total route-replacement basis, then the need for analogue and digital sharing on the same route is no longer a prime requirement. This can be turned to advantage by choosing a channelling plan that combines robustness against distortion and interference with good spectrum utilization within the band available.

Annexes II, III, V and VI show examples applied to the 4, 6, 7 and 8 GHz bands [CCIR, 1982-86].

REFERENCES

COONEY, R. T. and HARVEY, S. A. [1 December, 1982] TD-45A, a system for 45-Mb/s digital transmission over the TD radio network. Conf. Record, Vol. 2, D3.6, 794-797. IEEE Global Telecommunications Conference (GLOBECOM '82), Miami, FL, USA.

JAEGER, W. P., PENNEY, P. L. and VONRUMP, S. L. [1 December, 1982] Measured performance of 45-Mb/s transmission over the Bell System 4-GHz radio. Conf. Record, Vol. 2, D3.7, 798-801. IEEE Global Telecommunications Conference (GLOBECOM '82), Miami, FL, USA.

RICHMAN, G. D. [29 November, 1983] The variation in XPD during multipath fading and its effect on co-frequency cross-polarized RB QPSK digital radio. Conf. Record, Vol. 1, 1.6.1-1.6.6. IEEE Global Telecommunications Conference (GLOBECOM '83), San Diego, CA, USA.

YOSHIDA, T., KOMAKI, S. and MORITA, K. [June, 1983] System design and new techniques for an over-water 100 km span digital radio. Conf. Record, Vol. 1, Session C2: Radio propagation and its effects on digital radio performance, C2.7.1-C2.7.6. IEEE International Conference on Communications (ICC '83), Boston, MA, USA.

CCIR Documents

[1982-86]: 9/48 (Italy).

ANNEX I

USE OF CCIR CHANNEL ARRANGEMENTS FOR HIGH AND MEDIUM-HIGH CAPACITY DIGITAL SYSTEMS

For high order modulation methods (e.g. 8 and 16-state) good spectrum efficiency may be obtained with interleaved frequency plans. Only the existing CCIR RF channel arrangements are considered and some of the characteristics, when these arrangements are used for high capacity digital systems, are summarized in Tables I, II, III and IV.

1. **Analogue/digital compatibility**

1.1 *On the same route*

8-PSK at 70 Mbit/s or 16-QAM at 90 Mbit/s and 1800 channel FDM-FM systems can operate compatibly with acceptable impairments over common routes using existing radio frequency plans with spacing of 29 to 29.65 MHz taking into account the possible shaping of digital spectrum and a difference in transmitted power between analogue and digital systems of the order of 4 to 5 dB. With 16-QAM, the spacing between a 2700 channel system and a 140 Mbit/s digital channel must not be less than 60 MHz, whereas taking into account a difference in transmitted power of the order of 3 dB between analogue and digital systems a 40 MHz spacing between a 1800 channel system and a 140 Mbit/s digital channel can be possible with very low impairments.

1.2 *Systems converging at the same station*

The same carrier frequencies can be used on two converging routes, one being analogue modulated and the other digital modulated. With orthogonally polarized emissions the protection between the two routes may be sufficient to allow relatively low convergence angles, but this benefit may be offset by the higher interference sensitivity of 16-QAM compared with other types of modulation. These matters are further considered in Report 610.

Rep. 934-1

TABLE I

Modulation 8-PSK, 2 × 34 Mbit/s (70 Mbit/s)				
Frequency band (MHz)	1900-2300	3800-4200	5925-6425	7725-8275
Type of arrangement	Recommendation 382	Recommendation 382	Recommendation 383	Annex I to Recommendation 386
Number of channels	6	6	8	7
Guard band *ZS* (MHz) *Z*	 20 0.87	 17.5 0.76	 20.2 0.83	 22.7 0.99
Mid-band separation *YS* (MHz) *Y*	 68 2.96	 68 2.96	 44.5 1.93	 133.42 5.8
Cross-polarized channel spacing *XS/2* (MHz) *X*	 29 2.52	 29 2.52	 29.65 2.58	 29.65 2.58
Efficiency of spectrum utilization (bit/s/Hz)	2.1	2.1	2.24	1.78

Note. — It is not intended to prevent the use of higher modulation methods, if technically and economically advantageous.

TABLE II

Modulation 16-QAM, 2 × 45 Mbit/s (90 Mbit/s)				
Frequency band (MHz)	1900-2300	3800-4200	5925-6425	7725-8275
Type of arrangement	Recommendation 382	Recommendation 382	Recommendation 383	Annex I to Recommendation 386
Number of channels	6	6	8	7
Guard band *ZS* (MHz) *Z*	 20 0.89	 17.5 0.78	 20.2 0.9	 22.7 1
Mid-band separation *YS* (MHz) *Y*	 68 3.02	 68 3.02	 44.5 1.98	 133.42 5.9
Cross-polarized channel spacing *XS/2* (MHz) *X*	 29 2.58	 29 2.58	 29.65 2.64	 29.65 2.64
Efficiency of spectrum utilization (bit/s/Hz)	2.7	2.7	2.88	2.3

Note. — Other modulation methods (e.g. 8-level PSK) can also be used.

Rep. 934-1

TABLE III

Modulation 16-QAM, 140 Mbit/s		
Frequency band (MHz)	3800-4200	5925-6425
Type of arrangement	Recommendation 382	Recommendation 383
Number of channels	6	8
Guard band *ZS* (MHz) *Z*	17.5 / 0.5 (f_0 = 4003.5) or 21 / 0.6 (f_0 = 4000)	20.2 0.58
Mid-band separation *YS* (MHz) *Y*	68 1.95	44.5 1.27
Cross-polarized channel spacing *XS/2* (MHz) *X*	29 1.66	29.65 1.7
Efficiency of spectrum utilization (bit/s/Hz)	4.83	4.72

Note. – Other modulation methods (e.g. 64-QAM) can also be used.

TABLE IV

Modulation 64-QAM	90 Mbit/s	140 Mbit/s
Frequency band (MHz)	3700-4200	5925-6425
Type of arrangement	Annex 1 to Recommendation 382	Recommendation 383
Number of channels	12	8
Guard band *ZS* (MHz) *Z*	30/10 2.0/0.67	20.2 0.87
Mid-band separation *YS* (MHz) *Y*	Not applicable	44.5 1.91
Cross-polarized channel spacing *XS/2* (MHz) *X*	20 2.67	29.65 2.54
Efficiency of spectrum utilization (bit/s/Hz)	4.5	4.72

ANNEX II

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR THE 4 GHz AND LOWER 6 GHz* BANDS

This Annex describes radio channelling plans for the frequency bands 5850-6425 MHz and 3600-4200 MHz. They are based upon the use of 140 Mbit/s systems employing reduced bandwidth quaternary phase shift keyed (RB 4-PSK) modulation [de Belin and Chisholm, 1983].

The channel arrangement for the lower 6 GHz band is shown in Fig. 1, where it can be seen that six both way channels are accommodated and that both polarizations are used for transmission at each frequency. The channel spacing of 90 MHz results in a spectrum efficiency of 3.5 bit/s/Hz, including system overheads, taking into account the use of dual polarization [Richman, 1983].

The channel arrangement at 4 GHz also utilizes the six channel 90 MHz cross-polarized arrangement, but with a Z spacing of 50 MHz and Y spacing of 140 MHz (Fig. 2). The 4 GHz plan is, therefore, in accordance with the homogeneous frequency pattern of Recommendation 635.

The channel arrangements have been optimized, following conclusions from system field trials, to ensure that adequate margins against dispersive fading can be provided and to ensure that CCIR performance standards can be achieved on established networks utilizing hops of length up to 65 km [Hart and Chisholm, 1985]. Systems complying with these plans will be brought into service in the United Kingdom in 1985.

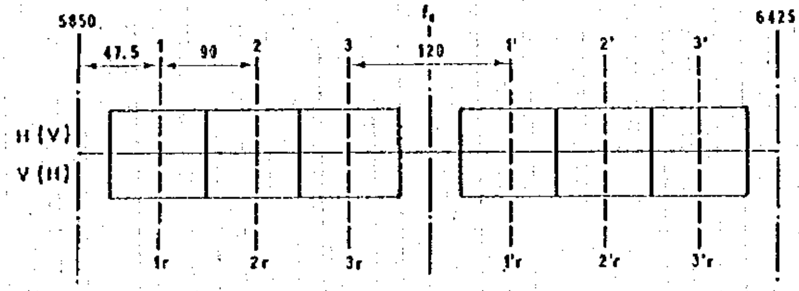


FIGURE 1 – *Radio frequency channel arrangements for the lower 6 GHz band*
(All frequencies are in MHz)

f_0 : centre frequency = 6137.5 MHz
Symbol rate = 74 MBd
X = 1.22 Y = 1.62 Z = 0.64

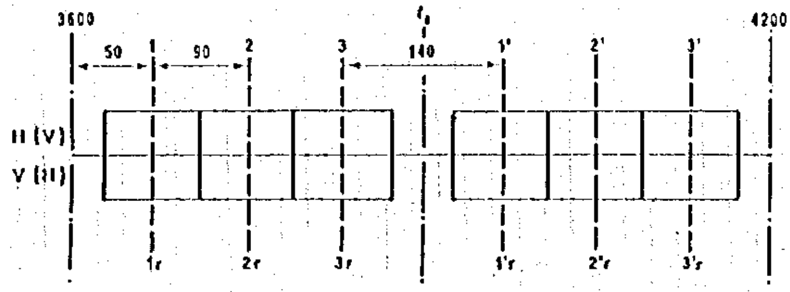


FIGURE 2 – *Radio frequency channel arrangements for the 4 GHz band*
(All frequencies are in MHz)

Symbol rate = 74 MBd
X = 1.22 Y = 1.89 Z = 0.68

* Some administrations may use the lower 6 GHz band from 5850 to 6425 MHz and this Annex takes account of this.

Rep. 934-1

REFERENCES

de BELIN, M. J. and CHISHOLM, J. A. [6-8 September, 1983] Field evaluation of a 140 Mbit/s digital radio system with a spectrum efficiency of over 4 bit/s/Hz. IEE Conference on Spectrum Conservation Techniques, Birmingham, United Kingdom.

HART, G. and CHISHOLM, J. A. [March, 1985] Radio performance standards. Third IEE International Conference on Telecommunication Transmission, London, United Kingdom.

RICHMAN, G. D. [29 November, 1983] The variation in XPD during multipath fading and its effect on co-frequency cross-polarized RB QPSK digital radio. Conf. Record, Vol. 1, 1.6.1-1.6.6. IEEE Global Telecommunications Conference (GLOBECOM '83), San Diego, CA, USA.

ANNEX III

A RADIO-FREQUENCY CHANNELLING ARRANGEMENT FOR THE 8 GHz BAND

This Annex describes a digital radio-frequency channelling arrangement for the 8 GHz band. The arrangement provides for up to 12 go and 12 return channels each accommodating about 90 Mbit/s. The use of a QPRS modulation scheme allows for the possibility of cross-polar operation.

In implementing the cross-polar option the co-channel centre frequencies have been offset by 5.56 MHz to allow for simplified hardware to detect the loss of one of the orthogonal signals. It is also possible to operate an interleaved channel arrangement however with the loss of one RF channel pair.

1. The radio-frequency channel arrangement for the co-channel arrangement is shown in Fig. 3 and is derived as follows:

Let f_0 be the frequency at the centre of the band:

$$f_0 = 8000 \text{ MHz}$$

f_n is the centre frequency of one radio-frequency channel in the lower half of the band (MHz);

f'_n is the centre frequency of one radio-frequency channel in the upper half of the band (MHz);

Then the centre frequencies of the individual channels are expressed by the following relationships:

lower half of the band: $f_n = f_0 - 275 + 20.37\, n$,

upper half of the band: $f'_n = f_0 + 30.56 + 20.37\, n$,

where:

$n = 1, 3, 5, 7, 9, 11$

and lower half of the band: $f_n = f_0 - 295.37 + 20.37\, n + 5.56$

upper half of the band: $f'_n = f_0 + 10.19 + 20.37\, n - 5.56$

where:

$n = 2, 4, 6, 8, 10, 12.$

2. All the go channels should be in one half of the band and all the return channels should be in the other half of the band.

3. For growth beyond 6 go and 6 return channels, orthogonal polarizations are used on a co-channel basis.

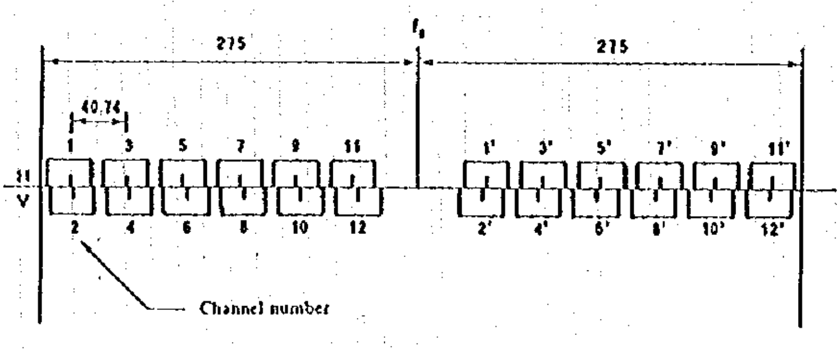


FIGURE 3 – *Radio-frequency channel arrangement for the 8 GHz band co-channel plan*

(All frequencies are in MHz)

ANNEX IV

COMPATIBILITY BETWEEN ANALOGUE AND DIGITAL HIGH CAPACITY SYSTEMS IN THE 6 GHz BAND

Practical experience gained in the United States with 16-QAM 90 Mbit/s digital and 1800 voice circuit FDM-FM analogue systems using the existing CCIR RF channel arrangement in the 5.925 to 6.425 GHz band has confirmed the practicality of coexistence on the same route and permitted the better definition of the criteria for compatible operation [Kenny, 1980]. Figure 4 shows the spectra and pertinent data for the two systems, and Table V lists the critical co-channel and adjacent channel interference characteristics. The following comments and data are helpful in establishing compatibility criteria for similar applications.

