

REPORT 945-2*

METHODS FOR THE ASSESSMENT OF MULTIPLE INTERFERENCE

(Question 46/10, Study Programme 46L/10)

(1982-1986-1990)

1. Introduction

The usable field strength, E_u , is defined in Recommendation 638 and may be used as a criterion for the interference situation in a given channel and in a given area. It takes account, in principle, of natural and man-made noise as well as of the combined effect of the entirety of interfering transmitters. If the usable field strength is large, the influence of the interfering transmitters is also large, whereas this influence is small if the usable field strength is small.

The usable field strength is independent of the characteristics of the wanted transmitter and does not normally exhibit large variations with location. It can be determined for any location of interest. For international planning purposes, it may be convenient to calculate the usable field strength at the site of the wanted transmitter. As a first approximation, this value may be considered to be representative of the situation in the whole coverage area.

For the calculation of these interferences basically two categories of methods are in use:

- statistical methods;
- non-statistical methods.

Normally use is made either of the 'simplified multiplication method' as an example of a statistical method or of the non-statistical 'power-sum method'. Experience has also been gained in the successful use of the statistical 'log-normal method' [Kubrakov *et al.*, 1985].

These three methods are described and indications are given for their efficient use.

The simplified multiplication method and the log-normal method incorporate the effects of location variability on the assumption that they follow a Gaussian law and are intended for use at VHF and higher frequencies. The power-sum method applies for point-to-point reception and must be applied successively with different receiver locations in coverage studies.

Details for the use of the simplified multiplication method and its physical bases are to be found in Annex I and in [O'Leary and Rutkowski, 1982], while similar information on the log-normal method is contained in Annex II and in [Bobkova and Pavliouk, 1987].

2. Power-sum method

Use has been made of the power-sum method for the assessment of multiple interference at the LF/MF Broadcasting Conference for Regions 1 and 3, Geneva, 1975, and at the Administrative Radio Conferences for the Broadcasting-Satellite Service, Geneva, 1977 and 1983. A similar method called the "RSS method" has been used at the Regional Administrative MF Broadcasting Conference (Region 2), Rio de Janeiro, 1981.

* This Report should be brought to the attention of Study Groups 1 and 11.

3. Statistical methods

Four statistical computation procedures which can be used to calculate the effects of multiple interference have been developed to date [*Ad hoc* Committee 1949, 1950]. These are:

- the integration method,
- the log-normal method,
- the multiplication method,
- the simplified multiplication method.

These procedures attempt to make use of the statistical (in locations) nature of propagation curves such as those given in Recommendation 370. Although, essentially based on a single theoretical approach, these procedures differ from one another as a result of different physical assumptions. These are made in each procedure in order to simplify the mathematical calculations. The use of any of these procedures results in distribution functions which describe the location probability of reception used in conjunction with Reports 228 and 485 to calculate coverage.

The simplified multiplication method and the log-normal method are the least complex. The former was used for the assessment of multiple interference at the VHF/UHF European and African Broadcasting Conferences in 1961 and 1963, and at the Regional Administrative Conference for FM Sound Broadcasting in the VHF band (Geneva, 1984).

3.1 The simplified multiplication method

This method is based on the following assumptions:

- no correlation exists between the fields of interest;
- the time dispersion of the field strength of the desired transmitter can be neglected, compared to that of the unwanted transmitter;
- one interfering field dominates at the reception location;
- the influence of noise can be neglected, to compensate for the errors introduced by the other approximations.

The usable field strength E_u , is determined for a specified coverage probability (with respect to time and location) and depends on the values of the nuisance fields:

$$E_{si} = P_i + E_{ni(50, T)} + A_i + B_i \quad (3)$$

where:

- E_{si} : nuisance field corresponding to the i -th unwanted transmitter.
- P_i : the e.r.p., in dB(kW), of the i -th unwanted transmitter.
- $E_{ni(50, T)}$: the field strength, in dB(μ V/m), normalized to an e.r.p. of 1 kW, of the i -th unwanted transmitter. This field strength is exceeded at 50% of the locations during at least $T\%$ of the time.
- A_i : the radio-frequency protection ratio associated with the i -th unwanted transmitter, expressed in dB.
- B_i : the receiving antenna discrimination, expressed in dB.

