RECOMMENDATION ITU-R F.1334[*, **]

Protection criteria for systems in the fixed service sharing the same frequency bands in the 1 to 3 GHz range with the land mobile service

(Question ITU-R 133/9)

(1997)

The ITU Radiocommunication Assembly,

considering

a) that systems in the fixed service (FS) and land mobile service (LMS) share many frequency bands between 1 and 3 GHz;

b) that many systems in the FS are operational or are planned for operation in these shared bands, both analogue and digital for point-to-point (P-P) and point-to-multipoint (P-MP) applications;

c) that it is necessary to specify the maximum allowable interference into the FS;

d) that reasonable geographic separations are necessary to permit sharing of overlapping frequency assignments;

e) that geographic separations are necessary in certain cases to permit sharing of orthogonally polarized assignments;

f) that the typical receiver thermal noise of systems in the FS as given in Recommendation ITU-R F.758 is of the order of –140 dB(W/MHz),

recommends

1 that the protection criteria for the FS sharing frequency bands between 1 and 3 GHz with the LMS be established as follows (see Note 1):

– the maximum aggregate interference from the LMS including base stations and mobile stations should be such that the degradation to a FS receiver threshold does not exceed 1 dB under normal propagation conditions;

2 that Annex 1 should be referred to for the additional information relating to the protection of systems in the FS sharing frequency bands between 1 and 3 GHz with the LMS.

NOTE 1 – In certain situations of unfavourable propagation conditions, it may become necessary to establish an additional criterion to avoid excessive degradation to a FS threshold (for example, degradation exceeding 10 dB) for a small time percentage. The level of such degradation and the time percentage should be agreed by the administrations concerned.

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[*] This Recommendation should be brought to the attention of Radiocommunication Study Groups 3 (Working Parties 3K and 3M) and 8 (Working Parties 8A and 8F).

[**] Radiocommunication Study Group 9 made editorial amendments to this Recommendation in 2004.

NOTE 2 – Further study should be continued to improve this Recommendation in close collaboration with Radiocommunication Study Group 8 (Working Party 8A). Administrations and other organizations are requested to submit contributions to the ITU-R.

Annex 1

Considerations for the protection of the FS sharing frequency bands between 1 and 3 GHz with the LMS

1 Introduction

The World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992) (WARC-92) made many amendments and additions to the Table of Frequency Allocations. In the case of future public land mobile telecommunication systems (FPLMTS), identification of the bands 1 885-2 025 MHz and 2 110-2 200 MHz was made by way of No. 5.388 of the Radio Regulations. These bands are already extensively used by radio-relay systems. Now that WARC-92 decisions are known, sharing studies of affected services should continue.

Resolution 113 (WARC-92) specifically addressed sharing and adjustments to the FS as consequences of changes to frequency allocations in the range 1-3 GHz.

Fixed wireless systems operating in the 1-3 GHz band form a vital part of the telecommunications service of many administrations. Thus, the study of spectrum sharing with other services must include due consideration for maintaining the high availability and performance standards required for telecommunications services.

This Annex examines, by way of example, the feasibility of frequency sharing between point-to-point fixed wireless systems in the FS and systems in the LMS.

The approach adopted in this Annex recognizes that:

– the formulation of sharing guidelines for both the fixed systems and land-mobile systems should reflect the characteristics of, and performance objectives for the respective systems;

– a study based on the consideration of several spectrum sharing examples can provide a broader understanding of the technical issues involved, and

– the mutual interference between the FS and land-mobile systems may be meaningfully described on a statistical basis, and consequently by applying a statistical approach to this spectrum sharing question guidelines can be formulated which will properly reflect the performance under sharing. The actual levels of interference may also need to be considered deterministically for each situation.

Systems in the mobile service (MS) encompass a number of operating environments. They include, for example, personal, mobile and satellite communications. In this Annex, the mobile (R1 interface) segment is concerned with the communications services between vehicles and base stations. The personal (R2 interface) segment postulates the use of personal communications in a pedestrian environment indoors and outdoors. The satellite segment may be concerned with services such as paging functions, linking remote base stations or providing temporary system extension. This sharing study is restricted to the R1 and R2 interfaces of systems in the LMS.

