

RECOMMENDATION ITU-R RA.769-2

Protection criteria used for radio astronomical measurements

(Question ITU-R 145/7)

(1992-1995-2003)

The ITU Radiocommunication Assembly,

considering

- a) that many of the most fundamental astronomical advances made in the past five decades, (e.g. the discovery of radio galaxies, quasars, and pulsars, the direct measurement of neutral hydrogen, the direct measurement of distances of certain external galaxies, and establishment of a positional reference frame accurate to ~ 20 arc μ s) have been made through radio astronomy, and that radio astronomical observations are expected to continue making fundamental contributions to our understanding of the Universe, and that they provide the only way to investigate some cosmic phenomena;
- b) that the development of radio astronomy has also led to major technological advances, particularly in receiving and imaging techniques, and to improved knowledge of fundamental radio-noise limitations of great importance to radiocommunication, and promises further important results;
- c) that radio astronomers have made useful astronomical observations from the Earth's surface in all available atmospheric windows ranging from 2 MHz to 1 000 GHz and above;
- d) that the technique of space radio astronomy, which involves the use of radio telescopes on space platforms, provides access to the entire radio spectrum above about 10 kHz, including parts of the spectrum not accessible from the Earth due to absorption in atmosphere;
- e) that protection from interference is essential to the advancement of radio astronomy and associated measurements;
- f) that radio astronomical observations are mostly performed with high-gain antennas or arrays, to provide the highest possible angular resolution, and consequently main beam interference does not need to be considered in most situations, except when there is the possibility of receiver damage;
- g) that most interference that leads to the degradation of astronomical data is received through the far side lobes of the telescope;
- h) that the sensitivity of radio astronomical receiving equipment, which is still steadily improving, particularly at millimetre wavelengths, and that it greatly exceeds the sensitivity of communications and radar equipment;
- j) that typical radio astronomical observations require integration times of the order of a few minutes to hours, but that sensitive observations, particularly of spectral lines, may require longer periods of recording, sometimes up to several days;

- k) that some transmissions from spacecraft can introduce problems of interference to radio astronomy and that these cannot be avoided by choice of site for an observatory or by local protection;
- l) that interference to radio astronomy can be caused by terrestrial transmissions reflected by the Moon, by aircraft, and possibly by artificial satellites;
- m) that some types of high spatial-resolution interferometric observations require simultaneous reception, at the same radio frequency, by widely separated receiving systems that may be located in different countries, on different continents, or on space platforms;
- n) that propagation conditions at frequencies below about 40 MHz are such that a transmitter operating anywhere on the Earth might cause interference detrimental to radio astronomy;
- o) that some degree of protection can be achieved by appropriate frequency assignments on a national rather than an international basis;
- p) that WRCs have made improved allocations for radio astronomy, particularly above 71 GHz, but that protection in many bands, particularly those shared with other radio services, may still need careful planning;
- q) that technical criteria concerning interference detrimental to the radio astronomy service (RAS) have been developed, which are set out in Tables 1, 2, and 3,

recommends

- 1 that radio astronomers should be encouraged to choose sites as free as possible from interference;
- 2 that administrations should afford all practicable protection to the frequencies and sites used by radio astronomers in their own and neighbouring countries and when planning global systems, taking due account of the levels of interference given in Annex 1;
- 3 that administrations, in seeking to afford protection to particular radio astronomical observations, should take all practical steps to reduce all unwanted emissions falling within the band of the frequencies to be protected for radio astronomy to the absolute minimum. Particularly those emissions from aircraft, high altitude platform stations, spacecraft and balloons;
- 4 that when proposing frequency allocations, administrations take into account that it is very difficult for the RAS to share frequencies with any other service in which direct line-of-sight paths from the transmitters to the observatories are involved. Above about 40 MHz sharing may be practicable with services in which the transmitters are not in direct line-of-sight of the observatories, but coordination may be necessary, particularly if the transmitters are of high power.