Assuming a normal distribution of the field strength, expressed in dB(μ V/m), appropriate account of the effect of multiple interference can be taken by the use of the simplified multiplication method. With this method the usable field strength, E_u , can be calculated by iteration from:

$$p_c = \prod_{i=1}^n L(x_i) \quad (4)$$

with:

$$x_i = \frac{E_u - E_{si}}{\sigma_n \sqrt{2}}$$

where:

p_c : coverage probability (e.g. 50% of locations (100 - T)% of time), in the presence of n nuisance fields;

$L(x)$: coverage probability in the presence of a single nuisance field, which equals the probability integral for a normal distribution (see Annex I);

σ_n : standard deviation with location of the wanted and interfering field strengths (dB(μ V/m)) (see Annex I).

For further details see Annex I and [O'Leary and Rutkowski, 1982].

3.2 The log-normal method

This method is based on the following assumptions:

- no correlation exists between the fields of interest;
- the location variability in the field strength of the wanted and all interfering transmitters is taken to be identical;
- the effect of certain interfering field strengths, each of which obeys a log-normal law, is replaced at the point of reception by the effect of one resultant interfering field strength subject to the log-normal law with the following parameters [Fenton, 1960; Bobkova and Pavliouk, 1987]:

$$E_r = 0.1152 \sigma^2 + 10 \log \left(\sum_i m_{si} \right) - 5 \log U$$

$$\sigma_r = 6.58 \sqrt{\log U}$$

$$U = \frac{(k - 1) \sum_i m_{si}^2}{\left(\sum_i m_{si} \right)^2} + 1$$

$$k = \exp \left[\left(\sigma / 4, 34 \right)^2 \right]$$

$$m_{si} = 10 E_{si} / 10$$

- where:
- E_{si} - nuisance field corresponding to the i th unwanted transmitter, given by equation (3);
 - E_r - median value of resultant nuisance fields, expressed in decibels;
 - $\sigma; \sigma_r$ - standard deviations with location of interfering field strengths and resultant interfering field strength respectively, expressed in decibels;

- the usable field strength (for purposes of sound and TV broadcasting planning) is defined for $L\%$ of locations, at which the following conditions are simultaneously fulfilled:

a) the wanted signal exceeds the noise level by the required amount, and

b) the necessary protection ratio, i.e.:

$$E_u \geq E_{\min} \quad (50\% \text{ of locations and } 50\% \text{ of time})$$

$$E_u \geq E_{si} \quad (50\% \text{ of locations and } T\% \text{ of time}),$$

Condition b) is fulfilled when the usable field strength E_{u1} is equal to E_r . The probability of the fulfilment of both conditions a) and b) is equal to the product of their probabilities:

$$p_c = p_1 \cdot p_2 = L \left(\frac{E_{u1} - E_r}{\sqrt{\sigma^2 + \sigma_r^2}} \right) \cdot L \left(\frac{E_{u1} - E_{\min}}{\sigma} \right)$$

where: p_1, p_2 - probabilities of fulfilment of conditions a) and b) respectively; their values are determined by a normalized distribution curve for the normal law.

and, $L(x)$ is the probability integral, see equation (8) of Annex I.

If the value found for p_c satisfies the predetermined value of the coverage probability, p_{cp} (generally $p_{cp} = 0.5$, i.e., E_u is defined for 50% of the points of reception), then $E_u = E_{u1}$ and the calculation is completed. However, if $p_c \neq 0.5$, the further calculation of the usable field strength is performed by iteration using the formula:

$$E_u = E_{u1} + \frac{0.5 - p_c}{0.05}$$

The detailed calculation is shown in Annex II and in [Bobkova and Pavliouk, 1987].

