

RECOMMENDATION ITU-R F.1765

Methodology for determining the aggregate equivalent isotropically radiated power from point-to-point high-density applications in the fixed service operating in bands above 30 GHz

(2006)

Scope

This Recommendation provides methodologies which may be used to derive the aggregate equivalent isotropically radiated power (a.e.i.r.p) for transmitting point-to-point (P-P) high density applications in the fixed service (HDFS) stations in bands above 30 GHz which may be used by administrations wishing to assess the potential interference from P-P HDFS stations to other interfered-with services.

The ITU Radiocommunication Assembly,

considering

- a) that an estimate of the aggregate equivalent isotropically radiated power (a.e.i.r.p.) from a deployment of point-to-point (P-P) high density applications in the fixed service (HDFS) transmitting stations referred to a central point may be required by administrations to assess the potential interference from P-P HDFS stations to other victim services on a national and bilateral basis;
- b) that using automatic transmitter power control (ATPC) in P-P transmitters would reduce the aggregate radiated power;
- c) that it is also necessary to determine the a.e.i.r.p. as a function of the elevation angle to be evaluated, taking account of mode (2) propagation mechanisms,

recognizing

1 that No. 5.547 of the Radio Regulations (RR) identifies the bands 31.8-33.4 GHz, 37-40 GHz, 40.5-43.5 GHz, 51.4-52.6 GHz, 55.78-59 GHz and 64-66 GHz as being available for high-density applications in the fixed service (HDFS),

noting

- a) that Resolution 75 (WRC-2000) invites ITU-R to develop, as a matter of urgency, the technical basis for determining the coordination area for coordination of a receiving earth station in the space research service (deep space) with HDFS transmitting stations in the 31.8-32.3 GHz and 37-38 GHz bands;
- b) that Resolution 79 (WRC-2000) invites ITU-R to conduct studies on the coordination distance between radio astronomy stations operating in the 42.5-43.5 GHz band and HDFS systems,

recommends

1 that the following mathematical models may be provisionally used to derive the a.e.i.r.p. for transmitting P-P HDFS stations under the assumption that the elevation angles of all HDFS transmitting antennas are 0° (see Notes 1, 2, 3, 5, 6 and 9):

1.1 when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 0°:

$$a.e.i.r.p. = P_t + 1.061 (\log N_t)^2 + (-0.1164 G_t + 6.103) \log N_t + 0.9428 G_t - 2.62 \text{ dBW}$$

1.2 when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 2.5°:

$$a.e.i.r.p. = P_t - 0.13743 (\log N_t)^3 + 1.8243 (\log N_t)^2 + 1.5569 \log N_t + 0.0052917 G_t^3 - 0.57530 G_t^2 + 19.985 G_t - 200.77 \text{ dBW}$$

1.3 when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 5°:

$$a.e.i.r.p. = P_t + 0.54858 (\log N_t)^2 + 5.6488 \log N_t - 0.0036218 G_t^3 + 0.42380 G_t^2 - 16.645 G_t + 227.44 \text{ dBW}$$

1.4 when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 10°:

$$a.e.i.r.p. = P_t + 9.086 \log N_t - 0.25 G_t + 8.30 \text{ dBW}$$

1.5 when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 15°:

$$a.e.i.r.p. = P_t + 9.344 \log N_t - 0.25 G_t + 5.19 \text{ dBW}$$

1.6 when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 20°:

$$a.e.i.r.p. = P_t + 9.522 \log N_t - 0.25 G_t + 3.19 \text{ dBW}$$

1.7 when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 25°:

$$a.e.i.r.p. = P_t + 9.663 \log N_t - 0.25 G_t + 1.78 \text{ dBW}$$

1.8 when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 30°:

$$a.e.i.r.p. = P_t + 9.775 \log N_t - 0.25 G_t + 0.74 \text{ dBW}$$

where:

P_t : transmitter power at the antenna input (dBW)

N_t : number of transmitters

G_t : antenna gain (dBi);

N_t : number of transmitters;

2 that the following mathematical models may be provisionally used to derive the a.e.i.r.p. for transmitting P-P HDFS stations under the assumption that the HDFS transmitting antennas have variable elevation angles as described in Annex 1 (see Notes 1, 2, 4, 5, 6, 8 and 9):

2.1 when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 0°:

$$a.e.i.r.p. = P_t + 0.82096 (\log N_t)^3 + (-0.15210 G_t - 0.92771) (\log N_t)^2 + (0.024504 G_t^2 - 1.0198 G_t + 27.270) \log N_t - 0.077296 G_t^2 + 5.1982 G_t - 73.62 \text{ dBW}$$

2.2 when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 2.5°:

$$a.e.i.r.p. = P_t + 0.93906 (\log N_t)^3 + (-0.31918 G_t + 3.4110) (\log N_t)^2 + (0.023524 G_t^2 + 0.096937 G_t - 4.8156) \log N_t + 0.0011791 G_t^3 - 0.21452 G_t^2 + 8.5619 G_t - 82.88 \text{ dBW}$$

