RECOMMENDATION ITU-R M.1316-1*

Principles and a methodology for frequency sharing in the 1 610.6-1 613.8 MHz and 1 660-1 660.5 MHz bands between the mobile-satellite service (Earth-to-space) and the radio astronomy service

(Question ITU-R 201/8)

(1997-2005)

Scope

This Recommendation provides the principles and methodology that may be applied for the protection of the radio astronomy observations from emissions of land and maritime mobile earth stations in the 1 610.6-1 613.8 MHz and 1 660-1 660.5 MHz bands. Annex 1 describes the three steps to be followed, with Annex 2 describing the calculation of the "separation distance by default" using the Monte Carlo methodology based on the principle of sampling random variables. Annex 3 calculates the restriction zones. Step 3 is the calculation of exclusion zones using the specific characteristics of the systems involved.

The ITU Radiocommunication Assembly,

considering

a) that the World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992) (WARC-92) allocated the band 1 610-1 626.5 MHz on a primary basis to the mobile-satellite service (MSS) in the Earth-to-space direction, and the band 1 610.6-1 613.8 MHz on a primary basis to the radio astronomy service (RAS);

b) that the frequency band 1 610.6-1 613.8 MHz is used by radio astronomers to observe the spectral line of the hydroxyl molecule near 1 612 MHz;

c) that No. 5.372 of the Radio Regulations (RR) states that "Harmful interference shall not be caused to stations of the radio astronomy service using the band 1 610.6-1 613.8 MHz by stations of the radiodetermination-satellite and the mobile-satellite services (No. **29.13** applies)";

d) that the mobile-satellite systems operating in the 1 610-1 626.5 MHz band are likely to be utilizing mobile earth stations (MESs) with omni-directional antennas;

e) that the 1 660-1 660.5 MHz frequency band is allocated to the RAS on a shared, primary basis with the land-mobile satellite service (LMSS) in the Earth-to-space direction;

f) that the importance of the allocation at 1 660-1 660.5 MHz to the RAS was confirmed by Resolution 6 of the 20th General Assembly of the International Astronomical Union (IAU) (Baltimore, United States of America, August, 1988) and reconfirmed at the 21st General Assembly of the IAU (Buenos Aires, Argentina, July, 1991) and at the 22nd General Assembly of the IAU (The Hague, The Netherlands, 1994);

g) that Recommendation ITU-R RA.1031 does not fully take into account the statistical nature of the interference caused by mobile transmitters,

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

recommends

1 that principles and methodologies similar to those described in Annex 1 may be used in coordination between radio astronomy stations and land and maritime MESs in the bands 1 610.6-1 613.8 MHz and 1 660-1 660.5 MHz;

2 that further studies are needed by ITU-R, including studies for aircraft earth stations, in order to review the applicability of this Recommendation for detailed coordination between the MSS and the RAS;

3 that in any application of a methodology the input parameters should be agreed by the parties concerned during coordination;

4 that the ITU-R should, in cooperation with the Radiocommunication Bureau, jointly develop a computer program to implement the methodology given in Annexes 1 to 4.

Annex 1

Assessment of the interference from MES/MSS into radio astronomy observations

The protection of radio astronomy observations can be provided through three different steps:

Step 1: by setting a **separation distance by default** between an RAS site and an MES, which defines an area around an RAS site outside of which no restriction applies to the operation of MESs.

Step 2: by setting a **restriction zone** around an RAS site, which defines an area within which there may be some restriction to the operation of MESs. These restrictions should be defined by the regulator and agreed by the radio astronomy community and MSS operator.

Step 3: by setting an **exclusion zone** around an RAS site, defined by means of detailed assessment of the characteristics of the systems involved and measurements if necessary, within which no operation of MESs should be allowed.

Annex 2 and Annex 3 describe methodology which should be used for the calculations respectively for Step 1 and Step 2. Precise details for the conditions for the operation of the mobiles in the restriction zone need to be agreed by the concerned parties, in order to arrive at an exclusion zone, following the definition above in Step 3.

Annex 4 provides the list of the set of characteristics which are necessary for running a simulation.

Step 1 calculation is intended to provide separation distances by default. Annex 2 describes a general methodology of calculation which can be used for that purpose, using Monte Carlo methodology.

The basis of this model is to calculate the statistics of the interfering power produced at an RAS site by MESs in operation.

In order to protect radio astronomy observations, it is stated that:

"a 2000 second integration taken at any time of the day should have at least (100 – x)% of being interference free, i.e. the mean interference power is below the levels specified in Recommendation ITU-R RA.769.

The figure of 90% (x = 10) has its origin in propagation calculations (ITU-R Handbook on Radio Astronomy, § 4.2.4. See also Recommendation ITU-R RA.1031). The wider interpretation of this figure is under consideration within ITU-R".

Thus, Annex 2 methodology should be used with the following assumptions:

– 2 000 s integration time (constant for all trials);
– peak traffic assumption;
– x% of time maximum interference criteria for the RAS (10% is the current value subject to revision by the ITU-R).

