

RECOMMENDATION ITU-R SM.1599-1*

Determination of the geographical and frequency distribution of the spectrum utilization factor for frequency planning purposes

(2002-2007)

Scope

This Recommendation serves as a guideline for determining the geographical and frequency distribution of the spectrum utilization factor for frequency planning purposes.

Keywords

Frequency distribution, geographical distribution, spectrum utilization, frequency planning

The ITU Radiocommunication Assembly,

considering

- a) that the availability of unoccupied radio-frequency spectrum is a condition for meeting the demand for spectrum;
- b) that in frequency planning, i.e. the assignment of frequencies to new radio stations, limited use is in practice made of quantitative methods of finding the best assignments that will lead to the most economical use of the spectrum;
- c) that in the process of redistributing frequency bands in the interests of other radio services, the approach is, as a rule, to use heuristic methods, together with individual empirical data indicating the probability of harmful interference between radio stations;
- d) that for the purposes of frequency planning it is useful to know the potential capacity of the frequency resources available by geographical location at the notified site of the radio station and that to this end it is necessary to have sufficiently accurate methods of determining the geographical and frequency distribution of the spectrum utilization factor as defined for general purposes in Annex 1 to Recommendation ITU-R SM.1046,

recommends

- 1 that administrations should, in the planning process, use data on the geographical and frequency distribution of the spectrum utilization factor;
- 2 that the methods used to determine the geographical and frequency distribution of the spectrum utilization factor should be those given in Annex 1.

* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the years 2018, 2019 and 2023 in accordance with Resolution ITU-R 1.

Annex 1

Methods of determining the geographical and frequency distribution of the spectrum utilization factor

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1 General description of methods

There are a number of ways of obtaining detailed information on the degree of spectrum congestion which are based on calculating the power characteristics of the electromagnetic environment (EME) formed by radio station emissions.

One of them calls for the construction of a so-called frequency panorama of spectrum congestion, showing the field strength or spectral power flux-density of emissions at a given geographical point as a function of frequency, and for determination of the frequency bands in which the level of the EME characteristics in question exceeds a certain threshold value. This method as a whole gives an idea of the situation with regard to spectrum utilization. However, the results obtained by this means are approximate. This is due to the following reasons. In the process of determining the EME characteristics, practically no account is taken of the time parameters of emissions. In particular, continuous signal modulation parameters and class of emission data are completely lost. Pulse signals are treated as continuous with constant mean power. The variety of signals emitted by existing radio stations makes it necessary to fix a floating value (different for different signals) for the permissible level of EME characteristics determining the boundaries between congested sectors of the spectrum, which becomes a rather laborious business when the EME is a complex one. Setting a single threshold is not really appropriate and leads to approximate results.

Similar shortcomings affect another well-known method of evaluating spectrum use, which involves constructing two-dimensional representations of the isolines for equal strength of the combined electromagnetic field of sources of radio interference (EME maps). As a result no simple answer can be given to the question of whether the frequency under consideration is or is not congested for a particular radio station at a point with a given level of field strength. Accordingly, these methods find practical application mainly in situations where the signals emitted by different sources belong to one and the same class.

A more logical approach to the task of obtaining detailed data on the degree of spectrum utilization in different areas is based on the method of sampling the geographical and frequency resource in question with the aid of a reference radio station and checking whether conditions are met for ensuring the compatibility of this radio station with existing ones to which frequencies have been assigned previously.

The main disadvantages of this method, which limit its widespread use in practice, are as follows:

- the calculation takes a long time because of the need to directly determine the power conditions of the interaction between signals and interference in relation to all the given geographical and frequency sampling points;
- the radio-frequency bodies responsible for examining frequency notices need to have available a large volume of initial data, particularly on the technical characteristics of radio stations, which in many cases may be very difficult to get hold of.

A rather simpler and more convenient method of obtaining detailed data on the degree of spectrum utilization in different geographical areas, which is based on wide use of the frequency-distance rules set forth in general terms in Annex 2 to Recommendation ITU-R SM.337, is given below.

The main approach taken as a basis for this method is also applicable for the determination of the degree of spectrum-orbit congestion in application to satellite communication systems. In this case detailed data concerning orbital positions and technical parameters of satellites should be available.

