ERC REPORT 49

European Radiocommunications Committee (ERC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

ERC REPORT ON SHARING BETWEEN MOBILE EARTH STATIONS AND RADIOASTRONOMY OBSERVATORIES

Moscow, September 1997

ERC REPORT ON SHARING BETWEEN MOBILE EARTH STATIONS AND RADIOASTRONOMY OBSERVATORIES

ERC REPORT ON THE SHARING BETWEEN MOBILE EARTH STATIONS AND RADIOASTRONOMY OBSERVATORIES

1 INTRODUCTION

WARC 92 allocated the band 1610-1626.5 MHz on a primary basis worldwide to the Mobile Satellite Service (MSS) in the earth-to-space direction (uplink) and the band 1613.8-1626.5 MHz on a secondary basis worldwide to the MSS in the space-to-earth direction (downlink). The band 1660-1660.5 MHz is allocated on a primary basis worldwide to the land mobile satellite service (LMSS) in the earth-to-space direction (uplink).

The bands 1610.6-1613.8 MHz and 1660-1670 MHz are used, as primary allocations, by radio astronomers to observe the spectral line of the Hydroxyl molecule, which is considered to be among the most important lines below 275 GHz. The band 1660-1670 MHz is also used by radioastronomers for measurements of continuum observations and for VLBI.

The radioastronomy service in these bands is protected by footnote S5.149 stating that "in making assignments to stations of other services to which the bands 1610.6-1613.8 MHz and 1660-1670 MHz are allocated [...], administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be a particularly serious source of interference to the radio astronomy service (see Nos. S4.5 and S4.6 and Article S29)".
Footnote S5.372 stating that "harmful interference shall not be caused to stations of the radio astronomy service using the band 1610.6-1613.8 MHz by stations of the radiodetermination-satellite and mobile-satellite services (No S29.13 applies)" also applies.

2 PROTECTION OF THE 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 a radio astronomy site and Mobile Earth Station (MES), which defines an area around a radio astronomy site outside of which no restriction applies to the operation of mobile earth stations.

Step 2: by setting a restriction zone around a radio astronomy site, which defines an area within which there may be some restriction to the operation of mobile earth stations. 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 a radio astronomy site, defined by means of detailed assessment of the characteristics of the systems involved and measurements if necessary, within which no operation of mobile earth stations should be allowed.

Annex 1 and Annex 2 describe methodology which can be used for the calculations respectively for Step 1 and Step 2. Until precise details are included in Annex 4 in order to evaluate the conditions for the operation of the mobiles in the restriction zone, the restriction zone has to be considered as an exclusion zone, following the definition above in Step 3.
Annex 3 provides the list of the set of characteristics, which are necessary for running the simulation.
Annex 4 gives examples of results which can be obtained using Step 1 methodology.

3 GENERAL PRINCIPLE USED IN THE METHODOLOGY STEP 1 - INTERFERENCE CRITERIA

Step 1 calculation is intended to provide separation distances by default. Annex 1 describes a general methodology of calculation, which can be used for that purpose, using the Monte Carlo method. The basis of this model is to calculate the statistics of the interfering power produced at a radio astronomy site by MES in operation.

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

> "a 2000 seconds integration taken at any time of the day should have at least (100 - x)% probability 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, chapter 4.2.4.). The wider interpretation of this figure is under consideration within ITU-R WP 7D."

Thus, the Annex 1 methodology should be used with the following assumptions:

- 2000 seconds integration time (constant for all trials)
- peak traffic assumption
- x% of time maximum interference criteria may be exceeded (10 % is the current value subject to revision by ITU-R WP 7D).

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.

Some operators and Administrations have the opinion that the ITU-R RA.769 threshold is a single entry threshold to trigger coordination, compatible with the concept of default separation distance, and therefore interference splitting is not appropriate. In addition, CEPT should ensure a level playing field for the entry into operations of individual satellite personal communication systems. Any interference splitting should be considered with extreme caution.

Some operators and Administrations also have technical arguments against splitting. For example, existing services cannot be constrained to a portion of the interference threshold if they already use up all of the interference allowance. Further, interference from different sources may not overlap in time or frequency. Also, the statistical effect of summing interference according to the central limit theorem mitigates the interference effect. Hence, interference splitting may be unnecessarily restrictive.

It is considered by some, including the radio astronomy community, that the levels of harmful interference, as given in ITU-R RA769, refer to the mean power produced by the population of users belonging to all services operating in the band during the radio astronomy integration time.

4 CONCLUSION

The methodology described in this report is to be used for the determination of the protection distances and zones around radio astronomy observatories in the band 1610.6-1613.8 MHz and 1660-1670 MHz. It has been determined with the cooperation of radioastronomers and operators of MSS systems and, hence, has taken into account all relevant aspects of the interfering phenomenon. The use of such methodology for other frequency bands is obviously highly recommended.

