RECOMMENDATION ITU-R M.1635

General methodology for assessing the potential for interference between IMT-2000 or systems beyond IMT-2000 and other services

(2003)

Summary

Consideration of the potential for interference between IMT-2000 and systems beyond IMT-2000 and other services is essential for administrations in planning the use of frequency bands where the mobile service exists on a co-primary basis with other services.

Networks of IMT-2000 and systems beyond IMT-2000 are likely to accommodate significant numbers of cellular customers and hence networks will require significant transmission capacity, involving the deployment of high-density infrastructures. This needs to be considered in analysis to assess sharing between IMT-2000 and systems beyond IMT-2000 and other services.

This Recommendation provides recommendations for administrations for a methodology for assessing the potential for interference between IMT-2000 and systems beyond and other services under co-frequency as well as adjacent band conditions.

The ITU Radiocommunication Assembly,

considering

a) that shared use of the frequency spectrum is supportive for the general objective of efficient use of the spectrum;

b) that due to congestion in frequency bands suitable for broadband mobile service applications shared use of the spectrum with other services has to be considered as one possible option;

c) that shared use of frequency bands by IMT-2000 and/or systems beyond IMT-2000 and other services needs careful consideration of the coexistence conditions concerned;

d) that reducing the necessary guardband to services operated in frequency bands adjacent to IMT-2000 to the greatest extent possible is a supportive measure to improve efficient use of the spectrum,

recognizing

a) that IMT-2000 and its enhancements will continue to operate in the bands identified by the ITU at WARC-92 and WRC-2000;

b) that the further development of systems beyond IMT-2000 may require spectrum in addition to that now identified for IMT-2000;

c) that the suitable frequency ranges for systems beyond IMT-2000 that support broadband wide area full mobility services may be, among others, the ones that are not far away from the existing frequency bands identified for IMT-2000;

d) that the additional spectrum is requested especially in densely populated regions;

e) that Recommendation ITU-R M.1461 provides a methodology for conducting sharing studies between the radiodetermination service and other services,

recommends

1 that the procedures in Annex 1 be used for assessing the potential for interference between IMT-2000 and systems beyond IMT-2000 and systems in other services under co-frequency as well as adjacent band conditions taking into account other relevant ITU-R Recommendations on the subject of interference assessment concerning the services under consideration.

Annex 1

General methodology for assessing the potential for interference between IMT-2000 or systems beyond IMT-2000 and other services

1 Introduction

Consideration of potential for interference between IMT-2000 and systems beyond IMT-2000 and other services is essential for administrations in planning the use of frequency bands where the mobile service exists on a co-primary basis with other services or in adjacent frequency bands.

This Annex describes the principles of a compatibility assessment methodology in order to perform sharing studies between the mobile service and other services in co-frequency and adjacent band scenarios. This methodology covers worst-case considerations as well as a more representative approach, in order to get a full picture of the interference scenarios under consideration. Parts of the assessment procedures need to be based on a statistical methodology, well known as the Monte Carlo technique. The results may be focused on the cumulative distributions of I/N or C/I at the receivers of the applications concerned, in order to demonstrate the probability of interference.

The equations in this Annex describe a general calculation methodology. The units for the parameters in the equations must be consistent when they are applied to a specific study.

2 Interference assessment methodology

In order to perform sharing studies between mobile services and other services in co-frequency and adjacent band scenarios, simulation models need to be applied analysing the different parts of the interference path:

– transmitter,

– receiver,

– antennas,

– propagation.

On the other hand, it is necessary to operate with assumptions concerning future mature deployments of the mobile networks and applications in other services, in the phase before rolling out these networks. This allows at an early stage to achieve results which are as realistic as possible. Since interference scenarios between various applications may be analysed using this methodology, the concept of calculating the power spectral density at a victim receiver should be applied. This allows consideration of all kinds of modulation and bandwidth combinations, as well as the various requirements concerning the tolerable interference levels.

The methodologies to model the different parts of the interference path should be based on ITU-R Recommendations to the extent possible.