2 A simplified method for detailed evaluation of the degree of spectrum congestion

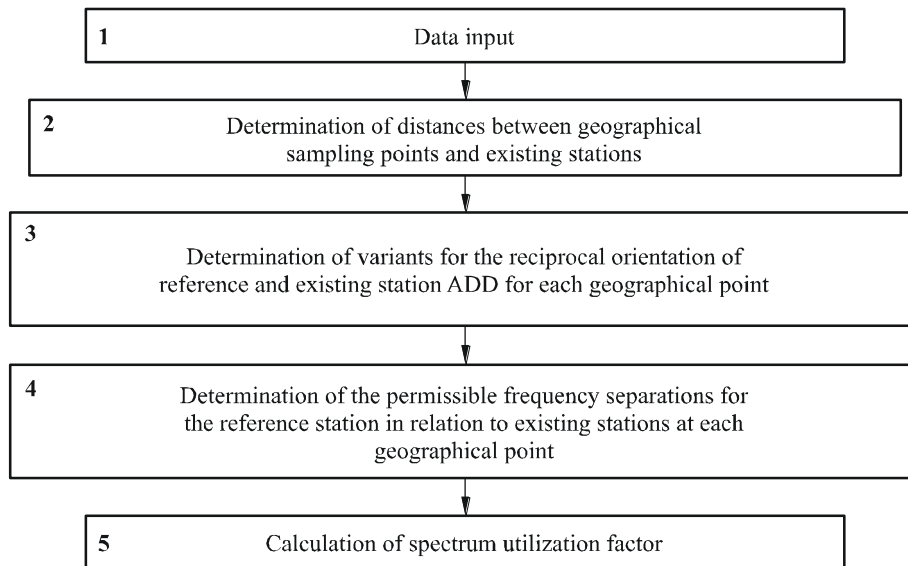
2.1 Description of the method

The aim of this method is to obtain objective data on the degree of spectrum congestion in the form of a function reflecting the limitations on the use of the spectrum by a particular additional reference radio station depending on its operating frequency and location.

Calculations by this method will be more accurate the more highly developed the frequency-distance rules are, covering in aggregate form all the necessary parameters and basic conditions relating to the interaction (co-, adjacent- and side-channel) of signals and interference and making it possible to check efficiently the conditions for ensuring the compatibility of radio stations in relation to the given geographical and frequency sampling points.

A consolidated flow chart of the algorithm method is given in Fig. 1.

FIGURE 1
Consolidated flow chart for the algorithm method



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The content of the boxes is as follows:

Box 1 – Input of initial data, including: dimensions of geographical area under consideration; lower and upper limits of the frequency band in question; characteristics of existing radio stations (assigned nominal frequencies, geographical coordinates, orientation of antenna directivity diagrams (ADD)); frequency-distance rules for the reference and existing radio stations; basis for carrying out calculations (at individual points in the area, over the whole area, over the whole band, at individual frequencies); geographical and frequency sampling intervals.

Box 2 – Determination of distances between geographical sampling points and existing radio stations. The initial data are the coordinates of the sites of existing radio stations and the corresponding sampling points.

Box 3 – Determination of variants for the reciprocal orientation of the reference and existing station ADD for each geographical sampling point. Possible variants are: interaction through the ADD side, side and main, or main lobes. The initial data used are the site coordinates of the existing and reference radio stations, antenna directivity azimuths, and ADD main lobe widths in the horizontal plane. If accurate data on the antenna azimuths of existing radio stations are not available, they can, for the purposes of the study, either be obtained deterministically or be produced with a random figure device.

Box 4 – Determination of minimum permissible frequency separations between existing radio stations and the reference one. For this purpose data on the frequency-distance rules and the distances between radio stations and antenna azimuths are used. The information obtained on the permissible frequency separations is submitted in the form of matrices. If data on the actual frequency assignments to existing radio stations are not available, frequencies can be assigned for the purposes of the study through the use of one or other of the recognized formal algorithms for frequency assignment.