System characteristics	16-QAM	1800 FM
Capacity	90 Mbit/s	1800 circuits
Transmitter power	1.0 W	10.0 W
Noise figure	4 dB	9 dB
Flat fade margin	40 dB	40 dB
At BER	10^{-6}	
At 9 MHz noise		316 000 pW0p
r.m.s per channel deviation		117.9 kHz

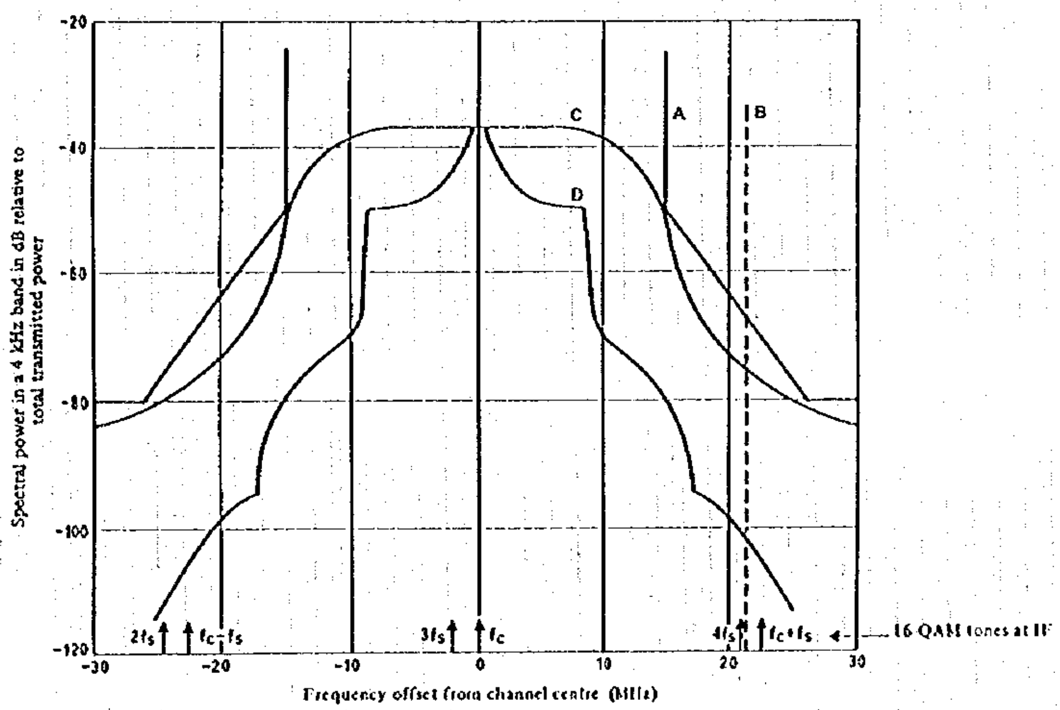


FIGURE 4 — *Spectra of 16-QAM and 1800 FM systems operating jointly in the 6 GHz band (Recommendation 383)*

A: FCC digital emission limitation, §21.106
B: top baseband circuit of adjacent 1800 FM channel
C: 16-QAM
D: 1800 FM ;

Rep. 934-1

Figure 4 also shows the limiting requirement for the emitted digital spectrum that has been imposed in the United States by the Federal Communications Commission (FCC). If Nyquist filtering is divided approximately equally between transmitter and receiver, as was the case in the 16-QAM system of Fig. 4, then digital spectra that fall below this "FCC mask" will allow trouble-free adjacent channel operation of similar digital systems. If adjacent operation of digital and analogue channels is desired, the requirements for the digital spectrum normally have to be tightened.

The FCC also requires that no discrete spectral components be emitted by the radio transmitter resulting from repetitive patterns in the bit stream. This is greatly helped by scrambling of the bit stream except that certain tones due to carrier leak (f_c = 70 MHz), harmonics of the clock signal (f_s = 22.63 MHz), and tones at $f_c \pm f_s$ have to be controlled by separate means. Some of these tones (see Fig. 4) could cause serious interference into co-channel and adjacent channel analogue systems.

This means that tones within the 29.65 MHz digital channel bandwidth should be kept below the power level of the continuous digital spectrum, as measured in a 4 kHz bandwidth. Tones outside the channel bandwidth have to be at least 76 dB below the total digital power or conform to the FCC mask in Fig. 4 for acceptable interference into the adjacent 1800 FM system.

Table V lists only the critical elements in the interference matrix. Interference cases not shown can be assumed to be negligible. Co-channel and adjacent channel interferences affect digital radio only during periods of fading, and it has been an unofficial objective to keep this effect limited to a 1.0 dB reduction in flat fade margin. The most important exposure here is the co-channel interference from the 10 W 1800 FM system into the 1 W 16-QAM system. Because of the 10 dB power difference, an isolation of 77 dB C/I + 10 is generally required to keep the reduction of flat fade margin limited to 1.0 dB. Since "net" fade margins (see Report 784) of high capacity digital radio systems are only around 30 dB, not too much harm is done with this degradation in flat (40 dB) fade margin.

Co-channel and adjacent channel interferences into analogue FM systems is mostly a consideration during non-fading periods and objectives of 2.5 pW0p are being used for each type of interference.

Finally, tertiary interference in analogue FM systems is an important source of degradation not shown in Table V. It is assumed that when the 16-QAM system is operated adjacent (a 29.65 MHz separation) to an analogue FM system, its contribution to tertiary interference should not exceed the levels caused by an 1800 channel FM system. This requires that the power of the 16-QAM transmitter be reduced to 0.5 W whenever the digital system operates adjacent to an 1800 channel FM system.

TABLE V — *Matrix of critical interference in a 6 GHz arrangement (Recommendation 383) using 16-QAM and 1800 FM systems*

		Interfering system			
		Co-channel		Adjacent channel	
		1800 FM	16-QAM	1800 FM	16-QAM
Interfered-with system	1800 FM (unfaded)	N_i = 1.25 for C/I = 69	N_i = 2.2 for C/I = 79	N_i = 0.13 for XPD = 30	P_t = 27 N_i = 0.6 for XPD = 30
	16-QAM (flat-faded)	δ_m = 1.0 for C/I = 67	δ_m = 1.0 for C/I = 67		δ_m = 0.66 for XPD = 0 D_f = 32

P_t: transmitter power (dBm)
N_i: worst interference power (pW0p)
C/I: carrier-to-interference ratio (dB)
XPD: cross-polarization discrimination (dB)
δ_m: degradation in flat fade margin (dB)
D_f: filter discrimination (dB), 16-QAM into 16-QAM

Rep. 934-1

REFERENCE

KENNY, J. J. [2 December, 1980] Impact of interference on 16-QAM system requirements. IEEE National Telecommunications Conference (NTC '80), Houston, Texas, USA. Conf. Record, Vol. 2, Session 43: A montage of radio communication topics, 43.4-43.6.

ANNEX V

A RADIO-FREQUENCY CHANNELLING ARRANGEMENT FOR THE 7 GHz BAND

This Annex describes a radio-frequency channel arrangement for the 7 GHz band derived from Recommendation 385. In the higher part of the band the original frequency pattern of Recommendation 284 (Los Angeles, 1959) has been maintained (see the Note in Recommendation 385), in order to have a regular frequency pattern for the whole band.

The arrangement provides for up to 10 go and 10 return channels, each accommodating about 70 Mbit/s, subdivided in two groups of 5 go and 5 return channels relating to the lower part and the higher part of the band.

The radio-frequency channel arrangement is as shown in Fig. 5 of this Annex and is derived as follows:

Let f_{0l} be the frequency at the centre of the lower part of the band:

$$f_{0l} = 7275 \text{ MHz}$$

f_{0h} be the frequency at the centre of the higher part of the band:

$$f_{0h} = 7597 \text{ MHz}$$

f_{nl} is the centre frequency of one radio-frequency channel in the lower half of the lower part of the band;

f'_{nl} is the centre frequency of one radio-frequency channel in the upper half of the lower part of the band;

f_{nh} is the centre frequency of one radio-frequency channel in the lower half of the higher part of the band;

f'_{nh} is the centre frequency of one radio-frequency channel in the upper half of the higher part of the band;

then the frequencies in MHz of the individual channels are expressed by the following relationships:

$f_{nl} = f_{0l} - 182 + 28\,n$

$f'_{nl} = f_{0l} + 14 + 28\,n$

$f_{nh} = f_{0h} - 168 + 28\,n$

$f'_{nh} = f_{0h} + 28\,n$

where:

$n = 1, 2, 3, 4, 5.$

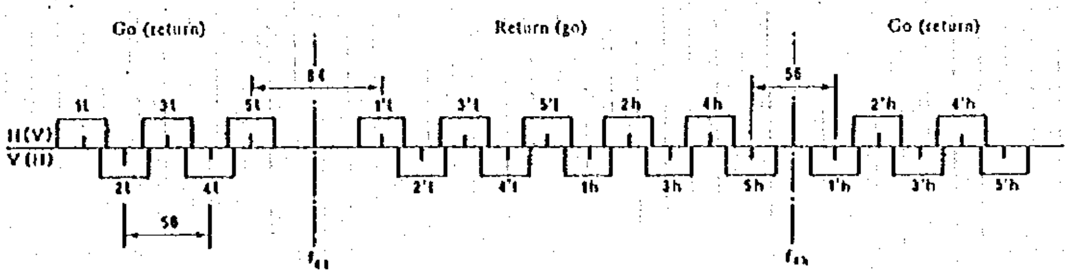


FIGURE 5 – *Radio-frequency channel arrangement for the 7 GHz band*

(All frequencies are in MHz)

Rep. 934-1

ANNEX VI

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR THE 4 AND 6 GHz BANDS

This Annex describes radio-frequency channel arrangements for the bands 3600-4200 MHz and 5925-6425 MHz. They are used for 16-QAM 200 Mbit/s systems.

The radio-frequency channel arrangements are shown in Figs. 6a, 6b and 6c and are based on a uniform pattern of 10 MHz. In the system using the arrangement in Fig. 6a, an "out-of-phase" combiner, and separate antennas for transmission and reception, with good cross-polarization characteristics, are used in commercial equipment [Matsumoto *et al.*, 1982; Segawa, 1983] in order to attain the high channel spectrum utilization efficiency of 5 bit/s/Hz.

Figure 6b shows the frequency channel arrangement for a 4-carrier digital radio system applicable to hops with very severe propagation conditions (for example, 100 km over-water hops). The system transmits 200 Mbit/s in an 80 MHz channel and 150 Mbit/s in a 60 MHz channel using 4 or 3 carriers respectively each spaced 20 MHz apart. The guard band spacing at the edge of the band is 20 MHz, and the minimum spacing between go and return channels is 40 MHz.

In this system, a single antenna can be shared by both transmitting and receiving signals, and a cross-polarization interference canceller is employed [Araki *et al.*, 1985].

In the 6 GHz band, six go and return 200 Mbit/s, 16-QAM channels are accommodated in a co-channel arrangement as shown in Fig. 6c.

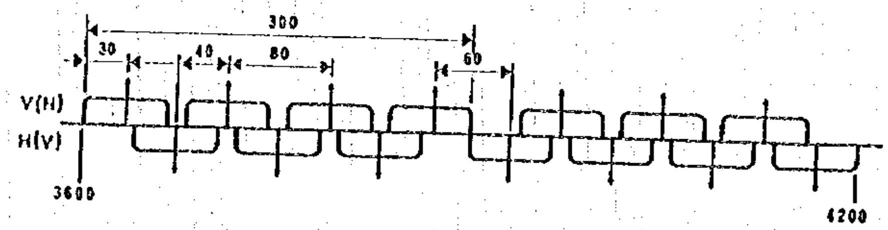


FIGURE 6a – *Radio-frequency channel arrangement for the 4 GHz band*

(All frequencies are in MHz)

Symbol rate (S) = 50 MBd

X = 1.6 Y = 1.2 Z = 0.6

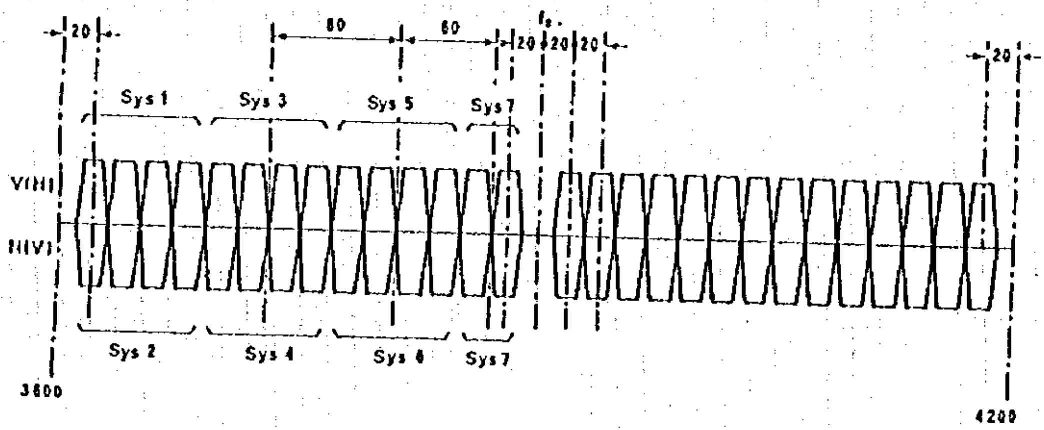


FIGURE 6b – *Radio-frequency channel arrangement for the 4 GHz band*

(All frequencies are in MHz)

Symbol rate (S) = 12.5 MBd

X = 1.6 Y = 3.2 Z = 1.6

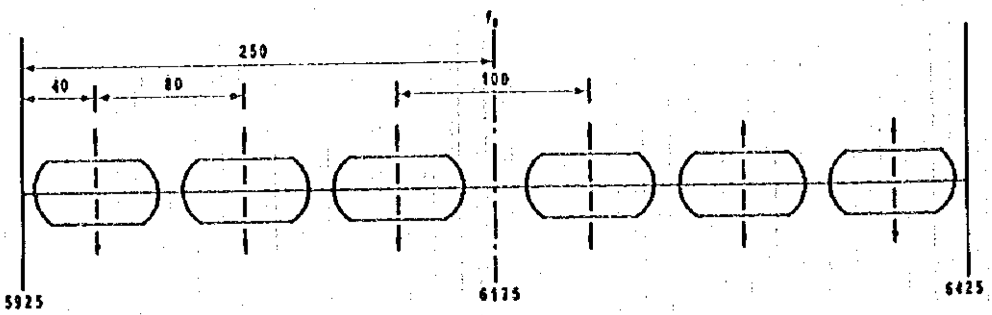


FIGURE 6c – *Radio-frequency channel arrangement for the 6 GHz band*
(All frequencies are in MHz)

f_0 : centre frequency = 6175 MHz
Symbol rate (S) = 50 MBd
$X = 1.6$ $Y = 2.0$ $Z = 0.8$

REFERENCES

ARAKI, M., ICHIKAWA, H. and HASHIMOTO, A. [June, 1985] 100 km overwater span digital radio system. Conf. Record, Vol. 1, 15.5.1-15.5.6. IEEE International Conference on Communications (ICC '85), Chicago, IL, USA.