The simplified log-normal method

If it is assumed, in the same way as for the power-sum method, that the effect of man-made interference and other noise may be covered by taking into account the minimum usable field-strength as a source of interference, the fluctuation in the corresponding field-strength also being subject to the log-normal law, this method may be simplified to give a non-iterative procedure for the determination of the usable field-strength for 50% of the receiving locations [Bobkova, 1988].

On this assumption, $E_{\min}$ may be introduced into the formula for determining the resultant field-strength as an additional source of interference:

$$E_{rs} = 0.1152 \sigma^2 + 10 \lg \left(\sum_i M_i + M_{\min} \right) - 5 \lg U_s,$$

$$\text{where } U_s = \frac{(k-1) \left(\sum_i M_i^2 + M_{\min}^2 \right)}{\left(\sum_i M_i + M_{\min} \right)^2} + 1,$$

$M_{\min}$ - median value of minimum usable field-strength, expressed in relative power units.

The value obtained for E_{rs} directly determines the median usable field-strength (i.e., for 50% of receiving locations). The usable field-strength value for any other percentage of locations required may be obtained by the same iterative procedure as that used in the standard log-normal method, by means of the formula:

$$P_{cp} = L \left(\frac{E_u - E_{rs}}{\sqrt{\sigma^2 + \sigma_{rs}^2}} \right)$$

where P_{cp} - predetermined value of the coverage probability

σ_{rs} - r.m.s. deviation of the resultant interference field, determined by the above formula, substituting into it the value U_s .

4. Comparison of the results obtained by the various methods

Sections 4.1 and 4.2 relate in particular to the simplified multiplication method and the power-sum method whilst section 4.3 includes considerations of the log-normal method.

4.1 *General considerations*

The comparison of calculations, using the two methods under equal conditions (no receiving antenna discrimination) is given below. This comparison is intended to enable the reader to estimate the difference to be expected, when applying one method or the other, rather than to advocate a specific method. It should be noted in this respect that either method can be expected to yield only approximate values of the usable field strength.

Differences between the results of both methods may be considerable, and the utmost care should be exercised when deriving further conclusions from these results, e.g. with respect to the number of channels required for satisfactory coverage by one programme.

It should, however, also be recognized that it would be possible to use, with comparable degree of precision, either method as a basis for comparison of different variants of a plan.

4.2 *Results*

Figures 1 and 2 exhibit the differences ΔE in usable field strengths when computed according to the simplified multiplication method (E_M) for a percentage of receiving locations of 45% and 50% respectively, or to the power sum method (E_P) for an undefined percentage of receiving locations. The differences ΔE depend on the relationship between the interference potentials of the various individual transmitters, i.e. their technical characteristics, their distance from the wanted transmitter and the frequency spacing. Normally there is one predominant source of interference producing nuisance field E_1 , following by a second and less harmful source of interference creating nuisance field E_2 and the remaining interfering transmitters causing gradually decreasing nuisance fields $E_3 \dots E_n$.