In the case where different sources of interference are identified for the radio astronomy observations, further studies are required on the possible splitting of the maximum interference power level.

Annex 2

Step 1 methodology: Calculation of separation distances by default between RAS sites and MESs

1 Introduction

This Annex describes a general methodology which can be used for the calculation of separation distances by default between RAS sites and the areas where MESs are allowed to transmit.

These separation distances, based on calculations using a Monte Carlo methodology, should ensure the protection of radio astronomy observations.

2 General principles used in the methodology

2.1 Monte Carlo methodology

In order to calculate the separation distances by default between RAS sites and MESs, it is necessary to evaluate the probability function of the interfering power produced by the mobiles and experienced by the RAS receivers.

This can be done by using statistical modelling of interference, such as a Monte Carlo methodology.

The Monte Carlo methodology is based on the principle of sampling random variables from their defined probability distributions.

The variables to be sampled are often various and numerous, as the accuracy of the model usually increases with their number.

In the particular case of the determination of separation distances by default, these variables may include the number of mobiles, the location of the mobiles, the propagation condition.

The statistics of the interfering power produced at an RAS site by MESs in operation is then derived from the calculation of interfering powers experienced for each sample.

2.2 Protection of radio astronomy observations

Radio astronomy observations are performed by using time averaging, to significantly reduce noise fluctuations.

In order to reflect such practice, statistics of received interfering power are based on integration time samples used during the observations.

The interference power coming from the MSS population is acceptable provided that no more than *x*% of the 2 000 s integration periods have mean interference power above the RAS detrimental level.

The following is based on this definition.

3 Presentation of the methodology of calculation

As stated in § 2, statistics of interfering powers are based on integration time samples:

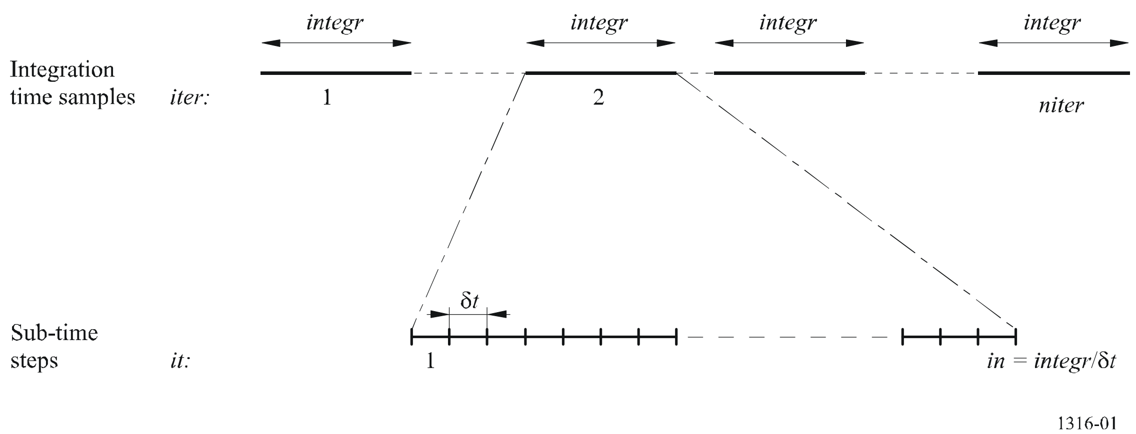
niter: number of integration time samples needed for the statistic.

integr: duration of the integration time sample. In the following, *integr* is supposed to be constant.

During each integration time sample *integr*, the mean interference power produced by MESs is calculated by averaging "instantaneous" interfering powers produced within sub-time steps of δt seconds duration.

