RECOMMENDATION ITU-R F.1766-0*, **

Methodology to determine the probability of a radio astronomy observatory receiving interference based on calculated exclusion zones to protect against interference from point-to-multipoint high-density applications in the fixed service operating in bands around 43 GHz

(2006)

Scope

This Recommendation provides a methodology which may be used to derive exclusion zones around radio astronomy sites for transmitting point-to-multipoint (P-MP) high density applications in the fixed service (HDFS) which may be used by administrations in national and bilateral discussions as method to protect radio astronomy sites from potential interference from P-MP HDFS stations.

The ITU Radiocommunication Assembly,

considering

a) that the frequency band 42.5-43.5 GHz is used or is planned to be used for continuum observations;

b) that the frequency bands 42.77-42.87 GHz, 43.07-43.17 GHz, and 43.37-43.47 GHz are used by radio astronomers to observe the spectral lines of silicon monoxide;

c) that these observations can be made from a single antenna or from a network of antennas using very long baseline array (VLBI) techniques;

d) that these observations employ very high-gain antennas and very low-noise amplifiers to receive extremely weak cosmic radio emissions over which astronomers have no control;

e) that point-to-multipoint (P-MP) high density applications in the fixed service (HDFS) could involve the deployment of a large numbers of terminals, for which individual coordination would not be feasible;

f) that administrations wishing to protect a Radio Astronomy (RAS) site from potential interference from P-MP HDFS stations may consider the use of an exclusion zone around the RAS site in their national and bilateral discussions;

g) that the determination of size of the exclusion zone could be improved by considering the topology and demographic data around RAS sites,

recognizing

a) that the frequency band 42.5-43.5 GHz is allocated to the radio astronomy service (RAS) on a primary basis worldwide;

b) that No. 5.149 of the Radio Regulations (RR) states that "in making assignments to stations of other services to which the bands 42.5-43.5 GHz, 42.77-42.87 GHz, 43.07-43.17 GHz,

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* This Recommendation should be brought to the attention of Radiocommunication Study Group 7.

** Radiocommunication Study Group 5 made editorial amendments to this Recommendation in the year 2017 in accordance with Resolution ITU-R 1.

43.37-43.47 GHz are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference”;

c) that the band 42.5-43.5 GHz is also allocated to the fixed service (FS) on a primary basis;

d) that RR No. 5.547 notes that the band 42.5-43.5 GHz is available for high density applications in the fixed service, and that administrations should take this into account when considering regulatory provisions in relation to this band,

noting

a) that Resolution 79 (WRC-2000) calls for ITU-R “to conduct studies on the coordination distance between radio astronomy stations operating in the 42.5-43.5 GHz band and P-MP HDFS stations with a view to developing ITU-R Recommendations”;

b) that Recommendation ITU-R F.1760 describes a methodology for the calculation of aggregate equivalent isotropically radiated power (a.e.i.r.p.) distribution from point-to-multipoint high-density applications in the fixed service operating in bands above 30 GHz,

recommends

1 that Annex 1 may be used to determine the probability of an RAS observation receiving interference from the deployment of P-MP HDFS outside a specified exclusion zone (EZ) based upon a.e.i.r.p. distributions;

2 that Annex 2 may be used to determine the EZ around the RAS site, defined by a propagation loss from the RAS site, outside of which stations of the P-MP HDFS may be deployed without likelihood of causing unacceptable interference into the RAS, using the methodology in Annex 1 to calculate probability of interference.

Annex 1

Methodology to determine the probability of an RAS observation receiving interference from the deployment of P-MP HDFS outside a specified EZ based upon a.e.i.r.p. distributions

1 Introduction

In order to be in a position to offer the RAS the required level of protection, it is necessary to be able to predict interference levels at a RAS site from potential deployments of P-MP HDFS stations. This interference level will depend upon the characteristics assumed for each service and the terrain and clutter around the RAS site.

A number of the input parameters are not available as a numerical constant, but vary according to a distribution. For example the propagation loss between two points depends upon a number of parameters including the percentage of time. The methodology described in this Annex is based upon Monte Carlo techniques, whereby these input distributions are convolved using an interference equation to produce a distribution of interference against probability that these levels of interference are exceeded.

This approach allows comparison against RAS thresholds defined in Recommendation ITU-R RA.769, which are defined in terms of an interference threshold (mean power over observation) and probability of an observation being interfered.

The calculation requires three stages:

1 definition of RAS model;

2 definition of P-MP HDFS model;

3 calculation of interference.

Each of these stages are described in the sections below.

2 RAS model

2.1 Interference threshold

The basis of the RAS model is the protection criteria for radioastronomical measurements described in Recommendation ITU-R RA.769. In order to protect radio astronomy it is necessary that there be a $(100 – x)$% probability that an observation is interference free.

An observation is interference free if the mean interfering power over the integration period T is less than the levels specified in Annex 1 of Recommendation ITU-R RA.769. A value of T = 2 000 s is typically used within this Recommendation and other analysis of sharing with the RAS.

This integration period also determines the sensitivity of the receiver, and hence the threshold or mean interference level. These vary depending upon the type of observation, whether continuum or spectral line observation. The continuum observations are more sensitive than those for spectral lines, and so require a lower threshold. Operation of a telescope as part of a VLBI system results in higher thresholds due to the low correlation of sources of interference.

The values in Table 1 of Recommendation ITU-R RA.769 specify mean interference thresholds in terms of spectral power flux-density, based upon an assumed receiver gain of 0 dBi. This corresponds to an antenna with side lobes as given in Recommendation ITU-R SA.509 at an off-axis angle of 19°. In order to be able to model RAS telescopes at lower elevation angles and to include other gain patterns for the telescope, it is necessary to define the threshold in terms of interference at the receiver, i.e. using ΔP_H as defined in equation (4) of that Recommendation.

