RECOMMENDATION ITU-R SM.1751-0*

An additional methodology for the evaluation of the effect of interference between radiocommunication networks operating in a shared frequency band

(2006)

Scope

This Recommendation offers an additional methodology for the evaluation of the effect of interference between radiocommunication networks operating in a shared frequency band.

Keywords

Shared frequency band, energy margin loss, methodology, interference evaluation

The ITU Radiocommunication Assembly,

considering

a) that the development of radiocommunication facilities could cause an increase in the mutual interference between radiocommunication networks working in the same frequency band;

b) that setting maximum acceptable emission parameters determining the value of interference caused to other radiocommunication networks is one of the most important ITU-R tasks;

c) that mutually acceptable emission levels are commonly a result of compromise;

d) that the ITU-R goal is to provide radiocommunication services with access to the spectrum on an equitable basis;

e) that to evaluate the effect of interference, various methodologies have been used which are based on assessing the signal quality at the radiocommunication channel output, channel unavailability, increase in the receiving link noise, etc., which makes such evaluations incomparable,

recommends

1 that when evaluating and comparing the effect of interference caused by other networks or radiocommunication systems operating in a shared frequency band, the energy margin loss (EML) methodology may be used by administrations as an additional tool for guidance in assessing and comparing the effects of interference. The methodology is equal to the relative value of the energy budget increase which would be necessary to preserve in the interfered link the performance and availability objectives which existed before the appearance of the interference (see Annex 1);

2 that the EML methodology should in no way replace or exclude the use of other methodologies for radio-system sharing that are contained in the Radio Regulations and in the existing ITU-R Recommendations;

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* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the year 2019 in accordance with Resolution ITU-R 1.

3 that the EML methodology should not be used by the Bureau in any technical and/or regulatory examination of any notice submitted to it;

4 that the EML methodology should not be used to evaluate the effect of interference on passive services;

5 that the following Notes should be considered as part of this Recommendation.

NOTE 1 – That in the event when the values of the wanted signal and interference powers are time-variant, it is appropriate to determine the value of EML which would preserve both long-term and short-term performance and availability objectives, and the maximum value of EML should be used to evaluate the effect of interference.

NOTE 2 – That in the event when the values of the wanted signal and/or interference powers are different for various cases of the location of mutually affecting networks (e.g. when these values depend on the location of stations of the networks on the Earth's surface or in the space), it is necessary to determine and take into account not only the maximum and average EML values but also the EML value providing for the necessary performance objective for the agreed percentage of situations.

NOTE 3 – That when considering the effect of additional interference on a radiocommunication link or system where a certain set of internal or external interference already exists, the noise power which existed before the appearance of the interference under consideration should mean the sum of the thermal noise and existing interference, i.e. the EML value caused by the effect of the additional interference should be determined.

NOTE 4 – That the EML value should be calculated in each specific frequency-sharing case taking into account the wanted and interfering signal properties (statistical and others) and corresponding performance objectives.

NOTE 5 – That the EML value should be calculated for the approved reference mutually interfering networks of the agreed structure and with the parameters (or a set of parameters) typical for these networks.

NOTE 6 – That the EML constitutes a calculated value directly indicating the effect of interference for comparing these effects in different cases, but it does not mean the need to increase the interfered-with link energy budget in all cases.

Annex 1

General provisions of methodology for calculation of EML for the evaluation of effect of the interference between radiocommunication networks operating in the shared frequency band

To calculate EML, for the interfered-with link, performance or availability objectives PO_n are required to be known (if established by appropriate regulations) or set (if these objectives are under consideration) for corresponding probability (per cent of time) value F_n when these objective values may be exceeded.

Taking into account signal transmission (modulation, encoding, etc.) and demodulation methods, existing formulas or experimental data make it possible to determine values r_n of the signal-to-noise ratio $r = C/N_\Sigma$ providing for the prescribed PO_n values.

Here N_Σ represents the sum of thermal noise and interferences affecting the victim link before the occurrence of the interference under study $N_\Sigma = N + \Sigma I_0$ converted to the receiver of the last link's terminal.

General solution

Cumulative time-distribution functions $F(C)$, $F(I)$ of signal $C(t)$ and interference $I(t)$ (whose effect is being studied) should be determined. Thermal noise-time variation is generally ignored.