FIGURE 1

Division of integration time samples

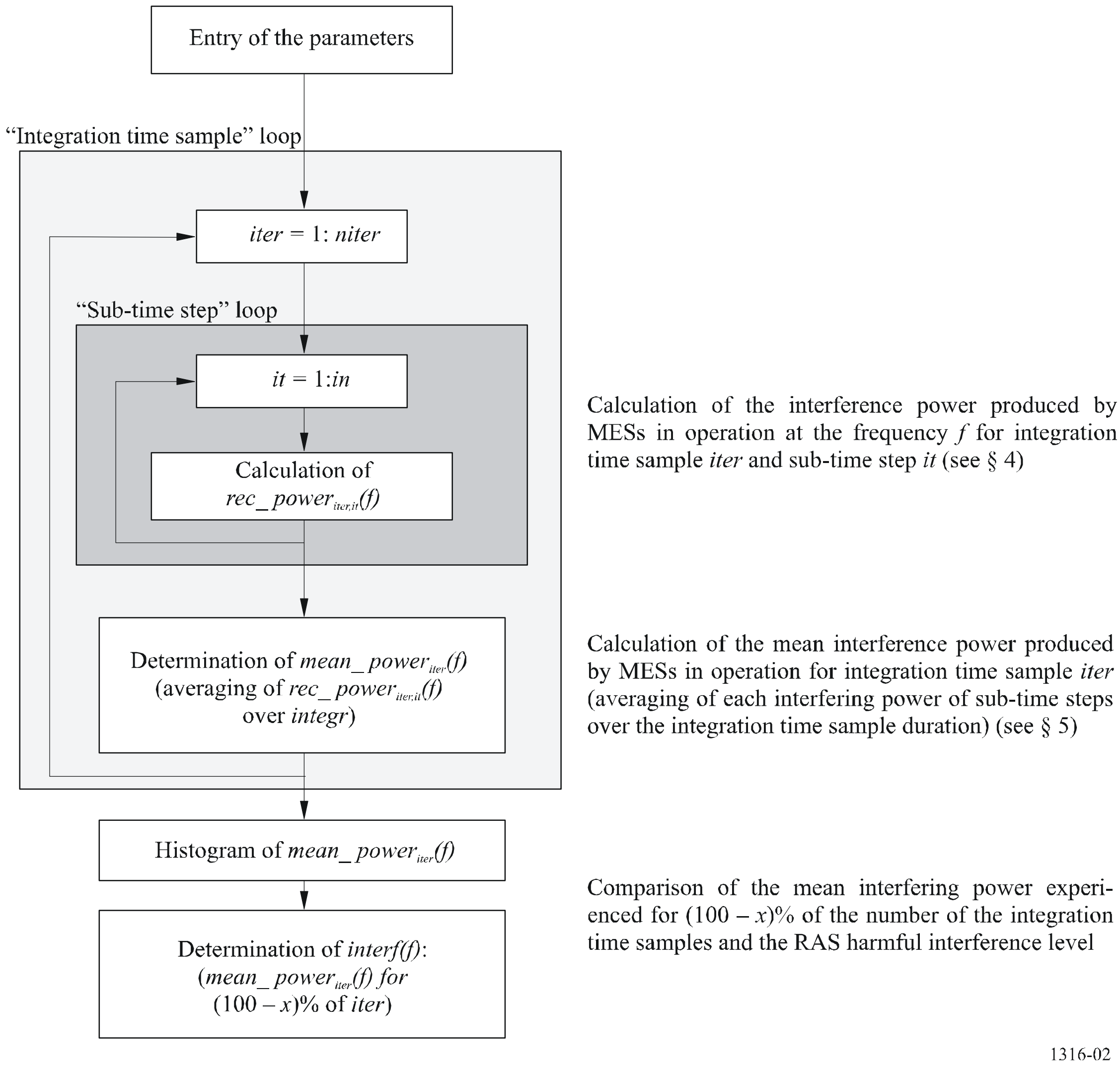


During each of the sub-time steps, interfering powers are determined by making random trials on the traffic load of the MSS system under consideration and on the location of each MES in operation.

The outline flow chart of the calculation is given in Fig. 2:

FIGURE 2

General flow chart of the calculation



4 Calculation of the interfering power experienced during a sub-time step – modelling of traffic

The interfering power experienced during each sub-time step at the frequency f is calculated by summing power produced by each mobile in operation during this time step.

For each time step *it*, it is thus necessary to determine:

– the number of mobiles in operation during *it* (derived from a given traffic law);

– the channels the active MESs are using;

– the location of the mobiles around the RAS site distance, azimuth, etc.

