

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.

* 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 [Mulwijk, 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; Mulwijk, 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.

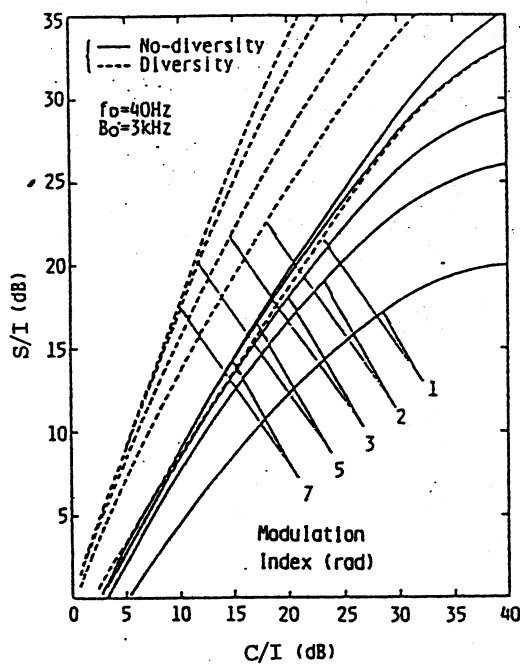


FIGURE 1 - Relation between C/I and S/I of FM system with selection diversity

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.

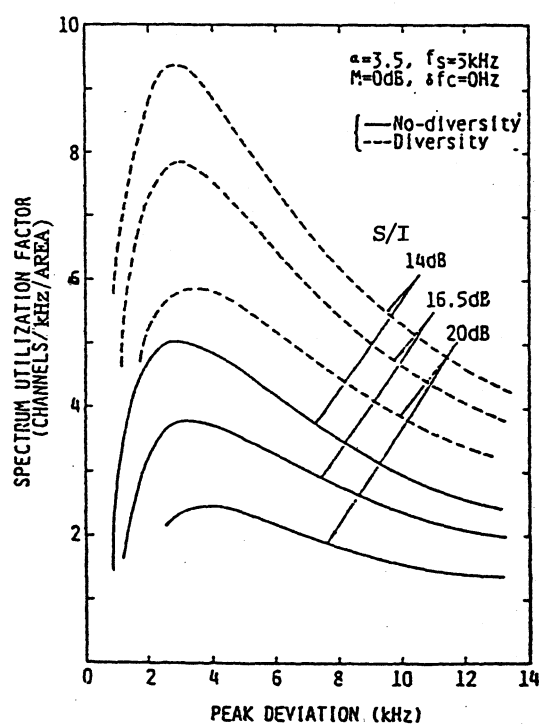


FIGURE 2 - Spectrum utilization factor with S/I parameter

- 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.

REFERENCES

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- Sakamoto M. and Hata, M., [Feb., 1987] Effects of channel narrowing in small zone FM mobile communication systems. *IEEE Trans. Veh. Technol.*, vol. VT-36, 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:

<i>Designations</i>			<i>Description</i>
(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 $+60^\circ\text{C}$, 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 ($+60^\circ\text{C}$). 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 $+60^\circ\text{C}$ and 5 parts in 10^6 over the range -10°C to $+40^\circ\text{C}$ can be achieved.