2.1 Interference level at victim receiver

2.1.1 Assessing the power spectral density at a victim receiver

The power spectral density of an interfering signal at a victim receiver is a key element of the interference calculation process. Due to the large variety of interference spectra and receivers to be considered in assessing the potential of interference between the mobile service and other services in co-frequency sharing as well as adjacent frequency band consideration, the concept of power spectral density calculation gives the most flexible approach. All kinds of combinations of frequency spectra and receiver selectivity may be applied in order to assess the potential for interference between systems in the mobile service and other services. Thus the method for calculation of the interference power spectral density at the input of a victim receiver is the essential part in any compatibility assessment.

The receiving power density spectrum at a victim receiver can be obtained from the following algorithm:

$$P_{Rx}(f,\ p) = \frac{P_{Tx}(f) \cdot G_{Tx}(\varphi) \cdot G_{Rx}(\theta) \cdot PM_{Rx}(\theta) \cdot S(f)}{R_{Tx} \cdot R_{Rx} \cdot L_b(f,\ p)} \tag{1}$$

where:

$P_{Rx}(f, p)$:	interfering power density spectrum at receiver
$P_{Tx}(f)$:	transmitter output power spectral density
$G_{Tx}(\varphi)$:	gain of the transmitting antenna in the direction of the receiver
$G_{Rx}(\theta)$:	gain of the receiving antenna in the direction of the transmitter
$PM_{Rx}(\theta)$:	polarization mismatch factor of receiving antenna
$S(f)$:	selectivity of receiver
R_{Tx}:	feeder loss of transmitting antenna
R_{Rx}:	feeder loss of receiving antenna
$L_b(f, p)$:	attenuation due to propagation effects
f:	frequency
p:	percentage of time
φ:	angle between the transmitting antenna boresight and the receiving antenna
θ:	angle between receiving antenna boresight and the transmitting antenna

with the isolation between transmitter and receiver:

$$I_S(p) = \frac{G_{Tx}(\varphi) \cdot G_{Rx}(\theta) \cdot PM_{Rx}(\theta)}{R_{Tx} \cdot R_{Rx} \cdot L_b(f,\ p)} \qquad (2)$$

where:

$I_S(p)$: isolation between transmitter and receiver

and the power spectrum at the output of the transmitter:

$$P_{Tx}(f) = P_{out} \cdot M_E(f) \qquad (3)$$

where:

$P_{Tx}(f)$: transmitter output power spectral density

P_{out}: transmitter power output level

$M_E(f)$: modulation envelope of the transmitter output.

The interfering power density spectrum is defined by:

$$P_{Rx}(f,\ p) = P_{out} \cdot \left(M_E(f) \cdot I_S(p) \cdot S(f)\right) \qquad (4)$$

This result represents the full picture of the interference level as a function of frequency and time percentage and thus allows assessment of all kinds of interference effects and scenarios in co-frequency as well as in adjacent band situations.

2.1.2 Aggregation of interference from several sources

Interference scenarios where several transmitters operate in the same frequency range and geographical area require methodologies for aggregating several interference signals suffered by a victim receiver. For assessing the overall interference prediction in such scenarios, the interfering signals should be aggregated by power:

$$P_I(f,\ p) = \sum_{I=1}^{N} P_{Rx}(f,\ p) \qquad (5)$$

where:

$P_I(f, p)$: aggregated interfering power density spectrum at receiver

N: number of interfering signals.

2.1.3 Effective interference power

Some interference considerations require that the effective interference power in a certain part of the frequency spectrum has to be calculated. This effective power level is calculated by integrating the power spectral density over the bandwidth under consideration:

$$P_{In}(p) = \int_{f_1}^{f_2} P_I(f, p) \quad \mathrm{d}f \tag{6}$$

where:

$P_{In}(p)$: effective interference power at receiver

f_1: lower edge of considered bandwidth

f_2: upper edge of considered bandwidth

which leads, if required, to the average interfering power density level in the frequency band under consideration:

$$P_{ds}(p) = \frac{P_{In}(p)}{f_2 - f_1} \tag{7}$$

where:

$P_{ds}(p)$: average interfering power density.