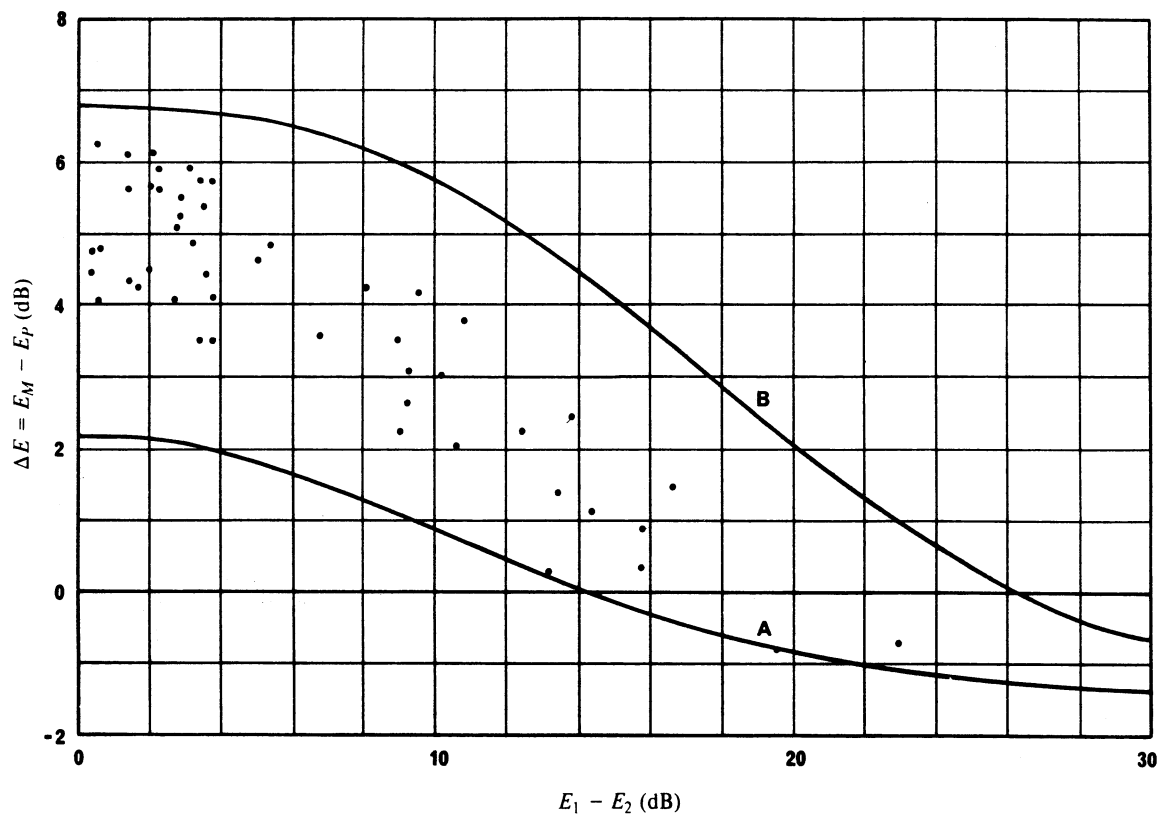


FIGURE 1 – Difference in usable field strength, ΔE , as a function of the difference between nuisance fields, E_1 and E_2 . Percentage of locations for the simplified multiplication method: 45%.

- : 50 transmitters
- $E_1 - E_2$: difference between nuisance fields of the two strongest interfering transmitters
- $\Delta E = E_M - E_P$: difference between the values of usable field strength obtained with either the simplified multiplication method (E_M), or the power sum method (E_P).
- Curves A : limiting curve obtained for the case of 2 nuisance fields, E_1 and E_2
- B : limiting curve obtained for the case of 10 nuisance fields, E_1 and 9 times the value of E_2

In Figs. 1 and 2 values of

$$\Delta E = E_M - E_P = f(E_1 - E_2)$$

are plotted for 50 ΔE values obtained for the first (in alphabetical order) 50 out of 345 transmitters operating at present in the Federal Republic of Germany. These 50 values are thought to be representative of these 345 VHF/FM transmitters. Moreover, two limiting curves, A and B, have been included between which all the 50 values obtained are situated. These limiting curves take account of the n interfering sources $E_1 \dots E_n$ in different ways: for the lower limiting curve (A) only nuisance fields E_1 and E_2 are taken into account, whereas for the upper limiting curve (B) there are $(n - 2) = 8$ additional sources of interference equal in severity with E_2 :