2 Characteristics of FS and MS

2.1 Fixed systems

Examples of the technical characteristics of some fixed wireless systems are given in Table 1.

TABLE 1a

Example 1-3 GHz digital fixed wireless systems

Modulation	O-QPSK	64-QAM
Antenna gain, G_{FS} (dBi)	33	33
Transmit power, P_{FS} (dBW)	7	1
e.i.r.p. (dBW)	40	34
Noise floor (dBW)	–125	–130
Bandwidth, B_f (MHz)	29	10
Maximum I (I/N = –6) (dBW)	–131	–136

O-QPSK: quadrature phase shift keying

64-QAM: quadrature amplitude modulation.

TABLE 1b

Example 1-3 GHz P-MP systems

Parameter	Central station	Outstation
Antenna type	Omni/sectoral	Dish/horn
Antenna gain (dBi)	10/13	20 (analogue) 27 (digital)
e.i.r.p. (maximum) (dBW): – analogue – digital	 12 24	 21 34
Noise figure (dB)	3.5	3.5
Feeder loss (dB)	2	2
IF bandwidth (MHz)	3.5	3.5
Maximum permissible long-term interference power (20% time): – total (dBW) – (dB(W/4 kHz)) – (dB(W/MHz))	 –142 –170 –147	 –142 –170 –147

Other characteristics relevant to the operation of fixed wireless systems include:

- the nature of the propagation, which is generally characterized by distinct non-fading and fading periods, where fading occurs as the result of anomalous propagation conditions (often late at night and/or during the early hours of the morning) including possible obstruction effects;
- the operating flat fade margin, which is typically 30-40 dB;
- the primary mechanism of errors. For low capacity systems (under 10 Mbit/s) this is signal level fading (rather than dispersive effects), and
- the performance requirements, which are described in Recommendations ITU-R F.594, ITU-R F.634, ITU-R F.696, ITU-R F.697, ITU-R F.1168 and ITU-R F.1703.

2.2 Systems in the LMS

The assumed technical characteristics of the LMS R1 and R2 interfaces are given in Table 2.

TABLE 2

Sharing parameters in the LMS

	Example 1	Example 2	Example 3	Example 4
Interface	R2 base/personal	R1	R2	R2
Access method	TDMA			FDMA/TDMA
Duplex method	TDD			TDD
Transmit power (W)	0.02	1	0.12	0.01
Antenna gain, G_m (dBi)	0	0	0	0
e.i.r.p. (dBW)	–17	0	–9	–20
Noise floor (dBW)	–152	–152.5	–146.2	
Channel bandwidth, B_m (kHz)	50	135	576	100
Maximum *I* (10% external *I*) (dBW)	–149			
Frequency reuse cluster	16			10-15
Interfering mobiles per channel(1), *m*	1/16	1	5	1/4

FDMA: frequency division multiple access

TDMA: time division multiple access

TDD: time division duplex

(1) The total number of mobiles, *n*, interfering with a fixed station is equal to $n = m\ B_f / B_m$. The values for *m* are those assumed in the calculations in this Recommendation.

The principal special consideration for the FPLMTS is the mobile nature of the personal stations. It is to be expected that the operation of personal stations of FPLMTS will be desired almost anywhere. Spectrum sharing by both the FS and FPLMTS should be carefully coordinated. Possible sharing features of FPLMTS include frequency agility that could permit dynamic avoidance of radio channels that could cause interference to the FS, and the use of dynamic power control.

