RECOMMENDATION ITU-R SM.1134*

INTERMODULATION INTERFERENCE CALCULATIONS IN THE LAND-MOBILE SERVICE

(Question ITU-R 44/1)

(1995)

The ITU Radiocommunication Assembly,

considering

a) that, in the most typical cases, the major factors which determine interference in the land-mobile service include:

– in-band intermodulation products which are generated by two (or more) high-level interfering signals;

– unwanted emission that can occur in a transmitter when any other signal from another transmitter is also presented at the input of RF stages of the influenced transmitter;

– the wanted and interfering signal levels are random variables which have a log-normal distribution;

b) that two (or more) unwanted signals must have specific frequencies so that the intermodulation products fall into the frequency band of a receiver;

c) that the probability of occurrence of intermodulation interference due to more than two high-level unwanted signals is very small;

d) that the intermodulation interference calculation procedure will offer a useful means of promoting efficient spectrum utilization by the land-mobile service,

recommends

1 that the receiver intermodulation model presented in Annex 1 should be used for intermodulation interference calculations in the land-mobile service;

2 that intermodulation interference calculations should follow the following procedure, details of which are presented in Annex 1;

2.1 to determine mean value and dispersion of a random wanted signal power at the receiver input;

2.2 to determine mean value and dispersion of a random intermodulation interference signal power at the receiver input;

2.3 to determine the probability that the intermodulation products generated both in the receiver itself and as a result of the intermodulation in the transmitter will occur during the reception;

3 that the zones affected by intermodulation interference and relevant necessary geographical separation of interfering transmitters and receivers should be determined on the basis of a given value of the interference probability, as it is described in Annex 1.

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* This Recommendation should be brought to the attention of Radiocommunication Study Group 8.

ANNEX 1

Intermodulation models

This Annex describes two intermodulation models; the receiver intermodulation (RXIM) model and the transmitter intermodulation (TXIM) model. It is divided into five sections.

Section 1 outlines the general formula for calculating receiver intermodulation interference. Section 2 describes the RXIM measurement procedure. Section 3 outlines a procedure for evaluating receiving intermodulation interference using the general formula. Section 4 outlines the formula for transmitter intermodulation interference. Section 5 describes how the probabilities of RXIM and TXIM interference are calculated.

1 Receiver intermodulation analysis model

The two-signal, third-order intermodulation interference power is given by the following formula (ex-CCIR Report 522-2, Düsseldorf, 1990):

$$P_{ino} = 2(P_1 - \beta_1) + (P_2 - \beta_2) - K_{2,1} \tag{1}$$

where:

- P_1 and P_2 : powers of the interfering signals at frequencies f_1 and f_2, respectively
- P_{ino} : power of the third-order intermodulation product at frequency f_0 ($f_0 = 2f_1 - f_2$)
- $K_{2,1}$: third-order intermodulation coefficient, may be computed from third-order intermodulation measurements or obtained from equipment specifications
- β_1 and β_2 : RF frequency selectivity parameters at frequency deviations Δf_1 and Δf_2 from the operating frequency f_0, respectively.

The values of β_1 and β_2 for example can be obtained from the equation to calculate the attenuation of a signal at an off-tune frequency.

$$\beta(\Delta f) = 60 \log \left[1 + \left(\frac{2 \Delta f}{B_{RF}} \right)^2 \right] \tag{2}$$

where B_{RF} is the RF bandwidth of the receiver.

It is worth noting that for a particular set of third-order intermodulation measurements for land mobile analogue radio receivers operating in the VHF and lower UHF bands, equation (1) may be manipulated to derive the following formula [McMahon, 1974]:

$$P_{ino} = 2P_1 + P_2 + 10 - 60 \log (\sigma f) \tag{3}$$

where σf is the mean frequency deviation (MHz) and is equal to:

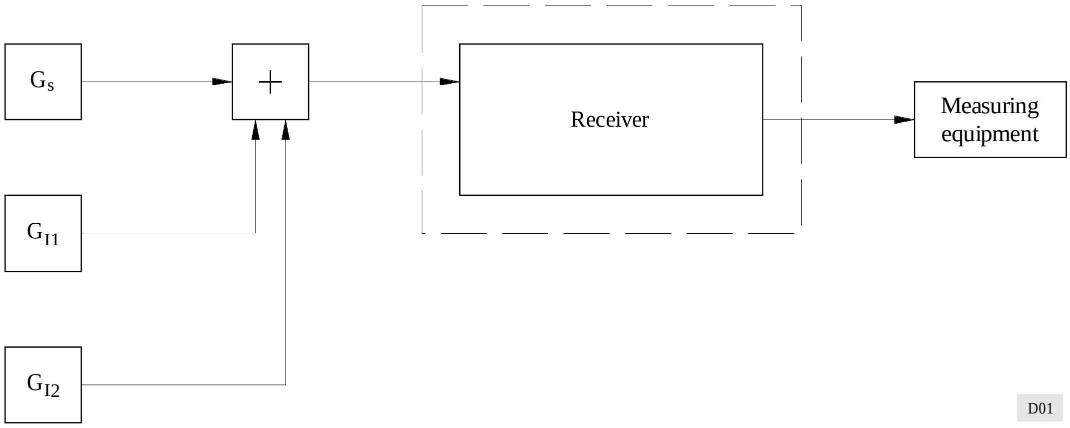
$$\frac{\Delta f_1 + \Delta f_2}{2}$$

2 Receiver intermodulation interference characteristics

In Fig. 1, G_s is the signal generator of the wanted signal (WS). G_{I1} and G_{I2} are the signal generators of the interfering signals (IS) which constitute the RXIM product. These signals are applied to the input of the receiver (RX).

FIGURE 1

Block diagram for receiver intermodulation measurements



When measuring the RX intermodulation characteristic, there are two IS with equal levels from the generators G_{I1} and G_{I2} and the WS with level P_{sr}, from the generator G_s that are carried to the RX input. The frequency detuning of the first IS is chosen equal Δf_0, as for the second IS – it is approximately equal $2\Delta f_0$. The level of both IS at the RX input is increased until $P_I(IM)$ is reached when the reception quality of the WS should not reduce below a specified value. The reception quality is definitely connected with protection ratio A.

Note that:

P_{sr}: sensitivity of radio receiver (dBW)

$P_I(IM)$: the sensitivity to intermodulation, that was measured for the receiver (dBW).

Therefore, according to equation (1):

$$P_{ino} = 3P_I(IM) - 2\beta(\Delta f_0) - \beta(2\,\Delta f_0) - K_{2,1} \tag{4}$$

This level is related to P_{sr} as follows:

$$P_{sr} - A = P_{ino} \tag{5}$$

$K_{2,1}$ is therefore:

$$K_{2,1} = 3P_I(IM) - 2\beta(\Delta f_0) - \beta(2\,\Delta f_0) - P_{sr} + A \tag{6}$$

3 Procedure for receiver intermodulation analysis

Interference caused by third-order intermodulation products in the receiver occurs when the following two conditions are fulfilled:

$$-\frac{B_{FI}}{2} < 2\,\Delta f_1 - \Delta f_2 < \frac{B_{FI}}{2} \tag{7}$$

and:

$$P_s - P_{ino} < A \tag{8}$$

where:

$\Delta f_1, \Delta f_2$: frequency detuning of interfering signals

B_{IF}: IF receiver bandwidth (in the same units as Δf_1 and Δf_2)

P_{ino}: equivalent on-tune interference power (dBm)

P_s: desired signal power (dBm)

A: co-channel protection ratio (dB).