2.1.4 Calculation of peak interference level

In interference scenarios where high gain antennas and/or rotating antennas have to be considered, the peak interference level is of interest in order to assess the probability aspects of interference levels. In such cases, the calculation procedure can be simplified to the main beam coupling scenario of the transmitters and receivers under consideration. The peak interference power spectral density level at the input of the victim receiver can then be obtained from the following algorithm:

$$P_{Rx}(f, p) = \frac{P_{Tx}(f) \cdot G_{Tx} \cdot G_{Rx}}{R_{Tx} \cdot R_{Rx} \cdot L_b(f, p)} \tag{8}$$

where:

$P_{Rx}(f, p)$: interfering power density spectrum at receiver

$P_{Tx}(f)$: transmitter output power spectral density

G_{Tx}: peak gain of the receiving antenna

G_{Rx}: gain de crête de l'antenne de réception

R_{Tx}: feeder loss of transmitting antenna

R_{Rx}: feeder loss of receiving antenna

$L_b(f, p)$: attenuation due to propagation effects

f: frequency

p: percentage of time.

Applying free space propagation conditions leads to the worst-case scenario.

2.2 Transmitter model

The transmitter emissions may be classified into the following categories:

- fundamental emission;
- harmonically related emissions;
- non-harmonically related emissions;
- broadband noise.

A transmitter spectrum mask has to describe the power spectral density emitted by a transmitter. Due to the complex structure of the transmitter spectrum, a more generalized model should be applied in the interference assessment process. The fundamental emission should be defined on the basis of a modulation envelope model with respect to the bandwidth of transmission covering 250% of the necessary bandwidth. Outside this frequency the relevant ITU-R Recommendations concerning the spurious emission levels should be applied. The attenuation relative to the spectral density of the wanted emission has to be defined as a function of frequency offset.

2.3 Receiver model

2.3.1 Receiver susceptibility

Receivers are designed to respond to certain types of electromagnetic signals within a predetermined frequency band. However, receivers also respond to undesired signals having various modulation and frequency characteristics. Potentially interfering signals are considered to be in one of the following three basic categories:

- Co-channel interference refers to signals having frequencies that exist within the narrowest passband of the receiver.
- Adjacent-channel interference refers to emissions having frequency components that exist within or near the widest receiver passband.
- Out-of-band interference refers to signals having frequency components which are outside of the widest receiver passband.

From the standpoint of adjacent band interference the radio-frequency (RF) selectivity is the most important parameter. This characteristic defines the frequency region over which interference may generally appear. On the other hand, the intermediate-frequency (IF) selectivity describes the ability of a receiver to discriminate against adjacent channel interference. In combination with the transmitter spectrum mask the RF and IF selectivity are essential for the frequency separation considerations.

If technical characteristics or measured data are not available, a good indicator for the selectivity characteristics of a receiver is given by the ratio of 60 dB bandwidth to 3 dB bandwidth. Receivers with high selectivity may have a shape factor of 2; whereas receivers with low selectivity may have shape factors of greater than 8.

Since the receiver IF selectivity describes the ability of a receiver to discriminate against signals in the widest passband of the receiver, it represents co-channel and adjacent channel interference. This selectivity should be defined by a mask with respect to the bandwidth of reception. For this purpose several combinations of bandwidth and susceptibility threshold levels in dB above sensitivity need to be defined. The maximum value of attenuation of signals should be derived from the fundamental out-of-band selectivity neglecting spurious responses.

2.3.2 Spurious response rejection

In general, receivers are susceptible to out-of-band signals that can generate a spurious response in the receiver. A spurious response may be generated if the frequency of an interfering signal is such that the signal or one of its harmonics can mix with a local oscillator or one of its harmonics to produce an output in the receiver IF passband. The most critical frequency in that respect is the image frequency of a receiver. For consideration of spurious response rejection the susceptibility threshold of the image frequency should be applied. If interference problems due to the image frequency are detected, further investigations are necessary focusing on the real spurious response characteristics of the receivers under consideration. However, this requires detailed information on these characteristics.

2.3.3 Receiver front-end desensitization

Strong interference signals inside the RF bandwidth of a receiver may cause interference, even if the emission is outside the passband of the IF bandwidth. Strong undesired signals inside the RF passband may result in a reduction of gain for the desired signal due to non-linearities in the receiver front end. This effect leads to a reduced S/N ratio of the receiver concerned, if a certain saturation reference power level is exceeded (blocking or desensitization). The interference power level at the front end of a receiver should be calculated by equation (6) integrating over the RF bandwidth.