MATSUMOTO, S., SANGO, J. and SEGAWA, J. [January, 1982] 200 Mb/s 16-QAM digital radio-relay system operating in 4 and 5 GHz bands. *Japan Telecomm. Rev.*, Vol. 24, 1, 65-73.

SEGAWA, J. [April, 1983] Performance monitoring of a 5 GHz 200 Mb/s 16-QAM digital radio-relay system. *Japan Telecomm. Rev.*, Vol. 25, 2, 126-130.

RECOMMENDATION 383-3 *

RADIO-FREQUENCY CHANNEL ARRANGEMENTS, FOR ANALOGUE RADIO-RELAY SYSTEMS WITH A CAPACITY OF 1800 TELEPHONE CHANNELS, OR THE EQUIVALENT, AND DIGITAL RADIO-RELAY SYSTEMS WITH A CAPACITY OF THE ORDER OF 140 Mbit/s OPERATING IN THE 6 GHz BAND

(Questions 1/9 and 35/9)

(1959-1963-1966-1982-1986)

The CCIR,

CONSIDERING

(a) that it is sometimes desirable to be able to interconnect radio-relay systems on international circuits in the 6 GHz band at radio frequencies;

(b) that, in a frequency band 500 MHz wide, it may be desirable to interconnect up to eight go and eight return channels;

(c) that economy may be achieved if at least four go and four return channels can be interconnected between systems, each of which uses common transmit-receive antennas;

* This Recommendation applies only to line-of-sight and near line-of-sight radio-relay systems.

(d) that many interfering effects can be substantially reduced by a carefully planned arrangement of the radio frequencies in radio-relay systems employing several radio-frequency channels;

(e) that it may sometimes be desirable to interleave additional radio-frequency channels between those of the main pattern;

(f) that there may be a desire to interconnect more than eight go and eight return radio-frequency channels, each with a capacity significantly lower than 1800 telephone channels;

(g) that it is also highly desirable to be able to operate systems using a mix of analogue and digital radio channels on the same route,

UNANIMOUSLY RECOMMENDS

1. that the preferred radio-frequency channel arrangement for up to eight go and return channels with each channel being either an analogue channel accommodating 1800 telephone channels, or the equivalent, or a digital channel with a capacity of the order of 140 Mbit/s, and operating at frequencies in the 6 GHz band, should be as shown in Fig. 1 and should be derived as follows:

Let f_0 be the frequency (MHz) of the centre of the band of frequencies occupied;

f_n be the centre frequency (MHz) of one radio-frequency channel in the lower half of the band;

f'_n be the centre frequency (MHz) of one radio-frequency channel in the upper half of the band;

then the frequencies (MHz) of individual channels are expressed by the following relationships:

lower half of the band: $f_n = f_0 - 259.45 + 29.65\ n$,

upper half of the band: $f'_n = f_0 - 7.41 + 29.65\ n$,

where

$n = 1, 2, 3, 4, 5, 6, 7$ or 8;

2. that, in a section over which the international connection is arranged, all the go channels should be in one half of the band, and all the return channels should be in the other half of the band;

3. that the go and return channels on a given section should preferably use polarizations as shown below:

	Go				*Return*			
H(V)	1	3	5	7	2'	4'	6'	8'
V(H)	2	4	6	8	1'	3'	5'	7'

The following alternative arrangement of polarization may be used by agreement between the administrations concerned:

	Go				*Return*			
H(V)	1	3	5	7	1'	3'	5'	7'
V(H)	2	4	6	8	2'	4'	6'	8'

4. that, when common transmit-receive antennas for double polarization are used and not more than four channels are accommodated on a single antenna, it is preferred that the channel frequencies be selected by either making $n = 1, 3, 5$ and 7 in both halves of the band or making $n = 2, 4, 6$ and 8 in both halves of the band (see Note 2);

5. that, when additional radio-frequency channels, interleaved between those of the main pattern, are required, the values of the centre frequencies of these radio-frequency channels should be 14.82593 MHz below those of the corresponding main channel frequencies; in systems for 1800 channels, or the equivalent, and digital systems operating at the order of 140 Mbit/s, it may not be practical, because of the bandwidth of the modulated carrier, to use interleaved frequencies;

6. that up to 16 go and return radio-frequency channels, each with a capacity of up to 600 telephone channels, may be obtained on the same route if the additional radio-frequency channels are used simultaneously, with those of the main pattern. Different polarizations should be used alternately for adjacent radio-frequency channels in the same half of the band (see Note 3);

7. that the preferred centre frequency is 6175.0 MHz; other centre frequencies may be used by agreement between the administrations concerned.

Note 1. – The radio-frequency arrangement shown in Fig. 1 is suitable for use with the preferred intermediate frequency of 70 MHz (see Recommendation 403). It is also suitable for use with an intermediate frequency of 74.12965 MHz, which enables a common oscillator (14.82593 MHz) to be used for generating all the local oscillations for the system, if desired.

Note 2. – When common transmit-receive antennas are used and not more than four channels are accommodated on a single antenna, channel frequencies may be selected, by agreement between administrations, by making n = 1, 3, 5 and 7 in the lower half of the band, and n = 2, 4, 6 and 8 in the upper half of the band. If a second similar antenna is used for four further channels, the channel frequencies may be selected by making n = 2, 4, 6 and 8 in the lower half of the band and n = 1, 3, 5 and 7 in the upper half of the band, but if only three further channels are required, the channel frequencies may be selected by making n = 2, 4 and 6 in the lower half of the band and n = 3, 5 and 7 in the upper half of the band to avoid the difficulty of separating frequencies 8 and 1'.

Note 3. – The primary purpose of this Recommendation is to facilitate the international interconnection of high-capacity radio-relay systems. It should therefore be noted, that the use of both the main and interleaved arrangements of radio frequencies on a route would limit the provision of systems with a capacity of 1800 telephone channels using analogue modulation or the equivalent and the provision of digital channels operating at the order of 140 Mbit/s, on that route.

Note 4. – In the USSR, a radio-frequency channel arrangement conforming to the scheme in Fig. 1 of Recommendation 497 is used in the frequency band 5925 to 6425 MHz and for systems with a capacity of 1800 telephone channels, or the equivalent. The reference frequency f_0 is then 6172 MHz.

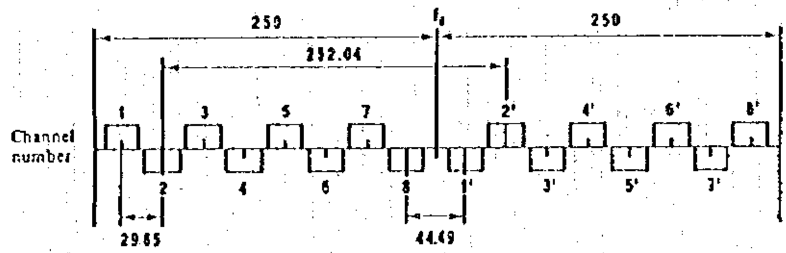


FIGURE 1 – *Radio-frequency channel arrangement for radio-relay systems operating in the 6 GHz band for use in international connections*
(All frequencies are in MHz)

RECOMMENDATION 384-4 *

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR ANALOGUE RADIO-RELAY SYSTEMS WITH A CAPACITY OF 2700 TELEPHONE CHANNELS OR UP TO 1260 TELEPHONE CHANNELS, OR THE EQUIVALENT, AND DIGITAL RADIO-RELAY SYSTEMS WITH A CAPACITY OF THE ORDER OF 140 Mbit/s, OPERATING IN THE 6 GHz BAND

(Study Programme 1A/9 and Question 35/9)

(1963-1966-1974-1982-1986)

The CCIR,

CONSIDERING

(a) that radio-relay systems with a capacity of 2700 telephone channels should prove to be feasible in the 6 GHz band, if due care is exercised in the planning of radio paths to reduce multipath effects;

(b) that it is sometimes desirable to be able to interconnect, at radio frequencies, radio-relay systems on international circuits in the 6 GHz band;

* This Recommendation applies only to line-of-sight and near line-of-sight radio-relay systems.

Rec. 384-4

(c) that it may be desirable to interconnect up to eight go and eight return channels in a frequency band 680 MHz wide;

(d) that economy may be achieved if at least four go and four return channels can be interconnected between radio-relay systems, each of which uses common transmit-receive antennas;

(e) that a common radio-frequency channel arrangement for both up to 1260 and 2700 telephone channel radio-relay systems offers considerable advantages;

(f) that the use of certain types of digital modulation (e.g. 16-QAM) permits the use of the radio-frequency channel arrangement defined for 2700 telephone channel systems for the transmission of digital channels with a bit rate of the order of 140 Mbit/s;

(g) that for 16-QAM 140 Mbit/s radio systems, further economies are possible by accommodating up to eight go and return channels on a single antenna with suitable performance characteristics;

(h) that many interfering effects can be reduced substantially by a carefully planned arrangement of the radio frequencies in radio-relay systems employing several radio-frequency channels;

(j) that the radio-frequency channels should be so arranged that an intermediate frequency of 70 MHz may be used for up to 1260 channel systems;

(k) that the radio-frequency channels should be so arranged that an intermediate frequency of 140 MHz may be employed for 2700 channel systems,

UNANIMOUSLY RECOMMENDS

1. that the preferred radio-frequency channel arrangement for up to eight go and eight return channels, each accommodating 2700 telephone channels, or the bit rate of the order of 140 Mbit/s, or the equivalent, and operating at frequencies in the 6 GHz band, should be derived as follows:

Let f_0 be the frequency (MHz) of the centre of the band of frequencies occupied;

f_n be the centre frequency (MHz) of one radio-frequency channel in the lower half of the band;

f'_n be the centre frequency (MHz) of one radio-frequency channel in the upper half of the band;

then the frequencies (MHz) of individual channels are expressed by the following relationships:

lower half of the band: $f_n = f_0 - 350 + 40\,n,$
upper half of the band: $f'_n = f_0 - 10 + 40\,n,$

where

$n = 1, 2, 3, 4, 5, 6, 7$ or 8;

2. that, in the section over which the international connection is arranged, all the go channels should be in one half of the band, and all the return channels should be in the other half of the band;

3. that different polarizations should be used alternately for adjacent radio-frequency channels in the same half of the band;

4. that, when common transmit-receive antennas are used, and not more than four channels are accommodated on a single antenna, it is preferred that the channel frequencies be selected by making either:

$n = 1, 3, 5$ and 7 in both halves of the band

or

$n = 2, 4, 6$ and 8 in both halves of the band (see Note 3);

5. that the preferred arrangement of radio-frequency polarization should be one of those shown in Fig. 1, depending upon whether antennas for single or double polarization are used;

6. that the preferred radio-frequency channel arrangement for up to 16 go and 16 return channels, each accommodating up to 1260 telephone channels, or the equivalent, should be obtained by interleaving additional channels between those of the main pattern and should be expressed by the following relationship:

lower half of the band: $f_N = f_0 - 350 + 20\,N,$
upper half of the band: $f'_N = f_0 - 10 + 20\,N,$

where

$N = 1, 2, 3, \ldots 15, 16;$

Rec. 384-4

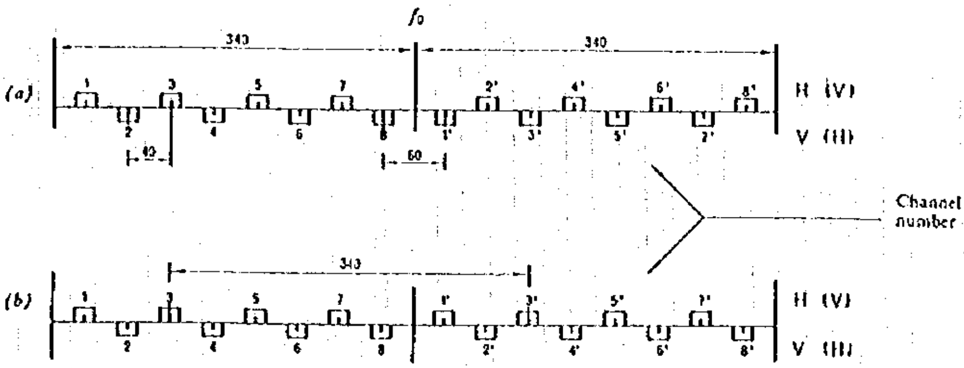


FIGURE 1

(a) Channel arrangement for antennas with double polarization
(b) Channel arrangement for antennas with single polarization
(All frequencies are in MHz)

7. that, in the section over which international connection is arranged, all the go channels should be in one half of the band and all the return channels in the other half of the band;

8. that different polarizations should be used alternately for adjacent radio-frequency channels in the same half of the band;

9. that when common transmit-receive antennas are used, and not more than four radio-frequency channels are accommodated on a single antenna, it is preferred that the channel frequencies be selected by making either:

N = 1, 5, 9, 13 or
N = 2, 6, 10, 14 or
N = 3, 7, 11, 15 or
N = 4, 8, 12, 16,

in both halves of the bands and the preferred arrangement of radio-frequency polarization is as shown in Fig. 2;

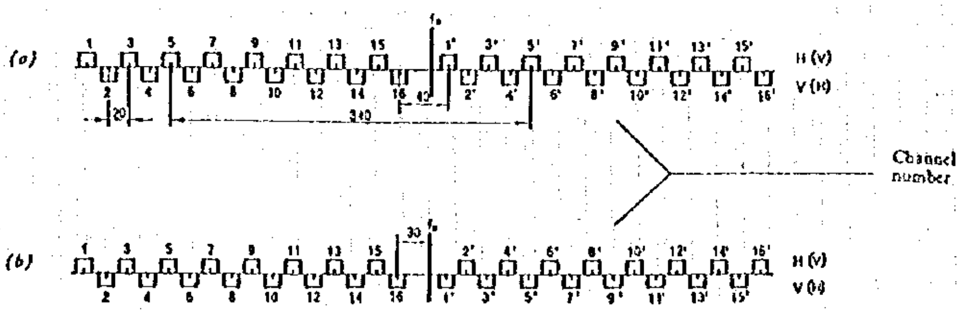


FIGURE 2

(a) Channel arrangement for antennas with single polarization
(b) Channel arrangement for antennas with double polarization
(All frequencies are in MHz)

10. that the preferred centre frequency (f_0) is 6770 MHz; other centre frequencies may be used by agreement between the administrations concerned.