ANNEX 1

Step 1 methodology: Calculation of separation distances by default between radio astronomy sites and mobile earth stations

1 Introduction

This annex describes a general methodology, which can be used for the calculation of separation distances by default between radio astronomy sites and the areas where MES 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.a Monte Carlo method

In order to calculate the separation distances by default between radio astronomy sites and MES, 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 method 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 be the number of mobiles, the location of the mobiles, the propagation condition, etc. The statistics of the interfering power produced at a radio astronomy site by MES in operation is then derived from the calculation of interfering powers experienced for each sample.

2.b 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 2000 seconds integration periods have mean interference power above the RAS harmful level.

The following is based on this definition.

3 Presentation of the methodology of calculation

As stated in Section 2 above, statistics of interfering powers are based on integration time samples.

niter is then the number of integration time samples needed for the statistic.

integr is the 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 *dt* seconds duration.

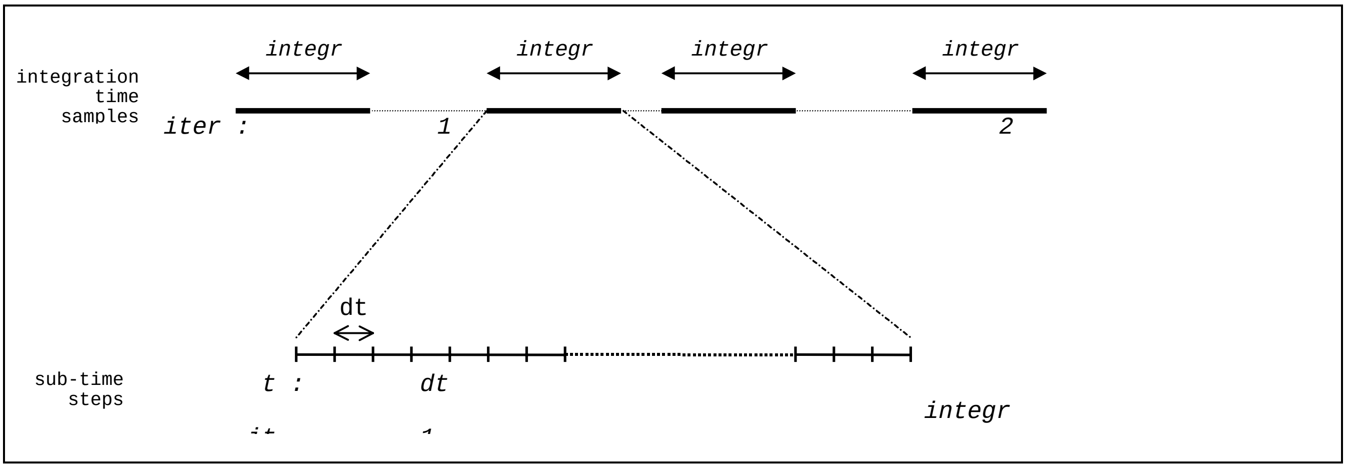


Figure 1: Division of integration time samples

During each 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 mobile in operation.
The outline flow chart of the calculation is given below:

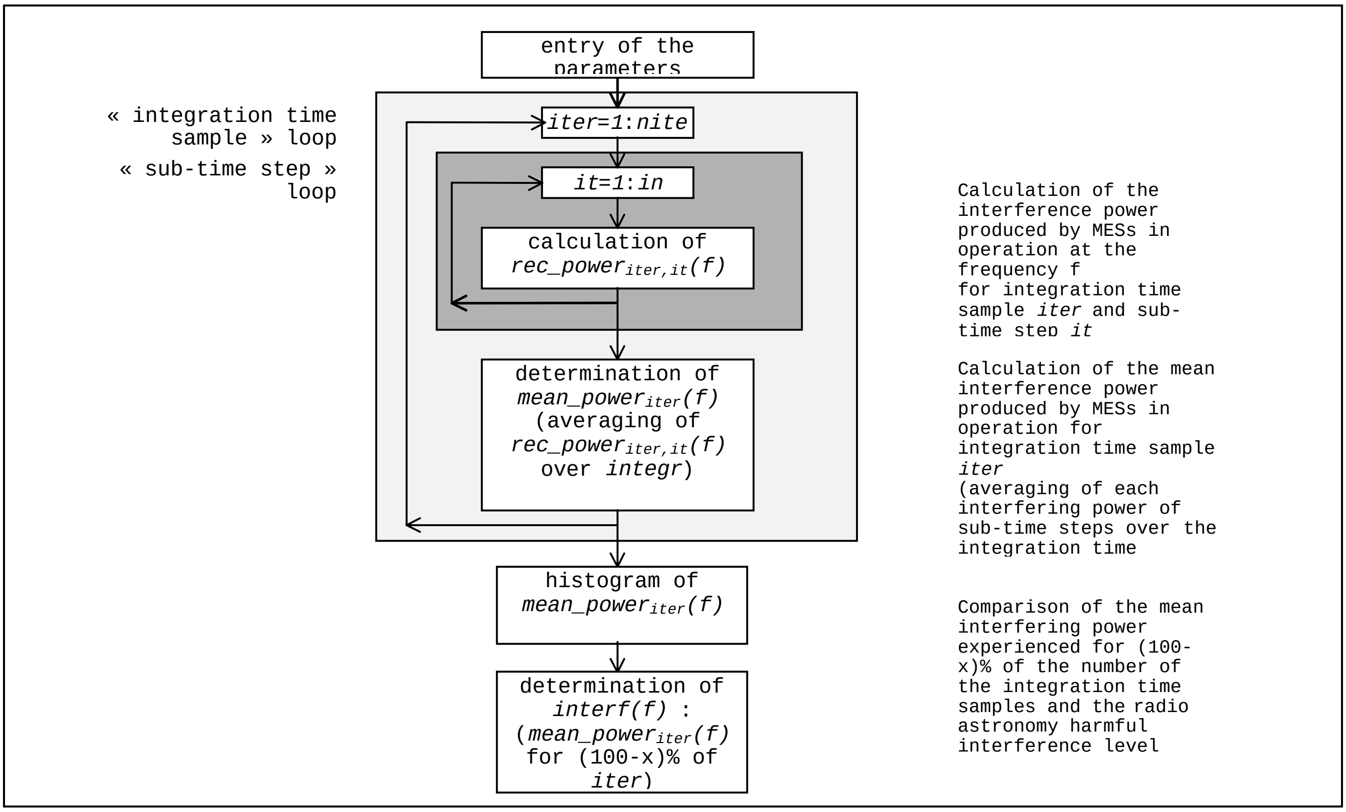


Figure 2: General flow chart of the calculation

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 MES are using;

the location of the mobiles around the radio astronomy site distance, azimuth ... .

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 call is calculated by making a random trial.
The following figure gives the outline flow chart for calculation of $rec\_power_{iter,it}$(f) (integration time sample *iter*, sub-time step *it*).

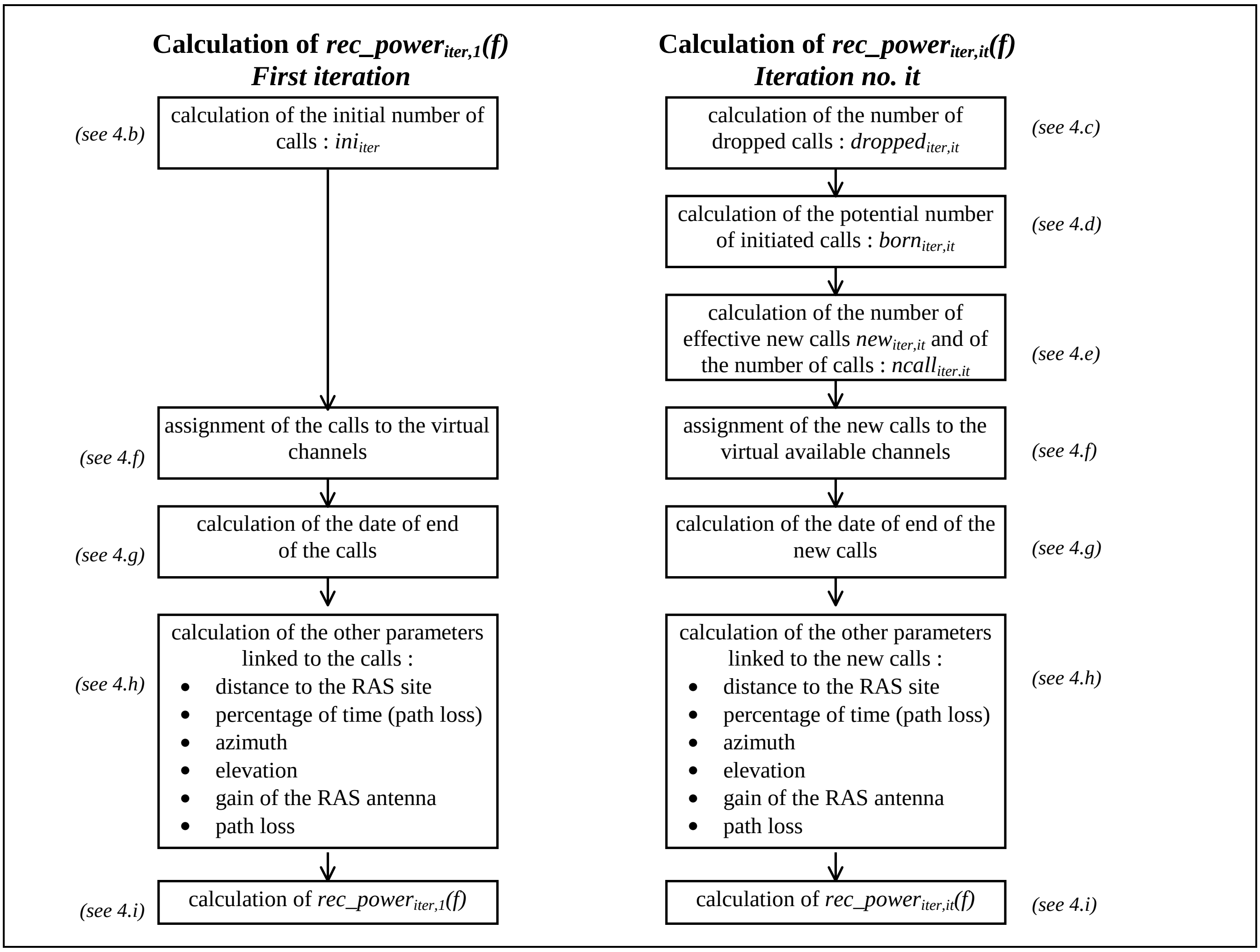
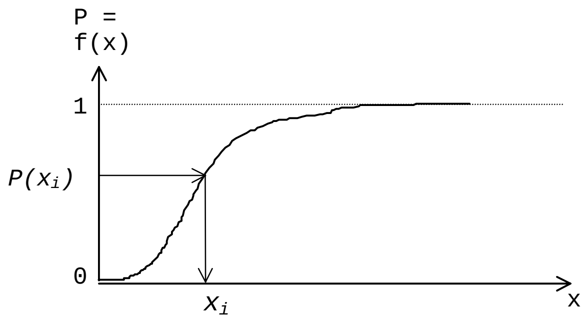