Other characteristics relevant to the MS including FPLMTS operation include:

– the nature of the propagation, notably, that fading occurs as the result of multipath propagation caused by reflections/refraction off buildings etc. rather than anomalous propagation;

– the statistical nature of the operating fade margin;

– the random nature that the MS's positions undertake within the FPLMTS service area, which gives rise to a statistically varying interference environment;

– the (expected) time-of-day nature of MS traffic. In particular, that heavy traffic generally occurs during the day (especially during working hours), and very light traffic late at night and during the early hours of the morning, and

– the performance requirements, which could require satisfactory performance over 90% of the service area for the R1 interface, and 99% of its service area for the R2 interface.

3 Interference scenarios

There are four basic interference paths to consider for the interference analysis. These are:

Forward link:

a) the FS interferes with the outdoor mobile stations;

b) the base station (BS) interferes with the FS.

Return link:

c) the personal outdoor stations interfere with the FS;

d) the FS interferes with the BS.

It is generally viewed that co-channel operation by the FS and MS in the same geographic area will cause unacceptable interference to the FS. The following analysis involves development of "sharing objectives" for b) and c) of the above interference paths. These sharing objectives could then be met by geographic and/or frequency separation of MS and fixed systems.

4 Sharing objectives

The sharing objectives define the conditions under which sharing is deemed to be feasible. To maximize the utilization efficiency of the spectrum the relevant characteristics of the respective systems need to be considered. It is then necessary to define the requirement for the wanted-to-interference power ratio and/or the requirement for the interference-to-noise power ratio, where either/both the wanted and interference powers may involve a statistical distribution.

For each of the two scenarios which are b) and c) of § 3, the following statistical sharing objectives are proposed to establish general guidelines for sharing, where the values of the parameters $A1$, $A2$, $X1$ and $X2$ are required to reflect the performance objectives of the respective systems:

– BS into FS: Allow spectrum sharing for position of the FSs and BSs where:

$$\text{Prob[Interference Power*} \geq A1 \text{ (dBm)]} < X1 \quad (1)$$

– MS into FS: Allow spectrum sharing in a region where at each location within the region:

$$\text{Prob[Interference Power**} \geq A2 \text{ (dBm)]} < X2 \quad (2)$$

* The power received under nominal propagation conditions is time-invariant and denoted the "long-term received power". However, during anomalous propagation conditions the power can be randomly time-varying.

** Mean interference power over signal variations caused by multipath propagation and when applicable, from the summation of multiple interference sources.

5 Sharing criteria

The sharing criteria define the required geographic separation of the MS and fixed systems in order to specify the respective sharing objectives.

For the calculation of sharing criteria the following system parameters are defined:

B_f: fixed system Nyquist bandwidth (MHz)

L_{ff}: fixed station antenna and feeder loss (dB).

The same nomenclature is used for both the R1 (vehicular and high powered portables) and R2 (personal) parts:

P_{tm}: MS mobile station transmit power (input to antenna feeder) (dBm)

L_{fm}: MS mobile station antenna and feeder loss

P_{tb}: MS base station transmit power (input to antenna feeder) (dBm)

L_{fb}: MS base station antenna and feeder loss (dB).

(For the purpose of this analysis, the term mobile station is used for both mobile stations operating over R1 and personal stations operating over R2.)

An appropriate statistical characterization of the radio channel between the FPLMTS mobile stations (R1 and R2 operation) and the fixed system stations is that characterized by:

– fast fading, which for narrowband signals gives rise to a Rayleigh distribution of the instantaneous received signal envelope over a sector (or local area);

– shadow fading, which gives rise to a lognormal distribution of the sector median received signal and is characterized by the "shadow fading (dB) spread" (i.e. the standard deviation) and denoted σ;

– median received signal, defined as the median of the sector median received signal.

It is convenient to define at the system point of interest:

U_s: median received power over sector (dBm)

U_m: median received power (median of U_s) (dBm).

The median transmission loss (between the transmit and receive antenna terminals, antenna and feeder losses not included) denoted L_t, which is given by many propagation models, e.g. Okumura, Lee, Elgi etc., is given by:

$$\text{Median transmission loss} = L_t = P_t - U_m \tag{3}$$

where P_t (dBm): transmit power and U_m (dBm) defined above.