Note 1. – This radio-frequency channel arrangement permits all local oscillator frequencies to be derived from a common oscillator, if desired.

Note 2. – The radio-frequency channel arrangements for systems of up to 1260-channel capacity and of 2700-channel capacity may be used on intersecting routes, as long as adequate antenna discrimination is provided.

Note 3. – The use of single antenna working allows for seven go and return channels. In order to use the eighth go and return channel, a high isolation is required between the closest transmit-receive channels.

REPORT 287-4

ANALOGUE RADIO-RELAY SYSTEMS OF CAPACITY GREATER THAN 1800 TELEPHONE CHANNELS, OR THEIR EQUIVALENT

(Study Programme 1A/9)

(1963-1970-1974-1978-1982)

1. Introduction

Radio-frequency channel arrangements for systems with a capacity of 2700 telephone channels operating in the upper 6 GHz band are given in Recommendation 384. Recommendation 387 refers to the use of the 11 GHz band for 2700 channel transmission. This Report presents additional information concerning radio-relay systems with capacities greater than 1800 telephone channels.

2. Use of the frequency band 4400 to 5000 MHz for 2700 telephone channel transmission*

In Japan, a radio-relay system with a capacity of 2700 telephone channels operating in the 5 GHz band (4400 to 5000 MHz) has been extensively used since 1972 [Matsuhashi, 1972]. High quality and high availability have been achieved. The parameters, such as intermediate frequency and r.m.s. test tone deviation are based on the CCIR Recommendations concerned. The radio-frequency channel arrangement is similar to Fig. 1 in Recommendation 384 with the difference that a 600 MHz wide frequency band is available, thus enabling seven go and seven return channels to be provided. The radio-frequency channel arrangement is based on a centre frequency of 4700 MHz, and on adjacent channel separation of 40 MHz. The spacing between adjacent transmitter and receiver is 60 MHz.

3. Systems with increased frequency band utilization

In Japan, the average cross-polarization discrimination *(XPD)* on paths using horn-reflector or parabolic antennas has been improved to more than 38 dB in the 5 and 6 GHz bands, by employing an improved technique for adjusting the antenna direction. No significant *XPD* variation as a function of time has been observed [Ohi *et al.*, 1977].

On the basis of these results, a radio-relay system with a capacity of 2700 telephone channels operating in the 6 GHz band (5925 to 6425 MHz) with a carrier separation of 29.65 MHz was brought into service in 1977 and two types of radio relays with a capacity of 3600 telephone channels, one operating in the 4 GHz band (3600 to 4200 MHz) and the other in the 5 GHz band (4400 to 5000 MHz) with a carrier separation of 40 MHz, were brought into service in 1979. All these systems have since maintained a satisfactory circuit quality [Nishino *et al.*, 1976; Matsumoto *et al.*, 1980].

* In many countries there are restrictions on the use of this frequency band for high-capacity radio-relay systems.

These systems have improved frequency use 1.3 to 1.5 times over conventional systems. It should be noted, however, that the design and operation of these high-capacity systems calls for numerous precautions. Among the many factors to be considered, the following are particularly important:

- A path *XPD* of 38 dB corresponds to an aggregate adjacent channel interference noise of about 1000 pW0p in a hypothetical reference circuit, which must be included in the total noise contribution.
- The choice of path is significant in ensuring that a satisfactory path *XPD* can be maintained; in particular, over-water paths will probably cause difficulties in meeting the path *XPD* objective.
- The rigidity of the towers required to support the antennas should be sufficient to cause minimum tilt and twist of the antennas. For a horn-reflector antenna, a deflection of less than 0.05° will typically cause a deterioration of the path *XPD* below 38 dB.
- The installation of such a high-capacity transmission system must be preceded by a thorough study of the propagation conditions.

An r.m.s. frequency deviation of 100 kHz per channel with a pre-emphasis factor of 10 dB seems to be optimum for a 3600 channel radio-relay system.

4. Auxiliary channels

It is customary, in devising radio-frequency channel arrangements for broadband systems, to provide for two pairs of auxiliary channel frequencies and some preliminary examination has been given to this problem. In the case of the radio-relay system operating in the upper 6 GHz band, it seems likely that the values $f_0 \pm 3$ and $f_0 \pm 337$ MHz will prove to be the most suitable, although, in certain of the polarization arrangements, great difficulty may be experienced in filtering the two inner auxiliary channel frequencies. The proposed arrangement is included in Fig. 1.

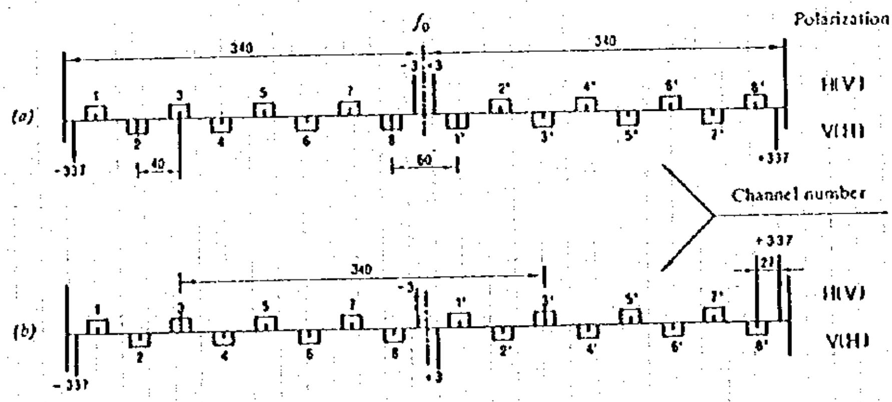


FIGURE 1

(a) Arrangement proposed for antenna with double polarization

(b) Arrangement proposed for antenna with single polarization

(All frequencies are in MHz)

REFERENCES

MATSUHASHI, S. [1972] 2700 channel radio-relay system operating in the 5 GHz band – SF-E1. *Japan Telecomm. Rev.*, Vol. 14, 3, 159-164.

MATSUMOTO, S., HASHIMOTO, A. and FUTATSUGI, H. [11 June, 1980] FDM/FM 3600 channel radio-relay systems in 4 GHz and 5 GHz bands. IEEE International Conference on Communications (ICC '80), Seattle, Wa., USA, Conf. Record, Session 41: Line of sight radio systems, Vol. 3, 41-1-1 – 41-1-5.

NISHINO, K., YAMADA, Y., HASHIMOTO, A. and SANGO, J. [July, 1976] 6 GHz 2700-channel radio-relay system – SF-U4. *Japan Telecomm. Rev.*, Vol. 18, 3, 156-162.

OHI, J., SANGO, J. and KOYAMA, K. [15 June, 1977] High capacity FDM/FM microwave system with increased efficiency of frequency utilization. IEEE International Conference on Communications (ICC '77), Chicago, Ill., USA, Conf. Record, Session 40: High capacity microwave systems; Vol. 3, 40.2, 83-87.

RECOMMENDATION 385-3*

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR 60, 120 AND 300-CHANNEL RADIO-RELAY SYSTEMS FOR TELEPHONY USING FREQUENCY-DIVISION MULTIPLEX AND OPERATING IN THE 7 GHz BAND**

(Question 1/9)

(1959-1963-1978-1982-1986)

The CCIR,

CONSIDERING

(a) that it is desirable to be able to interconnect 60, 120 and 300-channel radio-relay systems on international circuits at radio frequencies in the 7 GHz band;

(b) that frequency bands 300 MHz wide may be available for such systems;

(c) that economy may be achieved, if several go and return channels are connected to one common transmit-receive antenna;

(d) that many interfering effects can be minimized by a carefully planned arrangement of the radio frequencies in radio-relay systems employing several radio-frequency channels;

(e) that, for reasons of frequency economy, it is desirable to interleave additional radio-frequency channels between those of the main pattern;

(f) that it is desirable that the values of the mid-frequencies of the radio-frequency channels be the same for 60, 120 and 300-channel systems;

(g) that the spacing between the mid-frequencies of the radio-frequency channels should be such, that the systems can work with the maximum frequency deviation given in Recommendation 404 for such systems,

UNANIMOUSLY RECOMMENDS

1. that the preferred radio-frequency channel arrangement for several radio-relay systems, each accommodating 60, 120 or 300 telephone channels and operating in the 7 GHz band, should be derived as follows (see Fig. 1):

Let f_0 be the frequency of the centre of the band of frequencies occupied (MHz);

f_n be the centre frequency of one radio-frequency channel in the lower half of this band (MHz);

f'_n be the centre frequency of one radio-frequency channel in the upper half of this band (MHz);

then the frequencies (MHz) of the individual channels are expressed by the following relationships:

lower half of the band: $f_n = f_0 - 154 + 7\,n$ (see Note 1),
upper half of the band: $f'_n = f_0 + 7 + 7\,n$ (see Note 1),

where:

$n = 1, 2, 3, \ldots 20$;

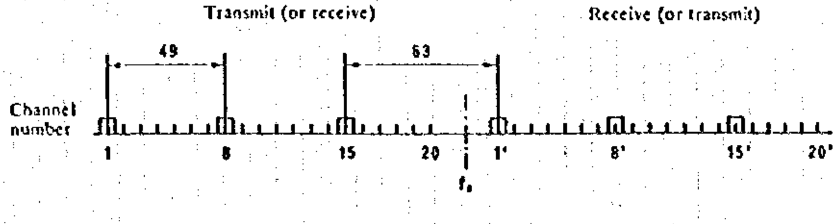


FIGURE 1 – *Radio-frequency channel arrangement for international connection of radio-relay systems for 60, 120 or 300 channels operating in the 7 GHz band*
(All frequencies are in MHz)

* This Recommendation applies only to line-of-sight and near line-of-sight radio-relay systems.

** Subject to agreement between the administrations concerned, other higher-capacity systems using the radio-frequency channel arrangement pattern defined in this Recommendation may be accepted if necessary.

2. that, in a section over which the international connection is arranged, all the go channels should be in one half of the band and all the return channels should be in the other half of the band;

3. that, when common transmit-receive antennas are used and three radio-frequency channels are accommodated on a single antenna, it is preferable that the channel frequencies be selected by making:

n = 1, 8 and 15, or
n = 2, 9 and 16, or
n = 3, 10 and 17, or
n = 4, 11 and 18, or
n = 5, 12 and 19, or
n = 6, 13 and 20,

in both halves of the band;

4. that for international connections, the centre frequency should preferably be:

f_0 = 7575 MHz for the band 7425 to 7725 MHz (see Note 1);

other centre frequencies may be used in certain geographical areas by agreement between the administrations concerned, e.g.:

f_0 = 7275, 7400 or 7700 MHz (see Note 1);

5. that the channel arrangement and antenna polarization should be agreed between the administrations concerned;

6. that, when systems with 300 telephone channels are operated in a radio-frequency band, channel combinations which result in differences between channel frequencies of less than 14 MHz, should in general be avoided. If sufficient antenna discrimination is available, this precaution may be disregarded.

Note 1. – The formulae for f_n and f'_n and the values for f_0 differ from those given in Recommendation 284 (Los Angeles, 1959). This change has been made so that the "centre frequency" f_0 falls, in reality, in the centre of the band of frequencies occupied.

Note 2. - Due regard should be taken of the fact that in some countries the radio-frequency channel arrangement described in Report 934 is in use for digital systems with a capacity of about 70 Mbit/s.

Note 3. -- Due regard should also be taken of the fact that in some countries the radio-frequency channel arrangements described in Report 1055 are in use for medium and small capacity digital systems.