Figure 3: Calculation of rec_poweriter,it(f)

4.a Monte Carlo random trials

As stated in section 2.a, the Monte Carlo methodology is based on the principle of sampling random variables from their defined cumulative distribution functions.
Consider for example a variable x, with the cumulative distribution function on the figure. 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 one single value of x_i, and enables to plot $x=f^{-1}(P)$.

4.b 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:

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

where:

P	is the cumulated probability of having iniiter simultaneous calls at the instant t (iniiter ≤ Ncall)
E	is the peak demanded load on the system measured in Erlangs
Ncall	is the maximum number of simultaneous calls the MSS system can support.

Thus, ini_{iter} can be derived from a uniform random trial of P by reversing formula (1) (see section 4.a).

4.c 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 date of end is less 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 date of end of call c is less or equal than it: this call is dropped, and is not retained for the calculation of rec_poweriter,it(f). This call is accounted with the dropped calls (droppediter,it).
- if the date of end of the call is more than it: this call is retained for it sub-time step calculation.

4.d Calculation of the potential number of attempted calls: $\boldsymbol{born_{iter,it}}$

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:

$$P = \sum_{i=0}^{born_{iter,it}} \frac{(\lambda.dt)^i}{i!} e^{-\lambda.dt} \qquad (2)$$

where:

P	is the cumulated 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
dt	is the sub-time steps duration

Thus, $born_{iter,it}$ can be derived from an uniform random trial of *P* by reversing formula (see section 4.a). (2)

4.e Calculation of the number of effective number of new calls $\boldsymbol{new_{iter,it}}$ and of the number of calls $\boldsymbol{ncall_{iter,it}}$

Among the potential number of calls (attempts of calls), all will not succeed just because of physical limitations of the system (maximum number of call).

If, $ncall_{iter,it-1}$ is the number calls of sub-time step *it-1*(*it*≠1) (used in the calculation of $rec\_power_{iter,it-1}(f)$)
$dropped_{iter,it}$ is the number of calls dropped between sub-time steps *it* and *it+1*,
$born_{iter,it}$ is the potential 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:

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

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

4.f Assignment of the (new) calls to the available traffic channels

Both with CDMA or TDMA several calls can be allocated on the same physical channel. Here a traffic channel is defined as 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 among the available traffic channels in an area with the radius of a spot beam. This means that:

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

– if *it* ≠ 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 method.

4.g Calculation of the date of end of the (new) calls

For each new call *c*, the date of end of the call 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	is the cumulated probability of having a call duration inferior than (T_c-t)
t	is the current sub-time step (date of birth of the call)
T_c	is the date of end of the call
m	is the mean call length of the satellite system

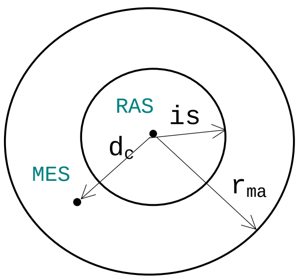
Thus, the date of end T_c of a (new) call *c* can be derived from an uniform random trial of *P* using the following formula (see section 4.a):

$$T_c = t - \mu.\ln(1 - P) \qquad (6)$$

4.h Calculation of the other parameters linked to the (new) calls

4.h.1) Calculation of the distance between the mobile and the RAS antenna

MES are supposed to be uniformly distributed around the radioastronomy service (RAS) site.
When a new call *c* is made on channel *i*, the cumulative distribution function of having the MES (which holds the call) at the distance d_c is given by the following formula:



$$P = \frac{d_c^2 - isol_i^2}{r_{\max}^2 - isol_i^2} \qquad (7)$$

where:
- P is the cumulated probability of having a MES holding call *c* on channel *i* at the distance d_c
- $isol_i$ is the separation distance by default between the MES and the radio astronomy site
- r_{max} is the maximum radius of search of MES around the radio astronomy site. r_{max} is defined as the minimum of 500 km and the radius of a spot beam.