$$E_2 = E_3 = E_4 = \dots = E_{10}$$

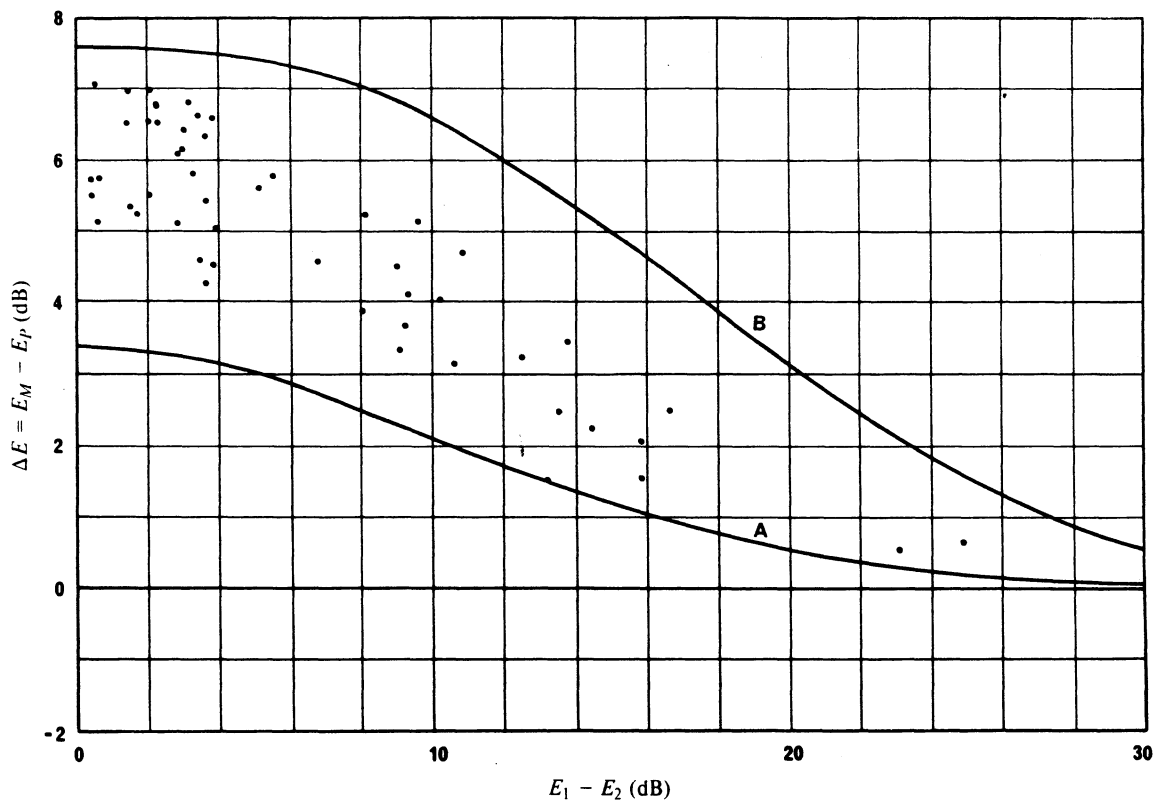


FIGURE 2 – Difference in usable field strength, ΔE , as a function of the difference between nuisance fields, E_1 and E_2 . Percentage of locations for the simplified multiplication method: 50%.

- : 50 transmitters
- $E_1 - E_2$: difference between nuisance fields of the two strongest interfering transmitters
- $\Delta E = E_M - E_P$: difference between the values of usable field strength obtained with either the simplified multiplication method (E_M), or the power sum method (E_P)
- Curves A : limiting curve obtained for the case of 2 nuisance fields, E_1 and E_2
- B : limiting curve obtained for the case of 10 nuisance fields, E_1 and 9 times the value of E_2

It can be seen from Figs. 1 and 2 that in the majority of cases the simplified multiplication method yields values which are up to about 7 dB higher than those obtained with the power sum method, depending on the network configuration.

Almost identical results were obtained from an analysis of usable field-strengths of 1177 UK assignments obtained in the Region 1 VHF/FM Plan, Geneva, 1984 as indicated below:

Percentage of assignments	Ratio (dB) of usable field-strengths exceeded Simplified multiplication: power sum
4	7
50	5
85	3

Note. — Calculations took account of the first 20 interfering sources.
— Results for simplified multiplication method based on 50% location probability.

It should be noted that all the above comparisons relate to the VHF bands. Differences between the two methods will be greater at UHF because of the larger values of standard deviation with location.