REPORT 319-7*

CHARACTERISTICS OF EQUIPMENT AND PRINCIPLES GOVERNING THE ASSIGNMENT OF FREQUENCY CHANNELS BETWEEN 25 AND 1000 MHz FOR LAND MOBILE SERVICES

(Resolution 20)

(1970-1974-1978-1982-1986-1990)

PART A

ASSIGNMENT METHODS

1. Suggested principles

1.1 The following broad principles are suggested for use in the assignment of frequencies in the land mobile service:

- the choice of the most advantageous mode of operation, i.e., single-frequency or two-frequency operation, according to the type of service, bearing in mind the need for coordination between administrations in border areas;
- the gradual adoption, as opportunity occurs, of the same blocks of frequencies for base stations by all administrations, and similarly the same blocks of frequencies for mobile stations, in order to minimize interference between services of different administrations;
- the gradual adoption by all administrations, as opportunity occurs, of the same blocks of frequencies for the same types of service or at least for those services required to provide similar coverage;
- the adoption of compatible frequency plans, with the same channel spacing and the same centre frequencies of the channels and, when suitable, with centre frequencies off-set, e.g. by one half channel, especially in areas where mutual interference might occur between the services of different administrations;
- the use of common channel spacing, preferably 25 kHz (see Note) and the use of equipments which are readily adaptable for a reduction in channel separation without replacement of the whole equipment;
- the allocation of channels in such a way as to minimize the production of interference due to intermodulation products;
- the adoption of optimum sizes and shapes for service areas in relation to frequency economy (Question 37/8 and Report 740 refer to this subject);
- the use of the minimum effective radiated power compatible with the required service range;
- the use of the minimum height of base station antennas compatible with the required service range;
- the siting of co-channel stations with the minimum geographical separation compatible with the protection ratios and minimum field strengths to be protected which are appropriate to the service. Information on this subject is given in Report 358;
- the use by all administrations of common propagation data. References to CCIR documents on this subject are included in Report 358;
- the assignment of the same frequency channel to a number of users in the same area, in such a manner as to permit optimum use of the channel.

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* The Director, CCIR, is requested to draw the attention of IEC to Part B, § 3.4. This Report should be brought to the attention of Study Group 1.

1.2 These principles can be applied to full advantage when planning land mobile services, only if all are applied, since they are highly interdependent.

Note. – It is recognized that some administrations use other channel separations. Every opportunity should be taken to achieve the use of common channel separations.

2. Single-frequency and two-frequency operation

It is not usually possible to use all the available frequencies in a given restricted area owing to intermodulation problems, adjacent channel disturbances, receiver desensitization, etc. The problems which arise may be somewhat different with single-frequency and two-frequency operation.

2.1 *Single frequency operation*

- Direct mobile-to-mobile communication independent of base stations is possible.
- Direct base-to-base communications when base stations are within range of each other is possible.
- Mobiles not within range of each other may transmit simultaneously causing interference at the base station.
- Base station can effectively control channel usage.
- Possibility for interference between base stations using the same channel.

2.2 *Two frequency operation-non-repeater mode (at base station)*

- Prevents direct mobile-to-mobile communication.
- Permits full control of channel usage by base station.
- Mobiles may transmit simultaneously causing interference at base station.
- Base-to-base communication not possible.
- Necessary for mobile telephone systems providing full duplex arrangements and interfacing with telephone networks.
- Prevents interference between base stations using the same channel.

2.3 *Two frequency operation-automatic repeater mode (at base station)*

- Mobile-to-mobile communications are automatically rebroadcast (repeated) by the base station thus mobile-to-mobile range is equal to that of base station coverage.
- Every user is aware of every transmission.
- Remote control of repeater easily accomplished from fixed control points by a radio equipment operating on mobile radio frequencies.
- Lends itself to shared use [Muilwijk, 1978].
- Permits use of mobile units in repeater mode to act as relay for portables.
- Permits totally unattended operation of base station.
- Failure of the automatic repeater results in total system failure, i.e. mobile-to-mobile communications is impossible without specially configured mobile units.
- Total channel occupancy may be determined by monitoring the base station frequency only.
- Prevents interference between base stations using the same channel.

2.4 Other factors to be considered when administrations develop two-frequency channelling plans for land mobile services are:

- practical values of transmit/receive frequency separation;
- practical values of maximum channel separation in multi-channel equipment;
- the use of a constant separation between the transmit and receive frequencies over the whole of a band or the sub-bands within a band.

3. Channel spacing considerations

3.1 *Spectrum efficiency*

During the technical development of the land mobile service a progressive reduction of channel spacing has occurred, thus making available an increased number of channels.

Some administrations, taking into account the need for new channels, especially in limited areas with high-density population, have decided to use frequency modulation with very narrow channel spacing. Despite some disadvantages these administrations consider that they derive substantial benefits from the use of this technique (see Part C, § 1.4).

Nevertheless some conflicting factors have to be taken into account when considering whether it is effective to reduce the spacing between channels by narrowing the bandwidth of the emissions and correspondingly narrowing the bandwidth of the receivers. Therefore, rather than concentrating only on finding ways to increase the number of channels to be derived from a given block of spectrum, the search should be directed to finding the combination of channel spacing and technical characteristics that will result in accommodating the maximum amount of information and/or the maximum number of radio users per MHz in a given geographic area.

Wide-channel spacing affords a large modulation index and hence efficient geographical frequency reuse. The number of available channels, however, is small when the channel spacing is wide. In order to make a valid comparison of different channel spacing in terms of spectrum efficiency, it is necessary to study the relationship between the modulation index and the spectrum utilization factor determined as a consequence of considering available channel numbers and geographical frequency reuse.

Spectrum efficiency in mobile radio communications is usually defined as the product of efficiencies in space, frequency, and time domains [Colavito, 1974; Mullwijk, 1978]. The time factor is determined by how much traffic can be sent through a radio channel in a unit time, and has no relationship to a modulation index.

Co-channel interference performance is the most important characteristic for a cellular system, because the same radio frequency channels are reused in a service area. Figure 1 [Suwa and Hattori, 1985] shows a relationship between carrier-to-interference ratio (C/I) and baseband signal-to-interference ratio (S/I) of FM system under Rayleigh fading condition. The results for various modulation indices which correspond to the peak deviation show that improvement of C/I and S/I performance by increasing modulation index does eventually saturate.