Thus, d_c can be derived from an uniform random trial of *P* using the following formula
(see section 4.a):

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

4.h.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 call *c* is supposed to be uniformly distributed between 0 and 100%. Here p_c has the same meaning as p in Recommendation ITU-R P. 452-7, defined as « Required percentage of time during which the propagation path loss is not exceeded ». Thus, p_c can be derived from an uniform trial (see section 4.a). 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% (very particular propagation conditions). This percentage of time remains the same until the call is dropped.

4.h.3) Calculation of the angles

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

azRAS : azimuth of the pointing direction of the RAS antenna (may be the result of a uniform random trial at the beginning of each iteration step)

elevRAS: elevation of the pointing direction 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:

$$P = \frac{\sin(\varphi) - \sin(elev\ \min)}{\sin(elev\ \max) - \sin(elev\ \min)} \qquad (9)$$

where:

P is the cumulated probability of working with an elevation angle less than φ

elevmin is the minimum elevation angle

elevmax is the maximum elevation angle

az_c : azimuth of the pointing direction of the antenna of the MES holding call c (only if directional)

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

$az_{c,RAS}$: azimuth under which the RAS antenna « sees » the MES holding call c.
Result of a uniform random trial between 0 and 360° (see section 4.a)

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:

$$\alpha_c = \cos^{-1}(\cos(az_{c,RAS} - az_{RAS}).\cos(elev_{RAS})) \qquad (10)$$
$$\beta_c = \cos^{-1}(\cos(az_{MES} - az_{c,RAS} - 180).\cos(elev_{MES}))$$

An alternative pointing distribution may be provided.

4.h.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 the following formula (Recommendation ITU-R SA.509):

$$\begin{aligned} G_{c,RAS} &= 32 - 25\log(\alpha_c) \quad if \quad 1° \le \alpha_c \le 48° \\ &= -10 \quad\quad if \quad \alpha_c \ge 48° \end{aligned} \qquad (11)$$

α_c is supposed to be always greater than 1°.

This 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.h.5) Calculation of the gain of the MES antenna in the direction of the RAS site

When a new call is made, the gain of the MES antenna $G_{c,MES}$ is calculated using β_c.
This gain remains the same until the call is dropped.

4.h.6) Calculation of the path loss

Path loss L_c is calculated using tropospheric scatter (Recommendation ITU-R P.452-7) for large distances and spherical diffraction (Recommendation ITU-R P.526-4) for short distances. Attention must be paid to that continuity between the two models. The continuity can be achieved by choosing for each call the model that gives the minimum path loss, depending on the trialed distance and percentage of time p_c considered. Further, the path loss is calculated with the assumption of clear sky 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.452-7 are respectively d_c and 0, to represent a general situation.

When a spherical diffraction model is to be used, calculation of k (multiplying factor of the earth radius) is made using formula (12) of Recommendation ITU-R P.452-7.

The values of the parameters d_{lt} and d_{lr} that are used in the formula (13a) of Recommendation ITU-R P.452-7 are the distances from the antennas respectively of the transmitter and of 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} is the height of the antenna of the mobile;
h_{ras} is the height of the RAS antenna;
R is the earth radius (6371 km).

When using the recommendation ITU-R P.526-4, the relevant paragraph to be considered is 3.1.2. The value of β in equations (7) and (8) of Recommendation 526-4 is set to 1 and equation (11a) of Recommendation 526-4 is applied, because of the nature of the interference scenario represented.

When a tropospheric scatter model is to be used, calculation of θ is made according to appendix 2 of annex 1 of Rec. ITU-R P.452-7 by adding (to the angular distance between MES and RAS) θ_d , the horizon elevation angle seen by the MES (with no terrain shielding) and a supplementary angle (e.g. 1°). This supplementary angle is intended to take into account possible protection (trees, buildings, hills, mountains, etc.) 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 $-arcsin(d_{lt}/R)$. 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 mobile earth station and 30 m for the radio astronomy antenna. Any application of the methodology to specific sites may require different height values.

4.i 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 this MES at the RAS antenna site at the frequency f is:

$$I_c(f) = P_i(f) + G_{c,MES} - L_c + G_{c,RAS} \qquad (11)$$

where:

$P_i(f)$ is the mean power produced by the MES holding call *c* (in channel *i*) at the frequency *f*. The value at a certain frequency *f* can be derived using the approved emission mask 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*. The mask defines the attenuation of the emission power outside the nominated bandwidth as a function of this frequency separation.