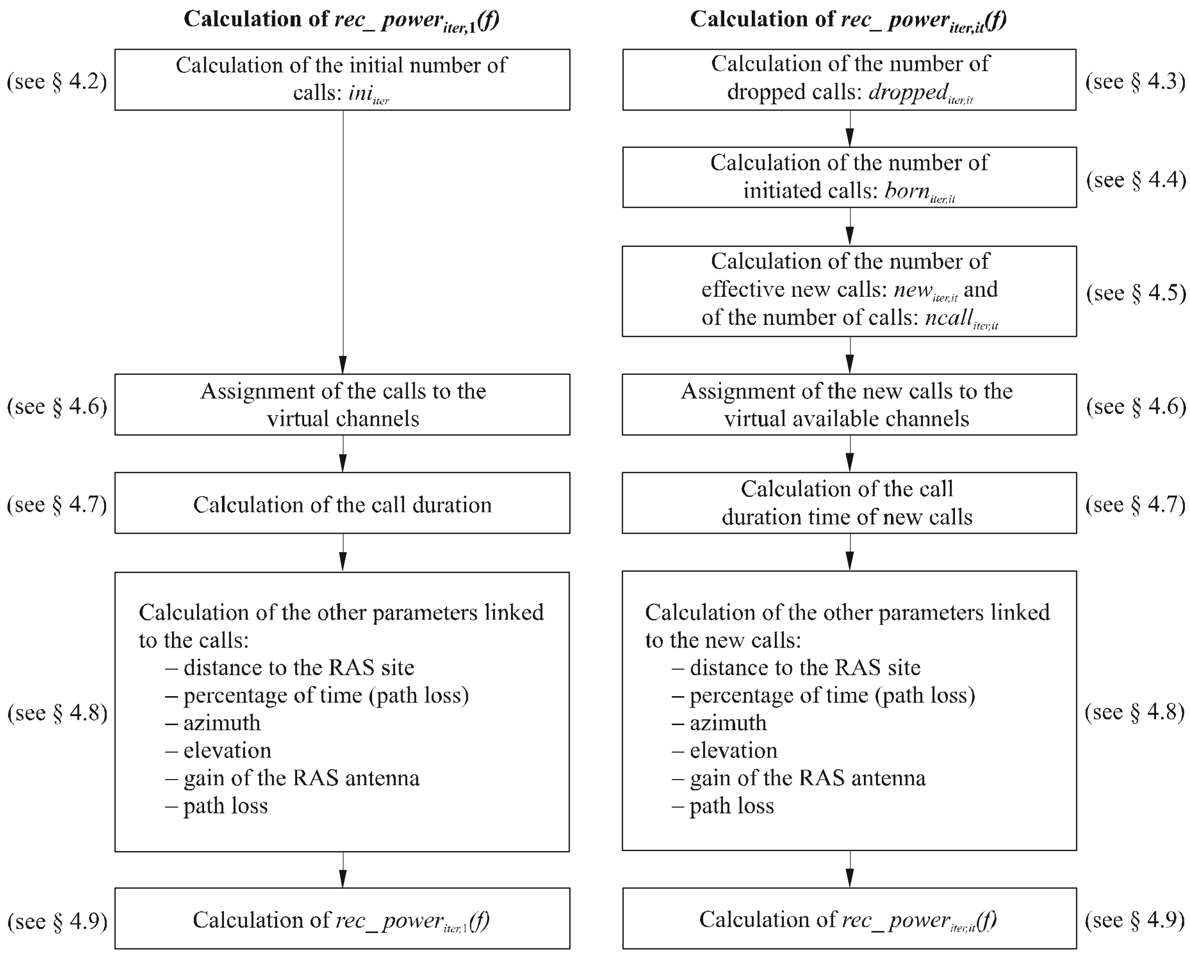
In order to keep the correlation between each sub-time steps, the number of mobiles in operation for sub-time step *it* is derived from the number of mobiles in operation for $it – 1$, by taking into account the number of calls dropped and initiated in-between.

For the first sub-time step, the initial number of calls is calculated by making a random trial.

Figure 3 gives the outline chart for calculation of $rec\_power_{iter,it}(f)$ (integration time sample *iter*, sub-time step *it*).

FIGURE 3

Calculation of $rec\_power_{iter,it}(f)$



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4.1 Monte Carlo random trials

As stated in § 2.1, the Monte Carlo methodology is based on the principle of sampling random variables from their defined cumulative distribution functions.

Considering for example a variable x, with the cumulative distribution function $P(X)$, is then the probability $p(x \leq X)$.

$P(x)$ is uniformly distributed between 0 and 1.

So, a random uniform trial of $P = P(x_i)$ between 0 and 1 leads to a single value of x_i, enabling $x = f^{-1}(P)$ to be plotted.

4.2 Calculation of the initial number of calls: ini_{iter}

At the beginning of each integration time sample, the initial number of calls is calculated using the formula giving the cumulative distribution function of having ini_{iter} simultaneous calls at any instant t:

$$P = \frac{\sum_{i=0}^{ini_{iter}} \frac{E^i}{i!}}{\sum_{i=0}^{Ncall} \frac{E^i}{i!}} \tag{1}$$

where:

P: cumulative probability of having ini_{iter} simultaneous calls at the instant t ($ini_{iter} \leq Ncall$)

E: peak demanded load on the system measured (E)

$Ncall$: maximum number of simultaneous calls the MSS system can support.

Thus, ini_{iter} can be derived from an uniform random trial of P by using formula (1) (see § 4.1).

4.3 Calculation of the number of dropped calls: $dropped_{iter,it}$

The number of dropped calls for the $iter^{th}$ integration time sample is calculated by determining the number of calls for which the call duration is less than or equal to it:

If $ncall_{iter,it-1}$ is the number of calls of sub-time step $it - 1$ ($it \neq 1$), consider one specific call c of this sub-time step:

– if the call termination time of call c is less or equal than it then this call is dropped and is not retained for the calculation of $rec\_power_{iter,it}(f)$. This call is added to the dropped call count ($dropped_{iter,it}$).

– if the call termination time of call c is more than it, then this call is retained for the calculation performed at sub-time step it.

4.4 Calculation of the potential number of attempted calls: $born_{iter,it}$

For each time step, the potential number of initiated calls is calculated using the formula giving the cumulative distribution function of birth of calls over a specified interval of time:

$$P = \sum_{i=0}^{born_{iter,it}} \frac{(\lambda\, \delta t)^i}{i!} e^{-\lambda\, \delta t} \tag{2}$$

where:

P: cumulative probability of having $born_{iter,it}$ calls attempted between sub-time steps it and $it + 1$

λ: is the mean call rate of the satellite system

δt: is the sub-time step's duration.