As noted above there must be an $(100 – x)$% probability that an observation is interference free, i.e. that this threshold is not exceeded. Recommendation ITU-R RA.1513 identifies that for a single network, in this case for a P-MP HDFS deployment, a value of x = 2% should be used.

2.2 Location

The location of the RAS antenna is defined by its latitude, longitude and height above local terrain.

2.3 Gain pattern

The RAS antenna should be modelled by a suitable gain pattern, such as that specified in Recommendations ITU-R S.1238 or ITU-R RA.1630, or, where available, measured data. As noted above the interference threshold is based upon mean interference over an observation period, typically 2 000 s. Assuming that the propagation environment and P-MP HDFS deployment is constant over that period, then the mean interference will be that calculated using the mean gain over the observation.

The mean gain of an RAS telescope can be determined by:

– locating a number of test points (e.g. every 3°) on the horizon around the test RAS site;
– set the RAS antenna to the gain pattern selected as described above;
– set the antenna elevation to the minimum for observations at this site (e.g. 5°) and azimuth = 0;
– increase the antenna elevation at a rate equal to the Earth's rotation for 2 000 s;
– determine the mean gain at each test point over this period. Note that the averaging should be in linear units rather than dBi, even if the resulting table may be presented in dBi.

The table of {(mean gain over 2 000 s), (angle from RAS azimuth)} can be used to represent the mean gain pattern of the RAS antenna towards the horizon over an observation.

2.4 Summary

The input parameters required to define the RAS in the model are summarized in Table 1.

TABLE 1

RAS model parameters

Input	Source
Interference threshold	Mean interference over 2 000 s observation period calculated from Recommendation ITU-R RA.769 for the relevant observation type
Acceptable probability of observation receiving interference	From a P-MP HDFS network, 2% from Recommendation ITU-R RA.1513
RAS latitude	From RAS site location
RAS longitude	From RAS site location
RAS antenna height above terrain	From RAS site location
Mean gain over observation	Table of {(mean gain over 2 000 s), (angle from RAS azimuth)}, calculated using the algorithm described above

3 P-MP HDFS model

3.1 a.e.i.r.p. distribution(s)

A wide range of services, architectures and characteristics could be employed by P-MP HDFS systems. To support regulation of this band, reference models can be defined, with characteristics such as maximum cell size, e.i.r.p., antenna heights, etc. From these reference models it is possible to derive distributions of aggregate e.i.r.p. (a.e.i.r.p.) that define the probability that the a.e.i.r.p. within an area, or building block (BB) is no more than a certain value. The algorithm to derive these a.e.i.r.p. distributions is described in Recommendation ITU-R F.1760 – Methodology for the calculation of aggregate equivalent isotropically radiated power (a.e.i.r.p.) distribution from point-to-multipoint high-density applications in the fixed service operating in bands above 30 GHz identified for such.

The a.e.i.r.p. encapsulates the characteristics of all transmitters within the BB, including aspects such as power control, gain patterns, aggregation, and clutter. The deployment of P-MP HDFS terminals will vary between BBs: however a large number of BBs are likely to produce a range of a.e.i.r.p.s as defined by the distribution.

A scenario could be based upon widespread deployment of a single P-MP HDFS reference model, in which case the input would be a single a.e.i.r.p. distribution. However, more complex deployments could involve different types of P-MP HDFS reference models, in which case there would have to be multiple a.e.i.r.p. distributions.

3.2 Transmitter height

The transmitter height will be the maximum that could be used for each reference model, and so is associated with the a.e.i.r.p. distribution.

3.3 Deployment area

The deployment area (DA) represents those locations where there could be P-MP HDFS transmitters and is typically between:

– the exclusion zone (EZ) around the RAS site within which P-MP HDFS deployment is not permitted. This could be in the form of a distance from RAS site, D, or locations for which the propagation loss using a model such as Recommendation ITU-R P.452 is at greater than a specified value, i.e. $L_{452} > X$ dB;

– the maximum distance D_{max} after which additional deployment would bring a negligible increase in the interference level calculated and therefore need not be considered.

EZs based upon distance are circles centred upon the RAS site. EZs based upon propagation loss can be polygon(s).

The maximum distance to consider will vary depending upon the size of the EZ. For example with an EZ defined by D = 50 km, it is not necessary to consider deployment of P-MP HDFS stations beyond D_{max} = 110 km. The value of D_{max} can be determine by continuing to add further interfering stations until the increase in interference level is negligible. If the DA is a narrow ring around the RAS site then it is likely that D_{max} should be increased.

Within the DA an array of test points should be located at regular intervals, each representing one BB. The area used to derive the a.e.i.r.p. determines the separation distance between test points.

The DA could contain a uniform distribution of BBs, all representing the same P-MP HDFS reference model or there could be locations with different types of service, architecture, etc., represented by different a.e.i.r.p. distributions. The DA could also include areas with no P-MP HDFS deployment.

The a.e.i.r.p. distribution could represent either in-band or out-of-band (OoB) emissions from P-MP HDFS transmitters. In the case of OoB analysis there could be an attenuation of signal with respect to in-band transmission, A_{OoB}.

Annex 2 to this Recommendation specifies various approaches and algorithms to define a DA.

3.4 Summary

The input parameters required to define the P-MP HDFS in the model are summarized in Table 2.