RECOMMENDATION 386-3

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR SYSTEMS WITH A CAPACITY OF 960 TELEPHONE CHANNELS, OR THE EQUIVALENT, OPERATING IN THE 8 GHz BAND

(Question 1/9)

(1963-1966-1982-1986)

The CCIR,

CONSIDERING

(a) that it may be desirable to be able to interconnect radio-relay systems on international circuits at radio frequencies in the 8 GHz band;

(b) that, for some administrations, a frequency band, 300 MHz wide, may be available in the 8 GHz range for such systems;

Rec. 386-3

(c) that it may be desirable to interconnect in such a band up to six systems with a capacity of 960 channels, or the equivalent;

(d) that such a frequency arrangement should also be suitable for 300-channel systems;

(e) that for reasons of frequency economy, it is desirable to interleave additional radio-frequency channels between those of the main pattern;

(f) that economy may be achieved, if at least three go and three return channels can be interconnected between systems using common transmit-receive antennas;

(g) that many interfering effects can be minimized by a carefully planned frequency arrangement for systems employing several radio-frequency channels,

UNANIMOUSLY RECOMMENDS

1. that the preferred radio-frequency channel arrangement in the 8 GHz band should be derived as follows:

let f_0 be the frequency of the centre of the band of frequencies occupied (MHz);

f_n be the centre frequency of one radio-frequency channel in the lower half of this band (MHz);

f'_n be the centre frequency of one radio-frequency channel in the upper half of this band (MHz);

then the frequencies of the individual channels are expressed by the following relationships:

lower half of band: $f_n = f_0 - 151.614 + 11.662\ n,$

upper half of band: $f'_n = f_0 + 11.662\ n,$

where for systems with a capacity of 960 telephone channels, or the equivalent:

$n = 1, 3, 5, 7, 9$ and 11;

for systems with a capacity of 300 telephone channels:

$n = 1, 2, 3, 4, 5, \ldots 12$;

2. that, in a section over which the international connection is arranged, all the go channels should be in one half of the band, and all the return channels should be in the other half of the band;

3. that, for adjacent radio-frequency channels in the same half of the band, horizontal and vertical polarization shall be used alternately;

4. that, when common transmit-receive antennas are used and three radio-frequency channels are accommodated on a single antenna, it is preferable that for systems with a capacity of 960 telephone channels, or the equivalent, channel frequencies be selected by making:

$n = 1, 5$ and 9
or } in both halves of the band;
$n = 3, 7$ and 11

when using systems with a capacity of 300 telephone channels it is preferable to select:

$n = 1, 5$ and 9 or
$n = 2, 6$ and 10 or } in both halves of the band;
$n = 3, 7$ and 11 or
$n = 4, 8$ and 12

5. that, when additional radio-frequency channels are required for 960-channel systems, or the equivalent, interleaved between those of the main pattern, the frequencies of the individual channels shall be obtained by making:

$n = 2, 4, 6, 8, 10$ and 12;

6. that for international connections the centre frequency should preferably be:

$f_0 = 8350$ MHz,

this value corresponds to the band 8200-8500 MHz. Other values may be taken by agreement between the administrations concerned;

7. that due regard be taken of the fact that, in some countries, another radio-frequency channel arrangement for systems with capacities of up to 1800 telephone channels, or the equivalent, is used. A description of this radio-frequency channel arrangement is given in Annex I.

Note 1. – The radio-frequency channel arrangement described in § 1 to 6 permits all local oscillator frequencies to be derived from the common oscillator frequency 11.662 MHz. The frequency pattern allows for economical use of the frequency band, but since the intermediate frequency of 70 MHz is a multiple of the channel spacing, adequate system selectivity will have to be provided to avoid undue interference.

Note 2. – Due regard should be taken of the fact that in parts of Region 2 a different radio-frequency channel arrangement is in use for digital systems with a capacity of about 90 Mbit/s. This arrangement is described in Annex III of Report 934.

Note 3. – Due regard should be taken of the fact that in some countries the radio-frequency channel arrangement described in Report 1055 is in use for medium and low capacity digital systems operating in the band 8275 to 8500 MHz.

ANNEX I

DESCRIPTION OF THE RADIO-FREQUENCY CHANNEL ARRANGEMENT REFERRED TO IN RECOMMENDS 7

1. The radio-frequency channel arrangement, in a frequency band 250 MHz below 7975 MHz and 250 MHz above 8025 MHz for up to eight go and eight return channels, each accommodating up to 1800 telephone channels, or the equivalent, operating in the 8 GHz band, is as shown in Fig. 1 and is derived as follows:

Let f_0 be the frequency of the centre of the band of frequencies occupied (MHz);

f_n be the centre frequency of one radio-frequency channel in the lower half of this band (MHz);

f'_n be the centre frequency of one radio-frequency channel in the upper half of this band (MHz);

then the frequencies of the individual channels are expressed by the following relationships:

lower half of band: $f_n = f_0 - 281.95 + 29.65\,n$,
upper half of band: $f'_n = f_0 + 29.37 + 29.65\,n$,

where:

$n = 1, 2, 3, 4, 5, 6, 7$ or 8.

2. That, in a section over which the international interconnection is arranged, all the go channels should be in one half of the band, and all the return channels should be in the other half of the band.

3. That the go and return channels on a given section should preferably use the polarizations shown below:

	Go								*Return*							
H(V)	1		3		5		7			1'		3'		5'		7'
V(H)		2		4		6		8			2'		4'		6'	8'

4. That, when additional radio-frequency channels, interleaved between those of the main pattern, are required, the values of the centre frequencies of these radio-frequency channels should be 14.825 MHz below those of the corresponding main channel frequencies; in systems for 1800 channels, or the equivalent, it may not be practical, because of the bandwidth of the modulated carrier, to use interleaved frequencies.

5. That, for international connections, the centre frequency should be:

$f_0 = 8000$ MHz.

This value corresponds to the band 7725-7975 MHz in the lower half and 8025-8275 MHz in the upper half.

Note 1. – The radio-frequency channel arrangement for eight go and eight return channels, shown in Fig. 1, is suitable for use with the preferred intermediate frequency of 70 MHz (see Recommendation 403). It is also suitable for use with an intermediate frequency of 74.13 MHz, which enables a common oscillator (14.82 MHz) to be used for generating all the local oscillations for the system, if desired.

Note 2. – The radio-frequency channel arrangement shown in Fig. 1 overlaps that of Recommendation 386 by 75 MHz, between 8200 MHz and 8275 MHz, and that mentioned in Recommendation 385, for a centre frequency of 7700 MHz, by 125 MHz between 7725 MHz and 7850 MHz. All due precautions to avoid mutual interference must be taken by radio-relay systems using these channel arrangements.

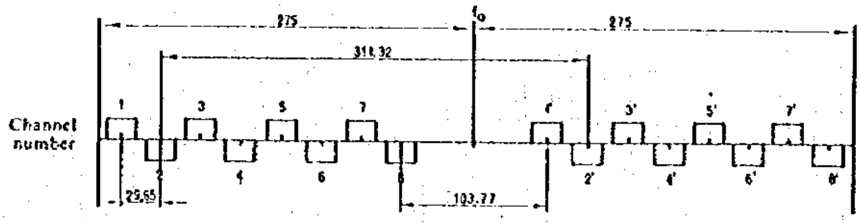


FIGURE 1 – *Radio-frequency channel arrangement, described in Annex I*
(All frequencies are in MHz)

REPORT 1055

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR MEDIUM AND SMALL CAPACITY DIGITAL RADIO-RELAY SYSTEMS OPERATING IN THE BANDS BELOW ABOUT 12 GHz

(Question 35/9 and Study Programme 35A/9)

(1986)

1. Introduction

Many criteria for determination of radio-frequency channel arrangements for small and medium capacity digital radio-relay systems can be deduced from the corresponding considerations concerning medium-high and high-capacity systems described in Report 934. Reference should therefore be made to Report 934, but contributions are invited from administrations on these topics. Of particular importance to medium and small capacity digital radio-relay systems are the methods of utilization of frequency bands below about 12 GHz, which Report 934 states as:

– either by the re-use of the channel arrangements recommended for analogue radio relays, which enables analogue and digital systems to coexist on the same artery and at nodal points and, in particular, is consistent with gradual digitization and direct replacement of analogue systems (see Report 610);

– or by the formulation of new channel arrangements specifically designed for digital transmission, sacrificing, if necessary, compatibility with existing channel arrangements.

The first method is likely to be of application to bands in which a channel arrangement exists which can be adapted to a 14/28 MHz or to a 5 MHz homogeneous plan. This method has been adopted for the 7 GHz band for a 14/28 MHz homogeneous plan based on Recommendation 385 which is suitable for the 2 Mbit/s multiplex hierarchy and for a 5 MHz homogeneous plan which is suitable for the 1.5 Mbit/s multiplex hierarchy. These are described in Annexes I and II respectively.

The second method is likely to be of application in bands in which the analogue channelling arrangement is designed for systems with specific FDM telephone channel capacities and is not optimized for digital use. This method has been adopted for the 8 GHz band, as described in Annex III, and based on Recommendation 386.

2. Specific channel arrangements

2.1 *7 GHz band*

2.1.1 *14/28 MHz plan*

The frequency channelling arrangement of Annex I for the 7 GHz band allows mixed use of analogue and digital channels and also allows the interleaving of analogue and digital channels on the basis of the 7 MHz homogeneous interval of Recommendation 385. This follows the guidelines of Report 610. However, the transmit-receive spacings differ for the channel plan of Recommendation 385 (161 MHz), the main and interleaved digital plans of Annex I (154 MHz), and the interleaved analogue plan of Annex I.

Digital radio-relay systems with small and medium capacities can be introduced into the band by utilizing the analogue 7 MHz frequency pattern of Recommendation 385.

2.1.2 *5 MHz plan*

The frequency channel arrangement of Annex II for the 7 GHz band allows mixed use of analogue and digital channels on the basis of a 5 MHz homogeneous interval. This also follows the guidelines of Report 610, and is suitable for bit rates of 6.3 Mbit/s (1.544 × 4), 12.6 Mbit/s (1.544 × 8) or 19 Mbit/s (1.544 × 12), using channel spacings of 10 or 20 MHz. The choice of channel spacing is dependent on the incidence of differential fading on adjacent channels in directions very close to the wanted channel.

2.1.3 *Medium-high capacity usage*

Medium-high capacity usage of this band is described in Report 934.

2.2 *8 GHz band*

The frequency channelling arrangement of Annex III for the 8 GHz band is more appropriate for medium and small capacity digital systems and provides a more efficient band utilization than that given in Recommendation 386. It also avoids overlap with other radio frequency channel arrangements used by some administrations. These arrangements are:

(a) for systems with capacities of up to 1800 telephone channels or the equivalent, in the band 7725 to 8275 MHz, given in Annex I of Recommendation 386;

(b) for digital systems of medium-high capacity in the band 7725 to 8275 MHz given in Annex III to Report 934;

(c) for systems with capacities of up to 960 telephone channels or the equivalent in the band 8200 to 8500 MHz given in the main part of Recommendation 386.

The channel arrangement described in Annex III to this Report, covering the band 8275 to 8500 MHz, is suitable for use with arrangements (a) and (b) above so as to avoid the overlap of 75 MHz that would occur with arrangement (c) above. However, because of this potential overlap, all due precautions to avoid mutual interference must be taken in the design of radio-relay systems using these channel arrangements.

ANNEX I

RADIO-FREQUENCY CHANNEL ARRANGEMENT FOR UP TO 300 CHANNEL RADIO-RELAY SYSTEMS FOR TELEPHONY USING FREQUENCY DIVISION MULTIPLEX OR MEDIUM CAPACITY DIGITAL SYSTEMS OPERATING IN THE 7 GHz BAND

1. This Annex describes a radio-frequency channel arrangement for digital radio-relay systems of 34 Mbit/s capacity and for coexistence of digital systems and analogue radio-relay systems up to 300 channels, operating in the band 7425 to 7725 MHz. The radio-frequency channel arrangement is shown in Fig. 1 and is derived as follows:

Let f_0 be the frequency (MHz) of the centre of the band of frequencies occupied;

f_n be the centre frequency (MHz) of one radio-frequency channel in the lower half of the band;

f'_n be the centre frequency (MHz) of one radio-frequency channel in the upper half of the band;

Rep. 1055

then the frequencies (MHz) of the individual channels are expressed by the following relationships:

lower half of the band: $f_n = f_0 - 161 + 28\,n$
upper half of the band: $f'_n = f_0 - 7 + 28\,n$

where:

$n = 1, 2, 3, 4$ and 5.

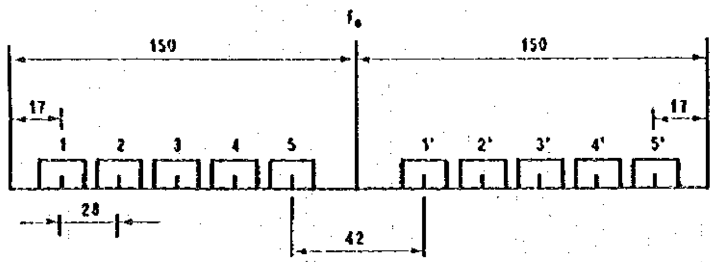


FIGURE 1 – *Radio-frequency channel arrangement of radio systems for radio-relay analogue and digital systems operating in the 7 GHz band*

(All frequencies are in MHz)

2. All go channels should be in one half of the band and all return channels should be in the other half of the band.

3. For adjacent radio-frequency channels in the same half of the band, different polarizations may be used for alternate channels or where it is possible, both polarizations may be utilized for each digital radio-frequency channel.

4. When additional analogue radio frequencies are required, they should be interleaved between those of the main pattern of Fig. 1, and can be realized by the same f_0 and the following relationship:

lower half of the band: $f_n = f_0 - 175 + 28\,n$
upper half of the band: $f'_n = f_0 + 7 + 28\,n$

where:

$n = 1, 2, 3, 4$ and 5.

5. When additional digital radio frequencies interleaved between those of the main pattern of Fig. 1 are required, they can be realized by the same f_0 and the following relationship:

lower half of the band: $f_n = f_0 - 147 + 28\,n$
upper half of the band: $f'_n = f_0 + 7 + 28\,n$

where:

$n = 1, 2, 3,$ and 4.

6. The preferred centre frequency f_0 is 7575 MHz.

7. The local oscillators for the lower half of the band should preferably be 70 MHz above the respective channel frequency and for the upper half of the band 70 MHz below the channel frequency. This will ensure that the image frequencies will fall within the band. However, the application of certain techniques, particularly the use of image frequency rejection mixers, helps to overcome this constraint.