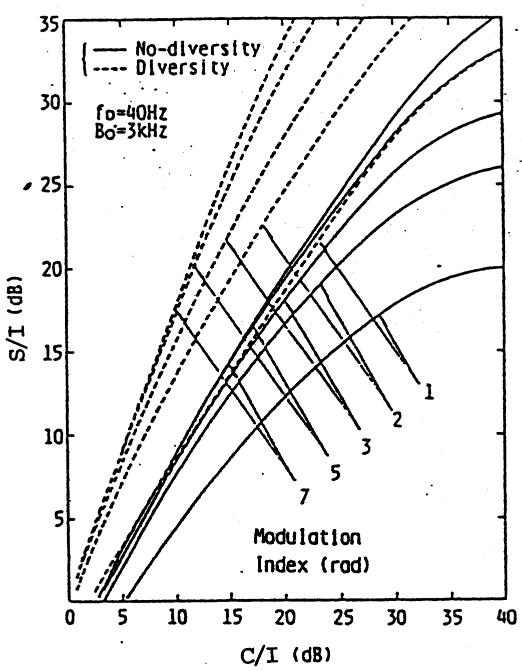

FIGURE 1 - *Relation between* C/I *and* S/I *of FM system with selection diversity*

f_D : maximum Doppler frequency
B_0 : passband of the baseband filter

Figure 2 [Sakamoto and Hata, 1987] shows a relationship between modulation index and spectrum efficiency. Peak deviation is assumed as 1/0.7 of the 1 kHz signal modulation level. For example, a 3.5 radian modulation index corresponds to a 5 kHz peak deviation. With regard to efficient spectrum utilization, Fig.2 shows that 1) it is suitable for the peak deviation to be set around 3 to 4 kHz, 2) the diversity technique is effective in improving the spectrum utilization, and the optimum peak deviation is almost the same as when there is no diversity.

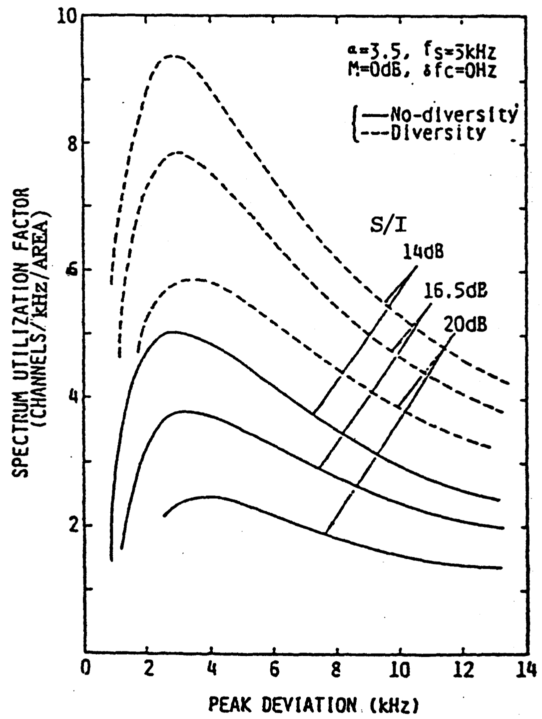

FIGURE 2 - *Spectrum utilization factor with S/I parameter*

f_s : maximum baseband signal frequency
δf_c : carrier drift
α : propagation constant
M : C/I margin for shadow-fading

3.2 *Experimental quality evaluation*

An experimental program has been used [AT&T, 1971] to determine listeners' subjective evaluation of a FM voice channel in the presence of rapid fading, for a variety of **wanted-to-unwanted signal ratio** (W/U) and radio-frequency S/N ratios. The result of this experiment were used to set E_i (local mean (W/U)) and E_n (local mean radio-frequency S/N). The peak frequency deviation of the transmitter was varied, and the effect on listener reaction and thus on E_i and E_n was noted. Listeners evaluated quality in terms of Circuit Merit ratings 5, 4, 3, 2 or 1 (excellent, good, fair, poor or unusable).

Tests were made using peak frequency deviation of ±12 kHz and ±6 kHz respectively, the parameters of E_i and E_n being those values which must be exceeded with 90% probability, and a criterion being that at least 75% of the listeners should rate the quality good or better, and at least 90% should rate it fair or better.

The tests showed that:

- For thresholds based on Merit 4 (good) with 75% rating the circuit good or better, the use of ±12 kHz peak deviation improved the co-channel protection ratio requirement by 8 dB for E_i and by 5 dB for E_n.

- For thresholds based on Merit 3 (fair) with 90% rating the circuit fair or better, the use of ±12 kHz peak deviation improved the co-channel protection ratio requirement by 6 dB for E_i and by 4 dB for E_n.

These tests were made at 800 MHz in preparation for a cellular system. Further study is necessary to establish the relationship between modulation index and optimum channel spacing, and to determine what values apply for other frequency bands and other service requirements.

3.3 *Carrier frequency offset*

Additional co-channel protection between cells can be obtained by offsetting the carriers of the channels used in those cells. One example is the use of 16K0F3E emissions on channels offset by 12.5 kHz, using equipment designed for 20 or 25 kHz channel spacing [Brusaferri *et al.*, 1979]. This retains the basic characteristics of the 16K0F3E system while increasing (but not doubling) the number of available channels and the traffic capacity.

In Toronto, Canada, a 150 MHz public mobile telephone system using 15 kHz offset channels to provide automated service has been interleaved with an existing manual service system on the prime channels, spaced 30 kHz. In order to achieve this all base transmitters are co-located and adjusted to give equal effective radiated powers. The following characteristics apply:

- base transmitters have ±3 ppm frequency tolerance;
- peak frequency deviation is reduced to ±4 kHz from ±5 kHz;
- average speech modulation on each transmitter is reduced by 3 dB;
- mobile telephone specifications are unchanged from those required for normal 30 kHz spaced operation;
- all channels use multiple-receive voting techniques to provide good quality audio from almost all locations, even in the presence of adjacent channel mobile transmissions.

4. Transmit/receive frequency separation for high capacity systems

Transmit and receive filters are necessary for full duplex operation of mobile radio telephone systems. In the design of such radio frequency filters, it is necessary to determine types and number of resonators considering such system parameters as transmit/receive frequency separation and allocated transmit and receive bandwidths, and such mobile unit parameters as size, cost, transmitter power, transmitter noise, spurious emission, spurious response, and so on.

However, further study of the transmit/receive frequency separation is required.

5. Use of computers in frequency assignments

Computers provide an economical way of maximizing the utilization of channels by optimizing frequency re-use. It is possible to use for planning detailed topographical data and representative propagation models. The application of computers to frequency assignment is under study in Study Group 1.

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PART B

COMPONENTS AND ENGINEERING TECHNIQUES

1. Integrated engineering at base stations

The generation of spurious emissions and intermodulation products at base stations in the land mobile service can be considerably reduced by using suitably designed filters at the outputs of transmitters and the inputs to receivers, in conjunction with combining networks, so that numbers of transmitters and/or receivers can be coupled to a common antenna. Similar techniques can be used in the UHF band and for larger numbers of circuits.

