

RECOMMENDATION ITU-R RA.611-4*, **

Protection of the radio astronomy service from spurious emissions

(Question ITU-R 145/7)

(1986-1990-1992-2003-2006)

Scope

This Recommendation provides guidance for administrations and/or operators to protect the radio astronomy service (RAS) from interference by spurious emissions that may be caused by active services with allocations in bands adjacent to or neighbouring to the RAS bands.

The ITU Radiocommunication Assembly,

considering

- a) that radio astronomy continues to be in the forefront of the expansion of scientific knowledge;
- b) that the radio astronomy service (RAS) requires frequency bands free of interference in order that astronomical observations can be made;
- c) that the growing use of the radio spectrum, particularly in space, increases the possibility of interference detrimental to the radio astronomy service from spurious emissions (see Annex 1 to this Recommendation);
- d) that the use of certain modulation techniques with inadequate filtering of spurious products can affect radio astronomy bands far removed from the wanted emission band;
- e) that Appendix 3 to the Radio Regulations (RR) establishes the maximum permitted levels of spurious emissions and provides for consideration of more stringent levels of spurious emissions for adequate protection of stations in the RAS;
- f) that in the case of radio systems using digital modulation techniques the spurious emission levels specified in Appendix 3 to the RR are not applicable, but may be used as a guide. It may be noted that protection of the RAS from unwanted emissions resulting from applications of wideband digital modulation is considered in Recommendation ITU-R RA.1237;
- g) that radio astronomy observations are conducted in frequency bands up to 1 000 GHz;
- h) that the threshold levels of interference detrimental to the RAS are given in Annex 1 to Recommendation ITU-R RA.769;
- j) that Recommendation ITU-R RA.1513 provides the acceptable levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the RAS on a primary basis;

* NOTE – The levels of the detrimental interference to the RAS referred to in Annex 1 to Recommendation ITU-R RA.769 are not accepted by the Arab Administrations, being unrealistic, as confirmed by previous Radiocommunication Conferences in 1995, 1997 and 2000 dealing with RR Recommendation 66.

** Radiocommunication Study Group 7 made editorial amendments to this Recommendation in the year 2017 in accordance with Resolution ITU-R 1.

k) that the technical criteria for the case of interference detrimental to the radio astronomy service due to spurious emissions from transmitters in GSO space stations should, in respect of the RAS be those set out in Annex 1 to Recommendation ITU-R RA.769 enabling radio astronomy observations to be made at 5° or more from the GSO;

l) that progress has been made in meeting the requirements of the RAS without detrimental effects on other services;

m) that there are continuing improvements in antenna design and in techniques for filtering spurious emissions,

recommends

1 that radio astronomy observatories should continue to be placed in locations that have good natural protection from interference that may be detrimental to the RAS;

2 that all practicable efforts should be made to minimize the side-lobe gains of radio astronomy antennas;

3 that, in bringing stations into operation, administrations should take into account, to the maximum extent practicable, interference to radio astronomy observations due to spurious emissions from high-powered terrestrial stations or from space stations;

4 that, for the case of GSO space stations, administrations should take into account, to the maximum extent practicable, the objective of the RAS to be free of interference detrimental to the RAS (see Recommendation ITU-R RA.769) from spurious emissions when observing at 5° or more from the GSO.

Annex 1

Interference to the RAS from spurious emissions

1 Protection criteria for the RAS

The sensitivity limit of most radio astronomy observations is at a pfd level far below that used for reception of radiocommunication signals. Annex 1 to Recommendation ITU-R RA.769 discusses threshold levels of interference and protection criteria for frequency sharing between RAS and other services; in Tables 1, 2 and 3 the sensitivity limits are listed for different frequencies. However, interference detrimental to the RAS can also occur from transmitters that do not share the same band, that may be classified as adjacent band interference (see Recommendation ITU-R RA.517) and interference from spurious emissions of transmitters in other bands. All other parameters being equal, the effect of spurious emission due to wideband digital modulation using spread-spectrum techniques in a transmitter will be more severe and is considered in Recommendation ITU-R RA.1237.

2 Harmonic and intermodulation interference

Interference from harmonic radiation or by the intermodulation of two or more signals may be caused by transmitters well separated in frequency from the radio astronomy band. Similarly, interference from inadequately filtered digitally modulated (e.g. spread-spectrum) signals can affect radio astronomy bands far removed from the carrier frequency.

