

RECOMMENDATION ITU-R SM.1271

EFFICIENT SPECTRUM UTILIZATION USING PROBABILISTIC METHODS

(Question ITU-R 45/1)

(1997)

The ITU Radiocommunication Assembly,

considering

- a) that communications technology has advanced rapidly during the past decade and the use of radiocommunication services by administrations has multiplied and placed new demands on the radio spectrum;
- b) that frequency sharing is one of the important aspects of efficient frequency spectrum utilization;
- c) that many guidelines and sharing criteria are based on the most unfavourable interference assumptions;
- d) that more efficient spectrum utilization may depend on the acceptance of performance criteria developed through the application of probabilistic methods;
- e) that the statistical characteristics of both the desired and interference signals would be necessary to evaluate spectrum sharing situations and spectrum utilization against performance standards;

recommends

- 1 that in order to achieve more efficient spectrum utilization, administrations should consider the use of the probability of interference and its impact on system performance.
- 2 that in order to assess fully the interference potential of introducing a new system into the environment, the probability of interference due to multiple interference sources should be considered using techniques such as those shown in Annex 1 and for calculation a probability of interference for base to mobile and mobile to base interference modes in a land mobile duplex system a methodology given in Annex 2 should be used.

NOTE 1 – Future examples will be included to explain how probabilistic methods be used to estimate characteristics of desired and interfering signals with the objective of increasing spectrum utilization.

ANNEX 1

(Example 1)

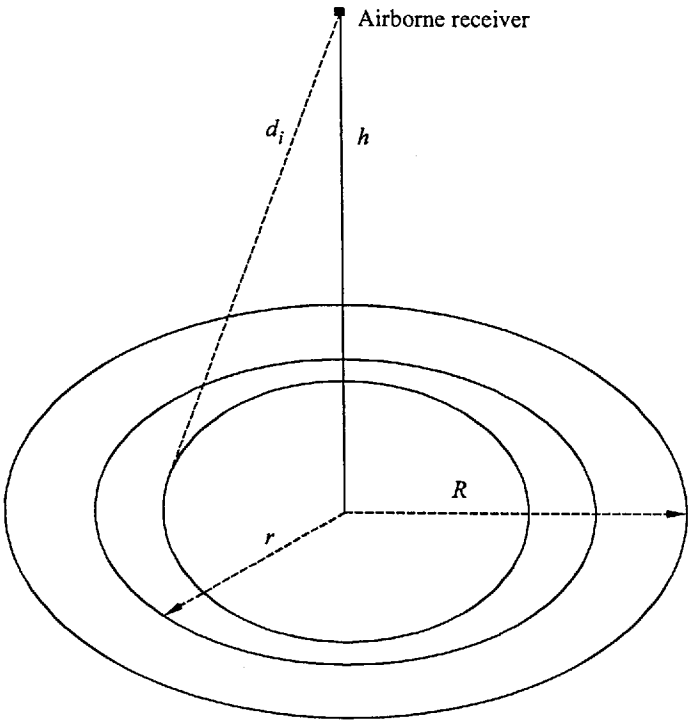
The calculation of the received voltage due to the radiation from multiple co-frequency sources

1 Introduction

There are many frequency sharing situations where interference may occur. In some situations the number and location of possible interfering sources are not known (e.g. when the interference is from land-mobile radio transmitters). In these situations, interference can be estimated using probabilistic methods.

This example describes a method that clearly demonstrates the concept of calculating interference levels due to multiple sources using probabilistic methods. Consider, for the sake of simplicity, the case of an airborne receiver flying over an urban area. In this particular case the effects of the earth curvature can be neglected. The airborne antenna will be assumed to be a half-wave dipole with a cosine pattern. The N interfering sources are assumed to be uniformly distributed over the area which is assumed to be circular of radius R as shown in Fig. 1.

FIGURE 1
Airborne receiver over an urban area with uniformly distributed interference sources



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The objective will be to derive a simple expression for the probability density function of the received r.m.s. voltage at the receiving antenna terminals. This example is based on several simplifying assumptions as follows:

- The number of the interfering transmitters, N , is large.
- The interfering transmitters are uniformly distributed, in geographical terms, over a circular area of radius R .
- All interfering transmitters have equal amount of radiated power.
- The receiver, which is subjected to interference from all the mobiles, is airborne at an altitude h , directly above the centre of the circular area that contains all the interfering sources.
- The propagation law from any interferer to the airborne receiver is approximated by the free-space propagation rule.

2 The method

Considering the airborne receiver now flying over the urban area, the voltage at the receiving antenna terminals can be written as follows:

$$V = \sum_{i=1}^N C_A A(d_i) K_i e^{j\phi_i} \tag{1}$$

C_A is the relationship between the field strength at an antenna and the voltage across its terminals when matched to a 50Ω load:

$$C_A = \frac{\lambda}{2\pi} \sqrt{\frac{50}{73}} \quad (2)$$

$A(d_i)$ is the complex antenna factor which is related to the interferer-to-antenna distance d_i as follows:

$$A(d_i) = a(d_i) e^{ja(d_i)} \quad (3)$$

K_i and φ_i are the amplitude and phase of the field at the receiving antenna due to interferer i and are defined as follows:

$$K_i = E_L \left(\frac{d_L}{d_i} \right) K_s \quad (4)$$

where E_L is the specified field strength limit (MV/m) at a distance d_L (m) from a single interfering source. K_s is the interferer radiation pattern factor, accounting for the reduction of the mean level compared to the maximum level. d_i is the interferer-to-antenna distance in (m).

$$\varphi_i = \varphi(0) + \frac{2\pi d_i}{\lambda} \quad (5)$$

where λ is the wavelength and $\varphi(0)$ is the initial phase of the signal as it leaves source i .

Equation (1) can therefore be rewritten as follows:

$$V = \sum_{i=1}^N v_i e^{j\psi_i} \quad (6)$$

where:

$$V_i = C_A E_L d_L \frac{a(d_i)}{d_i} \quad (7)$$

$$\psi_i = \varphi(0) + \frac{2\pi d_i}{\lambda} + \alpha(d_i) \quad (8)$$

where ψ_i is uniformly distributed between 0 and 2π .

It can be easily shown that $|v|$ follows a Rayleigh distribution such that:

$$p(|v|) = \frac{|v|}{\xi^2} \exp \left[-\frac{|v|^2}{2\xi^2} \right] \quad (9)$$

where $\xi^2 = (N/2) \cdot E(v_i^2)$ is the expected value of v_i^2 . The r.m.s. voltage is $v_{r.m.s.} = \sqrt{2\xi^2}$.

From the variables already stated, the r.m.s. voltage can be calculated as follows:

$$v_{r.m.s.} = \sqrt{N} C_A E_L K_S d_L \sqrt{E \left[\left(\frac{a(d_i)}{d_i} \right)^2 \right]} \quad (10)$$