REPORT 1023-1

FREQUENCY SHARING BETWEEN THE LAND MOBILE SERVICE AND THE BROADCASTING SERVICE (TELEVISION) BELOW 1 GHz

(Question 69/8)

(1986-1990)

1. Introduction

The WARC-79 increased the number of frequency bands that might be shared between the broadcasting service and the mobile service below 1 GHz.

If the same portion of the frequency spectrum is allocated to two or more services, sharing may be effected in one of the following ways:

a) use of the same frequency band by different services at different times;

b) simultaneous use of different parts of the shared bands by different services;

c) simultaneous use of the same parts of the shared bands by different services, but in separate geographical areas.

This Report examines the case of sharing in separate geographical areas as in c) above.

2. Characteristics of the two services

Television services typically operate with considerably larger radiated powers than mobile services (typically 40 dB more) and mobile services typically operate with considerably smaller usuable field strengths than television (typically 30 dB less). This total difference of 70 dB in the planning criteria of the two services suggests initially that sharing will have very limited application. However, in practice the following criteria assist the mobile services:

- the protection ratio required by the mobile services is typically less than that for the television service (typically 10 dB as opposed to 50 dB);
- the service areas in the mobile service are smaller, so antenna heights are less than broadcasting antenna heights and the height gain correspondingly less;
- the television service employs a much wider bandwidth than the mobile service (typically 8 MHz against 12.5 kHz) so the full power of the television signal will not be present in any one mobile channel. In fact, the power density of the television signal is not constant across the television channel, as discussed below.

3. Power spectral density of a television signal

Figure 1 shows the limit of the power spectral density of a television signal when measured in a 7 kHz bandwidth (appropriate to a 12.5 kHz channelled mobile radio receiver). This mask is a composite for the PAL and SECAM systems in use in Europe. The frequency separation between the various carriers is different for the different systems but the relative power levels do not change greatly. It can be seen that between the carriers the power is at least 30 dB below the total power and for much of the television channel is at least 40 dB below.

Figure 1 refers to normal picture scenes. The power spectral density of electronically generated pictures requires further study.

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* This Report should be brought to the attention of Study Groups 1 and 11.

4. Example of sharing

As an example of the sharing possibilities, consider the case of mobile operation around 200 MHz in television Band III (174-230 MHz). From Report 358 for Grade 4 signal quality the requirements of the mobile service are:

- median field strength to be protected: 22 dB(μV/m);
- protection ratio: 10 dB;
- maximum interfering field strength: 12 dB(μV/m).

Assume the following typical characteristics for the mobile service:

- base station effective antenna height: 75 m (height gain relative to 10 m: +9 dB)*;
- mobile station effective antenna height: 3 m (height gain relative to 10 m: −4.5 dB)*.

Assume the following to be typical for the television service:

- effective antenna height: 300 m;
- effective radiated power: 250 kW.

Then from Recommendation 370 the separation distances required (for 10% time 50% location) are given in Table I.

TABLE I – *Required separation distances to protect the mobile service (television radiated power between carrier frequencies assumed 30 dB below total radiated power)*

	On carrier frequencies (km)	Between carrier frequencies (km)
Base station	560	260
Mobile station	430	180

It can be seen that, whereas the distances are large for operation on the carrier frequencies, the distances are considerably reduced for operation on frequencies between the carriers. Thus, mobile operation may not be practicable on the television carrier frequencies, but a substantial amount of spectrum remains in which operation may be practicable.

5. Receiving antenna discrimination

Mobile services are constrained to use vertical polarization due to the difficulty otherwise of mounting the mobile antennas, particularly at the lower frequencies. Television services may, however, use horizontal or vertical polarization. The use of horizontal polarization by the television service greatly facilitates frequency sharing by the mobile and television services as advantage can be taken of an antenna discrimination factor of around 15 dB. This discrimination applies only to base stations. In the case of mobiles the discrimination will be much less – perhaps 3 dB – but the base station interference is the dominant case as shown in Table I. The separation distance of 260 km reduces to 160 km in the example of Table I if orthogonal polarization is assumed.

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* These values require further study.