The use of a single mast and antenna in this way minimizes spurious emissions arising in the external system. Another advantage is that it is possible to optimize the radiation pattern so as to obtain the best coverage of the desired area. Moreover, such a unified antenna and mast can be designed to be much more acceptable aesthetically than separate masts and antennas for each user. This is a consideration which is becoming increasingly important in view of the proliferation of base station antennas on prominent sites and buildings. Another important advantage is that the reduction in spurious emissions and intermodulation products enables better use to be made of the available frequency channels in a given area, as well as improving the quality of individual channels.

The transmit output filters attenuate any spurious emissions and harmonics. The filters may consist of bandpass filters (cavity resonators) and the insertion loss of each filter, for example, can be kept between 1 and 2 dB. The passband of the filter for each transmitter is centred on the transmit frequency and its impedance at that frequency is matched to the transmitter output and to the common cable ("throughline") connecting the transmitters to the combiner. At the frequencies of the other transmitters, the filter presents a high impedance to the "throughline". Whenever possible, the use of dissimilar metals at junctions should be avoided in order to avoid non-linear effects. Care should also be taken to ensure that the physical size and mechanical construction prevents the formation of corona, or brush discharges, which would otherwise cause electrical noise and interference.

On the receive side, two bandpass filters are used to attenuate the transmit frequencies and protect the receivers. This is followed by a low-noise preamplifier, followed by a cascade arrangement of passive hybrid couplers, depending upon the number of outlets required. The insertion loss of the cascade system between the antenna and any receiver can be compensated for by the preamplifier so that the performance of the system is not degraded. In practice, an improvement in signal/noise ratio is obtained compared with coupling the receiver directly to the antenna. For example, an improvement between 1 and 2 dB can be obtained with a VHF preamplifier of 3 dB noise figure and a gain of 18 dB.

If transmitters and receivers share a common antenna, then the combining network should have transmit and receive bandpass filters to provide sufficient additional isolation between the transmitters and receivers. The number of filter sections required depends upon the frequency spacing between transmitters and receivers. The filters in the transmitter arm attenuate any spurious emissions, especially those in the receiver band, and the filters also attenuate harmonics of the transmit frequencies. Care should be taken to avoid the formation of corona.

2. Tone squelch system

One method of providing more efficient use of the spectrum can frequently be achieved by placing more than one user on a single frequency or frequency pair and incorporating a continuous tone controlled squelch system (CTCSS) in the design of the base station and mobile station equipment. Each transmitter when keyed, transmits a tone unique to the particular system. Each receiver in the system must detect not only the presence of the radio frequency signal but also the unique tone before the squelch opens. Thus the user normally hears only those transmissions of his own system and is relieved of listening to the transmissions of others sharing the channel. The tone frequencies may be below 300 Hz or between 300 and 3000 Hz. In both cases they are filtered out of the audio heard by the user.

The selection and coordination of tone frequencies between separate users is necessary to avoid interference. For frequencies used in CTCSS reference should be made to IEC Publication 487-6A.

3. Crystals and oscillators

3.1 *Frequency variations with temperature*

3.1.1 Some commonly used crystals are listed below:

Designations			*Description*
(a)	(b)	(c)	
Style D	HC-6/U		Miniature metal can with short pins.
Style J	HC-18/U		Sub-miniature metal can with wires.
Style K	HC-25/U		Sub-miniature metal can with short pins.
Style L	HC-27/U	13	Miniature glass encapsulated with short pins.
Style M	HC-26/U	14	Sub-miniature glass encapsulated with wires.
Style N	HC-29/U	20	Sub-miniature glass encapsulated with short pins.

They exhibit a maximum frequency variation within 20 parts in 10^6 over the range -20 °C to $+60$ °C, when the power dissipated in the crystal does not exceed about 0.5 mW.

3.1.2 Crystals normally in use exhibit frequency/temperature curves with inversion points usually above the lowest temperature limits required (-20 °C) and around the upper temperature limit required ($+60$ °C). It is quite difficult to supply crystals to a given tight tolerance for temperature limits much in excess of the inversion points because of the high slope of frequency/temperature curves beyond these points.

3.1.3 With selected crystals fitted in soft-soldered cans, maximum frequency variations of 10 to 12 parts in 10^6 over the range -20 °C to $+60$ °C and 5 parts in 10^6 over the range -10 °C to $+40$ °C can be achieved.

3.1.4 Glass encapsulated crystals in cold-welded cans may be supplied to similar limits and can be supplied to close tolerances, for example 5 parts in 10^6.

3.1.5 Smaller frequency variations can be achieved by using crystal ovens. The penalty is higher cost, greater power demand and a degraded mean-time-between-failure (MTBF).

3.1.6 Temperature Compensated Crystal Oscillators (TCXO), which include the maintaining oscillator, can be supplied with maximum frequency variations from a lower limit of about 2 parts in 10^6 to about 6 parts in 10^6 over a range $-20\,^\circ C$ to $+60\,^\circ C$. Adjustment accuracy is better than for a crystal in isolation from its maintaining oscillator and the TCXO may be set to a nominal frequency at a designed temperature.

3.2 *Ageing*

All crystals and their maintaining oscillators age to some degree. The ageing rate in service is reduced if the crystals are pre-aged during manufacture.

The best commercial performance limits for total variation for the various types of crystal in common use in the land mobile service are as follows:

Soft-soldered can crystals	5 to 20 parts in 10^6 per year
Glass encapsulated crystals	1 to 3 parts in 10^6 per year, after 30 days ageing
Cold-welded can crystals	as for glass encapsulated units.

These figures can be met for ageing of crystals at any temperature in the range $-20\,^\circ C$ to about $+60\,^\circ C$, but ageing rates increase as the temperature increases.

3.3 *Effect of maintaining oscillators on frequency variations*

Except for TCXO's, all the figures given above are for crystals alone. Most maintaining oscillators contribute appreciably to the frequency variations in practice and these contributions vary widely within a given design as well as between designs. It is estimated that the average contributions of the maintaining oscillator to total frequency variation could be as much as 4 parts in 10^6 over the range $-20\,^\circ C$ to $+60\,^\circ C$, for a change of $\pm$ 15% in the voltage supplied to the oscillator.

3.4 *Frequency synthesizers*

In synthesized equipment there is a danger, particularly during synthesizer settling time, of unwanted emissions, which should be avoided by proper design of the equipment.