Thus, $born_{iter,it}$ can be derived from an uniform random trial of P by using formula (2) (see § 4.1).

4.5 Calculation of the effective number of new calls $new_{iter,it}$, and of the number of calls $ncall_{iter,it}$

Among the calls (attempted), not all will succeed because of the physical limitations of the system (maximum number of calls).

If $ncall_{iter,it-1}$ is the number of calls at sub-time step $it-1$ ($it \neq 1$) (used in the calculation of $rec\_power_{iter,it}(f)$) then:

$dropped_{iter,it}$ is the number of calls dropped between sub-time steps it and $it+1$,

$born_{iter,it}$ is the number of calls attempted between sub-time steps it and $it+1$,

then the effective number of calls to be taken into account for the calculation of $rec\_power_{iter,it}(f)$ is calculated using the following formula:

$$ncall_{iter,it} = \min(Ncall, ncall_{iter,it-1} + born_{iter,it} - dropped_{iter,it}) \qquad (3)$$

and the number of effective new calls is then:

$$new_{iter,it} = ncall_{iter,it} - ncall_{iter,it-1} + dropped_{iter,it} \quad (new_{iter,it} \leq born_{iter,it}) \qquad (4)$$

If $it = 1$, $ncall_{iter,1} = ini_{iter}$.

4.6 Assignment of the (new) calls to the available traffic channels

With both code division multiple access (CDMA) and time division multiple access (TDMA), several calls can be allocated to the same physical channel. We define a traffic channel each of the possible call slots (identified in the time domain for TDMA or by the code for CDMA), so that there are *nmax* traffic channels for any physical channel.

The total traffic is uniformly distributed amongst the available traffic channels in an area having a radius of one spot beam. This means that:

– if $it = 1$, the ini_{iter} calls are uniformly distributed over all the *Ncall* traffic channels,

– if $it \neq 1$, the $new_{iter,it}$ calls are uniformly distributed over the $ncall_{iter,it-1} - dropped_{iter,it}$ available traffic channels.

If different distributions for the assignment of traffic among the available traffic channels are provided by operators, these may be incorporated into the methodology.

4.7 Calculation of the call termination time of the (new) calls

For each new call *c*, the call termination time is determined by using the formula giving the cumulative distribution function call duration:

$$P = 1 - e^{\frac{-(T_c - t)}{\mu}} \qquad (5)$$

where:

P: cumulative probability of having a call duration of less than $(T_c - t)$

t: current sub-time step (date of birth of the call)

T_c: call termination time

μ: mean call length of the satellite system.

Thus, T_c can be derived from an uniform random trial of P using the following formula (see § 4.1):

$$T_c = t - \mu.\ln(1 - P) \tag{6}$$

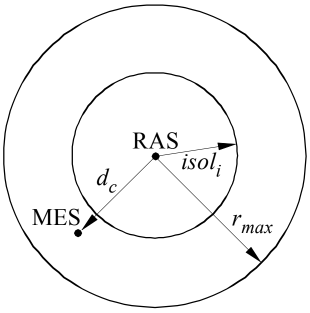
4.8 Calculation of the other parameters linked to the (new) calls

4.8.1 Calculation of the distance between the mobile and the RAS antenna

MESs are assumed to be uniformly distributed around the RAS site.

When a new call c is made on channel i, the cumulative distribution function of having the MES at the distance d_c is given by the following formula:

$$P = \frac{d_c^2 - isol_i^2}{r_{max}^2 - isol_i^2} \tag{7}$$



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where:

P: cumulative probability of having a MES holding call c on channel i at the distance d_c

$isol_i$: separation distance by default between the MES and the RAS site

r_{max}: maximum radius of search of MESs around the RAS site.

Thus, d_c can be derived from an uniform random trial of P using the following formula (see § 4.1):

$$d_c = \sqrt{P(r_{max}^2 - isol_i^2) + isol_i^2} \tag{8}$$

4.8.2 Calculation of the percentage of time to be used for the calculation of path loss

When a new call is made, the percentage of time p_c to be used for the calculation of path loss between the RAS site and the MES holding the call c is assumed to be uniformly distributed between 0% and 100%. Here p_c has the same meaning as p in Recommendation ITU-R P.452, defined as "Required time percentage(s) for which the calculated basic transmision loss is not exceeded".

Thus, p_c can be derived from a uniform trial (see § 4.1). If the result of the trial exceeds 50%, it is set to 50% (worst case calculation). If the result of the trial is less than 0.001%, it is set to 0.001%.

This percentage of time remains the same until the call is dropped.

4.8.3 Calculation of the angles

Let us consider a new call c made by a MES and:

az_{RAS}: azimuth angle of the RAS antenna (may be the result of a uniform random trial at the beginning of each iteration step)

$elev_{RAS}$: elevation angle of the RAS antenna (may be the result of a solid angle uniform random trial at the beginning of each iteration step).