P_{ino} is given by equation (1). In view of equation (1), condition (8) may be rewritten as:

$$2P_1 + P_2 - P_s > R_0 \tag{9}$$

where:

$$R_0 = -A + 2\beta_1 + \beta_2 + K_{2,1} \tag{10}$$

4 Power of transmitter intermodulation products

The power P_i of the intermodulation product occurring in the transmitter and subsequently reaching the receiver input may be written as:

$$P_i = P_2' - \beta_{12} - \beta_{10} - K_{(2),1} - L_{10} \qquad \text{dBW} \tag{11}$$

where:

- P_2': interfering transmitter power (with frequency f_2) at the output terminals of the affected transmitter (with frequency f_1), in which the intermodulation products occur (dBW)
- β_{12}, β_{10}: attenuation due to the output and antenna circuits of the affected transmitter at frequency f_1 to interfering transmitter at frequency f_2, and to intermodulation product at frequency f_0, respectively (dB)
- $K_{(2),1}$: intermodulation conversion losses in the transmitter (dB) which is different from $K_{2,1}$ in equation (1)
- L_{10}: attenuation of intermodulation product on the path between the transmitter with frequency f_1 and the receiver (dB).

Interference caused by TXIM occurs when:

$$P_s - P_i < A \tag{12}$$

where A is the co-channel protection ratio.

5 Probability of interference

5.1 Probability of RXIM interference

Recommendations ITU-R P.370, ITU-R P.1057 and ITU-R P.1146 point out that, due to fading, the wanted and interfering signal levels are random variables with a log-normal distribution. Hence, the left side of condition (9), expressed in dBW, represents the sum of independent normal random quantities and constitutes a normal random quantity. The mean value $\bar{R}$ and dispersion σ_R^2 of the random quantity $R = 2P_1 + P_2 - P_s$ are equal, respectively, to:

$$\bar{R} = 2P_{1m} + P_{2m} - P_{sm}$$

$$\sigma_R^2 = 4\sigma_1^2 + \sigma_2^2 + \sigma_s^2$$

where:

P_{1m}, P_{2m}, P_{sm} are mean values and σ_1^2, σ_2^2, σ_s^2 are dispersions of wanted and interfering signal power levels at the receiver input (determined on the basis of the data contained in ITU-R P.370, ITU-R P.1057 and ITU-R P.1146.

5.2 Probability of TXIM interference

Taking account of equation (11), condition (12) assumes the form:

$$P_2' - P_s - L_{10} > T_0 \tag{13}$$

where:

$$T_0 = \beta_{12} + \beta_{10} + K_{(2),1} - A$$

The mean value $\overline{T}$ and dispersion σ_T^2 of the random quantity:

$$T = P_2' - P_s - L_{10}$$

are equal respectively to:

$$\overline{T} = P_{2m}' - P_{sm} - L_{10m}$$

$$\sigma_T^2 = \sigma_2^2 + \sigma_s^2 + \sigma_1^2$$

where:

P_{2m}', P_{sm}, L_{10m} : mean values

σ_2^2, σ_s^2, σ_1^2 : dispersions of the random quantities P_2', P_s and L_{10}.

5.3 Probability of intermodulation products

The probability α that intermodulation products, generated both in the receiver itself and as a result of intermodulation in the transmitter (conditions (9) and (13), respectively), will occur during reception is equal to:

$$\alpha = \int_x^\infty e^{-t^2/2} \frac{dt}{\sqrt{2\pi}} \quad (14)$$

$x = (R_0 - \overline{R}) / \sigma_R$: on determination of the probability of intermodulation products occurring in receivers (condition (9))

$x = (T_0 - \overline{T}) / \sigma_T$: on determination of the probability of interference due to intermodulation products occurring in transmitters (condition (13)).

In determining the zones affected by intermodulation interference on the basis of a given value of probability of interference α, the value of x is first determined from equation (14). Then for a known value of P_{sm} one can determine the permissible values of P_{1m} and P_{2m} (or P_{2m}' and L_{10m}) and the corresponding necessary geographical spacings of interfering transmitters and receiver, on which the zone affected by the interference will depend.

NOTE 1 – Additional information may be found in:

McMAHON, J.H. [November 1974] Interference and propagation formulas and tables used in the Federal Communications Commission Spectrum Management Task Force Land Mobile Frequency Assignment Model. *IEEE Trans. Vehic. Techn.*, Vol. VT-23, **4**, 12-134.

BYKHOVSKY, M.A. and MERMELSTEIN, D.V. [1990] Analysis of receiver EMC with regard to blocking, intermodulation and crosstalk. *NIIR Proc*., **4**, 11-15.