Rep. 1055

ANNEX II

RADIO-FREQUENCY CHANNEL ARRANGEMENT FOR MEDIUM CAPACITY RADIO-RELAY SYSTEMS UP TO 960 CHANNELS FOR TELEPHONY USING FREQUENCY DIVISION MULTIPLEX OR UP TO 19 Mbit/s DIGITAL SYSTEMS OPERATING IN THE 7 GHz BAND

1. This Annex describes a radio-frequency channel arrangement suitable for digital radio-relay systems up to 19 Mbit/s (1.544 × 12) and allows coexistence of digital systems and medium capacity analogue systems spaced on a 20 MHz interval operating in the band 7435 to 7750 MHz. Coexistence can also be achieved with analogue 960 telephone channels. The radio-frequency channel arrangement is shown in Fig. 2 and is derived as follows:

Let f_0 be the frequency (MHz) of the centre of the band of frequencies occupied;

f_n be the centre frequency (MHz) of one radio-frequency channel in the lower half of the band;

f'_n be the centre frequency (MHz) of one radio-frequency channel in the upper half of the band;

then the frequencies (MHz) of the individual channels are expressed by the following relationships:

lower half of the band: $f_n = f_0 - 152.5 + 5n$
upper half of the band: $f'_n = f_0 + 7.5 + 5n$

where:

$n = 1, 2, 3, 4, 5, 6, \dots 28.$

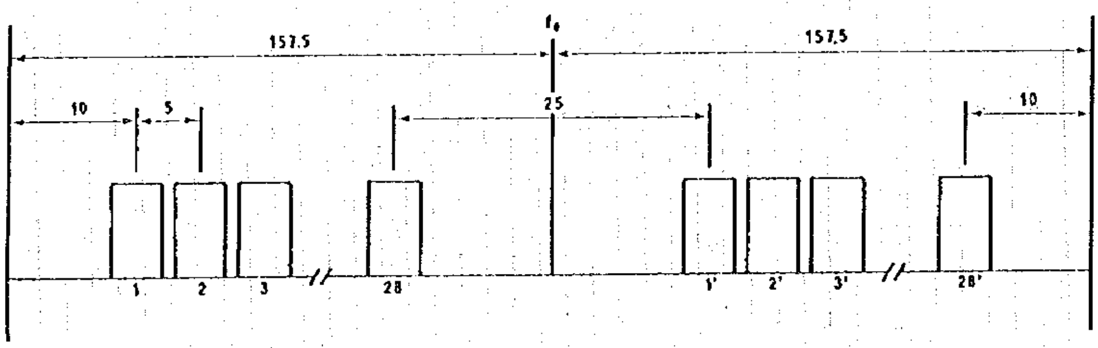


FIGURE 2 – *Radio-frequency channel arrangement of digital systems operating in the 7 GHz band*
(All frequencies are in MHz)

2. All go channels should be in one half of the band and all return channels should be in the other half of the band.

3. The centre frequency f_0 is 7592,5 MHz.

4. For all radio-frequency channels in the same half of the band, the same polarization may be used or, where it is necessary because of the existence of interference, different polarizations may be utilized.

Where it is possible, both polarizations may be utilized for each digital radio-frequency channel.

5. Digital radio-frequency channels for 12.6 Mbit/s (1.544 × 8) or 19 Mbit/s (1.544 × 12) systems, can be realized by use of a 10 MHz or 20 MHz interval.

ANNEX III

A RADIO-FREQUENCY CHANNEL ARRANGEMENT FOR MEDIUM AND SMALL CAPACITY DIGITAL SYSTEMS OPERATING IN THE 8 GHz BAND

1. This Annex describes a radio-frequency channel arrangement for digital radio-frequency systems with capacities of 34 Mbit/s and 2 × 8 Mbit/s operating in the band 8275 to 8500 MHz. The radio-frequency channel arrangement is shown in Fig. 3 and is derived as follows:

Let f_0 be the frequency (MHz) of the centre of the band of frequencies occupied;

f_n be the centre frequency (MHz) of one radio-frequency channel in the lower half of the band;

f'_n be the centre frequency (MHz) of a radio-frequency channel in the upper half of the band;

then the frequencies of individual channels are expressed by the following relationships:

1.1 for systems with a capacity of 34 Mbit/s:

lower half of the band: $f_n = (f_0 - 108.5 + 14\,n$ (MHz)

upper half of the band: $f'_n = (f_0 + 10.5 + 14\,n$ (MHz)

where:

$n = 1, 2, 3, 4, 5,$ or 6;

1.2 for systems with a capacity of 2 × 8 Mbit/s:

lower half of the band: $f_n = (f_0 - 108.5 + 7\,n)$ MHz

upper half of the band: $f'_n = (f_0 + 17.5 + 7\,n)$ MHz

where:

$n = 1, 2, 3, \ldots 12.$

2. All go channels should be in one half of the band and all the return channels should be in the other half of the band.

3. The centre frequency f_0 is 8387.5 MHz.

4. For small-capacity systems (2 × 8 Mbit/s), RF channel arrangements may be adopted in conformity with the pattern shown in Fig. 3, by adding interleaved channels at 7 MHz.

5. For adjacent radio-frequency channels in the same half of the band, different polarization should be used alternately, in the interleaved channel arrangement of Fig. 3.

6. Both horizontal and vertical polarization should be used for each radio-frequency channel in a co-channel arrangement.

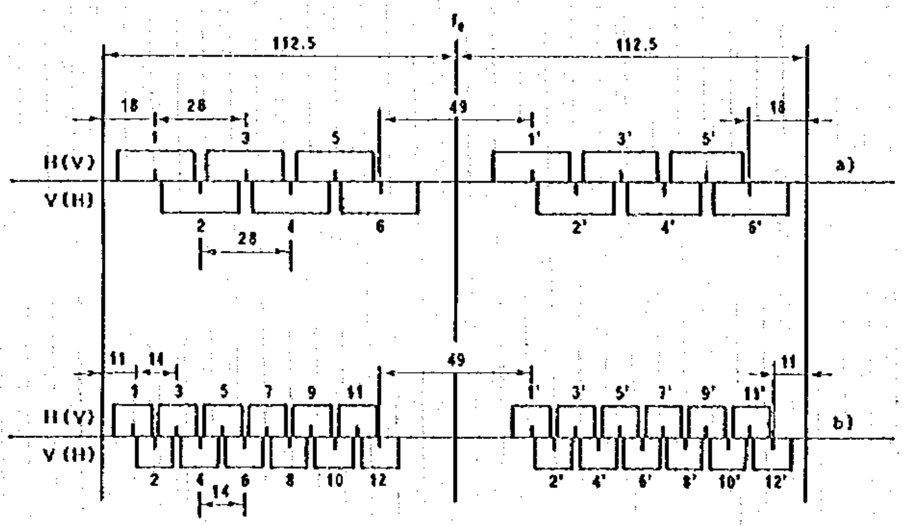


FIGURE 3 – *Radio-frequency channel arrangement for medium- and small-capacity digital radio-relay systems operating in the 8275 to 8500 MHz band*

(All frequencies are in MHz)

(a) For systems with a capacity of 34 Mbit/s

(b) For systems with a capacity of 2 x 8 Mbit/s

RECOMMENDATION 387-4

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR ANALOGUE TELEVISION AND TELEPHONY RADIO-RELAY SYSTEMS WITH A CAPACITY OF 600 TO 1800 TELEPHONE CHANNELS, OR THE EQUIVALENT, OR DIGITAL SYSTEMS WITH A CAPACITY OF UP TO 140 Mbit/s, OPERATING IN THE 11 GHz BAND*

(Questions 1/9 and 35/9)

(1963-1970-1974-1978-1986)

The CCIR,

CONSIDERING

(a) that, at 11 GHz, analogue radio-relay systems with a capacity of up to 1800 telephone channels, or the equivalent, or digital systems with a capacity of up to 140 Mbit/s seem to be feasible, subject to rainfall conditions;

(b) that repeater spacing as well as other aspects of system design in this frequency range must take due cognizance of significant meteorological factors;

(c) that it is desirable to interconnect such systems at radio frequencies on international circuits;

(d) that for analogue systems a uniform radio-frequency channel arrangement for both smaller and larger capacities offers considerable advantages;

(e) that, in a frequency band 1000 MHz wide, it may be desirable to interconnect up to twelve go and twelve return analogue channels;

(f) that economy may be achieved if at least three go and three return analogue channels can be accommodated on a common antenna;

(g) that it may sometimes be desirable to interleave additional radio-frequency channels between those of the main pattern;

(h) that the channels should be so arranged as to enable an intermediate frequency of 70 MHz to be used,

UNANIMOUSLY RECOMMENDS

1. that the preferred radio-frequency channel arrangement for analogue radio-relay systems with a maximum capacity of 1800 telephone channels, or the equivalent, and operating in the 11 GHz band should be derived as follows:

Let f_0 be the frequency (MHz) of the centre of the band of frequencies occupied;

f_n be the centre frequency (MHz) of one radio-frequency channel in the lower half of the band;

f'_n be the centre frequency (MHz) of one radio-frequency channel in the upper half of the band;

then the frequencies (MHz) of individual channels are expressed by the following relationship:

lower half of the band: $f_n = f_0 - 525 + 40\,n$,
upper half of the band: $f'_n = f_0 + 5 + 40\,n$,

where:

$n = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11$ or 12.

The frequency arrangement is illustrated in Fig. 1;

2. that, when additional analogue radio-frequency channels, interleaved between those of the main pattern are required, the values of the centre frequencies of these radio-frequency channels should be 20 MHz below those of the corresponding main channel frequencies;

Note. – Channel 1 of the interleaved pattern in the lower half of the band is beyond the lower extremity of a 1000 MHz band and may therefore not be available for use.

* Subject to agreement between the administrations concerned, 2700 telephone channel systems employing an intermediate frequency of 140 MHz and following the main pattern of the radio frequency plan of this Recommendation, may be accommodated in the 11 GHz band when required for special cases.

Rec. 387-4

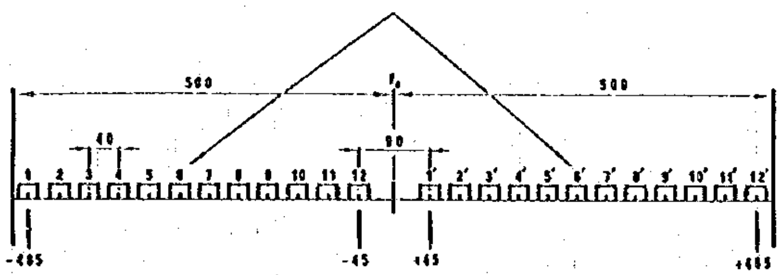


FIGURE 1 – *Radio-frequency channel arrangement for radio-relay systems operating in the 11 GHz band (Main pattern)*
(All frequencies in MHz)

3. that, when analogue radio-frequency channels are also required for auxiliary radio-relay systems, the preferred frequencies for eleven go and eleven return channels, including two pairs of auxiliary channels in both the main and interleaved patterns should be derived by making:

n = 2, 3, 4, ... 12 in the lower half of the band,
n = 1, 2, 3, ... 11 in the upper half of the band.

The radio frequencies (MHz) for the auxiliary systems should be chosen as shown below:

	Main pattern	*Interleaved pattern*
lower half of the band	$f_0 - 485$	$f_0 - 495$
	$f_0 - 15$	$f_0 - 25$
upper half of the band	$f_0 + 15$	$f_0 + 25$
	$f_0 + 485$	$f_0 + 465$

The radio-frequency arrangement is illustrated in Fig. 2, which also shows a possible polarization arrangement;

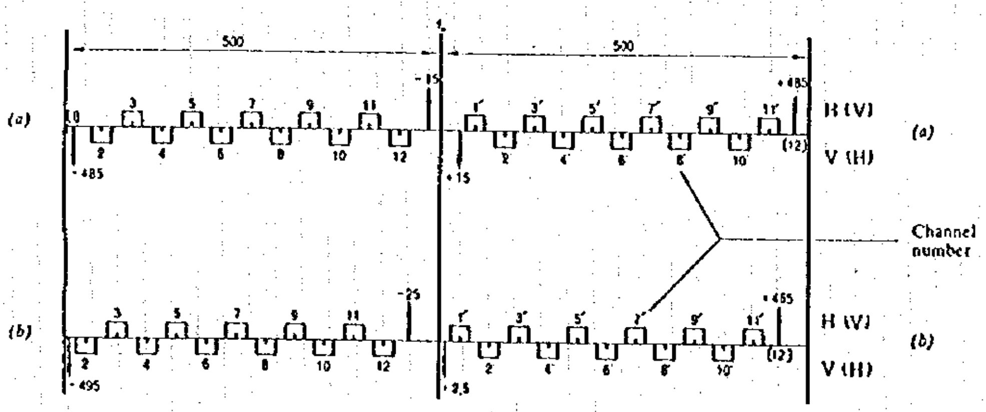


FIGURE 2 – *Radio-frequency channel arrangement for main and auxiliary radio-relay systems operating in the 11 GHz band*
(All frequencies in MHz)

(a) Main pattern
(b) Interleaved pattern

4. that, in a section over which the international connection is arranged, all the go channels should be in one half of the band and all the return channels should be in the other half of the band;

5. that if, for example, only three go and three return channels are accommodated on a common transmit-receive antenna, it is preferable that the channel frequencies (MHz) be selected by making:

n = 1, 5, 9 or
n = 2, 6, 10 or
n = 3, 7, 11 or
n = 4, 8, 12
in both halves of the band;

6. that for adjacent analogue radio-frequency channels in the same half of the band different polarizations should preferably be used alternately;

7. that the preferred centre frequency is 11 200 MHz; other centre frequencies may be used by agreement between the administrations concerned;

8. that when digital radio-relay systems of low or medium capacity are to be used in the 11 GHz band, the radio-frequency channel arrangement should be in accordance with RECOMMENDS 1 and 2 above. A description of these channel arrangements is given in Annex I;

9. that when high-capacity digital radio-relay systems of up to 140 Mbit/s are to be used in the 11 GHz band, the radio-frequency channel arrangements should utilize the central frequencies defined in RECOMMENDS 1, 2 and 3 (certain administrations are considering systems with capacities up to 200 Mbit/s). A description of these channel arrangements is given in Annex II.

Note. – It is recognized that some administrations are using alternative 140 Mbit/s channel arrangements as described in Report 782.

ANNEX I

DESCRIPTION OF THE RADIO-FREQUENCY CHANNEL ARRANGEMENT REFERRED TO IN RECOMMENDS 8

1. Suitable channel arrangements for low and medium-capacity digital radio-relay systems requiring channel spacings of 40 MHz can be provided by this Recommendation if co-channel assignments are made for both polarizations.