The formula giving the cumulative distribution function for the solid angle uniform random trial is:

$$P = \frac{\sin(\varphi) - \sin(elev_{min})}{\sin(elev_{max}) - \sin(elev_{min})} \tag{9}$$

where:

P: cumulative probability of working with an elevation angle less than φ

$elev_{min}$: minimum elevation angle

$elev_{max}$: maximum elevation angle

az_c: azimuth angle of the antenna of the MES holding call *c* (only if directional)

$elev_c$: elevation angle of the antenna of the MES holding call *c* (only if directional)

$az_{c,RAS}$: azimuth angle from the RAS antenna "toward" the MES holding call *c*. Result of a uniform random trial between 0º and 360º (see § 4.1)

α_c: off-axis angle to be taken into account for the calculation of the gain of the RAS antenna in the direction of the MES holding call *c*

β_c: off-axis angle to be taken into account for the calculation of the gain of the antenna of the MES holding call *c* in the direction of the RAS (if directional)

Then:

$$\begin{aligned} \alpha_c &= \cos^{-1}\left(\cos(az_{c,RAS} - az_{RAS})\cos(elev_{RAS})\right) \\ \beta_c &= \cos^{-1}\left(\cos(az_{MES} - az_{c,RAS} - 180)\cos(elev_{MES})\right) \end{aligned} \tag{10}$$

An alternative pointing distribution may be provided.

4.8.4 Calculation of the gain of the RAS antenna in the direction of the MES under consideration

When a new call *c* is made, the gain of the RAS antenna $G_{c,RAS}$ is calculated using formula (11) (see Recommendation ITU-R SA.509):

$$\begin{aligned} G_{c,RAS} &= 32 - 25 \log \alpha_c \quad &\text{for} \quad 1^\circ \le \alpha_c \le 48^\circ \\ &= -10 \quad &\text{for} \quad \alpha_c \ge 48^\circ \end{aligned} \tag{11}$$

α_c is assumed to be greater than 1º.

The gain remains the same until the call is dropped.

In the application of the methodology to specific sites, alternative antenna gain models might be necessary.

4.8.5 Calculation of the gain of the MES antenna in the direction of the RAS site

When a new call *c* is made, the gain of the MES antenna $G_{c,MES}$ is calculated using β_c.

The gain remains the same until the call is dropped.

4.8.6 Calculation of the path loss

Path loss L_c is calculated assuming tropospheric scatter (see Recommendation ITU-R P.452) for large distances and spherical diffraction (see Recommendation ITU-R P.526) for short distances. Attention must be paid to the continuity between the two models. Continuity can be achieved by choosing, for each call, the model that gives the minimum path loss depending on the distance and percentage of time p_c considered. Further, the path loss is calculated assuming assumption of clear sky, i.e. where scattering by hydrometeors, airplanes and satellites has not been taken into account.

The values for d_{tm} and d_{lm} to be used in equations (3) and (3a) of the Recommendation ITU-R P.452 are d_c and 0 respectively in order to represent a general situation.

When the spherical diffraction model is used, calculation of k (the effective Earth radius) is made using formula (12) of Recommendation ITU-R P.452. The values of the parameters d_{lt} and d_{lr} used in the formula (13a) of Recommendation ITU-R P.452 are respectively the distances from the antennas of the transmitter and the receiver to their horizons (worst case). They can be evaluated as:

$$d_{lt} = \sqrt{(h_{mes} + R)^2 - R^2}$$

$$d_{lr} = \sqrt{(h_{ras} + R)^2 - R^2}$$

where:

- h_{mes}: height of the MES antenna
- h_{ras}: height of the RAS antenna
- R: Earth radius (6 378.1 km).

When using Recommendation ITU-R P.526, the relevant paragraph to be considered is § 3.1.2. The value of β in equations (7) and (8) of the Recommendation ITU-R P.526 is set to 1 and equation (11a) of the Recommendation ITU-R P.526 is applied.

When the tropospheric scatter model is used, calculation of θ is made according to Appendix 2 of Annex 1 of Recommendation ITU-R P.452 by adding (to the angular distance between MES and RAS) θ_d, the horizon elevation angle seen by the MES (with no terrain shielding) together with a supplementary angle θ_r (e.g. 1°). This supplementary angle is intended to take into account possible protection (trees, buildings, hills, mountains ...) around the radio astronomy observatory. The value of θ_d is negative, since MES antenna height is positive. It is possible to evaluate it as $-d_{lt}/R$, with the previous definitions of these two variables, making an approximation of the $-asin(d_{lt}/R)$. Finally the equation used for the calculation of the angular distance is:

$$\theta = d_c / R + \theta_r - d_{lt} / R$$

Default values for antenna heights are 1.5 m for the MES and 30 m for the RAS antenna. Any application of the methodology to specific sites may require different height values.