TABLE 2

P-MP HDFS model parameters

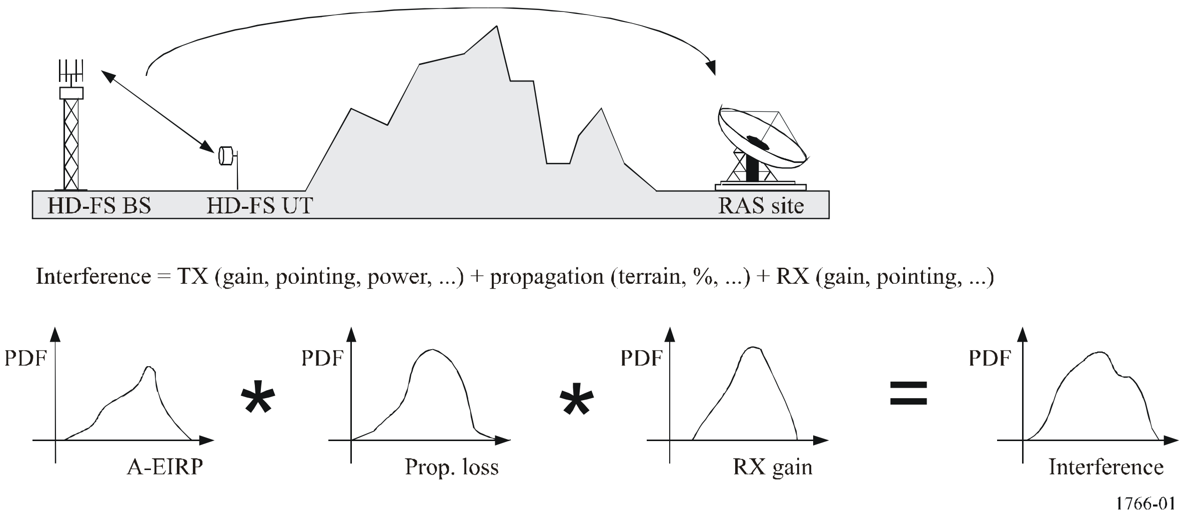
Input	Source
a.e.i.r.p. distribution(s)	Calculated using algorithm in Recommendation ITU-R F.1760
Transmitter height	As defined for each reference model, i.e. could vary between a.e.i.r.p. distribution
Deployment area	A set of test points between the EZ and the maximum distance to consider, D_{max}. Each test point is associated with a transmitter height and a.e.i.r.p. distribution
If required, A_{OoB}	If required, an attenuation between in-band and OoB operation. For in-band analysis this field can be set to zero

4 Interference calculation

The Monte Carlo methodology consists of calculating the mean aggregate interference for a series of samples. It consists of the convolution of three varying inputs, the P-MP HDFS deployment, the propagation environment, and the azimuth of the RAS observation. This convolution is shown in Fig. 1.

FIGURE 1

Monte Carlo approach to calculate aggregate interference



For each sample the mean aggregate interference I is calculated using:

$$I = \sum_j AEIRP(p_{i,j}) - L_{452}(p_i, j) + G_{RAS}(j, az_i) - A_{OoB} \qquad (1)$$

where:

i: i-th sample number

j: j-th building block

$AEIRP(p_{i,j})$: aggregate e.i.r.p. for probability $p_{i,j}$

$p_{i,j}$: probability for i-th sample for j-th building block

$L_{452}(p_i, j)$: Recommendation ITU-R P.452 loss for probability p_i from j-th building block

p_i: probability to use in ITU-R P.452 for i-th sample

$G_{RAS}(j, az_i)$: RAS receive mean gain over observation towards j-th building block for RAS pointing angle az_i

A_{OoB}: attenuation between in-band and OoB emissions. In the case of in-band analysis this field can be ignored or set to zero.

Note that L_{452} is assumed to be a positive number representing a loss.

The antenna heights of P-MP HDFS transmitter and RAS receiver are used with the Recommendation ITU-R P.452. propagation model to determine the loss as required.

Based upon equation (1), the probability of an observation receiving interference can be calculated using the following steps:

Step 1: Set sample count $N = 0$.

Step 2: Set interfered observations $M = 0$.

Step 3: While the sample count $N < N_{max}$ repeat Steps 4 to 17.

Step 4: Calculate azimuth of RAS antenna Az = random(–180, +180).

Step 5: Calculate Recommendation ITU-R P.452 percentage of time p_i = random (0, 100).

Step 6: Set aggregate mean interference $I = 0$.

Step 7: For each test point within the DA, j, repeat Steps 8 to 14.

Step 8: Calculate BB deployment probability for the j-th test point $p_{i,j}$ = random (0, 1).

Step 9a: In the case of FDMA systems, using the a.e.i.r.p. distribution for the j-th test point, determine a.e.i.r.p.($p_{i,j}$).

Step 9b: In case of TDMA systems, using the a.e.i.r.p. distribution for the j-th test point, the a.e.i.r.p.($p_{i,j}$), may be determined by randomly choosing x samples where x represents the number of subdivision time slots of the TDMA systems, then the a.e.i.r.p. may be calculated by averaging the x samples.

Step 10: Calculate the ITU-R P.452 loss between j-th test point and the RAS site for p_i% of time, $L_{452}(p_i,j)$.

Step 11: Calculate the difference in azimuth ∇Az_j between RAS observation Az, and azimuth at the RAS site towards the j-th test point.

Step 12: Calculate the mean gain $G_{RAS,j}$ at the RAS site towards the j-th test point by looking up the mean gain associated with difference in azimuth ∇Az_j, using linear interpolation where necessary.

Step 13: Calculate interference from this test point at the RAS site using (noting that for in-band analysis $A_{OoB} = 0$):

$$I_j = AEIRP(p_{i,j}) - L_{452}(p_i,j) + G_{RAS,j} - A_{OoB}$$

Step 14: Increment aggregate mean interference I by I_j:

$$I \Rightarrow I + 10\hat{}(I_j/10)$$

Step 15: When all test points have been included, convert aggregate mean interference I into dB:

$$I \Rightarrow 10 \log_{10}(I)$$

Step 16: If the aggregate mean interference I exceeds the RAS threshold then increment the interfered observations count, M.

Step 17: Increment the sample count, N.

Step 18: Calculate the probability an observation receives interference, $P_{ob} = 100M/N$.

NOTE 1 – Number of samples required – test for statistical significance.