Box 5 – Determination of different values for the spectrum utilization factor, showing the extent to which it is occupied:

Individual factor values (for each point):

$Z(f_i, x_j, y_j) = 1$ if the frequency separation between the i -th sampled frequency assigned to the reference radio station at the point in space j with coordinates (x_j, y_j) and at least one frequency of any of the existing radio stations is less than the permissible limit;

$Z(f_i, x_j, y_j) = 0$ in the opposite case.

General factor values:

– by averaging over all geographical points:

$$Z_f = \frac{1}{N_p} \sum_{j=1}^{N_p} Z(f_i, x_j, y_j) \quad (1)$$

– by averaging over all frequency points:

$$Z_k = \frac{1}{N_f} \sum_{i=1}^{N_f} Z(f_i, x_j, y_j) \quad (2)$$

– by averaging over all frequency and geographical points:

$$Z_{\Sigma} = \frac{1}{N_f \cdot N_p} \sum_{i=1}^{N_f} \sum_{j=1}^{N_p} Z(f_i, x_j, y_j) \quad (3)$$

where N_f and N_p are the number of frequency and geographical sampling points respectively.

2.2 Example of use of the method

An example for illustration purposes only is given in Attachment 1 to Annex 1.

Attachment 1 to Annex 1

Problem: It is necessary to determine the geographical and frequency distribution of the spectrum utilization factor indicating the degree of congestion of a 1 MHz frequency band in the range 169-170 MHz for a square area $A \times A$ ($A = 10$ km) on the assumption that it contains 50 radio stations of the same type (the coordinates of the radio station sites and their frequencies are given in Table 1 and shown by points in Fig. 2) in order to determine the preferred frequencies for a new (reference) radio station of the same kind as the existing ones for three alternative cases with regard to the site:

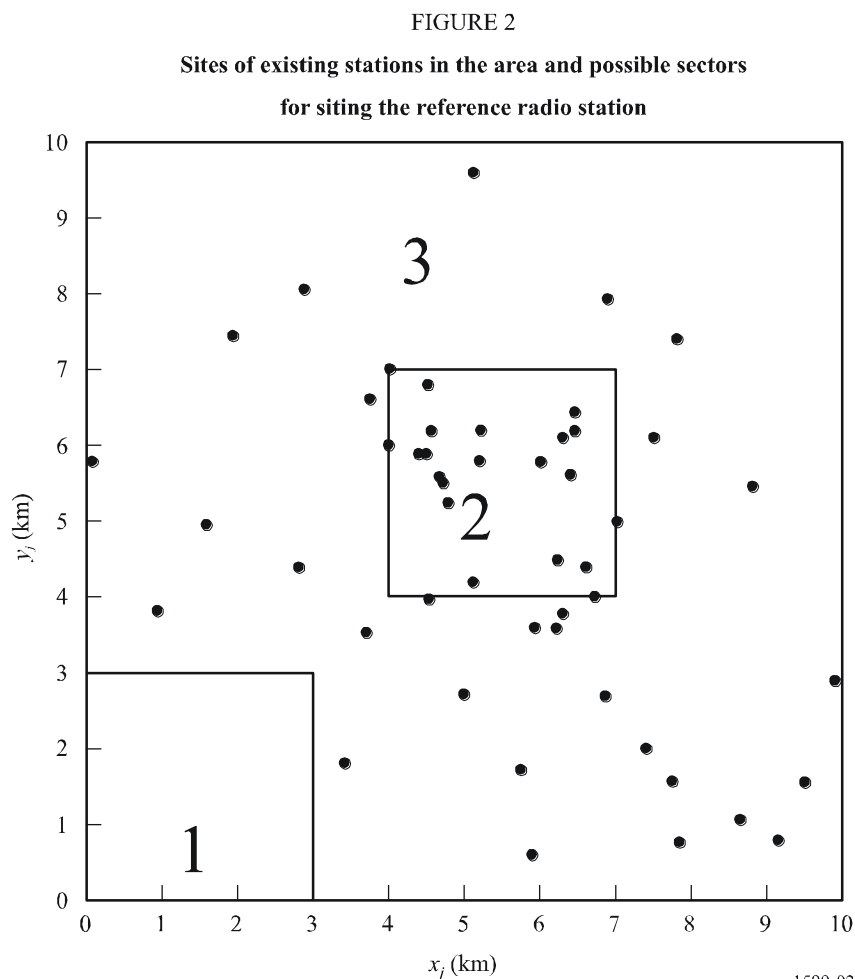
Case 1: The area for the possible site of the new radio station is bounded by the sides of the square $a_1 \times a_1$ ($a = 3$ km), with vertex coordinates (0;0), (0;3), (3;0), (3;3) km (Sector 1 in Fig. 2);