4.9 Calculation of $rec\_power_{iter,it}(f)$

When considering one call c of time step it and integration time sample $iter$ using channel i, the interfering power $I_c(f)$ produced by the MES at the RAS antenna site at the frequency f is:

$$I_c(f) = P_i(f) + G_{c,MES} - L_c + G_{c,RAS} \qquad (12)$$

where:

- $P_i(f)$: mean power produced by the MES engaged in call c (in channel i) at the frequency f. The value at a certain frequency f can be derived using the emission mask provided for the particular class of mobile and knowing the frequency separation $(f - f_i)$ from the central frequency f_i of the channel used for the call c
- $G_{c,MES}$: gain of the antenna of the MES holding call c in the direction of the RAS site
- L_c: path loss between the MES holding call c and the RAS site
- $G_{c,RAS}$: gain of the RAS antenna in the direction of the MES holding call c
- r_{max}: maximum radius of search of MES around the RAS site.

$rec\_power_{iter,it}$ is then the sum of the interfering powers produced by the $ncall_{iter,it}$ MESs functioning in the same time:

$$rec\_power_{iter,it}(f) = 10 \log \left(\sum_{c=1}^{ncall_{iter,it}} 10^{\frac{I_c(f)}{10}} \right) \tag{13}$$

5 Determination of $mean\_power_{iter}(f)$

The mean interfering power experienced during an integration time sample is calculated by averaging interfering powers of each sub-time step over the integration time sample. Then:

$$mean\_power_{iter}(f) = 10 \log \left(\frac{1}{in} \sum_{it=1}^{in} 10^{\frac{rec\_power_{iter,it}(f)}{10}} \right) \tag{14}$$

where:

$mean\_power_{iter}(f)$: mean interfering power experienced at the RAS site during the $iter^{th}$ integration time sample at the frequency f

$rec\_power_{iter,it}(f)$: interfering power experienced at the RAS site at the frequency f during the it^{th} sub-time step of the $iter^{th}$ integration time sample

$integr$: integration time sample duration

in: number of sub-time steps within the integration time samples.

Appendix 1 to Annex 2

List of variables

α_c: off-axis angle to be taken into account for the calculation of the gain of the RAS antenna in the direction of the MES holding call c

β_c: off-axis angle to be taken into account for the calculation of the gain of the antenna of the MES holding call c in the direction of the RAS (if directional)

λ: mean call rate of the satellite system (/s). (The mean call rate of the satellite system, λ, is the mean call rate per mobile, (λ_{MES} multiplied by the number of mobiles in an area the radius of which is the one of a spot beam N_{MES}: $\lambda = \lambda_{MES} N_{MES}$)

μ: mean length of a call of the satellite (s)

az_c: azimuth angle of the antenna of the MES holding call c

$az_{c,RAS}$: azimuth angle from the RAS antenna toward the MES holding call c

az_{RAS}: azimuth angle of the RAS antenna

$born_{iter,it}$: number of calls attempted between time steps it and $it + 1$ of the $iter^{th}$ integration time sample. Used to calculate $ncall_{iter,it}$. The number of calls effectively initiated is less or equal to this figure

d_c: distance between the RAS site and the MES holding call *c*

$dropped_{iter,it}$: number of calls dropped between time steps *it* and *it* + 1 of the *iter*th integration time sample. Used to calculate $ncall_{iter,it}$

δt: sub-time step duration

$elev_c$: elevation angle of the antenna of the MES holding call *c*

$elev_{RAS}$: elevation angle of the RAS antenna

E: maximum Erlang rate of the satellite system

E may be:

– given directly by the MSS or LMSS operator

– calculated, knowing λ and μ, using the following formula: $E = \lambda\ \mu$, where λ is the mean call rate of the satellite system and μ is the mean length of calls

$G_{c,MES}$: gain of the antenna of the MES holding call *c* in the direction of the RAS site

$G_{c,RAS}$: gain of the RAS antenna in the direction of the MES holding call *c*

h_{mes}: height of the MES antenna

h_{ras}: height of the RAS antenna

ini_{iter}: number of calls of the *iter*th integration time sample

integr: integration time sample duration

$I_c(f)$: the interfering power produced by the MES used for call *c* at the RAS antenna site at the frequency *f*

interf(*f*): mean interfering power received at the RAS site for (100 – *x*)% of all integration time samples at the frequency *f* [(100 – *x*)% of the *niter* $mean\_power_{iter}(f)$]

$isol_i$: isolation distance between the RAS site and MESs holding call *c* in channel *i* (isolation distances may depend on channels used)

in: maximum value of *it*

it: current sub-time step of integration time sample. Varies from 1 to *in*

iter: current integration time sample. Varies from 1 to *niter*

k: effective Earth radius

$mean\_power_{iter}(f)$: mean interfering power received at the RAS site over the *integr*th integration time sample. Calculated by averaging $rec\_power_{iter,it}(f)$ over *integr*

Ncall: maximum number of calls. Physical constraint determined by the maximum number of channels *nchannel* and the maximum number of calls per channel *nmax*