2.3.4 Receiver intermodulation

Because of non-linearities within a receiver, two or more signals may intermodulate to produce signals at other frequencies. If these new frequencies are close enough to the received frequency band, they may cause interference since these signals are amplified and detected by the same mechanism which processes the desired signal. The purpose for performing intermodulation prediction is to identify pairs of transmitters within the electromagnetic environment that may degrade the performance of a particular receiver due to intermodulation effects.

2.4 Antennas

The antenna models used in the interference calculation should be selected from the following sources:

– ITU-R Recommendations;

– technical standards (e.g. ETSI);

– manufacturers' information (if available).

Polarization effects should be considered, if appropriate.

2.5 Propagation models

The propagation loss between a transmitting station and a victim receiver is one of the key issues of any interference assessment. In order to get a realistic picture of interference scenarios, propagation models should be used, utilizing a topographical database (terrain database and ground cover) to the extent possible. This allows the application of detailed propagation models. Concerning the modelling of the propagation the particular conditions of the applications under consideration have to be taken into account. In this respect, it has to distinguish between several general scenarios:

– point-to-point scenarios,

– point-to-area scenarios,

– in-house penetration scenarios.

If space services are concerned, the special conditions of space-to-Earth propagation paths have to be taken into account.

2.5.1 Point-to-point

In the case of fixed transmitting and victim receiving stations, the propagation loss should be calculated according to Recommendation ITU-R P.452. This Recommendation includes an analytical approach of the propagation conditions of the interference path. The following propagation effects are covered by the Recommendation in accordance with the defined value of time percentage and the frequency band concerned:

– attenuation due to atmospheric gases;

– diffraction;

– tropospheric scatter;

– surface super-refraction and ducting;

– elevated layer reflection and refraction;

– ground clutter site shielding;

– precipitation scatter.

This propagation model allows calculation of the attenuation for a large variety of time percentages, thus it can be applied for short-term and long-term propagation conditions as well.

2.5.2 Point-to-area

When point-to-area interference scenarios have to be considered, appropriate propagation models taking care of the particular conditions should be applied. In frequency bands below 3 GHz Recommendation ITU-R P.1546 may be an appropriate solution.

However, Recommendation ITU-R P.452 also gives a statistical approach of the amount of attenuation derived from additional diffraction losses if antennas are embedded in local ground clutter like buildings or vegetation. This correction model has been made using a conservative approach in recognition of uncertainties over the individual situation of a transmitter or receiver. Depending on the individual situation (antenna height, distance, etc.) the site-shielding effects will lead to attenuation of up to 20 dB. Thus Recommendation ITU-R P.452 may also be applied when investigations of interference scenarios of mobile stations are concerned, especially if scenarios in frequency bands above 3 GHz need to be considered.

Thus for distances below 1 km, Recommendation ITU-R P.1411 – Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz, may be applied. This Recommendation provides both general (i.e. site-independent) models as well as site-specific models.

2.5.3 In-house penetration and propagation

When a base station (BS)/mobile station (MS) in the mobile service or station of any other service is located in a building, additional penetration losses due to external walls (building entry loss) as well as internal walls or floors (penetration loss) have to be expected. However, the value of this penetration loss highly depends on the particular building considered. Since the real structures of the buildings are usually not available, it is not possible to cover all the necessary factors in a given environment in order to exactly calculate the in-house propagation conditions. Hence, there is a need to apply site-general models that require only little path or site information. On the other hand the variety of possible locations of stations inside a building will lead to strong variations of the interference levels as well. Thus various results have to be expected in the several environments. In some cases enormous attenuation will be found, for example in the basements of huge buildings. On the other hand, if outdoor operation (e.g. on roof top or balconies) is assumed, no additional loss will be the result. This leads to variations of up 60 or 70 dB for different situations in the same environment.

Environment, height and the size of the buildings will have a strong impact on the results. On the other hand, the variety of possible locations of stations inside a building will lead to strong variations of the interference levels as well. Thus various results have to be expected in the several environments. Recommendation ITU-R P.1238 – Propagation data and prediction methods for the planning of indoor radiocommunication systems and radio local area networks in the frequency range 900 MHz to 100 GHz, provides a site-general model distinguishing between residential, office and commercial environments. Building entry loss values can be found in Recommendation ITU-R P.679 – Propagation data required for the design of broadcasting-satellite systems.