5.1 Sharing criteria for MS stations into fixed systems

For this case difficulty arises in relating the parameters $A2$ and $X2$ to the performance objectives of the fixed system. This is due in part to the large flat fade margins generally associated with fixed systems, and the uncertainty as to their fading statistics. However, given the form of the sharing objective, it is reasonable to specify the sharing objective in the terms that the interference power to not degrade the fixed system fade margin by greater than 1 dB for a given percentage of time. However, an appropriate value for $X2$ is not clear, only that given the stringent performance objectives generally applicable to fixed systems, it should likely be small. As described below, the distribution for the total interference is modelled as log-normal, and for the present purposes a value for $X2 = Q(k)$, $k = 4$ or 5 would appear reasonable, where $Q(k)$ is the "area under the Gaussian tail", and is given by:

$$Q(k) = \frac{1}{\sqrt{2\pi}} \int_k^{\infty} \exp\left(-x^2/2\right) \mathrm{d}x \tag{4}$$

The interference power received by the fixed system will in general arise from a number of mobile stations. This number, denoted N, will be dependent on many factors. Suitable estimates may be:

– *R1 interference*: that when one mobile station on each carrier frequency operates within the common frequency segment.

– *R2 interference*: that when five mobile stations on each carrier frequency operates within the common frequency segment.

The distribution of the total interference power is calculated from the power sum of lognormal variates. If all the interferers have median power U_m and standard deviation σ, then the total interference can be approximated by a log-normal distribution of mean U_{mN} and standard deviation σ_N where:

$$U_{mN} = U_m + H \tag{5}$$

$$\sigma_N^2 = 43.43 \log_{10} \left[\left(\exp\left(\lambda^2 \sigma^2\right) + N - 1 \right) / N \right] \tag{6}$$

where:

$$H = 10 \log_{10} N + 5 \log_{10} \left[N \exp\left(\lambda^2 \sigma^2\right) / \left(N - 1 + \exp\left(\lambda^2 \sigma^2\right) \right) \right] \tag{7}$$

and $\lambda = 0.1 \log_e 10 = 0.2303$.

Under the definitions and propagation assumptions given above, U_{mN} (dBm) is characterized by a Gaussian distribution with median given by:

$$U_{mN} = P_{tm} - L_{fm} - L_{ff} - L_t + H \tag{8}$$

and standard deviation σ_N. The threshold for U_{mN} is then given by:

$$U_{mN} = A2 - k\,\sigma_N \tag{9}$$

which gives for the sharing criteria:

$$L_t > P_{tm} - A2 - L_{fm} - L_{ff} + H + k\,\sigma_N \tag{10}$$

5.2 Example at 2 GHz

The parameters used in the following examples are taken from Tables 1 and 2 (examples 2 and 3).

For mobiles operating over either the R1 or R2 interface, the shadow fading dB spread σ is taken as 6.0 dB. (Typical for urban and suburban environments.)

5.2.1 FPLMTS into fixed

The assumed interference power threshold is that 6 dB below the noise floor.

Sharing objective:

$$\text{Prob}[U_{mN} > -113.9 - 6.0 + 3.0 \text{ (dBm)}] < X2 \qquad X2 = Q(4) \text{ (see equation (4))} \tag{11}$$

5.2.2 FPLMTS-R1

Based on estimate given above, assume $N = 5.0$, which gives $H = 9.48$ dB and $\sigma_N = 3.80$ dB. The sharing criteria becomes:

$$L_t > 30.0 - (-116.9) - 3.0 + 9.48 + (4.0 \times 3.80) = 168 \text{ dB} \tag{12}$$

5.2.3 FPLMTS-R2

Based on estimate given above, assume $N = 10.0$, which gives $H = 13.2$ dB and $\sigma_N = 2.93$ dB. The sharing criteria becomes:

$$L_t > 20.8 - (-116.9) - 3.0 + 13.2 + (4.0 \times 2.93) = 159 \text{ dB} \tag{13}$$

These examples illustrate a possible approach to the assignment of values to the parameters *Ai* and *Xi*, and a method for the calculation of the sharing criteria. From the fixed and mobile antenna characteristics and suitable propagation models, the above calculated sharing criteria can be translated into the required exclusion distances.