One approach to determining the significance of the results is the Student *t*-distribution test. This is based upon calculating the difference from the population mean divided by the estimated standard error, namely:

$$t = \frac{\bar{x} - \mu}{s_{n-1} / \sqrt{n}}$$

where:

$\bar{x}$: mean calculated from sample

μ: mean from total population

s_{n-1}: standard deviation of sample

n: sample size.

This can then be compared against the *t*-distribution likelihood of a hypothesis (for example that $\mu > 2\%$) to the required level of certainty.

The following steps show how it could be implemented in the algorithm:

Step 1: Set simulation to log the probability I exceeded every 1 000 time steps.

Step 2: Run for 5 sets of 1 000 time steps.

Step 3: Test data to date for *t*-significance to required level of certainty.

Step 4: If not significant then run another 1 000 steps and go to Step 3.

Step 5: When significant, report results.

NOTE 2 – Use of Recommendation ITU-R P.452.

The Recommendation ITU-R P.452 percentage of time P is a random number from a uniform distribution between 0 and 100%. To be compatible with the ranges of probability accepted by the methodology in this Recommendation the following limits should be applied:

– if P is greater than 50%, then set P = 50%;

– if P is less than 0.001%, then set P = 0.001%.

Where terrain and clutter databases are available, they should be used to calculate the Recommendation ITU-R P.452 loss.

5 Output of methodology

The output from the methodology is a probability that an observation receives interference, P_{ob}.

This can be compared against the acceptable probability of observation receiving interference, namely 2% for a P-MP HDFS network.

Therefore, to protect the RAS site the following condition must be true:

$$P_{ob} \leq 2\% \qquad (2)$$

Attachment 1
to Annex 1

Example calculation

This Attachment gives an example of using the methodology in Annex 1 to determine the probability of an observation at Jodrell Bank being exposed to interference from wide-scale deployment of P-MP HDFS networks.

RAS model

The parameters in Table 3 were the inputs to the model of Jodrell Bank.

TABLE 3

RAS input parameters

Frequency band	43 GHz
Observation type	Continuum analysis
Minimum elevation	5°
Site latitude	+53° 14’ 1.2”
Site longitude	–02° 18’ 8.9”
Antenna height	30 m above terrain
Gain pattern model	Rec. ITU-R S.1428

From the observation type and frequency, the interference thresholds in Table 4 were derived from Recommendations ITU-R RA.769 and ITU-R RA.1513.

TABLE 4

RAS thresholds

Threshold of mean interference during 2 000 s observation	–220.6 dB(W/MHz)
Acceptable probability of observation receiving interference, P_{ob}	2%

From the minimum elevation angle and an observation period of 2 000 s, the antenna azimuth and elevation ranges in Table 5 were derived.

TABLE 5

Range of RAS azimuth and elevation angles

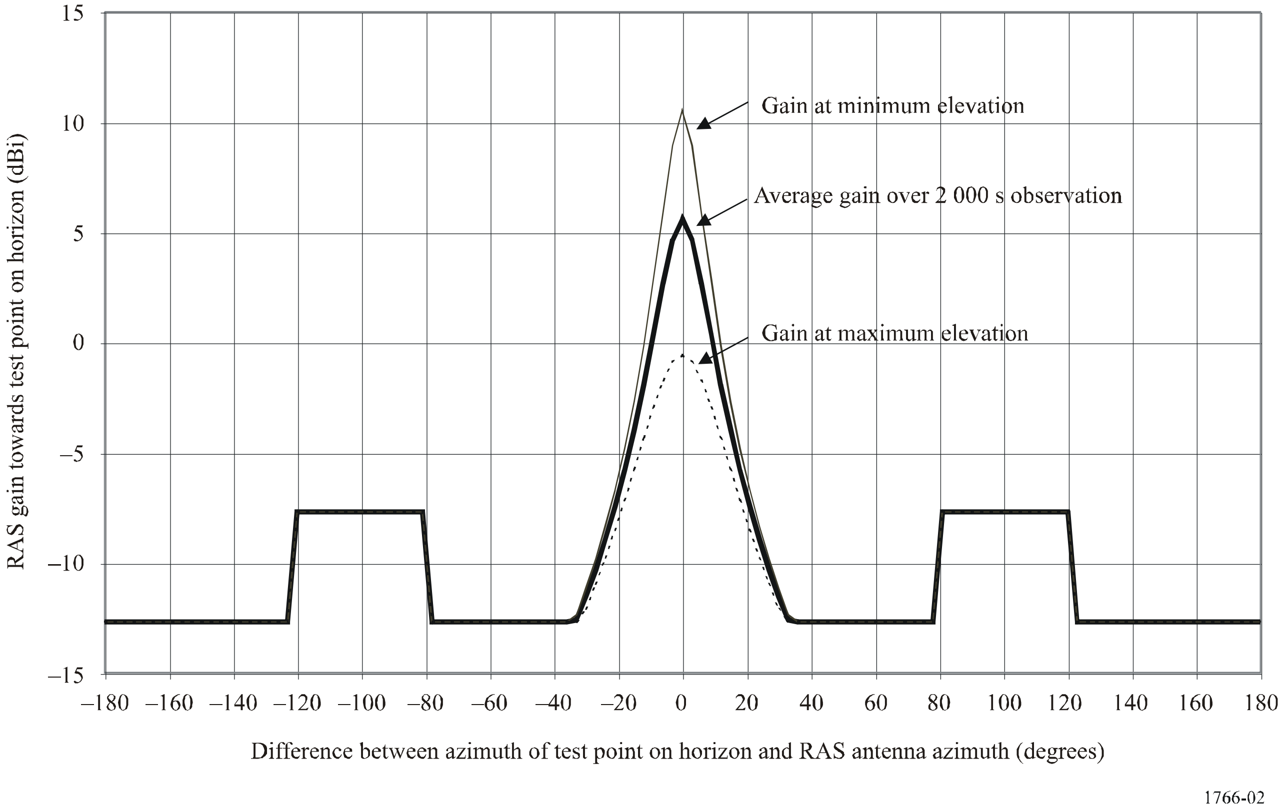
	Start	**End**
Azimuth	0°	0°
Elevation	5°	13.33° (1)

(1) After 2 000 s the Earth rotates 8.33°, and hence 13.33° = 5° + 8.33°.