- 2.3** when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 5°:

$$a.e.i.r.p. = P_t + (-0.10457 G_t + 3.0618) (\log N_t)^3 + (0.027889 G_t^2 - 1.1358 G_t + 9.7775) (\log N_t)^2 + (-0.15803 G_t^2 + 9.3247 G_t - 132.36) \log N_t + 0.20619 G_t^2 - 13.901 G_t + 247.30 \text{ dBW}$$

- 2.4** when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 10°:

$$a.e.i.r.p. = P_t + 9.263 \log N_t - 0.2511 G_t + 8.43 \text{ dBW}$$

- 2.5** when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 15°:

$$a.e.i.r.p. = P_t + 9.299 \log N_t - 0.25 G_t + 5.45 \text{ dBW}$$

- 2.6** when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 20°:

$$a.e.i.r.p. = P_t + 9.497 \log N_t - 0.25 G_t + 3.32 \text{ dBW}$$

- 2.7** when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 25°:

$$a.e.i.r.p. = P_t + 9.651 \log N_t - 0.25 G_t + 1.84 \text{ dBW}$$

- 2.8** when the elevation angle of the direction of the a.e.i.r.p. to be evaluated is 30°:

$$a.e.i.r.p. = P_t + 9.767 \log N_t - 0.25 G_t + 0.79 \text{ dBW};$$

3 that for a different elevation angle of the direction of the a.e.i.r.p. to be evaluated for which the formula is not given in *recommends* 1 or 2, the a.e.i.r.p. should be estimated by means of interpolation;

4 that the distance to the interfered-with station should be generally measured from the centre of the HDFS deployment area (see Note 7).

NOTE 1 – Annex 1 describes a method for determining a.e.i.r.p. values given in *recommends* 1 and 2. The a.e.i.r.p. values corresponding to 0 or low elevation angles of the directions to be evaluated will be useful for estimating interference through mode (1) propagation mechanisms, while those corresponding to high elevation angles of the directions to be evaluated will be useful for estimating interference through mode (2) propagation mechanisms.

NOTE 2 – The formulae in *recommends* 1 and 2 were derived as approximations for $G_t = 28$ to 46 dBi and $N_t = 32$ to 8 192. The probability of the a.e.i.r.p. exceeding the values in *recommends* 1 and 2 is 5% (that is, the confidence level of the calculations is 95%). The maximum errors of the approximations are typically in the order of 0.5 dB, but about 1 dB in some cases of complicated approximation formulae using the third order polynomials of G or $\log N_t$. Determination of the most appropriate confidence level requires further study.

NOTE 3 – The formulae in *recommends* 1 are based on an assumption that the azimuth angles of HDFS antennas are uniformly distributed over 0° to 360° and their elevation angles are 0°.

NOTE 4 – The formulae in *recommends* 2 are based on an assumption that the azimuth angles of HDFS antennas are uniformly distributed over 0° to 360° and their elevation angles are variable as described in § 2.3 of Annex 1. Further study is required in order to establish the most appropriate

probability distribution function of HDFS antenna elevation angles to be used in each frequency band.

NOTE 5 – The formulae in *recommends* 1 and 2 may over estimate the actual a.e.i.r.p. since no consideration is given to potential clutter loss. Further study is required to assess the magnitude of this factor.

NOTE 6 – In the case of HDFS systems employing ATPC, P_t in the formulae of *recommends* 1 and 2 should be the transmitter power under the normal condition where there is no precipitation. Generally speaking, the interference to the victim station will be less significant during precipitation.

NOTE 7 – In general, the distance defined in *recommends* 4 will be appropriate for evaluating the a.e.i.r.p. provided the distance between the victim receiver and the HDFS deployment area is not too short compared to the radius area of HDFS deployment area (see § 1.3 of Annex 1).

NOTE 8 – Recommendation ITU-R F.1498 contains other distributions of elevation angles of HDFS antennas operating in the 37-40 GHz range. Further study is required to extend this Recommendation to cover such distributions.

NOTE 9 – In order to facilitate computer implementation of this Recommendation, Appendix 1 to Annex 1 presents the approximate formulae in *recommends* 1 and 2 in a tabular form.

Annex 1

Methodology for determining the aggregate interference power from P-P HDFS

1 Simulation method

1.1 Introduction

Resolution 75 (WRC-2000) requests the development of the technical basis for determining the coordination area for coordination between receiving earth stations in the space research service (deep space) and transmitting stations of high-density applications in the fixed service (HDFS), in the 31.8-32.3 GHz and 37-38 GHz frequency bands. In addition, Resolution 79 (WRC-2000) invites ITU-R to conduct studies on the coordination distance between radio astronomy stations operating in the 42.5-43.5 GHz band and HDFS systems.

This Recommendation provides methodologies which may be used to derive the a.e.i.r.p. for transmitting P-P HDFS stations which may be used by administrations wishing to assess the potential interference from P-P HDFS stations to other interfered-with services in their national and bilateral discussions. The methodologies in this Recommendation may be used as a basis for further study by administrations wishing to answer the *resolves* under Resolutions 75 (WRC-2000) and 79 (WRC-2000).