Further study is needed to determine generalized values for the parameters *Ai* and *Xi* and the resulting isolation requirements. Both long- and short-term performance objectives need to be considered, as well as determination of the most representative propagation models for the various interference paths.

These propagation studies will be critical to sharing and urgent study of appropriate models by Radiocommunication Study Group 3 is requested.

6 Interference analysis

As a first estimate to the separation distances required between fixed services and the personal segment service areas of MS (R2 interface), this section considers the median interference powers between these services when the path loss between them is about 130 dB. It is noted that this analysis does not take account of the statistical nature of the interference powers about the median level (which was discussed in § 5), the distribution of which will impact on the exclusion distances required.

For a path loss of 130 dB then:

$$L_t = FSL - G_{FS} - G_M = 130$$

where:

FSL: free space loss

G_{FS}: FS antenna gain

G_M: MS antenna gain.

MS and other interference sources should not cause more than 25% degradation to the performance of FS systems. This corresponds to $I/N = –6$ dB and total interference level of $I_T = –136$ dBW in a 10 MHz wide FS radio receiver. Assuming dynamic channel assignment in example 4 of Table 2, up to 25 MS users may dwell around the worst –3 dBr point, and the most conservative single exposure interference $I_1 = I_T - 10 \log 25 \approx -150$ dBW may apply. If a mobile unit = e.i.r.p. -20 dBW (an output power is 10 mW, and antenna gain is 0 dBi), then an isolation of $-20 - (-150) = 130$ dB may be necessary. Since the ray path transmission loss L_t near the worst point (i.e. 3.3 km in front of an FS radio antenna and at –3 dBr of the boresight) is 78.5 dB, an additional isolation of $130 - 78.5 = 51.5$ dB is necessary. This may be achieved by an adjacent channel operation. In some cases, e.g. when an MS transmitter operates at the edge of an FS radio channel, a co-channel operation may apply.

At a distance of 3.3 km behind the FS radio antenna, $L_t = 78.5 - 3.0 + 60.0 \approx 135.5$ dB (the ray path transmission loss at the –3 dBr of boresight plus the front-to-back ratio of the antenna); here a front-to-back ratio of 60 dB is assumed, which relates to an ultra high performance antenna type. Since 135.5 > 130, mobile transmitters wandering 3.3 km away and behind the FS radio antenna may be able to use the same frequency as the corresponding FS radio receiver. However, an analysis needs to be extended to the whole FS radio network in the area. The 3.3 km point behind one FS receiver could be near the main beam of the adjacent hop which, in a two-frequency plan would have the same receive channel. This implies that there could be an annular exclusion zone around each FS station with odd-numbered stations receiving on one set of channels (e.g. the go channels) and even-numbered stations receiving on corresponding return set of channels. If a figure eight-shaped exclusion zone (e.g. the 130 dB contour) is applicable, the envelope of all co-frequency exclusion zones can form a corridor along the FS route in the worst case. However, there exists a strong possibility that other frequency channels will be available within this area.

6.1 Forward link analysis

The parameters used in the following examples are taken from Tables 1 and 2 (example 1).

Interference from the personal base station (BP) into the FS

A frequency reuse cluster of 16 may be assumed for the personal interface.

∴ Number of simultaneous users per FS channel bandwidth equals:

Base station (BS)

$$\frac{29\,000}{50 \times 16} = 36.2 \text{ (15.6 dB)}$$

$$\frac{10\,000}{50 \times 16} = 12.5 \text{ (11 dB)}$$

$$\frac{3\,500}{50 \times 16} = 4.4 \text{ (6.4 dB)}$$

The necessary path transmission loss between the BP and the FS receiver is:

$$\begin{aligned} L_t(\text{BP} \rightarrow \text{FS}) \quad & \geq -17 + (6.4 \text{ to } 15.6) - (-131 \text{ to } -140.5) \\ & \geq 129.6 \text{ dB (29 MHz)} \\ & \geq 130.0 \text{ dB (10 MHz)} \\ & \geq 129.9 \text{ dB (3.5 MHz)} \end{aligned} \tag{14}$$

This is approximately equal to the 130 dB ray path transmission loss requirement. No additional isolation is required between the BP and the FS.