Using a set of test points on the horizon every 3°, the mean gain for the gain pattern defined in Recommendation ITU-R S.1428 was calculated, as shown in Fig. 2.

FIGURE 2

Mean gain of RAS antenna based upon Recommendation ITU-R S.1428



P-MP HDFS model

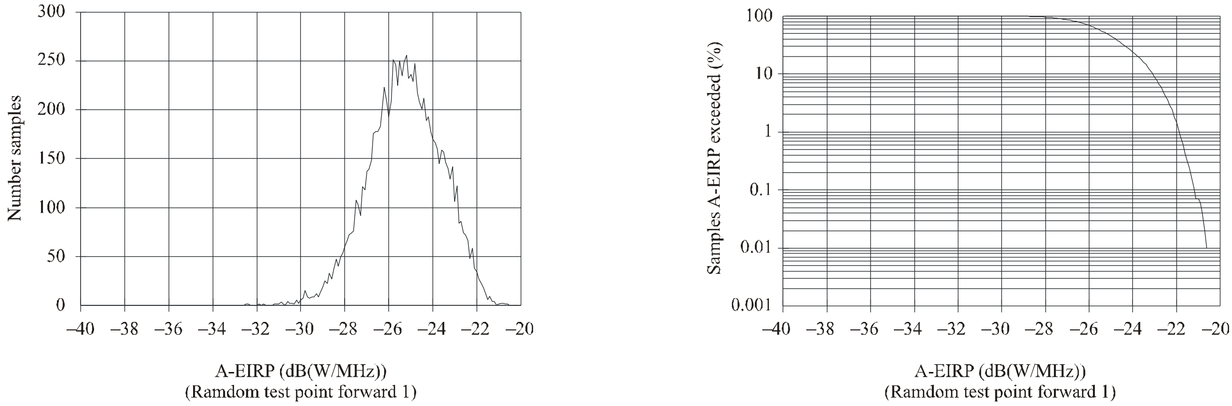
The reference model used to calculate the a.e.i.r.p. distribution defines the P-MP HDFS characteristics. In this case it was a broadband fixed wireless access (BFWA) network using base station (BS) antennas at 20 m, serving commercial customers with antennas at 5 m, considering the uplink (UL) direction from customer to base station.

The objective of the analysis was to determine whether an EZ based upon $L_{452}(10\%) \geq 161$ dB would be sufficient to protect the RAS from OoB emissions of wide-scale deployment of this type of P-MP HDFS network.

The algorithm in Recommendation ITU-R F.1760 was used to derive the a.e.i.r.p. distribution in Fig. 3 as a histogram and cumulative distribution function (CDF).

FIGURE 3

a.e.i.r.p. histogram and CDF for P-MP HDFS reference model



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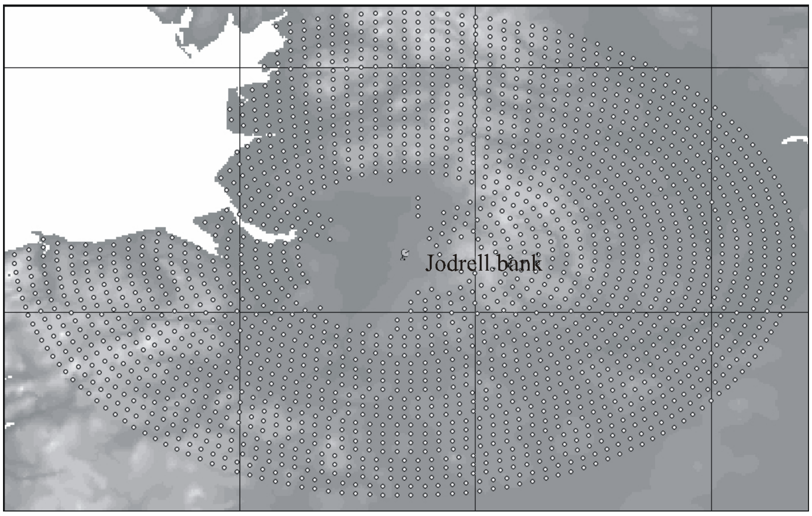
Each BB represented all transmissions within a 4 × 4 km area.

The customer equipment was considered to be 5 m above the terrain, and the attenuation of the OoB signal was determined to be 46.79 dB with respect to in-band emissions.

The EZ of $L_{452}(10\%) \geq 161$ dB corresponds to a deployment area (DA) of test points as shown in Fig. 4.