$ncall_{iter,it}$: number of calls made between sub-time steps *it* and *it* + 1, to be taken into account for the calculation of the interfering power $rec\_power_{iter,i}$. Either calculated using $ncall_{iter,it-1}$, $dropped_{iter,it}$ and $born_{iter,it}$, or equal to *Ncall*

nchannel: maximum number of channels of the MSS system

$new_{iter,it}$: effective number of new calls initiated between sub-time steps *it* and *it* + 1 of the *iter*th integration time sample. $new_{iter,it} \leq born_{iter,it}$

niter: number of integration time samples needed for the statistics. Represents the number of samples needed for the drawing of the histogram

nmax: maximum number of calls per channel of the MSS system (= 1 for a TDMA system, > 1 for a CDMA system)

$P_i(f)$: mean power produced by channel number *i* at the frequency *f*

p_c: percentage of time to be taken into account for the calculation of path loss between RAS site and the MES holding call *c*

$rec\_power_{iter,it}(f)$: interfering power received at the RAS site between time steps *it* and *it* + 1 of the $iter^{th}$ integration time sample

r_{max}: maximum radius for the determination of the location of the mobiles (km). r_{max} is defined as the minimum of 500 km and the radius of a spot beam

t: current sub-time of the integration time sample. Varies from δt to *integr*

T_c: call termination time of the call *c*

L_c: path loss of call *c*

d_{tm}: as in Recommendation ITU-R P.452, length of longest continous land (inland + coastal) section of the great-circle (km)

d_{lm}: as in Recommendation ITU-R P.452, length of longest continous inland section of the great-circle (km)

d_{lt}, d_{lr}: as in Recommendation ITU-R P.452, distance between transmitting and receiving antennas and their respective horizons

θ: as in Recommendation ITU-R P.452, angular distance of the path

θ_t, θ_r: as in Recommendation ITU-R P.452, elevation angles toward the horizon at the transmitter and at the receiver

β: as in Recommendation ITU-R P.526 § 3.1.2, a parameter that takes into account the nature of the ground and the polarization.

Annex 3

Step 2 methodology: Calculation of restriction zones around RAS sites for sharing with MES

1 Introduction

This Annex provides guidance for the determination of restriction zones around RAS sites for the protection of radio astronomy observations.

The basis of the methodology of calculation of restriction zones is the same as that used for the calculation of separation distances by default, as described in Annex 2.

Additional features are incorporated in the model, in order to take into account site specific information. Thus, § 2 of this Annex gives Step 2 additional considerations in relation to Step 1 methodology for the determination of restriction zones around RAS sites.

2 Possible enhancements to Step 1 methodology

In general, all the additional considerations deal with the handling of geographical data specific to a given RAS site. A software tool intended to define restriction zones around specific RAS sites should consider the following:

– *Propagation model*:

The incorporation of the path-loss calculation methods as set out in Recommendation ITU-R P.452 would require actual topographical data.

Moreover, given that the MES antenna is not very high above the ground (it may be assumed to be located at a height of 1.5 m), any obstruction of the path, will affect the propagation between the MES and the RAS antenna.

As a first approximation, a limited application of Recommendation ITU-R P.452 using information on the elevation of the horizon in all directions surrounding the RAS observatory, on the local terrain elevation of the MES and possibly the local MES clutter might suffice.

– *Mobile distribution*:

The assumption of uniform distribution of MESs around an RAS site should be reviewed to take into account the specific characteristics of the interfering network.

The simulation should also take into account the characteristics of the movement of the MESs rather than assuming that they will remain stationary for the duration of the call.

It should be noted that the movement of the MESs may have some influence on both the gain of the RAS antenna and the discrimination of the MES one.

Other factors, such as power control, should be taken into account. However, this would require some operational/measured data which may not be available for some of the MSS networks under study.

The list of proposed additions to the basic methodology may not be comprehensive and other features could be incorporated by the parties involved in establishing the actual coordination zones.

Annex 4

Information needed from MSS operators as input for the calculation of separation distances by default between an RAS site and an MES

	Comment
Type of access	TDMA or CDMA
Channelling: – centre frequencies of the channels (MHz) – nominated bandwidths (kHz) – frequency reuse factor	
Emission mask	e.i.r.p. with respect to the carrier frequency
Determination of the MES mean power (dB(W/4 kHz)): – peak power density in the nominated bandwidths (dB) – power reduction factor for TDMA systems (averaging over time slots) (dB) – power reduction factor for power control (mean power control attenuation) (dB). NOTE 1 – Please indicate if these factors apply only within the nominated bandwidths or also to the emission mask	
Maximum number of calls per channel	
MES maximum antenna gain towards the horizon (dBi)	
MES antenna pattern if directional in the horizontal plane	
Pointing azimuth angle of the MES antenna (degrees)	Only if the MES antenna is directive
Pointing elevation angle of the MES antenna (degrees)	Only if the MES antenna is directive
Mean call rate per MES (peak traffic) (/s)	
Mean call length per MES (peak traffic) (s)	
Probability of system access blocking	Needed for the calculation of the number of Erlang from Erlang B curves. Represents the probability of an attempted call being blocked
Maximum density of users (/km^2)	
Maximum density of active users (/km^2)	