6.2 Return link analysis

Interference from the personal (P) outdoor stations into the FS.

The necessary path transmission loss between the P station and the FS is:

$$\begin{aligned} L_t(\text{P} \rightarrow \text{FS}) \quad & \geq -17 + (6.4 \text{ to } 15.6) - (-131 \text{ to } -140.5) \\ & \geq 129.6 \text{ dB (29 MHz)} \\ & \geq 130.0 \text{ dB (10 MHz)} \\ & \geq 129.9 \text{ dB (3.5 MHz)} \end{aligned} \tag{15}$$

No additional isolation beyond the 130 dB requirement is necessary between the P stations and the FS.

7 Summary: 130 dB isolation (ray path transmission loss)

7.1 Forward link

Base station interference into the FS:

BP-sufficient isolation.

7.2 Return link

Personal station interference into the FS:

P-sufficient isolation.

7.3 Separation distance for 130 dB ray path transmission loss

With an antenna front-to-back (F/B) ratio of approximately 44 dB:

$$L_t = 92.5 + 20 \log f + 20 \log d - 33 + 44\ (F/B) = 130 \text{ dB} \qquad (16)$$

$$\therefore d = 0.2 \text{ km}$$

For a free space loss of 130 dB at 2 GHz, $d = 37$ km. It is to be expected that the actual separation distance required to achieve 130 dB isolation will depend on results of detailed frequency coordination and actual system link designs, considering such parameters as antenna height, terrain conditions, available cross-polarization discrimination, etc. Appendix 1 provides an additional example coordination calculations.

8 Conclusions

– Separation distances of the order of 70-120 km (assuming free-space loss propagation conditions) or more will permit co-channel operation between the FS and the personal segment of the MS.

– By extension, assuming typical 50-70 dB adjacent channel interference rejection, the FS could be used in the same geographic area as the MS if the frequencies of operation are not overlapping.

– To facilitate sharing, further study is required to develop statistical descriptions of the mutual interference between fixed systems and the MS and appropriate propagation models.

– Modelling of propagation conditions relevant to the mobile environment should be urgently carried out.

Appendix 1
to Annex 1

Example coordination distances for interference from the MS into the FS

Calculations performed for the main lobe interference case, assuming 25 dB cross polarization discrimination (XPD) between the FS and BPs.

$$I = -131 \text{ to } -140.5 = \text{e.i.r.p.} + 10 \log (\text{reuse eff.}) - 92.5 - 20 \log f - 20 \log d - 25 + G_{FS}$$

For O-QPSK: $-131 = -17 + 15.6 - 92.5 - 6.02 - 20 \log d - 25 + 33$ with $d = 90$ km

For 64-QAM: $-136 = -17 + 11 - 92.5 - 6.02 - 20 \log d - 25 + 33$ with $d = 94$ km

Sufficient isolation is provided at a separation distance of the order of 90-95 km. As with example 1, without XPD advantage at a separation distance of approximately 120 km, an additional isolation of the order of 23 dB would be necessary which may be obtained through small off-mainlobe discrimination angles.

For the adjacent channel case, which provides on the order of 50-70 dB isolation, co-polar operation in the same geographic area by the R2 segment of the MS and the FS is possible.

Table 3 provides a summary of example bandsharing requirements.

TABLE 3

Example of bandsharing requirements between MS and FS

Case	Adjacent channel	Co-channel
R2 → FS	*Crosspole*: same geography (co-located) *Co-polar*: separation 0-5 km	*Crosspole*: separation 90-95 km *Co-polar*: separation 120 km plus 23 dB antenna discrimination