2.5.4 space-to-Earth

If interference assessments between terrestrial and space stations have to be considered, the propagation loss should be calculated according to Recommendation ITU-R P.619. This Recommendation covers the three principle propagation mechanisms:

– clear air propagation;

– precipitation scatter, and

– differential attenuation on adjacent Earth-to-space paths,

for calculating the propagation loss along space-to-Earth propagation paths for interference assessment purposes.

2.6 Deployment scenarios

In order to conduct sharing studies between mobile services and other radio services in co-frequency and adjacent frequency bands, it is absolutely necessary to consider the fully deployed mobile network, since the large numbers of BSs and MSs operating in the same frequency band may have a strong impact on the results. In cases where future systems have to be considered, simulations of mature deployment scenarios (as realistic as possible) need to be applied for the assessment of interference problems with existing services. The basis of such a simulation methodology of mature future mobile networks is the calculation of the expected communication demand which leads to the necessary network structures in order to accommodate communication demand. The communication demand and the resulting structures of mobile networks may be determined, applying:

– demographic statistics;
– economical structures;
– distribution of inhabitants;
– penetration ratios due to ground clutter classes etc.,

and appropriate market forecast models for the identification of the capacity requirements of mobile service applications as well.

For other services, existing and planned deployment of transmitters and receivers should be considered in the interference calculation process to the extent possible.

3 Assessment of interference scenarios

In the interference calculation procedures between mobile networks and other services it is necessary to distinguish between scenarios of BSs and MSs. The mobility of the MS in combination with the relatively short access period of the MS, leads to the necessity to include these aspects into simulation procedures. On the other hand, the location of the BS is fixed and full-time operation can be expected. This leads to different procedures for the interference calculations of BS and MS.

Furthermore, any assessment process for interference has to take into consideration the special conditions of the radio services concerned:

– systems operating with omnidirectional, vertical high-gain antennas located well above the local clutter (e.g. fixed wireless access central stations, etc.);
– systems operating with high-gain antennas where interference may appear over long distances along the boresight of the antenna (e.g. FS, FSS, radio astronomy, aeronautical radionavigation service, etc.);
– user premises equipment operated in the close vicinity of IMT-2000 terminals;
– systems gathering from or causing interference to huge areas (e.g. space stations in the GSO and non-GSO or airborne systems).

Principally, each scenario requires careful consideration focussing on the dominating physical effects.

3.1 Calculation of interference power spectral density

3.1.1 Interference scenarios for BSs

The interference between BSs in the mobile service and other services should be based on the existing or future planned systems in the service under consideration. In order to get an impression on the various interference situations in the different regions and the deployment of different services, typical scenarios need to be investigated.

Based on the network structures under consideration, all the BSs expected to be in operation in the considered frequency band with a certain maximum distance to victim receiver, have to be analysed:

– calculation of the isolation between the stations under consideration;

– application of time variant processes in order to calculate the time variation of the interference levels (e.g. antenna pointing, propagation conditions);

– calculation of the aggregated interference spectral density level at the victim receiver.

In the case of mobility of the victim receiver or moving/rotating antennas the interference levels will be time variant. Thus, for the assessment of potential interference, it is necessary to investigate variation of the interference levels with time. In order to get stable cumulative distributions of the interference levels, it might be necessary to calculate several scenarios depending on the characteristics of the victim receiver. Neglecting the time variant process and real propagation conditions (means application of free space conditions) as well, will lead to the worst-case scenario. These values should always be compared with the worst-case potential interference based on main beam-to-main beam coupling and free space path loss conditions.

3.1.2 Interference scenarios of MSs

In comparison to the interference scenarios of BSs, the investigation of the interference between MS and stations of other services is generally more complicated. The main problem is the fact that MS will not be operated 24 h/day and they will be operated in motion as well.