$G_{c,MES}$ is the gain of the antenna of the MES holding call *c* in the direction of the radio astronomy site

L_c is the path loss between the MES holding call *c* and the radio astronomy site

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

r_{max} is the maximum radius of search of MES around the radio astronomy 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:

$$rec\_power_{iter,it}(f) = 10\log\left(\sum_{c=1}^{ncall_{iter,it}} 10^{\frac{I_c(f)}{10}}\right) \tag{12}$$

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:

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

where:

$mean\_power_{iter}(f)$ is the mean interfering power experienced at the radio astronomy site during the *iter*th integration time sample at the frequency *f*

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

integr is integration time sample duration

in is the number of sub-time steps within the integration time samples

LEFT BLANK

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)

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

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

az_c : azimuth of the pointing direction of the antenna of the MES holding call *c*

$az_{c,RAS}$: azimuth under which the RAS antenna « sees » the MES holding call *c*

az_{RAS} : azimuth of the pointing direction of the RAS antenna

$born_{iter,it}$: number of calls potentially born between time steps *it* and *it+1* of the *iter*th integration time sample. Enables to calculate $ncall_{iter,it}$. The number of calls effectively born 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. Enables to calculate $ncall_{iter,it}$

dt : sub-time step duration

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

$elev_{RAS}$: elevation of the pointing direction of the RAS antenna

E : maximum number of Erlang of the satellite system.
E may be :
- given directly by the MSS or LMSS operator,
- calculated, knowing l and µ, using the following formula : $E = l.\mu$, where l 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} : initial 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 radioastronomy 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 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 : multiplying factor of the earth radius

$mean\_power_{iter}(f)$: mean interfering power received at the radioastronomy 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 $rec\_power_{iter,it}$. Calculated using $ncall_{iter,it-1}$, $dropped_{iter,it}$ and $born_{iter,it}$. Majored by the maximum number of calls *Ncall*.

nchannel : maximum number of channels of the MSS system.

$new_{iter,it}$: effective number of new calls born 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 radioastronomy site between time step *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 *dt* to *integr*.

T_c : date of end of the call *c*

L_c: path loss of call *c*;

d_{tm}: as in Recommendation ITU-R P.452-7, lenght of longest path upon the earth;

d_{lm}: as in Recommendation ITU-R P.452-7, lenght of longest path upon the water;

d_{lt}, d_{lr}: as in Recommendation ITU-R P.452-7, distance between transmitting and receiving antennas and their respective horizons;

θ: as in Recommendation ITU-R P.452-7, angular distance of the path;

θ_t , θ_r: as in Recommendation ITU-R P.452-7, elevation angles upon the horizon at the transmitter and at the receiver;

β: as in Recommendation ITU-R P.526-4 paragraph 3.1.2, a parameter that takes into account the nature of the ground and the polarization.

LEFT BLANK

ANNEX 2

STEP 2 METHODOLOGY :
CALCULATION OF RESTRICTION ZONES AROUND RADIO ASTRONOMY SITES
FOR SHARING WITH MOBILE EARTH STATIONS

1 Introduction

This annex provides guidance for the determination of restriction zones around radioastronomy sites for the protection of radioastronomy observations.
The basis of the methodology of calculation of protection zones is the same as the one used for the calculation of separation distances by default, as described in Annex 1 of this document (« Monte-Carlo method »). Additional features are incorporated in the model, in order to take into account site specific information. Thus, section 2 of this Annex gives Step 2 additional considerations in relation to Step 1 methodology for the determination of restriction zones around radio astronomy sites.

2 Proposed 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 for defining exclusion zones around specific radio astronomy sites should consider the following:

1. Propagation model:
   The incorporation of the path-loss calculation methods as set out in ITU-R Rec.PN.452-6 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, e.g. human construction or presence of vegetation, will affect the propagation between the MES and the RAS antenna.
   As a first approximation, a limited application of ITU-R Rec.PN.452-6 using information on the distance and height 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.

2. Mobile distribution:
   The assumption of uniform distribution of mobiles around a RAS site should be reviewed and take into account the specific characteristics of the interfering network (i.e. S-PCN networks may address different markets than the current GSO MSS and have a very different geographical distribution).
   The simulation should also take into account the characteristics of the movement of the mobiles rather than assuming that they will remain stationary for the duration of the call.
   It should be noted that the movement of the Mobile Earth Stations may have some influence in both the gain of the RAS antenna and the discrimination of the MES one.

Other factors, such as power control, should ideally 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 fully comprehensive and other features could be incorporated by the parties involved in establishing the actual coordination zones.