FIGURE 4

DA for EZ defined by $L_{452}(10\%) \geq 161$ dB



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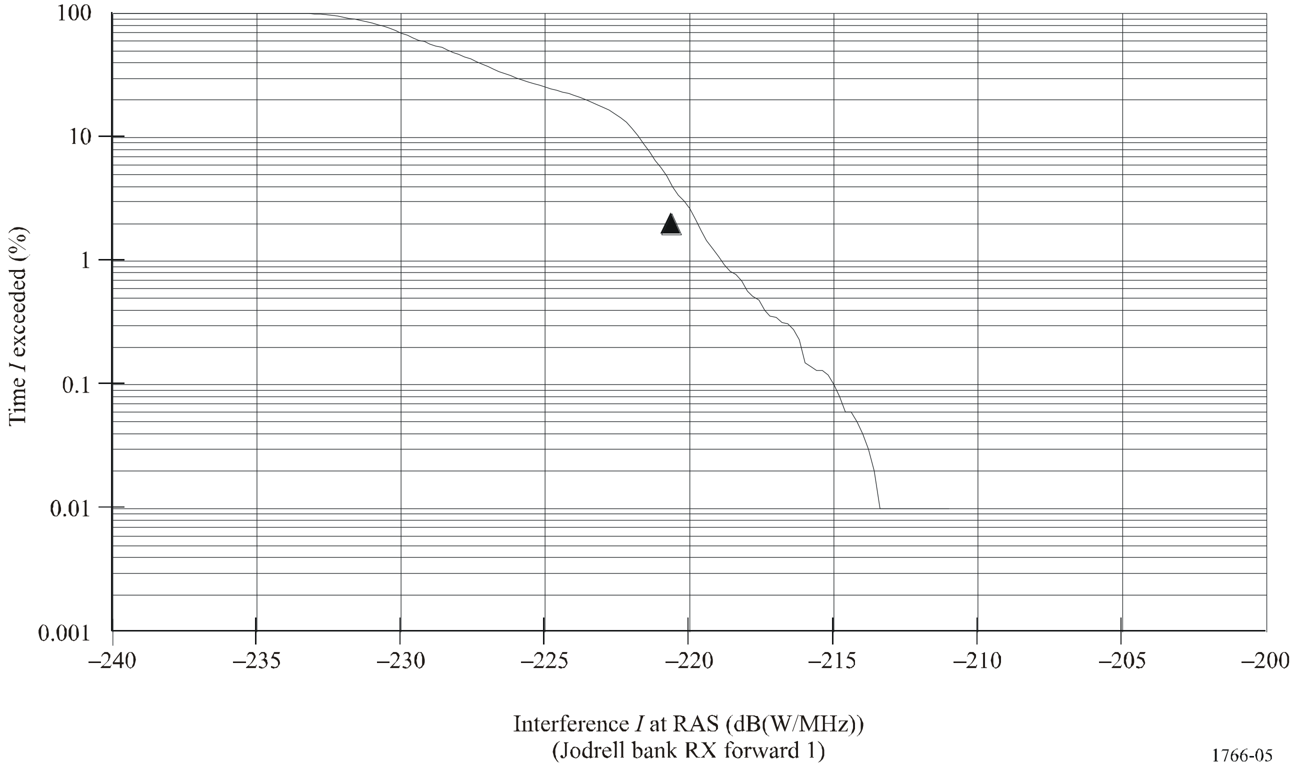
Interference calculated

Using the parameters defined above a distribution of interference vs. probability of interference exceeded was calculated for 10 000 samples. This plot is shown in Fig. 5. The RAS threshold is shown on this plot as a triangular mark.

FIGURE 5

Example of CDF of interference from P-MP HDFS into RAS



Output of methodology

The calculated P_{ob} = 4% was greater than the required level of 2%. Therefore the EZ would have to be increased to protect the RAS observatory.

Annex 2

Methodology to determine the exclusion zone (EZ) around the RAS site, defined by a propagation loss from the RAS site, outside of which stations of the P-MP HDFS may be deployed without likelihood of causing interference into the RAS

This Annex provides a methodology which may be used to derive an EZ around an RAS site for transmitting P-MP HDFS stations which may be used by administrations in national and bilateral discussions as method to protect RAS sites from potential interference from P-MP HDFS stations.

1 Propagation loss exclusion zone

A method to protect services such as RAS from interference is to define an exclusion zone (EZ) around the site within which transmission is not permitted. One approach to define an EZ is based upon distance, but this can lead to large EZs as there are often worst case azimuths for which large separation distances are required.

A more efficient approach is for the EZs to be defined based upon propagation loss, such that the separation distance required varies depending upon azimuth. Coordination contours include a degree of propagation loss by taking account of the different characteristics of radiowave propagation over land and sea. This approach can be extended to use the local terrain and a detailed propagation model such as that described in Recommendation ITU-R P.452.

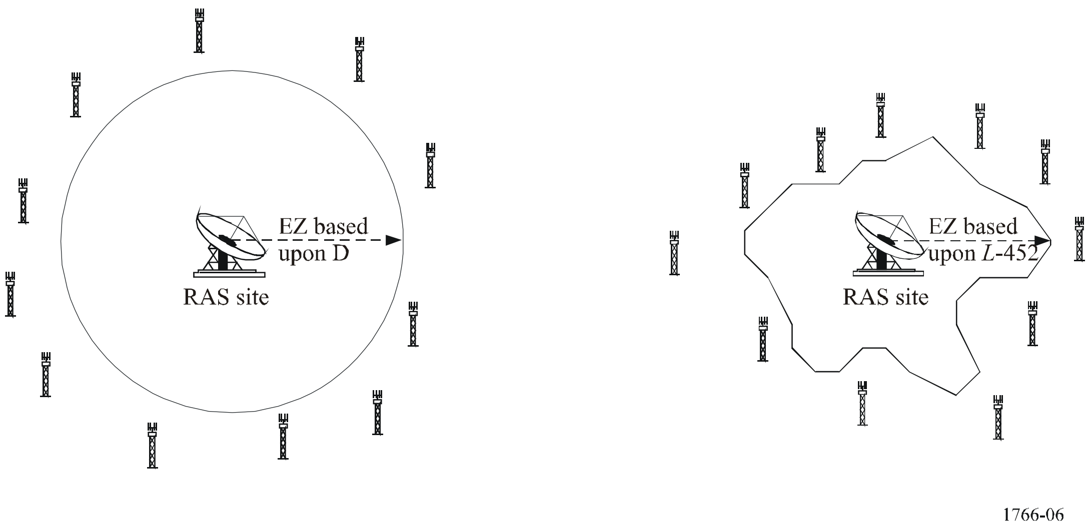
The EZ is then defined by allowing transmission at locations for which the propagation loss to the RAS site as calculated by Recommendation ITU-R P.452, or L_{452}, for a specified percentage of time such as 10% is greater than a defined value, i.e.:

$$L_{452}(10\%) \geq X \text{ dB} \tag{3}$$

Figure 6 shows examples of P-MP HDFS deployment outside EZs defined by distance and L_{452}.