To prevent the emission of unwanted frequencies (including harmonic and other spurious products) some of the following techniques could be considered:

- in phase locked synthesizers a circuit can be included in the loop to detect the out of lock condition;
- inverse translation of the division ratio to check that the correct channel frequency has been generated;
- correct choice of loop filter and other phase locked loop design parameters;
- generation of the carrier frequency directly by a voltage controlled oscillator in a single phase locked loop;
- adaptive phase locked loop which has a narrow bandwidth when locked, and then reduces spurious responses and noise, but a wider bandwidth (with shorter pull-in-time) when unlocked;
- direct synthesis with high stability oscillators.

The attention of the IEC should be drawn to this problem and they should be invited to prepare suitable methods of measurement.

4. Diversity reception

Diversity reception is considered to be an effective technique to mitigate multipath fading when dual space diversity is used with the mobile unit. Difference in the spacing between two antennas may result in differences in diversity efficiency. The signal from the two antennas can either be combined in some manner, or the signal from one antenna can be selected according to defined criteria. Various criteria may be used, such as:

- highest signal level,
- best signal-to-noise ratio [Jakes, 1974].

The statistical results obtained from measurements using the criterion of highest signal level, on field experiments at 900 MHz in metropolitan areas of Shanghai, are shown in Figure 4 and Figure 5 [Yang, 1986], where d is the distance between the two antennas expressed in terms of the wavelength λ.

In Figure 3, for d = 0.75, the mean signal level received with dual diversity is increased by 2.85 dB compared with that received with one antenna.

In Figure 4, for the instantaneous signal received with one antenna, the level is 15 dB or more below the mean signal level for 8.2 percent of the time and 20 dB for 2.9 percent of the time. For dual space diversity, with d = 0.75, the level is 15 dB or more below the mean signal level received with one antenna for 2.6 percent of the time and 20 dB for 0.52 percent of the time.

On the basis of these fading statistics, it seems reasonable to highlight the following two points for consideration:

a) to obtain satisfactory diversity efficiency, the distance between two co-located mobile station antennas should be greater than 0.6 wavelength, i.e. $d > 0.6\lambda$ and it should preferably correspond approximately to odd multiples of $\lambda/4$;

b) if d is reduced, even to a value as low as $\lambda/4$, reasonable diversity efficiency can still be obtained.

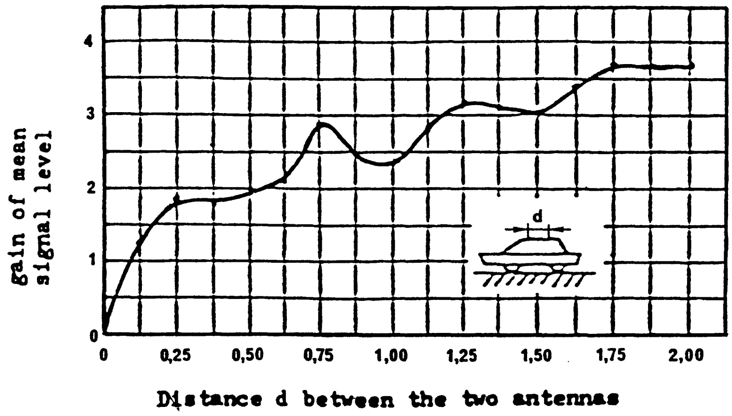

FIGURE 3

Increase of mean signal level versus distance d

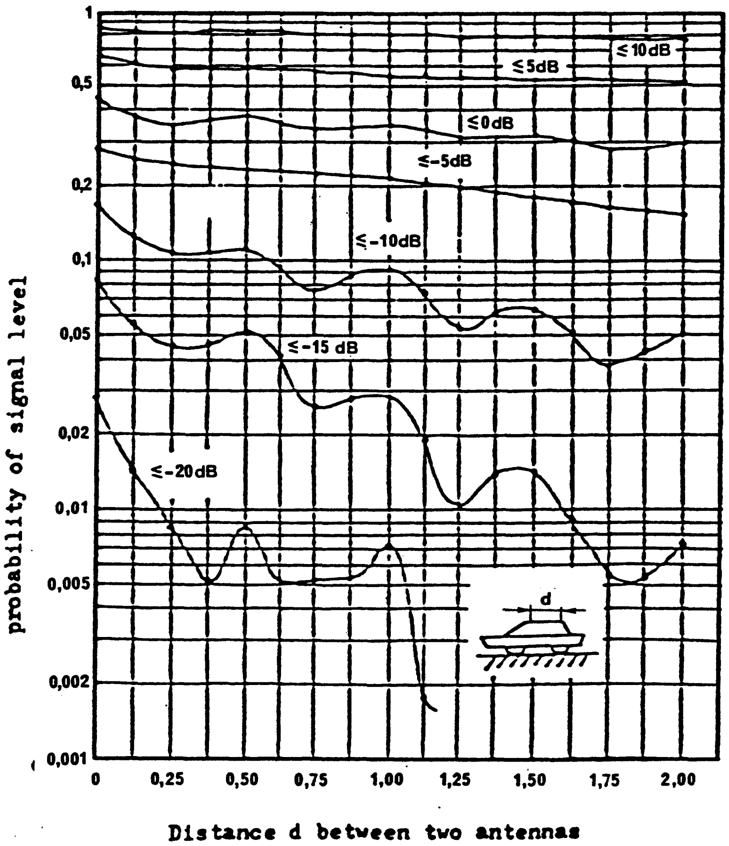

FIGURE 4

Signal level distribution function

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PART C

NATIONAL PRACTICES

1. Summary of contributions

1.1 The information on separations between adjacent channels furnished by administrations, is reproduced in § 2 below. The names of countries are replaced by the appropriate symbols shown in Table I in the Preface to the International Frequency List.

1.2 The Federal Republic of Germany has described methods of the assignment and coordination of frequencies of public and private land mobile services. The planning methods described are, among others, based on the assumption that in an extended network the distance between stations using the same frequencies (co-channel spacing) should be as small as possible for the benefit of a good frequency economy. This can be reached on the one hand by reducing the transmitter range as far as possible and on the other hand by using so-called lattice plans. These lattice plans are set up in such a way that the co-channel spacing is the same for all frequencies and that the number of frequencies for one complete coverage of an extended area is as small as possible. A lattice plan for a public land mobile service using 7 duplex-frequencies for a complete coverage has been developed and a plan for a private land mobile service using 9 simplex-frequencies has been described. Furthermore, two different methods are described by which – when lattice plans are used – the frequency requirements of high traffic areas also can be fulfilled.

The described planning methods have been used in the Federal Republic of Germany with good results for the frequency assignment of about 140 000 land mobile stations.

1.3 Some special information concerning the coordination of frequencies on a multilateral basis is given in the Special Agreement between the Administrations of Belgium, the Netherlands and the Federal Republic of Germany, relating to the use of metric and decimetric waves for fixed and mobile services in border areas (Brussels, 1963).