Signal and interference time-variations are known to be caused by changes in signal propagation conditions (atmospheric precipitation, multipath propagation), change of distance from signal and interference transmitters (satellite movement, station mobility), etc.

Based on distribution functions $F(C)$, $F(I)$ of signal $C(t)$ and interference $I(t)$ it is necessary to plot both the distribution function $F(r_0)$ of the signal-to-noise ratio $r_0 = C(t)/N_\Sigma$ which differs from $F(C)$ in argument scale only, and the distribution function $F(r_i)$ for the ratio of the signal to the sum of noise and evaluated interference $r_i = C(t)/(N_\Sigma + I(t))$. The distribution function $F(r_i)$ is calculated using the known equations of probability theory for a distribution function of the ratio of two random values with known distribution functions.

Note that there is a one-to-one correspondence between performance objectives PO and signal to noise ratio r. Therefore the condition for providing the necessary PO value with the probability (per cent of time) $(1 - F_n)$ exactly coincides with the condition $r \geq r_n$ with the same probability (for the same per cent of time). Based on it, the EML evaluation can be made with the help of distribution functions $F(r_0)$, $F(r_i)$ without calculating performance objective distribution functions. To clarify this important point: when any given performance objective value may be violated with probability F_n, it is necessary and sufficient to keep the signal-to-noise plus interference ratio lower than the corresponding value r_n with the same probability F_n. (In this document the cumulative distribution functions $F(r_0)$, $F(r_i)$ mean $F(r \leq r_0)$, $F(r \leq r_i)$.)

Based on the above, the EML value for the performance objective PO_n determined with the probability F_n of violating this value:

$$EML_n = 10 \log[(C_0 + \Delta C)/C_0] = r_0(F_n) - r_i(F_n) \qquad \text{dB} \qquad (1)$$

where $r_0(F_n)$, $r_i(F_n)$ are the values of the signal-to-noise ratio and the signal-to-noise plus interference ratio with the probability F_n established for the performance objective (also expressed in dB), C_0 is the nominal value of the useful signal power. Equation (1) is well illustrated by Fig. 1, where r_n is the threshold value of the signal-to-noise ratio corresponding to the necessary value of the performance objective with the probability F_n, M_0 is the energy margin in the absence of the interference under evaluation, M_i is the energy margin in the presence of the interference, $F(r_i^1)$ is the function of $F(r_i)$ with the signal power increased by the EML value.

Evidently, this equation is valid for any given probability value F, i.e. both for short-term and for long-term performance objectives. If several values of performance objectives are set for different probabilities F_n, the calculation should be made for each of them and the largest EML value should be selected.

If the value of the signal and/or interference is not only time-varied but also depends on other factors, e.g. on the location of the station in the service area, it would be necessary to determine the EML distribution for a set of situations or to confine ourselves with the determination of EML values exceeded in a certain per cent of situations and to evaluate the damage caused by the interference based on these values. A more general approach consists in plotting generalized distribution functions $F(r_0, L)$, $F(r_i, L)$ taking into account the change in the signal-to-noise and interference ratio in time and depending on situations (L). Then the calculation using equation (1) would give the EML value for a given probability taking into account both factors – time and station location.

Analysis of simple situations

1 Let us consider the simplest case when the signal C and interference I are time-invariant, i.e. $C = const$, $I = const$, $N = const$, as it is usually accepted for calculating mutual interference between geostationary-satellite networks.

