

RECOMMENDATION ITU-R SM.337-6

Frequency and distance separations

(1948-1951-1953-1963-1970-1974-1990-1992-1997-2007-2008)

Scope

This Recommendation provides the procedures for calculating distance and frequency separations for an acceptable interference level.

The ITU Radiocommunication Assembly,

considering

- a) that, in the more usual cases, the primary factors which determine appropriate frequency or distance separation criteria include:
 - the signal power and spectral distribution required by the receiver;
 - the power and spectral distribution of the interfering signals and noise intercepted by the receiver;
 - the distance dependence of the transmission losses of the radio equipments;
- b) that transmitters, in general, emit radiations outside the frequency bandwidth necessarily occupied by the emission;
- c) that many factors are involved, among which are the properties of the transmission medium (which are variable in character and difficult to determine), the characteristics of the receiver and, for aural reception, the discriminating properties of the human ear;
- d) that trade-offs in either frequency or distance separations of the radio equipment are possible,

recommends

- 1 that the frequency-distance (FD) separations of radio equipment should be calculated by the following method:
 - 1.1 determine the power and spectral distribution of the signal intercepted by the receiver;
 - 1.2 determine the power and spectral distribution of the interfering signals and noise intercepted by the receiver;
 - 1.3 determine the interactive effects among wanted signals, interference and receiver characteristics for various frequency or distance separations by using the basic equations given in Annex 1 along with, if necessary, simple approximations to the integral expressions and the concept described in Annex 2;
 - 1.4 determine, from these data, the degree of frequency or distance separation that will provide the required grade of service and the required service probability. Account should be taken of the fluctuating nature both of the signal and of the interference, and, whenever appropriate, the discriminating properties of the listener or viewer;

- 1.5 determine the appropriate ITU-R propagation model to be used;
- 2 that, at every stage of the calculation, comparison should be made, as far as possible, with data obtained under controlled representative operating conditions, especially in connection with the final figure arrived at for the frequency or distance separation among radio equipment.

Annex 1

Basic equations

This Annex describes basic equations which quantify the interactive effects among wanted signals, interference, and receiver characteristics for various frequencies and FD separations. The measures are:

- frequency dependent rejection (FDR) which is a measure of the rejection produced by the receiver selectivity curve on an unwanted transmitter emission spectra;
- FD which is a measure of the minimum distance separation that is required between a victim receiver and an interferer as a function of the difference between their tuned frequencies;
- relative radio-frequency protection ratio A (see Recommendation ITU-R BS.560) which is the difference (dB) between the protection ratio when the carriers of the wanted and unwanted transmitters have a frequency difference of Δf and the protection ratio when the carriers of these transmitters have the same frequency.

The FD and FDR are measures of the interference coupling mechanism between interferer and receiver and are the basic solutions required for many interference evaluations. They aid in the solution of co-channel frequency sharing and adjacent band or channel interference problems by providing estimates of the minimum frequency and distance separation criteria between interferer and receiver which are required for acceptable receiver performance.

The interference level at the receiver is a function of the gains and losses the interference signal will incur between the source and the receiver and is expressed by:

$$I = P_t + G_t + G_r - L_b(d) - FDR(\Delta f) \quad \text{dBW} \quad (1)$$

where:

- P_t : interferer transmitter power (dB)
 G_t : gain of interferer antenna in direction of receiver (dBi)
 G_r : gain of receiver antenna in direction of interferer (dBi)
 $L_b(d)$: basic transmission loss for a separation distance d between interferer and receiver (dB) (see Recommendation ITU-R P.341)

and

$$FDR(\Delta f) = 10 \log_{\infty} \frac{\int_0^{\infty} P(f) df}{\int_0^{\infty} P(f) |H(f + \Delta f)|^2 df} \quad \text{dB} \quad (2)$$

where:

$P(f)$: power spectral density of the interfering signal equivalent intermediate frequency (IF)

$H(f)$: frequency response of the receiver

$$\Delta f = f_t - f_r$$

where:

f_t : interferer tuned frequency

f_r : receiver tuned frequency.

The FDR can be divided into two terms, the on-tune rejection (OTR) and the off-frequency rejection (OFR), the additional rejection which results from off-tuning interferer and receiver.

$$FDR(\Delta f) = OTR + OFR(\Delta f) \quad \text{dB} \quad (3)$$

where:

$$OTR = 10 \log \frac{\int_0^{\infty} P(f) df}{\int_0^{\infty} P(f) |H(f)|^2 df} \quad \text{dB} \quad (4)$$

$$OFR(\Delta f) = 10 \log \frac{\int_0^{\infty} P(f) |H(f)|^2 df}{\int_0^{\infty} P(f) |H(f + \Delta f)|^2 df} \quad \text{dB} \quad (5)$$

The on-tune rejection also called the correction factor, can often be approximated by:

$$OTR \approx K \log \left(\frac{B_T}{B_R} \right) \quad B_R \leq B_T \quad (6)$$

where:

B_R : interfered receiver 3 dB bandwidth (Hz)

B_T : interferer transmitter 3 dB bandwidth (Hz)

$K = 20$ for non-coherent signals

$= 20$ for pulse signals.

Annex 2

Methodology to determine frequency and distance separation for radio systems

1 Introduction

It is well known that FD rules are an important part of the frequency management process in most radio services. In channelized services, these rules take the following form: co-channel transmitters must be separated by at least d_0 (km), the adjacent channel transmitters must be separated by at least d_1 (km), transmitters separated by two channels must be at least d_2 (km) away and so on. For older technologies the FD rules are usually well known by now. However, the introduction of new technologies raises the question: what kind of FD rules a spectrum manager should apply when new and old systems occupy the same frequency band? The methodology that is required to determine FD separation rules between both similar and dissimilar systems is given below.

2 Methodology

The development of a new FD rule requires the computation of the level of interference at the input of the victim receiver, and also requires the definition of an acceptable interference criterion.

2.1 Interference computation

This depends on two primary factors: a spectral factor and a spatial factor.

The *spectral factor* depends on the spectral characteristics of the interfering transmitter and the frequency response of the victim receiver. For computational purposes one must have accurate knowledge of the power spectral density of the interfering signal which depends on factors such as the underlying modulation technique and the bandwidth of the information signal for analogue systems and the transmitted data rate in the case of digital systems.

As far as the victim receiver is concerned, one must know the equivalent IF frequency response characteristics of the receiver. Manufacturer's specifications such as the 6 dB and the 40 dB bandwidth of the IF stage may be used as a basis for modeling the receiver's IF frequency response.

The spectral factor is represented by the off-channel-rejection factor $\text{OCR}(\Delta f)$, which is defined by the following relationship:

$$\text{OCR}(\Delta f) = -10 \log \frac{\int_{-\infty}^{+\infty} P(f) |H(f + \Delta f)|^2 df}{\int_{-\infty}^{+\infty} P(f) df} \quad \text{dB} \quad (7)$$

where:

$P(f)$: power spectral density of the interfering signal in (W/Hz)

$H(f)$: equivalent IF frequency response of the victim receiver

Δf : frequency separation between the victim receiver and the interfering transmitter.

Note that equation (7) is not different from equation (2), even though the lower limits of integration are different.