Case 2: The area for a site for the new radio station is a square $a_1 \times a_1$ ($a = 3$ km), with vertex coordinates (4;4), (4;7), (7;7), (7;4) km (Sector 2 in Fig. 2);

Case 3: The area for a site for the new radio station coincides with the initial area $A \times A$ (Sector 3 in Fig. 2).

TABLE 1
Calculation data

No.	1	2	3	4	5	6	7	8	9	10
x_j (km)	3.75	6.44	3.71	4.53	6.71	4.79	6.21	4.65	5.94	6.45
y_j (km)	6.61	6.4	3.57	3.99	4.00	5.25	3.58	5.58	3.58	6.21
Δf_i (MHz)	0	0.144	0	0.161	0.509	0.408	0.607	0.813	0.105	0.460
No.	11	12	13	14	15	16	17	18	19	20
x_j (km)	6.01	4.57	4.07	4.65	5.13	4.36	6.39	4.48	5.19	4.02
y_j (km)	5.78	6.20	5.98	5.45	4.22	5.88	5.57	6.84	5.75	6.99
Δf_i (MHz)	0.871	0.616	0.089	0.927	0.311	0.510	0.668	0.354	0.996	0.191
No.	21	22	23	24	25	26	27	28	29	30
x_j (km)	6.56	4.51	6.20	6.29	5.22	4.95	8.82	5.10	5.73	9.53
y_j (km)	4.35	5.87	4.53	3.80	6.20	2.73	5.44	9.61	1.74	1.57
Δf_i (MHz)	0.765	0.720	0.044	0.363	0.253	0.454	0	0	0.206	0.206
No.	31	32	33	34	35	36	37	38	39	40
x_j (km)	6.85	3.39	0.08	7.05	9.89	7.74	7.50	1.98	1.94	9.14
y_j (km)	2.68	1.77	5.77	4.98	2.85	1.56	6.10	7.40	7.46	0.80
Δf_i (MHz)	0.262	0.092	0	0.204	0.046	0	0.301	0.241	0.049	0.095
No.	41	42	43	44	45	46	47	48	49	50
x_j (km)	7.84	5.89	8.65	6.89	2.88	0.94	6.29	2.80	8.77	1.61
y_j (km)	0.76	0.60	1.07	7.96	8.06	3.82	6.12	4.37	7.41	4.94
Δf_i (MHz)	0.153	0.050	0.309	0.047	0.136	0.050	0.562	0.23	0.098	0.132



The main assumptions adopted for the purposes of the calculation are as follows:

- A figure zero in the Δf_i (MHz) box indicates a starting point of the particular frequency band.
- ADD are circular.
- In the calculation of frequency-distance rules, the Earth's surface is taken as being smooth and spherical.
- No allowance is made for harmful interference from blocking and intermodulation effects.