2. The preferred radio-frequency channel arrangement for digital radio-relay systems provides eleven go and eleven return channels derived as follows:

Let f_0 be the frequency (MHz) of the centre of the band of frequencies occupied;

f_n be the centre frequency (MHz) of one radio-frequency channel in the lower half of the band;

f'_n be the centre frequency (MHz) of one radio-frequency channel in the upper half of the band;

then the frequencies (MHz) of the co-channel pairs are expressed by the following relationship:

lower half of the band: $f_n = f_0 - 545 + 40\,n$,
upper half of the band: $f'_n = f_0 - 15 + 40\,n$,

where:

n = 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 or 12.

3. When digital radio channels are to be added to an existing analogue system that is not fully developed, the digital channels should preferably use the interleaved plan of RECOMMENDS 2 if the analogue channels are using the main pattern of § 1 and vice versa (Fig. 3 is included as an example).

However, it is recognized that in some cases it may be possible to add digital channels in the unused portions of an existing analogue system.

Note 1. – The general principles of compatibility between analogue and digital radio-relay systems are dealt with in Report 610.

Rec. 387-4

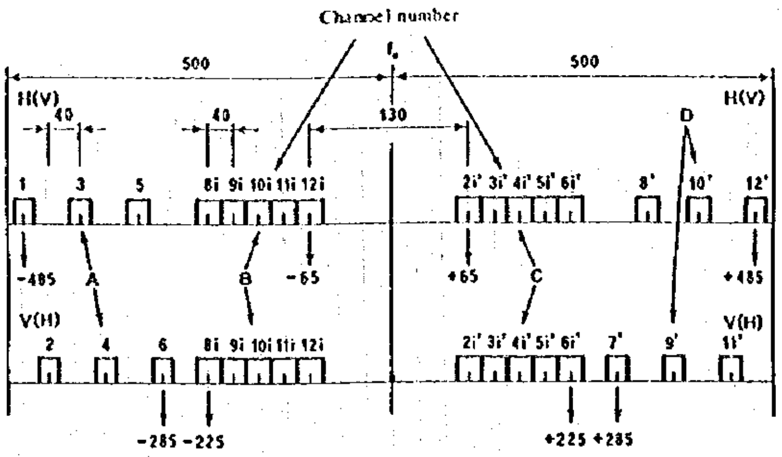


FIGURE 3 – *Example of a mixed analogue and digital radio-frequency channel arrangement for radio-relay systems operating in the 11 GHz band*

(All frequencies in MHz)

A: analogue B: digital C: interleaved pattern D: main pattern

ANNEX II

DESCRIPTION OF THE RADIO-FREQUENCY CHANNEL ARRANGEMENT REFERRED TO IN RECOMMENDS 9

1. The preferred radio-frequency channel arrangement providing 12 go and return channels based on the main pattern shown in Fig. 1 is defined by:

   $n = 1, 2, 3, \ldots 12$ in the lower half of the band,

   $n = 1, 2, 3, \ldots 12$ in the upper half of the band.

2. The preferred radio-frequency channel arrangement providing 11 go and return channels based on the main pattern shown in Fig. 1 is defined by:

   $n = 2, 3, 4, \ldots 12$ in the lower half of the band,

   $n = 1, 2, 3, \ldots 11$ in the upper half of the band.

This corresponds to the main radio-frequency channels shown in Fig. 2*(a)*.

3. The preferred radio-frequency channel arrangement providing 11 go and return channels based on the interleaved pattern shown in Fig. 2*(b)* is defined by:

   $n = 2, 3, 4, \ldots 12$ in the lower half of the band,

   $n = 1, 2, 3, \ldots 11$ in the upper half of the band (see Fig. 2*(b)*),

or:

   $n = 2, 3, 4, \ldots 12$ in the upper half of the band (see RECOMMENDS 2).

4. The preferred radio-frequency channel arrangement providing 12 go and return channels is based on § 2 above with two additional channels as shown in Fig. 4 and defined by the following relationships:

   lower half of the band: $f_n = f_0 - 505 + 40\,n$,
   upper half of the band: $f'_n = f_0 - 15 + 40\,n$,

where:

   $n = 1, 2, 3, \ldots 12$.

Note 1. – Channels 1 and 12' in the main pattern with a guard band of 15 MHz are generally considered unsuitable for high-capacity digital radio systems with a symbol rate of more than 25 to 30 MBd.

Note 2. – Channels 12 and 1' in Fig. 4 with a separation of 50 MHz are generally considered to require separate antennas if operated on the same hop. Interference between channels 12 and 1' may increase during periods of high rain rate due to back-scatter from rain. This effect should be taken into consideration in areas of the world where high rain rates are encountered.

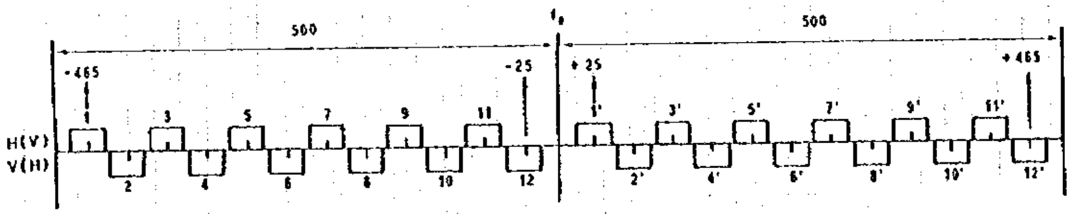


FIGURE 4 – *Radio-frequency channel arrangement for high capacity digital radio-relay systems operating in the 11 GHz band*

(All frequencies are in MHz)

REPORT 782-2

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR HIGH-CAPACITY DIGITAL SYSTEMS IN THE 10.7 TO 11.7 GHz FREQUENCY BAND

(Question 35/9 and Study Programme 35A/9)

(1978-1982-1986)

1. Introduction

The recommended RF channel arrangement for digital systems, with a capacity of up to 140 Mbit/s operating in the 11 GHz band, is given in Recommendation 387.

However, considerations of compatibility with existing radio-relay infra-structures, as well as propagation characteristics at 11 GHz in some climatic regions, have led some administrations to propose or adopt alternative radio-frequency plans, specifically designed for digital radio-relay systems having a bit rate of the order of 140 Mbit/s.

Two examples of such RF channel arrangements are described in Annexes I and II. In § 2, some aspects which should be considered when determining a channel arrangement at 11 GHz are briefly discussed.

2. Channel arrangement considerations

The determination of channel arrangements is a complex subject which depends on a number of interrelated factors.

Report 934 gives several comments on RF channel arrangements below about 10 GHz and the effects of this on system design, modulation methods, and spectral efficiency which, from a general standpoint, apply equally to the 11 GHz frequency band.

In the following sub-sections, consideration is given to some topics specifically related to 11 GHz channel arrangements.

ANNEX III

DESCRIPTION OF THE RADIO-FREQUENCY CHANNEL ARRANGEMENT REFERRED TO IN § 3.9 OF THIS REPORT

This radio-frequency channel arrangement uses the 14 500.0 to 14 714.5 MHz and 15 136.5 to 15 350.0 MHz portions of the available band with 2.5 MHz channel spacing as follows:

Let N be the number of RF channels pairs;

then the frequencies of the individual channels are expressed by the following relationships:

lower half of the band: $f_n = f_r + 2797.75 + 2.5\,n$ MHz

upper half of the band: $f'_n = f_r + 3647.75 - 2.5\,(N - n)$ MHz

where:

f_r: the reference frequency,

$n = 1, 2, \ldots N$ with $N \leq 84$

The frequency arrangement with $f_r = 11\,701$ MHz is illustrated in Fig. 3.

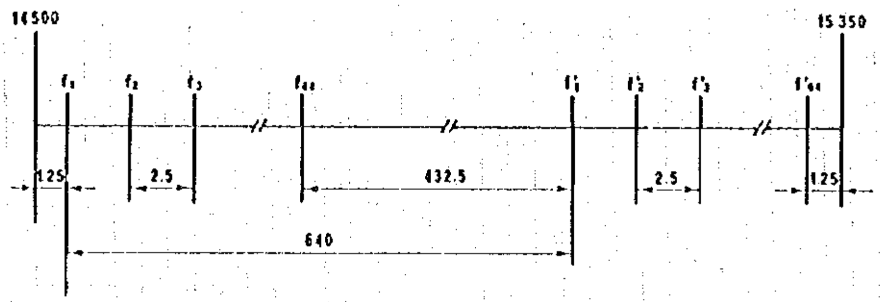


FIGURE 3 – *Radio-frequency channel arrangement for radio-relay systems operating in the 15 GHz band with 2.5 MHz spacing and N = 84*

(All frequencies are in MHz)

RECOMMENDATION 497-2

RADIO-FREQUENCY CHANNEL ARRANGEMENTS FOR ANALOGUE RADIO-RELAY SYSTEMS FOR TELEVISION AND FDM TELEPHONY WITH A CAPACITY OF 960 TELEPHONE CHANNELS OR THE EQUIVALENT AND FOR MEDIUM CAPACITY DIGITAL SYSTEMS OPERATING IN THE 13 GHz BAND

(Question 16/9)

(1974-1978-1982)

The CCIR,

CONSIDERING

(a) that the 12.75 to 13.25 GHz band is allocated to the fixed and mobile terrestrial services;

(b) that, at these frequencies, radio-relay systems for digital or analogue transmission are feasible with repeater spacings and other features chosen according to rainfall conditions;

(c) that it may be desirable to interconnect such systems at radio frequencies on international circuits;

Rec. 497-2

(d) that a uniform radio-frequency channel arrangement usable for both analogue and digital systems offers considerable advantages;

(e) that the homogeneous frequency pattern based on an interval of 14 MHz (see Report 607) is adaptable in this frequency band;

(f) that it may sometimes be desirable to interleave additional radio-frequency channels between those of the main pattern;

(g) that the radio-frequency channels should be so arranged that an intermediate frequency of 70 MHz be employed for analogue and for digital systems,

UNANIMOUSLY RECOMMENDS

1. that the preferred radio-frequency channel arrangement for FDM radio-relay systems with a maximum capacity of 960 telephone channels or the equivalent, and for digital radio-relay systems with a maximum capacity of 480 telephone channels or the equivalent, operating in the 13 GHz band, should be derived as follows:

Let f_0 be a reference frequency (MHz) near the centre of the 12.75 to 13.25 GHz band;
f_n be the centre frequency (MHz) of a radio-frequency channel in the lower half of the band;
f'_n be the centre frequency (MHz) of a radio-frequency channel in the upper half of the band;

then the frequencies of individual channels are expressed by the following relationship:

lower half of the band: $f_n = (f_0 - 259 + 28\ n)$ MHz
upper half of the band: $f'_n = (f_0 + 7 + 28\ n)$ MHz,

where:

n = 1, 2, 3, 4, 5, 6, 7 or 8.

The frequency arrangement is illustrated in Fig. 1;

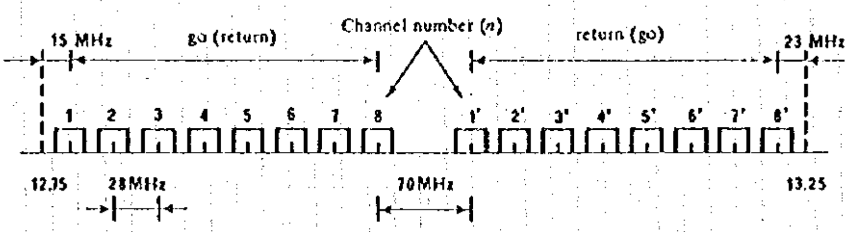


FIGURE 1 – *Radio-frequency channel arrangement for radio-relay systems operating in the 13 GHz band* (main pattern)

2. that, in the section through which an international connection is arranged to pass, all the go channels should be in one half of the band and all the return channels should be in the other half of the band;

3. that, in FDM systems, horizontal and vertical polarization shall be used alternately for adjacent radio-frequency channels in the same half of the band;

4. that, in digital systems, both horizontal and vertical polarization shall be used, where possible, for each radio-frequency channel;

5. that for digital systems with a capacity of 960 telephone channels the same radio-frequency channel arrangement may be used utilizing the RF channels number n = 2, 4, 6 and 8 in the case of a co-channel arrangement or n = 1, 2, 3, 4, 5, 6, 7 and 8 in the case of an interleaved arrangement (the possible use of the channel number 1 would depend on the radiated spectrum width);

Rec. 497-2

6. that, when additional radio-frequency channels with a maximum capacity of 300 FDM channels or of 240 digital channels, interleaved between those of the main pattern, are required, the values of the centre frequencies of these radio-frequency channels should be 14 MHz above those of the corresponding main channel frequencies. On the same route, it is advisable to use only systems having capacities no greater than these, when using this spacing;

7. that, when common transmit-receive antennas are used and no more than four channels are accommodated on a single antenna, it is preferred that the channel frequencies be selected by making either:

n = 1, 3, 5 and 7 or 2, 4, 6 and 8;

8. that, for international connections, the reference frequency should preferably be 12 996 MHz. Other values may be used by agreement between the administrations concerned;

9. that, in cases where smaller capacity radio channels having a capacity of 30 digital telephone channels (or the equivalent) are required, the following channel arrangements, (which occupy some of the bi-directional medium-capacity radio channels of the basic channel arrangement), should be used (see Note 2):

– Alternative I:

lower half of the band: $f_m = (f_0 - 276.5 + 28\,n + 7\,m)$ MHz

upper half of the band: $f'_m = (f_0 - 10.5 + 28\,n + 7\,m)$ MHz,

where:

m is equal to 1, 2, 3 or 4, and n refers to the channel number of the basic channel arrangement.

When n = 1, the channel arrangement of Fig. 2(a) is obtained.

Additional channels may be obtained by choosing n = 2.

By agreement between the administrations concerned, n may be greater than 2.

– Alternative II:

lower half of the band: $f_m = (f_0 - 66.5 + 7\,m)$ MHz

upper half of the band: $f'_m = (f_0 + 3.5 + 7\,m)$ MHz,

where:

m is preferably 3, 4, 5 or 6.