Harmonic interference can occur in any band, and is generated mainly in the output power amplifier stages of the transmitters. The second and third harmonics of the carrier frequency may occur at a fairly high level but transmitters are normally provided with filters (tuned or low-pass) that attenuate

all harmonics at the output of the transmitter to at least 60 dB below peak power. Carrier intermodulation will also occur when a proportion of the signal from one transmitter breaks through the combining filters to the output circuit of another transmitter feeding a common antenna. Relatively simple additional filters would attenuate these unwanted products, assuming they are not too close in frequency to the transmitter.

The levels discussed in the previous paragraph apply to interference generated in the output stages of the transmitter. In addition, harmonics and intermodulation products may be generated by non-linearity in the transmitter system¹.

3 Unwanted emissions from broadband modulation

In certain types of intended transmissions, often associated with data in digital form, spectral sidebands are generated over a much broader frequency band than is used in the reception of such signals. In particular, the biphasic phase-shift keying (2-PSK) modulation technique produces a power spectrum of the form $(\sin x/x)^2$ with recurring subsidiary maxima outside the wanted bandwidth that decrease only slowly with frequency. If unfiltered, the sidebands that occur at about ten bandwidths (3 dB) from the carrier frequency are reduced in power spectral density only about 36 dB below the power level at the band centre. If, in addition, the keying frequency of this 2-PSK transmission is 10-20 MHz, then these ten bandwidths encompass several hundred megahertz from the assigned frequency. For example, assume a simple 2-PSK transmitter with a keying frequency of 10 MHz centred on 1 615 MHz with 40 W of power and an isotropic transmitting antenna mounted on an aircraft at a line-of-sight distance of 400 km, which is the distance of the horizon at an aircraft flying at an altitude of about 10 000 m. Unwanted emissions from this transmitter would result in a pfd level even in the band 1 400-1 427 MHz at the receiver site that is 40 dB above the threshold levels of interference detrimental to the RAS given in Table 1 of Annex 1 to Recommendation ITU-R RA.769. Emission in the band 1 660-1 670 MHz, also allocated to radio astronomy, would of course, be at a significantly higher level. Transmitters of this type located on spacecraft could be even more troublesome sources of interference to radio astronomy. It is important that care be taken in the design of these types of transmitters to ensure adequate suppression of the unwanted emissions.

2-PSK with a keying frequency of several megahertz is used in some types of spread-spectrum modulation. A characteristic of common spread-spectrum techniques is a wideband signal with low power density that resembles random noise. This characteristic usually reduces the possibility of these spread-spectrum systems causing interference to conventional, narrow-band communication systems, but not to the RAS. In radio astronomy, the cosmic signals have the form of random noise, and wide bandwidths are often used. At the low signal levels with which radio astronomers are concerned, there is usually no practical way to distinguish between spread-spectrum signals and cosmic signals. The detrimental threshold levels of pfd for man-made signals falling within a radio astronomy band, which are given in Annex 1 to Recommendation ITU-R RA.769, apply to unwanted, as well as intentional emissions and to all types of modulation, including that discussed above. Present-day technology allows the design of new generations of such transmitters to ensure proper suppression of the unwanted out-of-band emissions. Such transmitters could well perform without radiating far sidebands, provided the carrier phase is not switched abruptly by 180°, in the 2-PSK modulation scheme, but rather more smoothly so as to produce a power spectrum of the form $(\sin x/x)^n$ with $n > 2$.

¹ Additional relevant technical material may be found at the ITU-R WP 7D website.

4 Interference from satellite transmissions

Satellite transmissions have the potential to cause severe interference to the RAS. Whereas terrestrial interference sources are usually in the far side-lobe region of the radio telescope antenna, and possibly further attenuated by the topography of the surroundings of the radio observatory, interference by satellite transmitters is likely to be received via the main beam and inner side lobes, with considerably higher gain. The nature of the interference depends on the type of transmitter and service provided by the system, whether the satellites are in GSO or in non-GSO, and the number of satellites in the system under consideration that are above the horizon at the radio observatory.