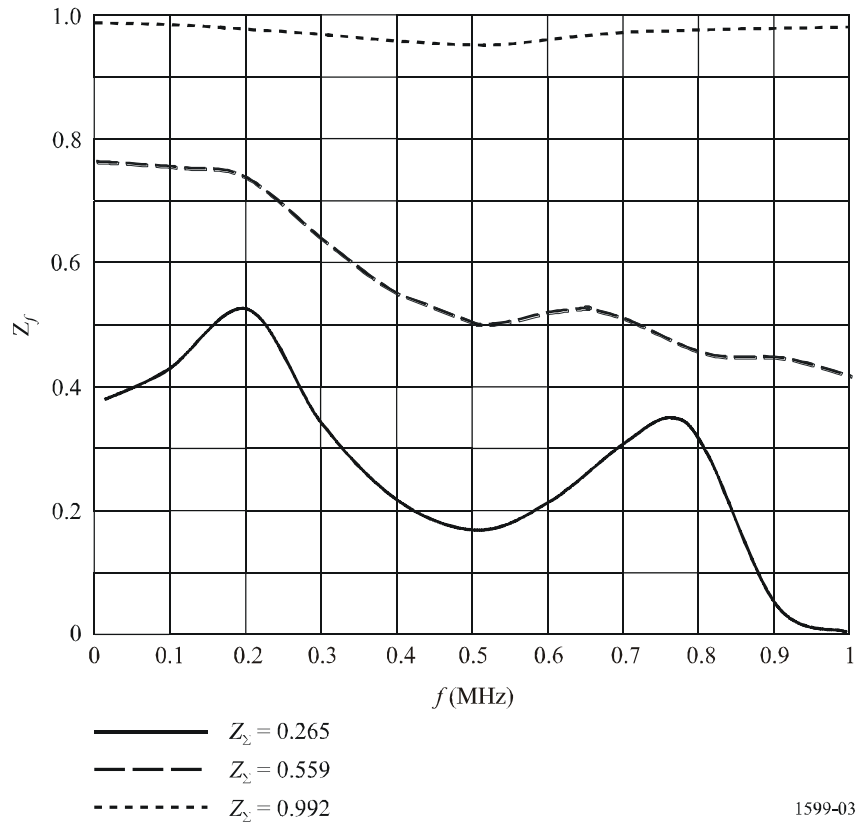
The results are shown in Fig. 3 as functions of the factor Z_f in the 1 MHz band for the three cases with regard to the site for the new radio station and also as average values for the indicator Z_Σ in accordance with equation (3).

From the results shown in Fig. 3, it can be seen that in the area with a high density of existing radio stations (Sector 2 in Fig. 2), the band in question is more or less fully occupied, so that it does not seem feasible in practice to assign frequencies in this band for a new radio station in that sector. On the other hand, there is quite a good chance of assigning frequencies in the same band when the location for the new radio station is Sector 1 or the area as a whole. Thus, as far as Sector 1 is concerned, the preferred frequencies for assignment to the new radio station from the standpoint of compatibility will be in the region of 0.4-0.6 MHz and 0.85-1 MHz of the band in question.

Further, assuming the highest possible geographical density of radio stations (highest duplication of frequency assignments) in order to meet their demand for the frequency resource as fully as possible, it would be more appropriate to choose frequencies for assignment to the new radio station in the range 0.8-1 MHz of the frequency band in question.

FIGURE 3

Variation of spectrum utilization factor in a
1 MHz band for different territorial sectors



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Similarly, for the case of new stations located anywhere in the area (Sector 3), in order to equalize the load over the whole 1 MHz frequency band, it will be desirable to use frequencies in the range 0.4-1 MHz, and the more so the higher the frequency.

It is very striking that Sector 1 as a whole shows more than 25% occupancy despite the fact that it does not contain a single radio station and that there is only one directly adjacent to its boundaries.

The geographical distribution of the spectrum utilization factor is shown in Fig. 4 as dependence of the factor Z_k from the possible setting of a new radio station coordinates (equation (2)). Sectors 1 and 2 are shaded differently than the rest of Sector 3.

From the results shown in Fig. 4, it can be seen, that there are some territorial places where 5-10% of the band in question is free even for Sector 2. At the same time the common spectrum utilization factor Z_Σ for Sector 2 equals to 0.992. There are no territorial limitations to set a new radio station in Sector 1. At any point of this sector about 50% of the frequency band in the question is free to accommodate a new radio station.

Thus, Figs 3 and 4 show clearly that by this method it is possible to identify the congested and available ranges of the spectrum and a territory in the given frequency band and geographical area. This makes it possible to facilitate the selection of frequencies for new radio stations being brought into operation and helps to increase the efficiency of the frequency planning process as a whole.

This method could be adapted or extended so that it may be applied to environments having more complex interference and propagation factors.

FIGURE 4
 Variation of spectrum utilization factor in area $10 \times 10 \text{ km}^2$
 and in the frequency band 169-170 MHz