Agreements also exist between the Administrations of Austria, Germany (Federal Republic of), Italy and Switzerland on the coordination of frequencies between 29.7 MHz and 470 MHz for fixed and land mobile services (Vienna, 1969) and between the Administration of Yugoslavia (Socialist Federal Republic of) and the Administrations of Italy (Vienna, 1969), Austria (Vienna, 1969: revised 1976), Romania (Socialist Republic of) (Belgrade, 1978), the Hungarian People's Republic (Budapest, 1976), Greece (Athens, 1979) and Bulgaria (People's Republic of) (Sofia, 1980). A document from Yugoslavia gives details of the procedures adopted [CCIR, 1978-82a].

1.4 The United Kingdom has drawn attention to the increased number of channels that become available when the spacing is reduced. It suggests that, whenever possible, a spacing of 12.5 kHz should be adopted and that equipment designed for wider channel spacing should be readily adaptable for smaller spacings without total replacement.

In the United Kingdom use is made of computers in frequency assignment [CCIR, 1982-86a]. For an inclusive assignment, a prediction of the field-strength contours representing service and interfering areas is made, and the assignment decided on the basis of overlap criteria with these areas and those of existing stations. For a shared assignment an assessment of the channel loading at the busiest time of the day is made and the assignment decided on the basis of an acceptable total loading.

Iraq reports [Al-Araji and Abdullah, 1982] that by selecting three bands in the audio frequencies delaying them by 0, 4 and 8 ms respectively during transmission and subsequently restoring them at the receiver, the peak impulsive noise level in the audio frequencies can be reduced.

1.5 The USA has provided information concerning disadvantages of decreasing frequency modulation-system deviations from the widely used ± 5 kHz to ± 2.5 kHz; it concludes:

– that increases in impulsive noise interference will be noted;
– that about seven times increase in the number of intermodulation products can be expected.

Other important factors are also listed as follows:

– problems of required increased frequency stability;
– degradation of receiver performance due to adjacent channel transmitter modulation and noise;
– loss in protection ratio;
– loss in frequency-modulation improvement ratio.

1.6 The Federal Republic of Germany has developed a rule which can be used to determine the channels that may be chosen from a number of evenly spaced channels, in such a way that third-order intermodulation products are avoided. According to the rule, channels should be chosen so that the frequency differences between sequential channels, and also the various sums of differences between channels, occur only once. For example, if the evenly spaced channels are numbered 1, 2, 3 etc., then their frequency differences are proportional to the differences between the channel numbers themselves. Thus, assuming that adjacent channels are not to be used, then the chosen channels would be 1, 3, 6, 10, 16, etc., to avoid third-order intermodulation products according to the rule. A proof of the rule is given.

1.7 The USA has studied the interference which is caused by intermodulation products in the land mobile service between 25 and 500 MHz. In areas where there are large concentrations of such services, intermodulation interference is more serious than co-channel interference. Methods are available for predicting the expected level of intermodulation products; these procedures are applied to special transmitters and receivers, but they may be applied generally.

1.8 The People's Republic of Poland has supplied information on the intermodulation response in receivers equipped with crystal filters in the first intermediate-frequency stage. The intermodulation response of such receivers is, in principle, flat over a relatively wide frequency band, in contrast to receivers without crystal filters, in which the slope of this response increases as a function of the degree of detuning the interfering signals from the desired frequency.

In the case of the flat configuration of intermodulation response, there is a greater risk for mobile networks with regard to intermodulation interference caused by the signals widely spaced from the desired frequency. This fact indicates that intermodulation should be measured in a wide frequency band and the results obtained, which constitute the intermodulation response, should be used in planning the allocation of frequencies.

When using receivers with a flat intermodulation response, it is necessary to attempt to achieve the better values of the intermodulation parameter, e.g. by using field effect transistors (FET) or special circuits in the input stages of receivers.

1.9 France has submitted the following list of characteristics and values for possible subsequent insertion in Recommendation 478. Later it may be possible to modify the values quoted in the light of experience.

1.9.1 *Transmitter characteristics*

1.9.1.1 *Transmitter response for modulating frequencies above 3 kHz*

Between 3 kHz and 6 kHz the frequency deviation should not exceed that at 3 kHz. At 6 kHz it should be not more than half the deviation at 1 kHz. For frequencies above 6 kHz and up to the channel spacing, the deviation should decrease with an increase of the modulating frequency and, in addition, the ratio of the initial and final deviations for a doubling of frequency should have a value of 5.

1.9.1.2 *Attenuation of the intermodulation of base station transmitters*

The attenuation of intermodulation, due generally to the non-linearities of the output stage of the transmitter, should be at least 20 dB. Higher values of attenuation might be necessary and may be obtained by means of appropriate protection devices.

1.9.2 *Modulator characteristics*

1.9.2.1 *Limitation*

For a signal at a frequency of 1 kHz, with a level 20 dB greater than that which produces 20% of the maximum permissible deviation, the frequency deviation should be between 70% and 100% of the maximum.

1.9.2.2 *Sensitivity*

For a sound level at the microphone diaphragm of 93 dB relative to 2×10^{-5} Pascal, the deviation should be between 60% and 90% of the maximum permissible deviation.

1.9.2.3 *Audio-frequency response of the transmitter*

For a constant level of the modulating signal, the modulation index (phase modulation) or frequency deviation (frequency modulation) should remain constant, within limits of +1 to −3 dB, when the modulating frequency varies between 300 Hz and 3000 Hz.

1.9.2.4 *Residual modulation*

The residual modulation, in the absence of a modulating signal, should be lower at the output of a linear demodulator by 40 dB relative to the signal corresponding to a deviation of 60% of the maximum permissible deviation.

1.9.2.5 *Harmonic distortion*

The level of harmonic distortion should in no case exceed 10%.

1.9.3 *Receiver characteristics*

1.9.3.1 *Operation of the limiter*

When the radio-frequency varies between 6 dB(μV) and 100 dB(μV), the audio-frequency output signal should not vary by more than 3 dB.

1.9.3.2 *Co-channel rejection*

When a wanted signal is applied in the presence of an interfering signal on the same frequency, a reduction in the signal-to-noise ratio at the output from 20 dB to 14 dB should occur when the ratio of interference to signal is not less than −8 dB for 25 kHz channel spacing and not less than −12 dB for 12.5 kHz channel spacing.

1.9.3.3 *Duplex working*

Desensitization of the receiver with simultaneous transmission and reception should not exceed 3 dB.

1.9.3.4 *Output power at audio-frequencies*

The output power at audio-frequencies should not be less than 200 mW in the loudspeaker and 1 mW in the handset earphone.