6. Protection of television services

According to Recommendation 417 the minimum (median) field strengths for which protection may be sought in planning television services are 48, 55, 65, or 70 dB(μV/m) for bands I (47-68 MHz), III (174-230), IV (470-582 MHz) and V (582-960 MHz), respectively. The use of lower values militates against sharing. It can be seen from Fig. 1, that (apart from in the vicinity of the carriers) moderate increases in television transmitter power to improve the field strength at the edge of the service area can have little effect on mobile usage. Also, since the carrier frequencies are unlikely to be usable by the mobile service, the interference will not be increased if low power "fill-in" transmitters are employed, providing that the carrier frequencies align to the same frequency grid. Sharing is further facilitated if higher protected field strengths can be accepted for the service areas of these fill-in transmitters.

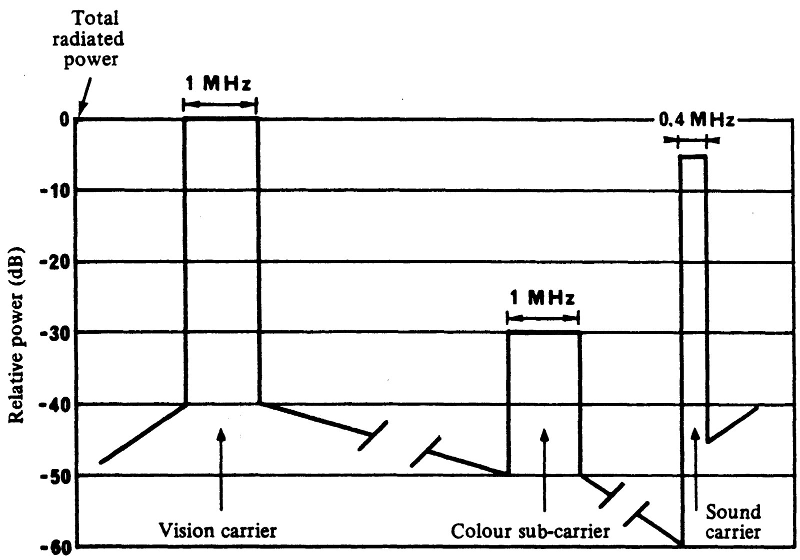

FIGURE 1 – *Relative values of peak radiated power (measured in a 7 kHz band)*

7. Protection ratios

Protection ratios for television signals are given in Recommendation 418 and Report 306. These references show that the protection ratio is not constant, for narrow-band interference across the television channel, being greatest (around 50 dB) near the vision carrier and least (around 30 dB) near the sound carrier. Mobile services can be planned to take advantage of this by assigning frequencies near the sound carrier to base station sites having the greatest interference potential and frequencies near the vision carrier to those having the least interference potential, or to mobiles.

8. Multiple interference

A new consideration that will arise with sharing between the mobile and television services is the effect on the television signal of multiple interfering sources. This arises because of the large difference in bandwidth used by the two services which implies that there could be 300 or 400 mobile service transmitters operating in a television channel.

It is possible that the simplified multiplication method as detailed in Report 945, is appropriate to this case, but further study is required. Also, it is unlikely that all the mobile service transmitters would be operating simultaneously and further study is required on the statistics of mobile operation noting that sharing will be facilitated if mobile operation can be confined to specific areas.

9. Interference from base and mobile stations

Base stations are likely to cause a greater interfering effect to television than mobile stations. The lower antenna height of mobiles, coupled with their limited radiated power and the general clutter effects caused by buildings, combine to make the interfering field strength from a mobile station to be around 20 dB less than that from the corresponding base station. This factor will not be achieved if the mobile is operating from a high clear site, (such interference may be transitory) or if mobiles operating on a co-channel basis encroach upon the television service area. While interference from mobiles in these situations may only occur for a small percentage of time the interference caused will be unacceptable if it results in severe disruption (as distinct from minor observable degradation) of the television reception.

A typical base-station radiated power in the mobile service is 25 W. By using directional antennas this can be effectively reduced, typically to 2.5 W, in the direction of the television broadcast service area.