FIGURE 6

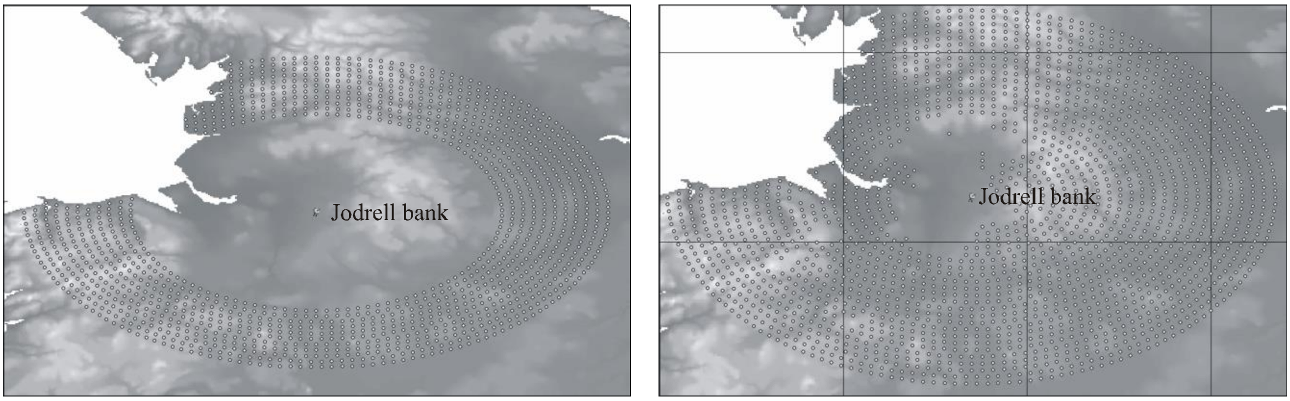
EZs based upon distance and L_{452}



Typically EZs based upon L_{452} are smaller in area than those based upon distance. For example the two deployments in Fig. 7 both just protect the RAS site from interference from the same P-MP HDFS reference model.

FIGURE 7

Example EZs based upon distance and L_{452}



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In both cases the test points located in the sea were removed. For these two cases the example EZs were defined as in Table 6:

TABLE 6

Comparison of EZ approaches using example results

EZ type	Distance based	L_{452}(10%) based
EZ parameter	$D \geq 66$ km	$L_{452}(10\%) \geq 176$ dB
EZ size	14 186 km^2	5 162 km^2

EZs based upon L_{452}(10%) are therefore an efficient and flexible method to protect services such as the RAS from interference.

2 Derivation of exclusion zone (EZ) size

Determination of a suitable EZ value of X such that $L_{452}(10\%) \geq X$ would protect the RAS requires an iterative procedure, as shown in the steps below. The algorithm uses the methodology in Annex 1 of this Recommendation to calculate the P_{ob}, the probability a RAS observation receives interference for a particular value of X.

Step 1: Make initial estimate of X_1 (for example $X_1 = 200$ dB).

Step 2: Calculate the probability an observation receiving interference from deployment of P-MP HDFS $P_{ob\text{-}1} = P_{ob}(X_1)$, using DA defined by locations for which the $L_{452}(10\%) \geq X_1$.

Step 3: If $P_{ob\text{-}1} > 2\%$ (the RAS threshold) then take the next estimate $X_2 = X_1 + 16$ dB.

Step 4: If $P_{ob\text{-}1} < 2\%$ (the RAS threshold) then take the next estimate $X_2 = X_1 - 16$ dB.

Step 5: Repeat Steps 2-5 until X_n and X_{n+1} result in $P_{ob\text{-}n}$ and $P_{ob\text{-}n+1}$ that bracket the required threshold of 2%.

Step 6: Binary chop X_n and X_{n+1} until the difference between the two is 1 dB i.e. $|X_n - X_{n+1}| = 1$ dB.

Step 7:The result is the greater of X_n and X_{n+1} i.e. the one for which the $P_{ob} < 2\%$.

NOTES:

a) Steps of less than or greater than 16 dB maybe used to search for a bracketed pair of X_n if applicable.

b) While it is feasible to continue iterating such that the difference between X_N and X_{n+1} is less than 1 dB, it should be noted that there are limits to the accuracy of the Recommendation ITU-R P.452 propagation model.

3 Types of EZ

3.1 P-MP HDFS reference models

The size of the EZ will depend upon the P-MP HDFS reference model as specified via the a.e.i.r.p. distribution and antenna height. The L_{452} (10%) uses this height, and the EZ is valid for antennas less than or equal to this height.

Within the band a number of different P-MP HDFS reference models could be considered, for example considering:

– architecture: point-to-multipoint (P-MP) or multi point-to-multipoint (MP-MP);

– direction: uplink (UL) or downlink (DL);

– environment: high density urban or low density rural.

Each reference model would result in different sizes of EZ, so there could be a set as in Table 7.

TABLE 7

Set of EZs for set of P-MP HDFS reference models

P-MP HDFS system	EZ	Maximum height
Reference model-1	EZ: $L_{452}(10\%) \geq X_1$	Height $\leq H_1$
:	:	:
Reference model-*n*	EZ: $L_{452}(10\%) \geq \mathrm{X}_n$	Height $\leq H_n$

The RAS site could be protected either by using the largest EZ size and associated height or having each reference model having its own EZ (e.g. band segmentation). To be effective, each EZ should be associated with the assumptions in the reference models used to derive the a.e.i.r.p.s.