When additional channels are required, channel values of m = 1, 2, 7 or 8, may be used. This arrangement is illustrated in Fig. 2(b);

– Alternative III:

To achieve double the number of low capacity channels using channels 1 and 1' of the basic plan as compared with Alternative I:

lower half of the band: $f_m = (f_0 - 273 + 28\,n + 3.5\,m)$ MHz

upper half of the band: $f'_m = (f_0 - 7 + 28\,n + 3.5\,m)$ MHz,

where:

m is equal to 1, 2, 3, 4, 5, 6, 7 or 8 and n refers to the number of the basic channel arrangement.

When n = 1, the channel arrangement of Fig. 2(c) is obtained.

Additional channels may be obtained by choosing n = 2.

By agreement between the administrations concerned, n may be greater than 2.

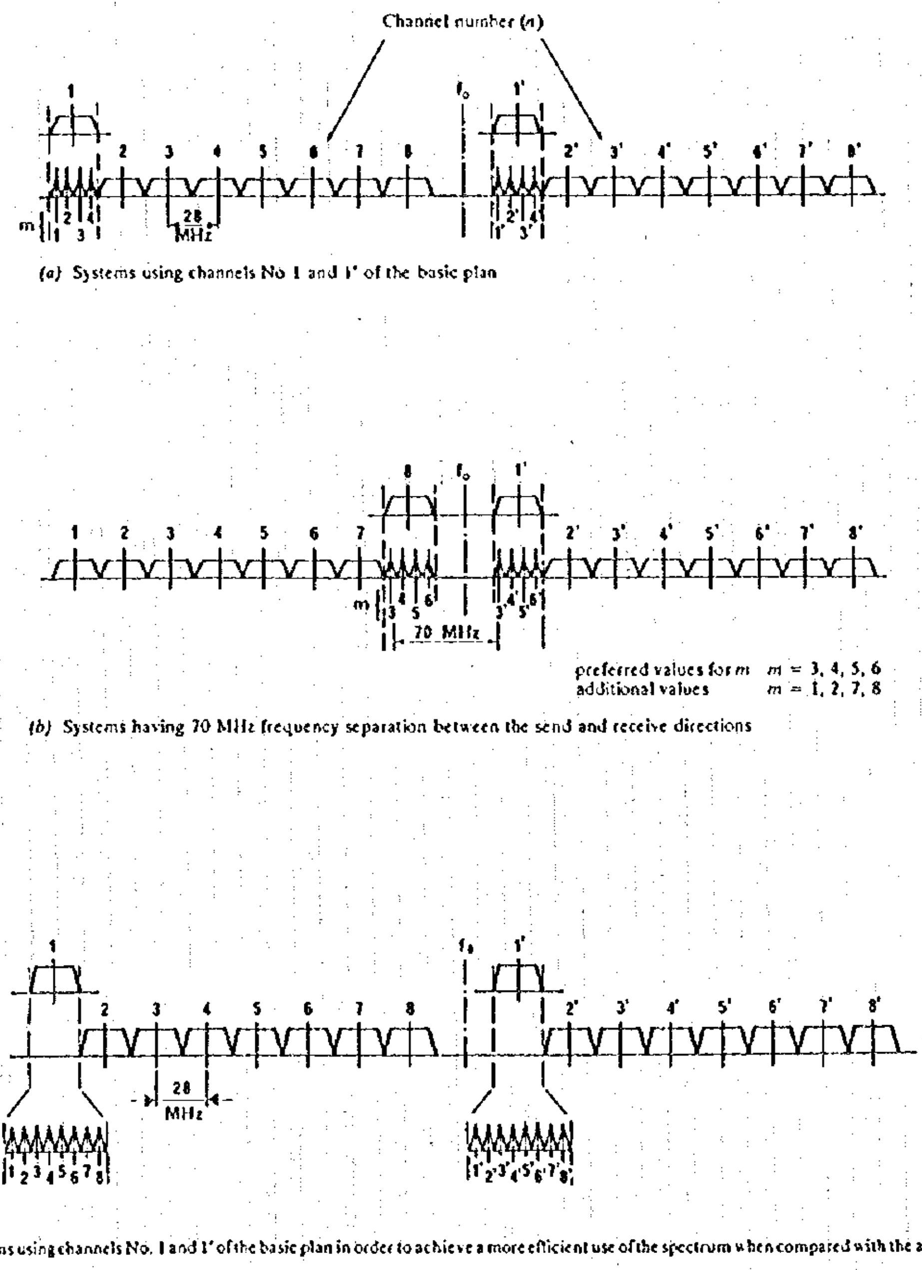
10. that due regard should be taken of the fact that a different channel arrangement for up to 960 telephone channel digital systems is also used; this arrangement is described in Annex I;

11. that Note 1 should be regarded as part of this Recommendation.

Note 1. – In some countries in Region 1, the basic channel spacing of this frequency pattern may be suitable for extension to adjacent frequency bands in the range 11.7 to 15.35 GHz, taking into account the appropriate Radio Regulations.

Note 2. – In order to reduce the possibility of an unacceptable degradation in performance occurring, care should be exercised in using mixed channel arrangements in a radio-relay network. This would especially apply if the low capacity channel arrangements described in § 9 and medium capacity radio-relay links, operating in accordance with the main channel arrangements are both present in the same network.

Rec. 497-2



(a) Systems using channels No 1 and 1' of the basic plan

(b) Systems having 70 MHz frequency separation between the send and receive directions

(c) Systems using channels No. 1 and 1' of the basic plan in order to achieve a more efficient use of the spectrum when compared with the arrangement in *(a)*

FIGURE 2 — *Examples of radio-frequency channel arrangements for smaller capacity digital systems* (as described in § 9)

ANNEX I

DESCRIPTION OF THE RADIO-FREQUENCY CHANNEL ARRANGEMENT REFERRED TO IN § 9 OF THIS RECOMMENDATION

For some digital applications with a capacity of up to 960 telephone channels, a radio-frequency arrangement having the following characteristics may be used:

lower part of the band: $f_n = (f_0 - 259 + 35\,n)$ MHz

upper part of the band: $f'_n = (f_0 + 21 + 35\,n)$ MHz,

where:

n = 1, 2, 3, 4, 5 or 6.

The arrangement is illustrated in Fig. 3.

The preferred reference frequency f_0 is the same as that given in § 8.

All the go channels should be in one half of the band and all the return channels should be in the other half of the band. For the adjacent radio-frequency channels in the same half of the band different polarizations should preferably be used alternately.

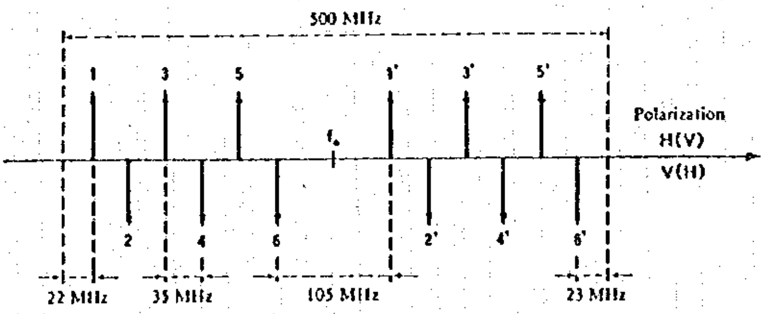


FIGURE 3 – *Radio-frequency channel arrangement for high capacity digital systems*

CHAPTER 9

Alternative Case of ATC-6 Project

1. Demand and Supply in ATC-6

Table 9-1 Demand (Business and Residential) and Supply in ATC-6 up to 2010

	1995	1996	1997	1998	1999	2000	2001	2002
Business	1,734	1,826	1,925	2,031	2,147	2,279	2,414	2,560
Residential	12,254	13,031	13,858	14,788	15,625	16,534	17,583	18,726
Total	13,988	14,857	15,783	16,819	17,772	18,813	19,997	21,286
Capacity	11,000	11,000	11,000	16,000	16,000	16,000	16,000	16,000
Supply	8,671	8,768	9,211	10,946	16,000	16,000	16,000	16,000

	2003	2004	2005	2006	2007	2008	2009	2010
Business	2,713	2,875	3,048	3,231	3,424	3,631	3,848	4,079
Residential	19,562	20,808	21,903	23,190	24,550	25,956	27,427	28,821
Total	22,275	23,683	24,951	26,421	27,974	29,587	31,275	32,900
Capacity	27,000	27,000	27,000	27,000	27,000	40,000	40,000	40,000
Supply	16,000	23,683	24,951	26,421	27,000	29,587	31,275	32,900

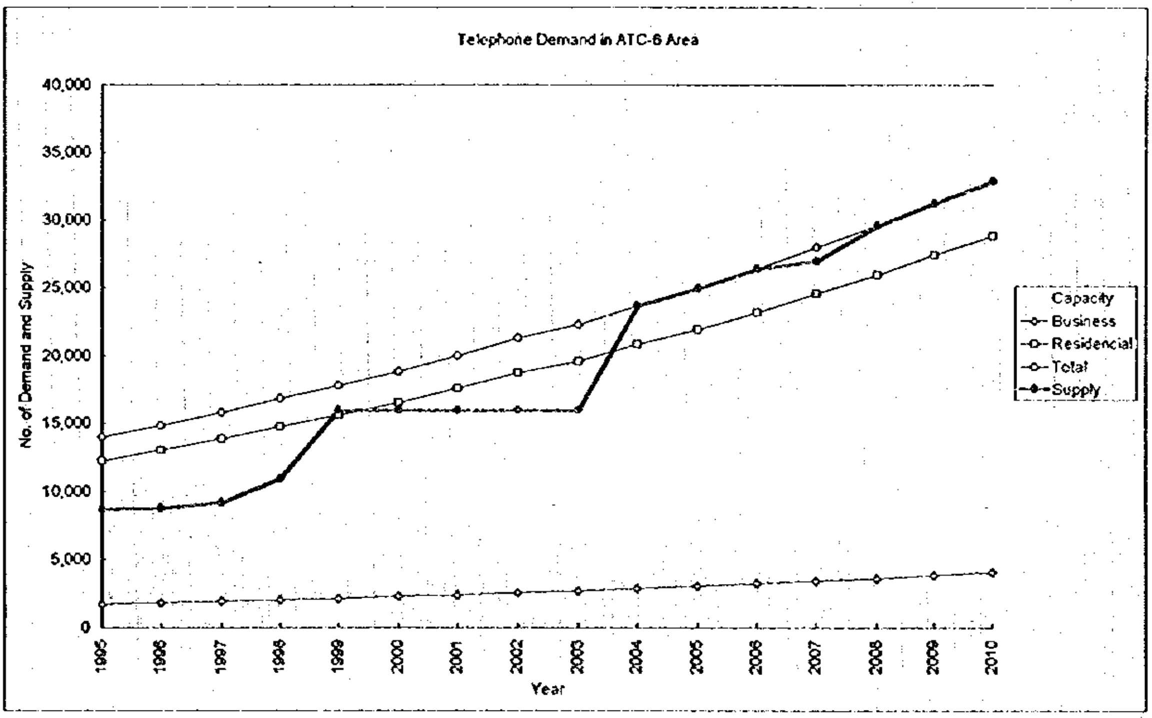


Figure 9-1 Demand (Business and Residential) and Supply in ATC-6 up to 2010

2. Traffic Forecast

2.1 Conditions

The same as Volume III, Chapter 2.

2.2 Local Traffic Calculation Outcome

The traffic of local exchanges of ATC-6 in 2000 and 2005 were calculated under the conditions stated in the Chapter-7. Table 9-2 and table 9-3 shows the traffic between local exchanges.

Table 9-2 Local Traffic of ATC-6 in 2000

From \ To		1	2	3	4	5	Total
		H06A	H03A	H03B	H05A	H07A	
1	H06A	193.20	455.23	27.37	292.39	27.29	995.48
2	H03A	463.67					
3	H03B	27.38					
4	H05A	300.80					
5	H07A	27.30					
Total		1012.35					

Table 9-3 Local Traffic of ATC-6 in 2005

From \ To		1	2	3	4	5	6	7	Total
		H06A	H03A	H03B	H02A	H04A	H05A	H07A	
1	H06A	383.02	547.14	103.63	196.66	75.46	628.75	58.82	1993.47
2	H03A	664.75							
3	H03B	103.73							
4	H02A	196.78							
5	H04A	75.53							
6	H05A	648.18							
7	H07A	58.86							
Total		2130.85							

Inter-local Exchange Circuit Requirements

The number of circuits required to local exchanges in the year 1998 was calculated based on the traffic matrix between local exchanges in the year 2000 which was obtained in the previous section.

In the calculation, the digital circuit modularity applied to was 30 channels, the per-link grade of service was 0.01, the lower threshold for direct circuit routing was 50.00 earlangs.

Table 9-4 and Table 9-5 shows the circuit matrix in the year 2000 and 2005.

Table 9-4 Circuit Matrix by the year 2000 (30 ch modularity)

From \ To		1	2	3	4	5	Total
		H06A	H03A	H03B	H05A	H07A	
1	H06A	7	16	2	10	2	37
2	H03A	16					
3	H03B	2					
4	H05A	11					
5	H07A	2					
Total		38					

Table 9-5 Circuit Matrix by the year 2005 (30 ch modularity)

From \ To		1	2	3	4	5	6	7	Total
		H06A	H03A	H03B	H02A	H04A	H05A	H07A	
1	H06A	13	19	4	7	3	21	2	69
2	H03A	23							
3	H03B	4							
4	H02A	7							
5	H04A	3							
6	H05A	22							
7	H07A	2							
Total		74							

3. Project Evaluation of ATC-6 Project

3.1 Results of Financial Analysis

- FIRR : 11.74

3.2 Results of Financial Analysis

- EIRR : 21.90

3.3 Comparison beyond Volume III Chapter 2-5

Table 9-6 shows comparison between base case and alternative case.

Table 9-6 Comparison between Base Case and Alternative Case

	Volume	
	Base Case	Alternative Case
Number of DTI (Digital Transmission Interface) (30ch Modularity)	81	117
FIRR	10.90	11.74
EIRR	20.34	21.90

The study on telecommunications network in Ulaanbaatar city : final report. Vol.IV