LEFT BLANK

ANNEX 3

INFORMATION NEEDED FROM MSS OPERATORS AS INPUT FOR THE CALCULATION OF SEPARATION DISTANCES BY DEFAULT BETWEEN RAS AND MES

	Unit	Comment
Type of access		TDMA or CDMA
Channeling: - center frequencies of the channels - nominated bandwidths - frequency reuse factor	 MHz kHz	
Emission mask		e.i.r.p. with respect to the carrier frequency
Determination of the MES mean power: - peak power density in the nominated bandwidths - power reduction factor for TDMA systems (averaging over time slots) - power reduction factor for power control (mean power control attenuation) NOTE - Please indicate if these factors apply only within the nominated bandwidths or also to the emission mask.	dB(W/4kHz) dB dB dB	
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 of the MES antenna	°	only if the MES antenna is directive
Pointing elevation of the MES antenna	°	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 for a demand for a call not to succeed because of overload of the switching system.
Radius of a spot beam		Needed for the determination of the maximum radius of search (of the interferers around the RAS site)
Maximum density of users	/km²	
Maximum density of active users	/km²	

Table 1: Information needed from MSS operators

LEFT BLANK

ANNEX 4

EXAMPLE OF RESULTS WITH STEP ONE METHODOLOGY CALCULATIONS

The simulations have been run with the examples of characteristics given in the Appendix 1 of this Annex. These characteristics are not expected to be exactly representative of particular systems. The assumption of 0 dBi antenna gain in the horizontal plane for a radio astronomy antenna has been used.

Example of a CDMA system

Nine channels are operated together with the following separation distances by default:

Channel number	Frequency (MHz)	Separation Distance by default (km)
1	1611.06	100
2	1612.30	100
3	1613.52	100
4	1614.76	60
5	1615.98	40
6	1617.22	40
7	1618.44	30
8	1619.68	30
9	1620.90	30

Table 2: Example of a CDMA system

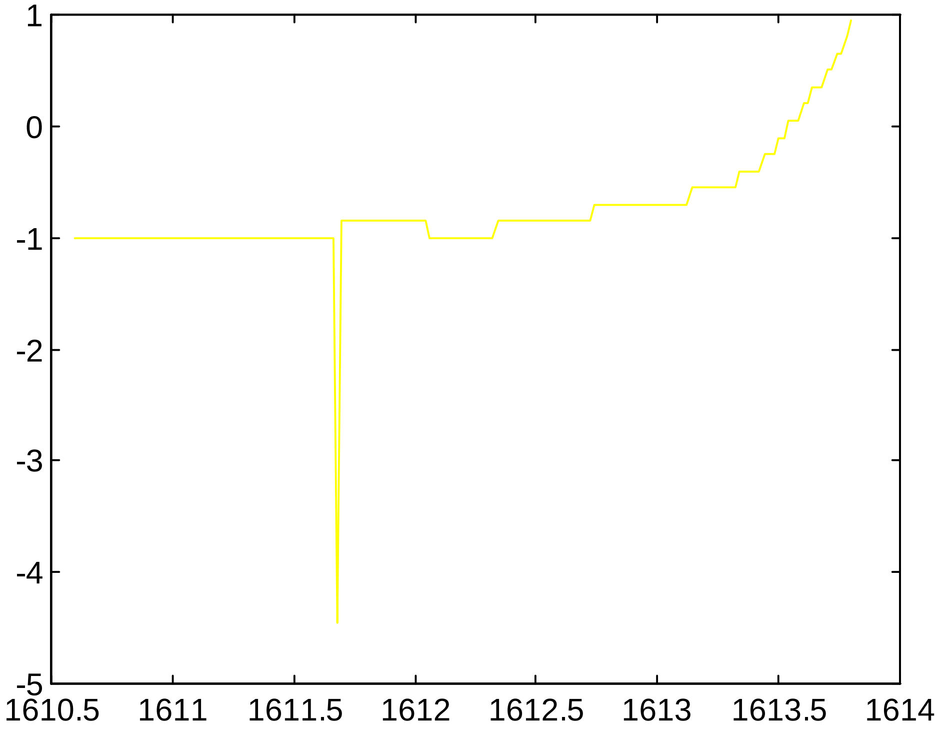


Figure 4: Maximum interfering power (in DB) relative to the RAS threshold

Figure 4 above gives the received maximum interfering power (in dB) relative to the RAS threshold (-262 dBW/Hz) experienced by 90% of the integration time (2000 s) samples, as a computation of the methodology described in Annex 1. On the horizontal axis the frequencies are in MHz.

The results show an excess of the interfering threshold in the upper part of the radio astronomy band.

Example of a TDMA system

The separation distance by default is evenly assumed to be 10 km.

Figure 5 below gives the received maximum interfering power (in dB) relative to the RAS threshold (-262 dBW/Hz) experienced by 90% of the integration time (2000 s) samples, as a computation of the methodology described in Annex 1.