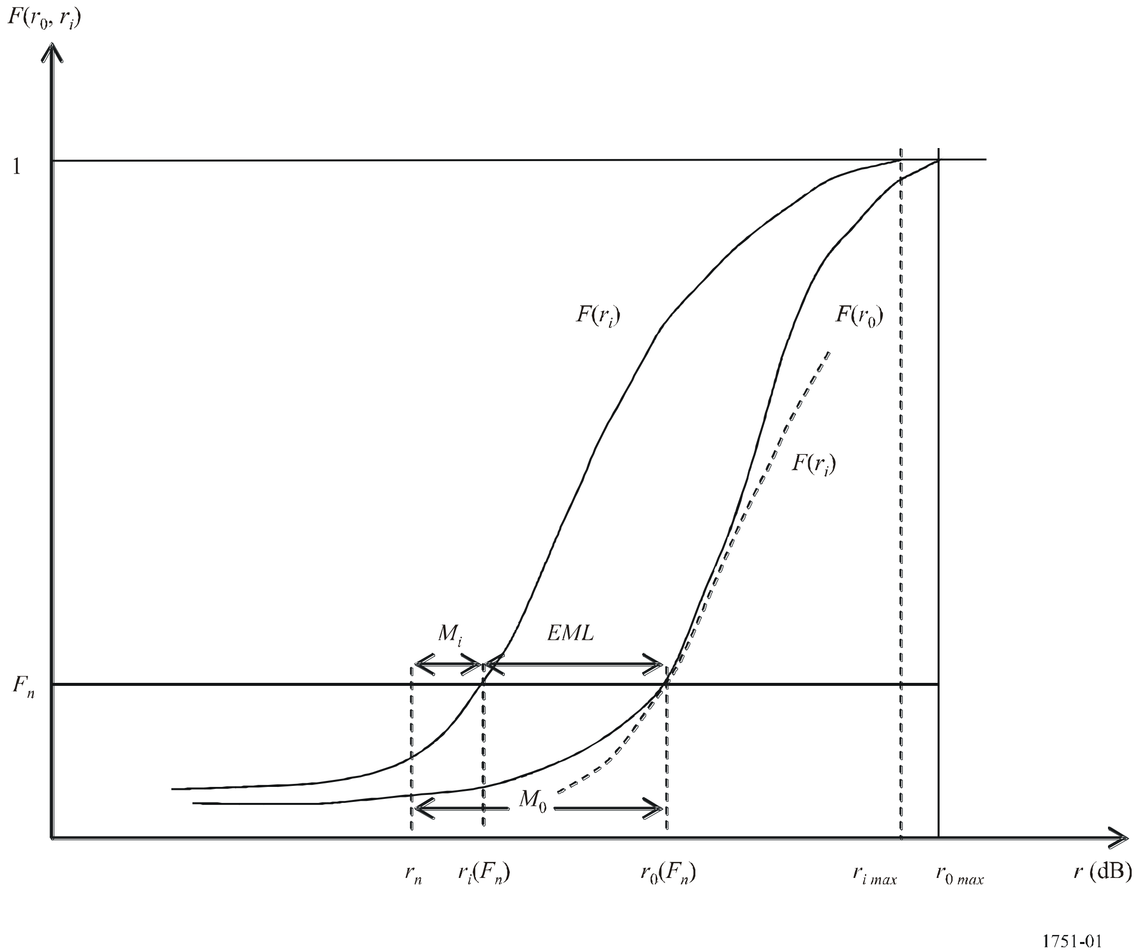
In this case $F(r_0)$ and $F(r_i)$ become δ-functions located at $r_0 = C/N_\Sigma$ and at $r_i = C/(N_\Sigma + I)$ and for any probability F:

$$EML = 10\ \log\left[\frac{C / N_\Sigma}{C /(N_\Sigma + I)}\right] = 10\ \log\,(1 + I / N_\Sigma) \tag{2}$$

2 Another simple case is the one of constant interference ($I = const$) with a time-variant signal ($C(t) = var$), e.g. for the interference to a terrestrial microwave link caused by a geostationary satellite.

In this case $F(r_i)$ has the same form as $F(r_0)$ differing in the change of the argument by the value of $(N_\Sigma + I)/N_\Sigma$ (i.e. with a shift to the left by this value shown in Fig. 1). It means that EML has the same value for any probability F, i.e. it is the same for the long- and short-term criterion calculation and can be evaluated by the simple equation (2).

FIGURE 1



3 In the case of a constant signal ($C = const$) and variable interference ($I(t)$ = var) (e.g. an interference to a geostationary-satellite earth station caused by a microwave link) $F(r_0)$ is a δ-function located at r_0, and $F(r_I)$ is determined only by interference distribution. In this case general equation (1) should be used.

NOTE 1 – As usual, the difference in the signal and interference spectrum should be considered taking into account a part of the power of the interference occurring in the receiver bandwidth. If necessary, the Gaussian distribution noise and the interference which is a modulated carrier can be summed taking into consideration the difference in their statistical characteristics and therefore the difference effect on the demodulation result (e.g. on the error probability); this difference is usually ignored in calculations connected with the electromagnetic compatibility.