1.9.3.5 *Audio-frequency response*

For a radio signal with a constant modulation index (phase modulation) or with a constant deviation (frequency modulation), the audio-frequency signal at the output should remain constant to within +1 dB to −3 dB when the modulating frequency varies between 300 Hz and 3000 Hz.

1.9.3.6 *Harmonic distortion*

The level of harmonic distortion should in no case exceed 10%.

1.9.3.7 *Noise and hum*

Noise and hum should not exceed −40 dB with respect to the output level produced by a strong radio signal modulated with a frequency of 1 kHz to a deviation equal to 60% of the maximum permissible deviation.

1.10 Japan has provided information [CCIR, 1978-82b] on tests performed on equipment designed for 12.5 kHz channelling FM systems in the 400 MHz band. The test confirmed that with special attention to protection against adjacent channel interference, a 12.5 kHz channelling FM system in the 400 MHz band, in accordance with characteristics and values of Recommendation 478 is possible. Other characteristics and values are as follows:

1.10.1 *Transmitter characteristics*

The maximum permissible frequency deviation should be 2.5 kHz. For modulating frequencies above 3 kHz, the level should decrease at a rate of 24 dB/octave.

1.10.2 *Receiver local frequency tolerance*

The receiver local frequency tolerance should be 3×10^{-6}.

1.10.3 *Co-channel interference*

The wanted-to-unwanted carrier power ratio (W/U ratio) giving a 12 dB SINAD ratio in the presence of co-channel interference (but with no adjacent channel interference) is shown in Table I. Measurements were made in the laboratory in accordance with IEC Publication 489. The tests showed that under these conditions the co-channel protection ratio required for 12.5 kHz-channelling equipment is only 2.4 dB higher than that required for 25 kHz channelling.

TABLE I

Channel spacing (kHz)	12.5	25
Maximum permissible frequency deviation (kHz)	2.5	5
Wanted-to-unwanted carrier power ratio (dB)	6.8	4.4

1.10.4 *Adjacent channel interference*

Subjective listener tests showed that adjacent channel interference in the 12.5 kHz channel spacing degraded the speech quality more severely, as compared to the case of 25 kHz channel spacing. Therefore, when introducing the 12.5 kHz channelling system, it is necessary to improve the wanted-to-unwanted power ratio by about 11 dB as shown in the Table II and Fig. 5 in order to keep speech quality in 12.5 kHz channel spacing as good as that in 25 kHz channel spacing.

TABLE II – *Opinion test conditions of adjacent channel interference*

Signal		Modulation level (dB)	Frequency drift (PPM)	
			12.5 kHz	25 kHz
Desired		0	0	0
Undesired (Adjacent channel)	Case 1	0	0	0
	Case 2	10	4	7

Note 1. – The 0 dB modulation level corresponds to the IEC Standard Test Modulation.

Note 2. – Case 2 represents the worst case, i.e. channel spacing reduced by the drift.

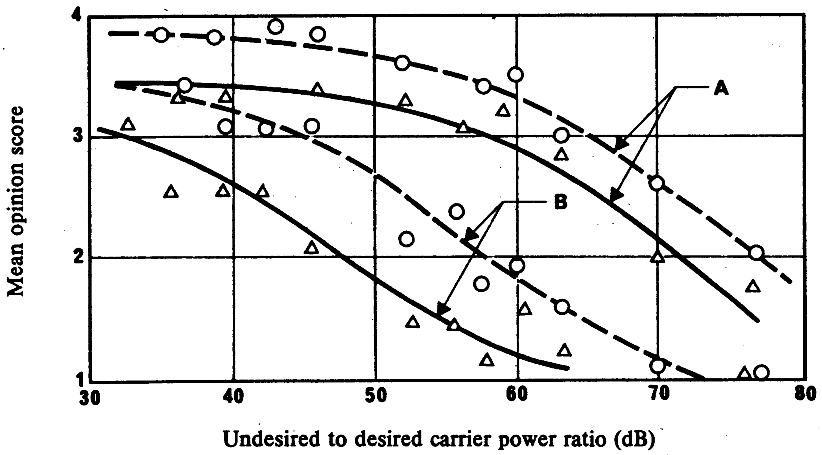


FIGURE 5

A: case 1

B: case 2

△——△ : 12.5 kHz

○— — —○ : 25 kHz

Desired carrier median power: 9 ~ 13 dBμV

1.10.5 *Receiver sensitivity*

Figure 6 below shows a comparison of the sensitivity of 12.5 kHz and 25 kHz channel spaced receivers. The reference sensitivities for a 12 dB $(S + N + D)/(N + D)$ (SINAD) ratio are −2.5 and −3 dB(µV), respectively.