Using the 38 GHz band as an example, simulations of P-P networks of HDFS have been used to develop a mathematical model from which to assess the equivalent aggregated interference power radiated from such networks. However, the calculation results are not frequency dependent. The aggregated power is expressed in terms of the number of transmitters, antenna gains and transmitter

power levels and is found to aggregate (logarithmically) at a lower rate than the $10 \log N$, where N is the number of transmitters.

This section describes a methodology for estimating aggregated radiated power from a distribution of P-P HDFS using computer simulation.

In order to determine the aggregated radiated power equivalent to a single transmitter at the edge of the network closest to the interfered-with station receiver, P-P transmitters of HDFS have been simulated by varying the number of transmitters, the antenna gains, elevation angles and the antenna azimuths. In this context, the total radiated power is defined in terms of an aggregate equivalent isotropically radiated power (a.e.i.r.p.). For the purpose of this simulation, this represents the sum of the radiated powers from a network of transmitters, distributed over an area, and received at a distant point, corrected for the free-space path loss between that point and the closest transmitter, i.e.:

$$a.e.i.r.p. = \sum_{all\ directions} P_{received} + L_{fs} \quad \text{dBW}^* \quad (1)$$

where:

L_{fs} : free-space path loss.

1.2 System parameters

An extensive survey of P-P HDFS was undertaken, including Recommendation ITU-R F.758, documentation submitted to ITU-R and from other sources, from which generic set of system parameters were derived and which were used in the simulations.

Three antenna gains, 28, 36 and 44 dBi, were considered as input parameters to the model. Recommendation ITU-R F.1245 was used as a typical antenna radiation pattern. Transmitter power of 20 dBW was used in the simulations, but the absolute value of the power is not important. The effects of polarization were not taken into account.

Test receiving stations with isotropic antennas with antenna gain of 0 dBi, to aggregate together signals from all the P-P transmitters were located at distances of 50, 100 and 150 km from the edge of the network.

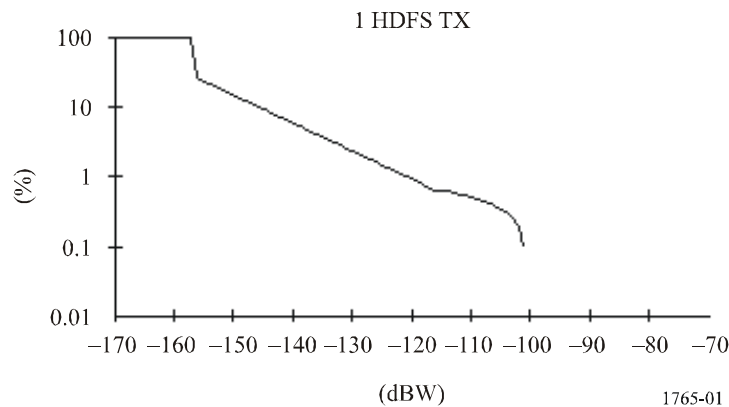
1.3 Analytical simulations

Simulations have been made with varying numbers of transmitters whose antennas are rotating in azimuth at random scan rates between 0 and 1 degree/s, while the starting azimuths were also set randomly between 0° and 360° . By sampling the aggregated power over a period of time, distributions are obtained which describe the probability that the antennas point in a given direction and which can then provide estimates of the worst-case power levels for a certain degree of risk. Examination of the power levels received at the three test receivers, at 50, 100 and 150 km from the edge of the network, indicated little difference when corrected for free-space path loss. Test receivers were located only in one direction from the network since circular symmetry was ensured through the azimuthal rotation of all the transmitting antennas. The transmitters were distributed uniformly over a circular area with a diameter of 25 km and some of the simulations were repeated with transmitters distributed over circular areas with diameters of 15 and 35 km. Figure 1 shows the cumulative distribution of power levels from a single transmitter with antenna gain of 44 dBi and antenna elevation angle of 0° , and shows clearly the antenna radiation pattern, as expected.

* Power received by an isotropic antenna (0 dBi antenna gain).

FIGURE 1

Cumulative probability distribution of power from a single randomly located antenna



As more antennas are included, the probability distribution changes. Figure 2 shows the distribution from 12 randomly-rotating antennas. Figure 2 illustrates that two distributions are forming: power from the main lobe of a single antenna is combining with power from the side lobes of the other antennas in the network to yield a power level of about -90 dBW (equivalent to about 68 dBW when corrected for free-space path loss), while the side lobes of all antennas are combining together to form a larger skewed distribution at lower power levels. As the number of transmitters increases, this lower peak from the antenna side lobes increases in magnitude until it eventually subsumes the main-lobe peak, and the distribution approaches a log normal distribution, as shown in the examples in Fig. 3.

FIGURE 2

Distribution of power levels from 12 randomly located antennas