Annex I gives a method showing how the effect of multiple interference from narrow-channel land mobile stations may be aggregated within the wider bandwidth of a television channel, and demonstrates the advantages accruing from the use of directional antennas.

10. Conclusions

Sharing between the mobile and broadcasting (television) services is practicable in separate geographical areas, particularly if the television carrier frequencies are avoided.

Sharing becomes easier as the protected field strength of both services is increased. Also, sharing is facilitated if horizontal polarization is used in the television service. However, where polarization discrimination could be employed to facilitate sharing within the broadcasting service, the overall spectrum advantages will need careful study.

The effects of multiple sources of interference on the television service are not fully understood and require further study.

ANNEX I

At sites close to the coast that offer a predominantly sea path, particular care should be taken to reduce field strengths that interfere with the television service. It is possible for a single base station installation to produce an interfering field strength equal to the value of field strength of the television service to be protected. This prevents use of the television channel by the land mobile service.

The interfering, or nuisance, field is calculated by (see Report 945):

$$E_n = \sqrt{\sum_{i=1}^{n} (a_i + b_i + e_i)^2}$$

where:

a_i: radio-frequency protection ratio (dB) associated with the ith unwanted transmitter;

b_i: receiving antenna discrimination (dB);

e_i: field strength of the unwanted transmitter (dB(μV/m)).

By using a directional base-station antenna, the interfering field strength can be reduced by at least 10 dB.

It now remains to demonstrate what this means in terms of channel usage.

The simplified multiplication method for the assessment of multiple interference (see Report 945) gives the following formula for calculating usable field strength (field strength to be protected):

$$p_c = 0.5 = \prod_{i=1}^{n} L(E_u - F_i)$$

These terms are defined in Report 945, but the following should be noted:

$$F_i \equiv E_{si} \text{ (in Report 945)}$$

$$F_i = P_i + E_{ni}(50, T) + A_i + B_i + K_i \qquad (1)$$

where:

K_i : directional antenna correction factor associated with the ith unwanted transmitter.

Now, if k interfering fields are introduced such that:

$$F_{(n+1)} = F_{(n+2)} = F_{(n+3)} = \ldots F_{(n+k)} = F'$$

and the new value of protected field strength $(E_u) = E_p$, then:

$$p_c = \prod_{i=1}^{n+k} L(E_p - F_i)$$

$$= \left[\prod_{i=1}^{n} L(E_p - F_i)\right] \times \left[L(E_p - F_{(n+1)}) \times L(E_p - F_{(n+2)}) \times \times L(E_p - F_{(n+3)}) \times \ldots \times L(E_p - F_{(n+k)})\right]$$

$$= \left[\prod_{i=1}^{n} L(E_p - F_i)\right] \times \left[L(E_p - F')\right]^k$$

therefore:

$$k \log_e \left[L(E_p - F')\right] = \log_e \left[\frac{p_c}{\prod_{i=1}^{n} L(E_p - F_i)}\right] \qquad (2)$$

Note. – $L(E_p - F_i) = 0.5 + 0.5\,\varphi\left(\frac{E_p - F_i}{8.3\sqrt{2}}\right)$ (see Report 945)

and $\varphi(x) = \frac{2}{\sqrt{2\pi}} \int_0^x [\exp(-t^2/2)]\,dt$

In this example E_p has been taken to be 70 dB(μV/m) and F_i to be 60 dB(μV/m).

$$k \log_e [L(70_p - F')] = \log_e \left[\frac{0.5}{L(70 - 60)}\right]$$

$$= -0.4736002$$

Therefore, various values of interfering field strength, F', can be equated to k extra interfering base-station transmitters, each giving rise to an interfering field strength F' (F' being calculated using equation (1)) and operating simultaneously with the re-engineered base station giving rise to the interfering field strength F_i.

TABLE II – *Number of base-station transmitters giving rise to an interfering field strength F'*

Interfering field strength F' (dB(μV/m))	No. of additional base stations k $\left[k = \frac{-0.4736002}{\log_e L(70-F')} \right]$
30	1446
40	89
50	10
60	2

The value of k can be increased still further by careful choice of base-station transmit frequency and keeping the antenna heights as low as possible.