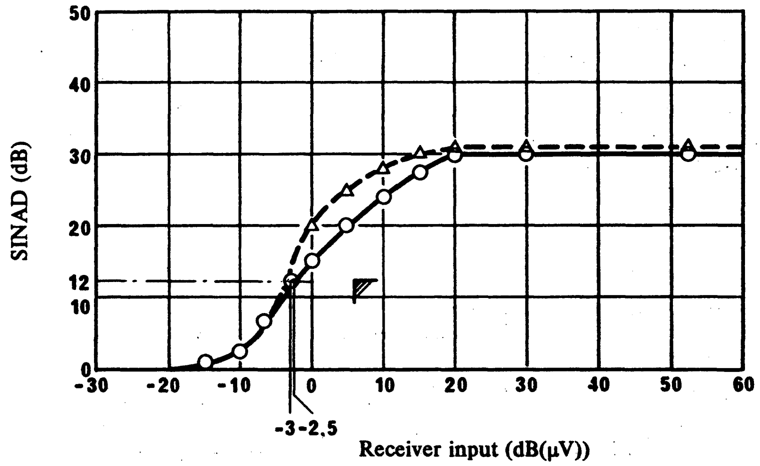
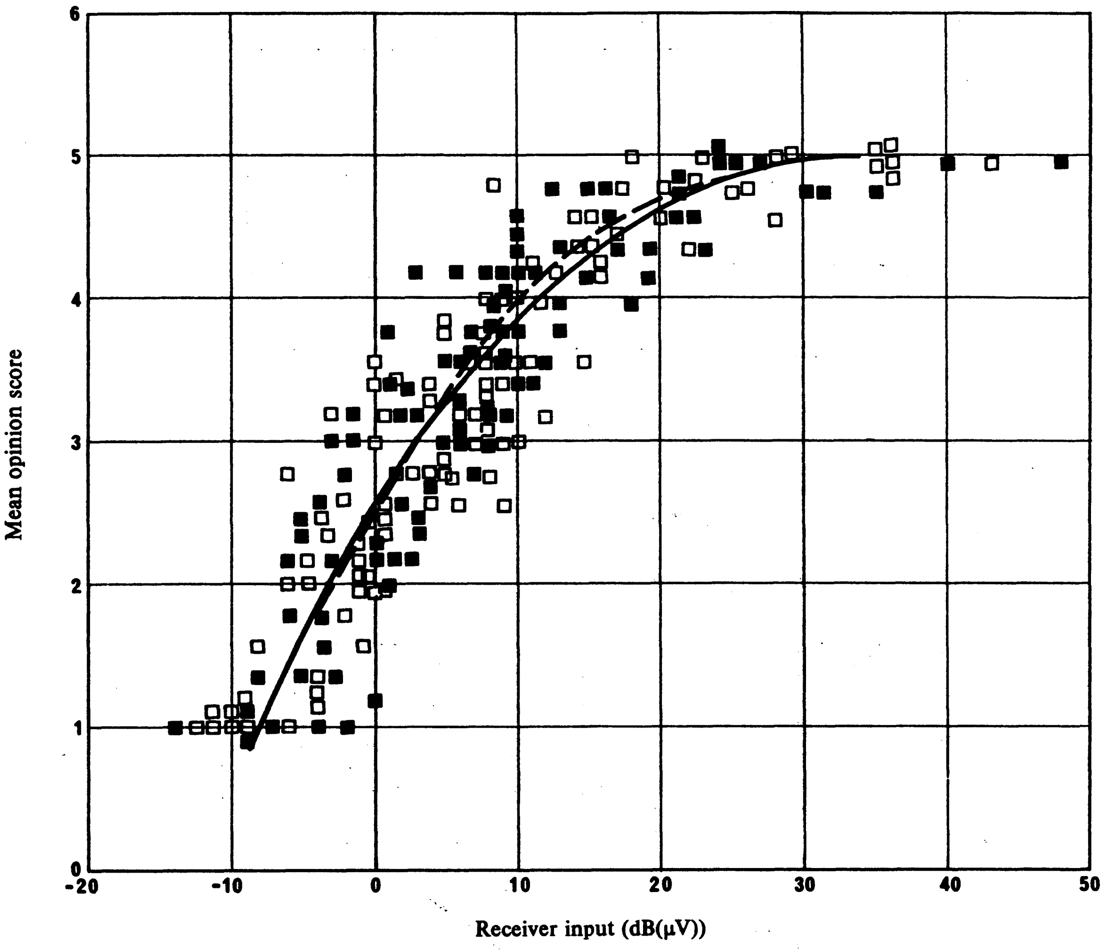


FIGURE 6

O——O——O: 12.5 kHz channel spacing (± 1.5 kHz deviation)

Δ– – –Δ– – –Δ: 25 kHz channel spacing (± 3 kHz deviation)

Figure 7 below shows a comparison of opinion tests on the speech quality of 12.5 kHz and 25 kHz channel spaced receivers.



Mean opinion score
0
1
2
3
4
5
6
-20
-10
0
10
20
30
40
50
Receiver input (dB(μV))

FIGURE 7

: 12.5 kHz
: 25 kHz

1.11 Japan has confirmed in the laboratory that a 12.5 kHz channelling FM system in the 900 MHz band is achievable in accordance with the specifications in Recommendation 478. Only the specification of frequency stability in the 900 MHz band should be improved to approximately twice that of the 400 MHz band. Frequency stability and speech quality in the presence of thermal noise and co-channel interference are as follows.

1.11.1 *Frequency stability*

The frequency drift in the 900 MHz band should be less than 1.5 × 10^{-6}. It is possible to achieve this frequency stability by adopting the digital TCXO, as shown in Fig.8.

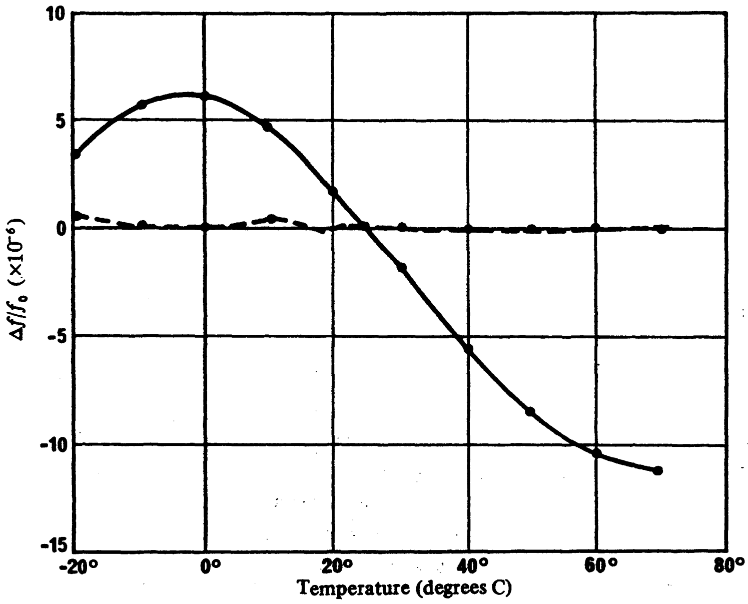


FIGURE 8 – *Frequency temperature characteristics of DTCXO*

f_0 = 12.79985 MHz (AT-cut, fundamental)

uncompensated

compensated

1.11.2 *Speech quality*

As shown in Fig. 9, the same speech quality with 12.5 kHz channel spacing as with 25 kHz channel spacing is obtained at almost the same receiver input voltage, since the *C/N* giving a MOS of 2.5 with 12.5 kHz channel spacing is only 2.5 dB larger than that with 25 kHz channel spacing. When introducing the 12.5 kHz channelling system, it is necessary to improve the required *C/I* by almost 3 dB to keep speech quality with 12.5 kHz channel spacing as good as that with 25 kHz channel spacing as shown in Fig.10. These conclusions remain to be confirmed by field tests.