In order to calculate the interference scenarios between MS and stations of other services, appropriate methodologies need to be applied. The mobile users should be distributed randomly in the region under consideration, with respect to defined penetration rates in the different areas. For each considered point in time the interference potential needs to be investigated:

– the active MSs are selected randomly out of the assumed population of users, with respect to assumptions concerning station call duration and probability and power control mechanisms of mobile systems, and the time variant cell capacity requirements in the cell under consideration;

– calculation of the isolation between all combinations of stations of the services under consideration (active users in the MS and other service stations expected to be in operation);

– calculation of the aggregated interference spectral density levels at victim receiver.

Depending on the interference scenarios under consideration, especially if time variant conditions have to be applied to both services, an enormous number of interference calculations have to be carried out in order to get a stable cumulative distribution of the interference scenario. These values should always be compared with the worst-case potential interference based on main beam-to-main beam coupling and free space path loss conditions.

If interference duration aspects are important to assessing the potential for interference, MS mobility and call access and duration need to be considered.

3.2 Probability of interference

The cumulative distribution of the interference power spectral density at the input of a victim receiver allows assessment of the probability of interference with respect to the tolerable interference levels of the service under consideration. Depending on the service requirements, the following philosophies of interference consideration may be applied, for the receiving station of a certain service:

– the tolerable interference level is referred to the inherent receiver noise level defining a certain amount of C/N degradation (I/N concept);

– the tolerable interference level is referred to the required wanted signal level (C/I concept).

For systems in some services, the effects of short-term interfering signals may also be important. In such cases, not only the probability of an interference event but also its duration and impact upon the performance of the victim receiver should be evaluated.

3.3 Coexistence consideration

The main question to be answered in any interference assessment consideration in co-frequency and adjacent band scenarios is the required separation in frequency and geographical distance in order to avoid harmful interference into the receivers under consideration.

In co-frequency scenarios, a certain geographical separation is necessary to reduce the interference signal to a tolerable level which is acceptable for a certain service. On the other hand, a frequency separation which reduces the interference signal in the receiver bandwidth to the level of spurious emissions may be appropriate to avoid harmful interference as well. This guardband depends on the spectral density of the emission in combination with the filtering ability of the affected receiver. In cases where high power applications and/or sensitive receivers have to be considered, the definition of a simple guardband may not be sufficient for all cases. Thus in such cases an additional geographical separation needs to be defined.

3.3.1 Guardband

The required frequency separation between emission and reception band is essential for the guardband considerations between two services. In order to achieve the maximum attenuation of an interfering signal within the passband of a receiver the following condition has to be met:

$$\Delta f = (2.5 \cdot B_{Tx}) / 2 + B_{Rx60} / 2 \qquad (9)$$

where:

Δf: frequency separation

B_{Tx}: emission bandwidth

B_{Rx60}: 60 dB receiver I-F bandwidth.

In many cases, not the full frequency separation is necessary to reduce interfering signals to the tolerable level of a receiver. Depending on spectral density of the unwanted emission and the filtering ability of the affected receiver, lower frequency separations may be appropriate according to the following conditions:

$$\int_{f_1}^{f_2} P_I(f + \Delta f, \ p) \, \mathrm{d} f \leq P_{tol} \tag{10}$$

where:

$P_I(f + \Delta f, p)$: aggregated interference spectral density at receiver

f_1: lower edge of 60 dB receiver I-F bandwidth

f_2: upper edge of 60 dB receiver I-F bandwidth

Δf: frequency separation

P_{tol}: tolerable aggregated interference power of receiver.

3.3.2 Geographical separation

Depending on the requirement concerning isolation due to the propagation conditions, the necessary geographical separation may be calculated, in order to reduce an interfering signal to the tolerable level of a receiver.

The worst-case level of separation distance is determined by the free-space propagation conditions. However, this may lead to large distances, which are in many cases unrealistic. On the other hand, the probability of interference is reduced to its theoretical minimum.

Systems in some radio services are designed with respect to an availability of service depending on their mission. Thus the tolerable interference for a receiver has to be defined with respect to its availability target. Considering realistic interference scenarios will take care of the requirements of the affected service and the efficient use of spectrum resources as well. Applying the cumulative distribution of aggregated interference in order to define the necessary geographical separation may be the more appropriate solution since it leads to lower and more realistic geographical separations. On the other hand, the risk of interference is aligned with the protection criterion. Thus a more spectrum efficient approach is available. The applicability of either approach referred to above should be evaluated with respect to the technical and operational requirements of systems in the various radio services.