Annex 1

Sensitivity of radio astronomy systems

1 General considerations and assumptions used in the calculation of interference levels

1.1 Detrimental-level interference criterion

The sensitivity of an observation in radio astronomy can be defined in terms of the smallest power level change ΔP in the power level P at the radiometer input that can be detected and measured. The sensitivity equation is:

$$\frac{\Delta P}{P} = \frac{1}{\sqrt{\Delta f_0 t}} \quad (1)$$

where:

P and ΔP : power spectral density of the noise

Δf_0 : bandwidth

t : integration time. P and ΔP in equation (1) can be expressed in temperature units through the Boltzmann's constant, k :

$$\Delta P = k \Delta T; \quad \text{also} \quad P = k T \quad (2)$$

Thus we may express the sensitivity equation as:

$$\Delta T = \frac{T}{\sqrt{\Delta f_0 t}} \quad (3)$$

where:

$$T = T_A + T_R$$

This result applies for one polarization of the radio telescope. T is the sum of T_A (the antenna noise temperature contribution from the cosmic background, the Earth's atmosphere and radiation from the Earth) and T_R , the receiver noise temperature. Equations (1) or (3) can be used to estimate the sensitivities and interference levels for radio astronomical observations. The results are listed in Tables 1 and 2. An observing (or integration) time, t , of 2000 s is assumed, and interference threshold levels, ΔP_H , given in Tables 1 and 2 are expressed as the interference power within the bandwidth Δf that introduces an error of 10% in the measurement of ΔP (or ΔT), i.e.:

$$\Delta P_H = 0.1 \Delta P \Delta f \quad (4)$$

In summary, the appropriate columns in Tables 1 and 2 may be calculated using the following methods:

- ΔT , using equation (3),
- ΔP , using equation (2),
- ΔP_H , using equation (4).

The interference can also be expressed in terms of the pfd incident at the antenna, either in the total bandwidth or as a spectral pfd, S_H , per 1 Hz of bandwidth. The values given are for an antenna having a gain, in the direction of arrival of the interference, equal to that of an isotropic antenna (which has an effective area of $c^2/4\pi f^2$, where c is the speed of the light and f the frequency). The gain of an isotropic radiator, 0 dBi, is used as a general representative value for the side-lobe level, as discussed under § 1.3.

Values of $S_H \Delta f$ (dB(W/m²)), are derived from ΔP_H by adding:

$$20 \log f - 158.5 \quad \text{dB} \quad (5)$$

where f (Hz). S_H is then derived by subtracting $10 \log \Delta f$ (Hz) to allow for the bandwidth.

1.2 Integration time

The calculated sensitivities and interference levels presented in Tables 1 and 2 are based on assumed integration times of 2000 s. Integration times actually used in astronomical observations cover a wide range of values. Continuum observations made with single-antenna telescopes (as distinct from interferometric arrays) are well represented by the integration time of 2000 s, typical of good quality observations. On the other hand 2000 s is less representative of spectral line observations. Improvements in receiver stability and the increased use of correlation spectrometers have allowed more frequent use of longer integration times required to observe weak spectral lines, and spectral line observations lasting several hours are quite common. A more representative integration time for these observations would be 10 h. For a 10 h integration, the threshold interference level is 6 dB more stringent than the values given in Table 2. There are also certain observations of time varying phenomena, e.g. observations of pulsars, stellar or solar bursts, and interplanetary scintillations for which much shorter time periods may be adequate.

1.3 Antenna response pattern

Interference to radio astronomy is almost always received through the antenna side lobes, so the main beam response to interference need not be considered.

The side-lobe model for large paraboloid antennas in the frequency range 2 to 30 GHz, given in Recommendation ITU-R SA.509 is a good approximation of the response of many radio astronomy antennas and is adopted throughout this Recommendation as the radio astronomy reference antenna. In this model, the side-lobe level decreases with angular distance (degrees) from the main beam axis and is equal to $32 - 25 \log \phi$ (dBi) for $1^\circ < \phi < 48^\circ$. The effect of an interfering signal clearly depends upon the angle of incidence relative to the main beam axis of the antenna, since the side-lobe gain, as represented by the model, varies from 32 to -10 dBi as a function of this angle. However, it is useful to calculate the threshold levels of interference strength for a particular value of side-lobe gain, that we choose as 0 dBi, and use in Tables 1 to 3. From the model, this side-lobe level occurs at an angle of 19.05° from the main beam axis. Then a signal at the detrimental threshold level defined for 0 dBi side-lobe gain will exceed the criterion for the detrimental level at the receiver input if it is incident at the antenna at an angle of less than 19.05° . The solid angle