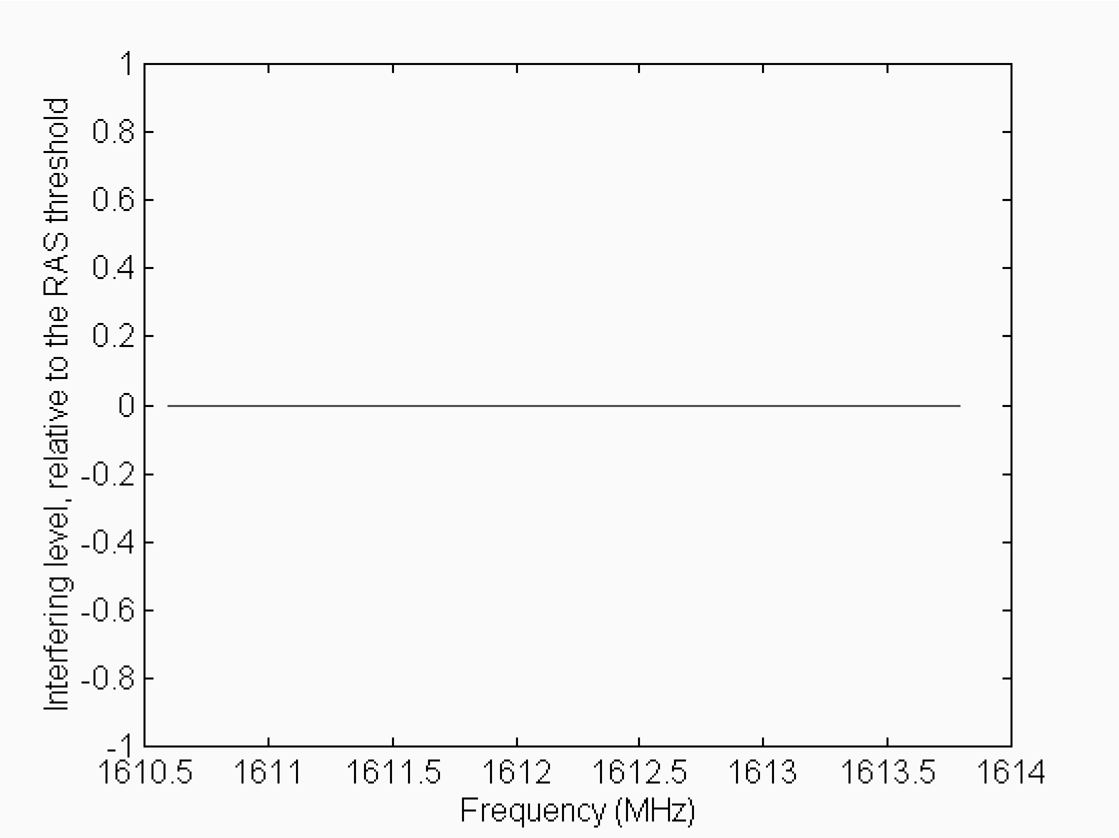


Figure 5: Maximum interfering power (in dB) relative to the RAS threshold

The interfering level is evenly distributed since for a wide frequency offset the TDMA emission mask is flat.

Parameter	**Value**
Type of access	CDMA
Channeling : - center frequencies of the channels - nominated bandwidths - frequency reuse factor	 1611.06 + (n-1) x 1.23 MHz n : 1..9 1230 kHz 1
Emission mask	According to WG SE response to public inquiry on ETS 300 733
Determination of the MES mean power : - peak power density in the nominated bandwidths - power reduction factor for TDMA systems (averaging over time slots) - power reduction factor for power control (mean power control attenuation) Note : please indicate if these factors apply only within the nominated bandwidths or also to the emission mask	 -2 dBW / 1.23 MHz 0 dB 7 dB
Maximum number of calls per channel	44
MES maximum antenna gain towards the horizon	2 dBi
MES antenna pattern if directional in the horizontal plane	Omnidirectionnal
Pointing azimuth of the MES antenna	N/A
Pointing elevation of the MES antenna	N/A
Mean call rate per MES (peak traffic)	1 / 2 hours
Mean call length per MES (peak traffic)	2 min
Probability of blocking	2 %
Radius of the spot beam	around 350 km
Maximum density of users	0.062 /km²
Maximum density of active users	0.001 /km²

Table 3: Example of a set of characteristics (CDMA system)

Parameter	Value
Type of access	TDMA
Channeling : - center frequencies of the channels - nominated bandwidths - frequency reuse factor	 1621.35 + n x 41.6 MHz n : 0..124 125 kHz 12
Emission mask	According to WG SE response to public inquiry on ETS 300 733
Determination of the MES mean power : - peak power density in the nominated bandwidths - power reduction factor for TDMA systems (averaging over time slots) - power reduction factor for power control (mean power control attenuation) Note : please indicate if these factors apply only within the nominated bandwidths or also to the emission mask	 N/A 10 dB 2 dB
Maximum number of calls per channel	4
MES maximum antenna gain towards the horizon	-1 dBi
MES antenna pattern if directional in the horizontal plane	omnidirectional
Pointing azimuth of the MES antenna	N/A
Pointing elevation of the MES antenna	N/A
Mean call rate per MES (peak traffic)	1 / 2 hours
Mean call length per MES (peak traffic)	2 min
Probability of blocking	2 %
Reuse distance	around 350 km
Maximum density of users	0.025 /km²
Maximum density of active users	0.0004 /km²

Table 4: Example of a set of characteristics (TDMA system)