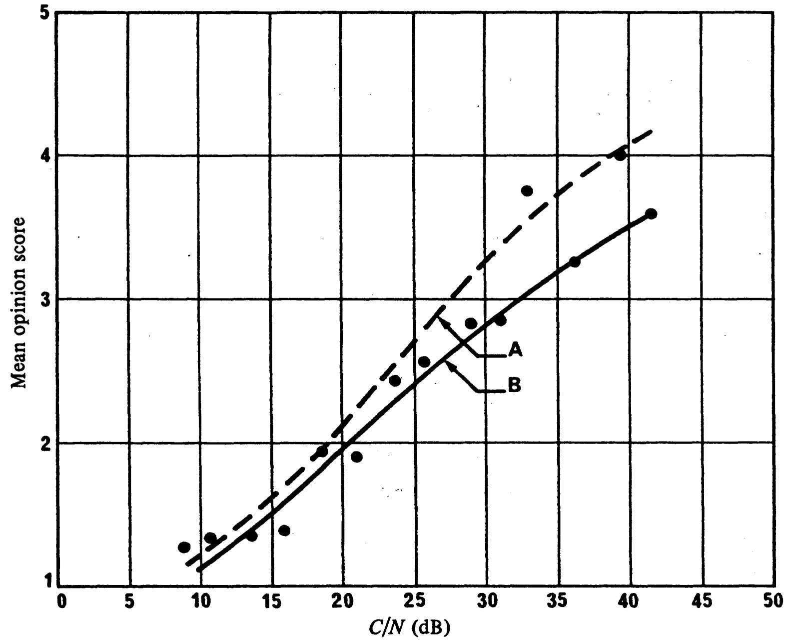


FIGURE 9 – *Mean opinion score versus C/N*

Curves A: standard modulating level = $3/\sqrt{2}$ rad r.m.s., channel spacing = 25 kHz

B: standard modulating level = $1.5/\sqrt{2}$ rad r.m.s., channel spacing = 12.5 kHz

Fading rate: 34 Hz

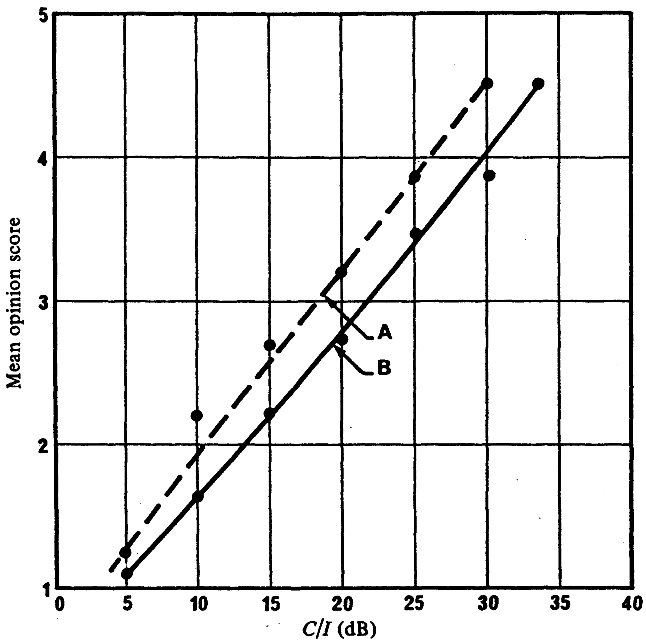


FIGURE 10 – *Mean opinion score versus C/I*

Curves A: standard modulating level = $3/\sqrt{2}$ rad r.m.s., channel spacing = 25 kHz

B: standard modulating level = $1.5/\sqrt{2}$ rad r.m.s., channel spacing = 12.5 kHz

Fading rate: 34 Hz

2. Adjacent channel separations in various frequency bands

2.1 *Separations for present and/or future use*

TABLE III

Channel separation (kHz)	Frequency ranges (MHz)				
	25-50	50-100	100-200	200-500	500-1000
10	I* D DNK DNK* NOR* S* SUI* USA NZL				
12.5	F I	F G IRL NZL	F G I IRL NZL E	F NZL AUS J G	J(8) S(8)
15	TCH*	J	USA (1)		
20	CAN D USA ARG AUS	BEL (2) CAN D ARG	BEL (2) D F J ARG	BEL D	
25	AUS CHN DNK E (6) F FNL NOR POL DDR S SUI ROU TCH USSR YUG I	BEL (3) CHN D (4) DNK E (6) F FNL G (7) IRL (7) NOR DDR ROU S SUI TCH USSR YUG	BEL (3) CHN D (4) DNK E (6) FNL G (3, 7) IRL (7) NOR POL DDR ROU S SUI TCH USSR YUG NZL F I	AUS CAN (5) CHN D (4) DNK E (6) F FNL G IRL J NOR POL DDR ROU S SUI TCH USA USSR YUG ARG NZL I	AUS CHN J SUI USA USSR CAN S FNL G(9) F I
30		AUS	AUS CAN (5) USA		USA (8) CAN(8) AUS(8) NZL(8)
40	USA*				USA (8)

* When a country symbol is followed by an asterisk, the value given for the separation refers to low-power portable equipment.

(1) An interleaved channel allocation plan is to be used and only alternate channels allocated in any one geographical area. Consequently, the equipment is designed for double the separation shown above.

(2) 20 kHz separation is being introduced gradually for new equipment.

(3) 25 kHz separation is still accepted in certain parts of the bands reserved for the fixed and mobile services.

(4) Only in exceptional cases upon multilateral agreement.

(5) An offset assignment plan is also used. The equipment is designed for the separation shown and advantage taken of geographic separation to assign offset channels at one half the separation shown.

(6) All assignments are being allowed with this separation since September 1975.

(7) Certain public services will continue to operate with 25 kHz channel separation.

(8) Acceptable for cellular mobile telephone systems only.

2.2 Various administrations have interpreted the term "adjacent channel separation" in section 2.1 above in different ways and this has led to some confusion as to where administrations should enter their systems on the table.

An attempt was made at the interim meeting to define "adjacent channel separation", but the resulting discussion revealed that no one definition adequately accounted for all the various national systems. To illustrate the difficulty, adjacent channel separation could be defined, for example, in any one of the following ways:

- minimum frequency separation between channels in the coverage area of a base station;
- the separation between channels as assigned in the national frequency allocation plan;
- the occupied bandwidth of a channel defined by its class of emission;
- frequency separation between adjacent channels which allows for the use of adjacent channels within the same geographical area.

These are only examples, and other and more precise definitions are possible.

Administrations had been invited to input to the Final Meeting 1989 their views on how the information that Table III is intended to contain should be included in the report. Such inputs were to include defining more than one parameter for systems as, for example, is the case of Table I in Part C of Report 742-3 which applies to cellular systems only.

Also administrations had been requested to review the notes associated with Table III to determine if any of them need to be deleted or amended. The attention of administrations was particularly drawn to Notes 2, 6 and 9.

In spite of two input documents to the Final Meeting 1989 no solution to the problems described above could be found during that meeting.

Some administrations expressed the view that Table III is of no value and/or could be misleading, and therefore supported its deletion. Some other administrations, however, could not agree to this and wanted it retained.

Administrations, especially those who would like to see Table III retained, are therefore invited to input to the next Study Group 8 meeting their views on possible solutions.

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[1978-82]: **a.** 8/467 (Yugoslavia (Socialist Federal Republic of)); **b.** 8/29 (Japan).

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