3.2 Demographics-based EZs

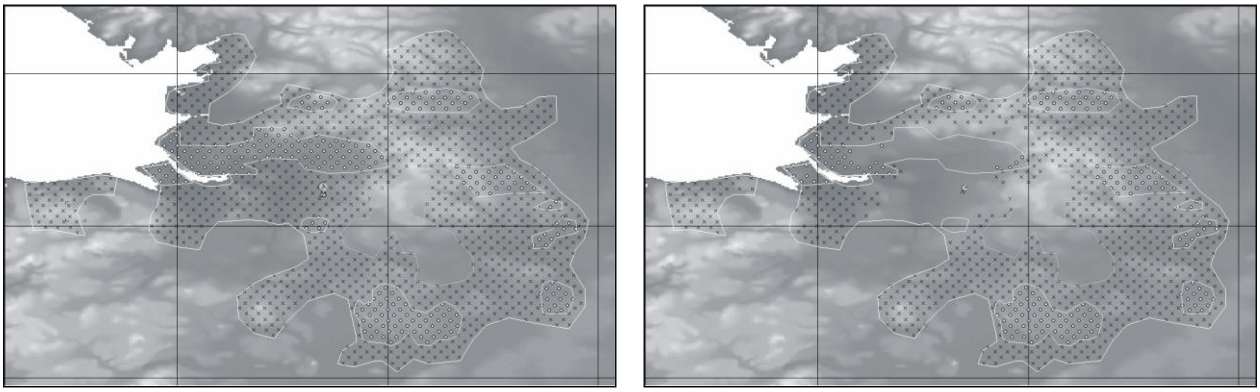
The deployment area (DA) discussed above assumed uniform distribution of a single reference model around the RAS site. This can lead to conservative situations – for example it could result in deployment of P-MP HDFS stations in mountainous areas. These locations, which are unlikely to provide a market for P-MP HDFS operators, could produce high levels of interference if there was line-of-sight to the RAS site.

Therefore it can be more realistic to exclude locations where no P-MP HDFS stations are planned and to use reference models that vary depending upon location.

An example is shown in Fig. 8, whereby two reference models are assumed to be deployed depending upon population density. This DA would then be used as the starting point to calculate the required EZ.

FIGURE 8

Demographic-based P-MP HDFS deployment area around Jodrell Bank: Baseline DA and DA including the impact of an example EZ



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In Fig. 8 circles represent P-MP HDFS reference models for urban areas and crosses represent rural areas.

3.3 Multiple zones

The approach described above was based upon a single EZ: within the EZ no transmissions were permitted. This exclusion zone could be combined with a restricted zone, with different behaviour in each:

Unrestricted zone (UZ): In the UZ, the P-MP HDFS operators would be free to operate, limited only by interoperator restrictions.

Restricted zone (RZ): Within the RZ P-MP HDFS operators would be allowed to transmit in accordance with defined and agreed restrictions on operation.

Exclusion zone (EZ): Within the EZ no P-MP HDFS transmissions would be allowed.

Examples of restrictions within the RZ could include avoid pointing antennas within a defined angle of the RAS site. This would require multiple a.e.i.r.p.s, one for use in the UZ and one for use in the RZ.

3.4 In-band and OoB EZs

As well as protecting the RAS from co-frequency P-MP HDFS operation, this methodology can also be used to determine EZs to protect the RAS from OoB emissions. The algorithm to calculate the probability of an observation receiving interference, P_{ob}, includes a term to account A_{OOB} for the attenuation between in-band and OoB emissions.

This approach can be used to generate two EZs, one for co-frequency operation and one for adjacent band operation.

Attachment 1
to Annex 2

Example calculation

This Attachment gives an example of using the methodology in Annex 2 to determine the EZ required to protect Jodrell Bank from unacceptable interference from wide-scale deployment of P-MP HDFS networks.

RAS model

The RAS model is given in Attachment 1 to Annex 1.

HF-FS model

The P-MP HDFS model is given in Attachment 1 to Annex 1.

Interference calculation

Table 8 identifies the iterations required to calculate the size of the EZ.

TABLE 8

Iteration of EZ size using methodologies in Annexes 1 and 2

Iteration	EZ size $L_{452}(10\%) \geq X$ dB	P_{ob} (%)
1	200	0.0
2	180	0.0
3	160	4.3
4	170	0.1
5	165	0.3
6	162	1.0
7	161	4.0

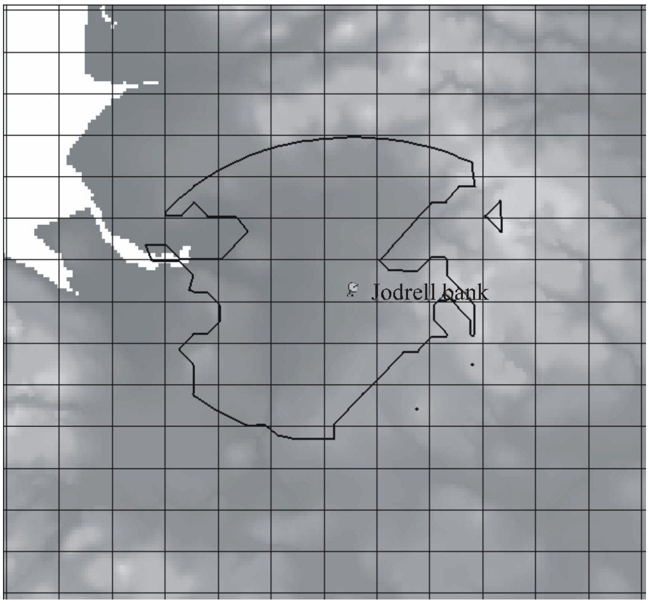
It was concluded that a suitable size of EZ to protect the RAS from this example P-MP HDFS reference model was:

$$L_{452}(10\%) \geq 162 \text{ dB}$$

This example EZ is shown in Fig. 9.

FIGURE 9

Example EZ: Contour of L_{452} (10%) = 162 dB



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