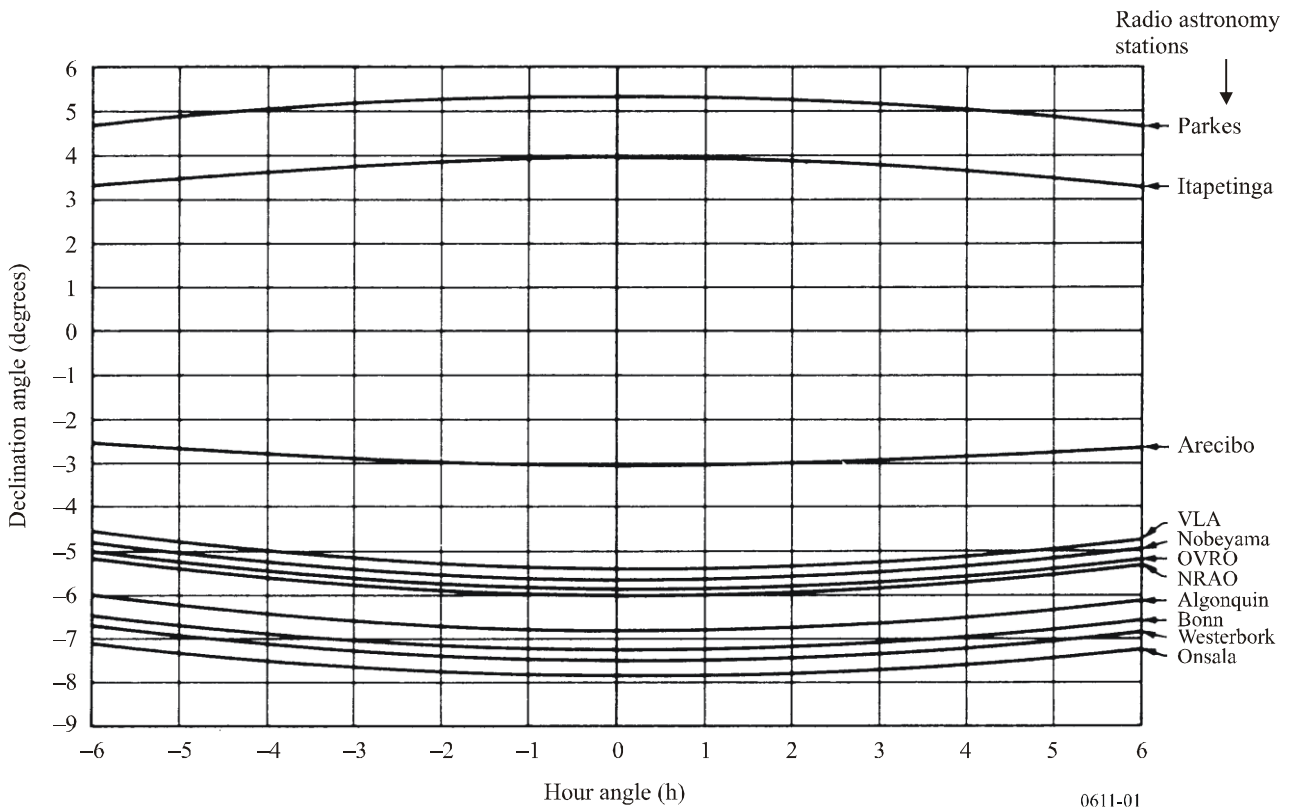
4.1 Geostationary satellites

Multiple geostationary satellites are visible from almost all the radio telescopes currently in operation, and occupy a more-or-less constant range of azimuths and elevations. They have therefore the potential to be troublesome sources of interference to radio astronomy observations. The radius of the GSO is approximately 6.6 times the radius of the Earth. At that radial distance a single satellite can illuminate a third of the Earth's surface – and consequently many radio telescopes – with line-of-sight signals. Figure 1 shows the position of the geostationary satellite belt in celestial coordinates as seen from the latitudes of some of major radio astronomy observatories. Plans for the development of some active services call for a large number of geostationary satellites. Such a series of potential sources of interference that may be received through the near side lobes of the radio telescope antenna pattern could present a unique interference problem to radio astronomers.

Threshold levels of interference that may be detrimental to radio astronomy are given in Annex 1 to Recommendation ITU-R RA.769. Listed there is the level, in each radio astronomy band, of the power into the receiver that is just sufficient to cause interference that is detrimental to the service. Also listed are the equivalent pfd ($\text{dB(W/m}^2\text{)}$) associated with this interference, which are calculated with the assumption that the gain of the radio telescope is 0 dBi in the direction of the interfering source. Such a gain is appropriate for consideration of terrestrial sources of interference confined to the neighbourhood of the horizon. For the case of geostationary satellites, the situation is different.

If we assume that the radio astronomy antenna has the side-lobe characteristics assumed in Recommendation ITU-R SA.509, the side-lobe gain would fall to 0 dBi at 19° from the axis of the main beam. For such an antenna the interference level detrimental to the RAS will be exceeded if the main beam is pointed within 19° of a satellite that produces within the radio astronomy bandwidth a pfd at the radio observatory equal to the detrimental threshold in Annex 1 to Recommendation ITU-R RA.769. A series of satellites spaced at intervals of about 30° along the GSO radiating interference at this level would result in a zone of width approximately 38° centred on the orbit in which radio astronomy observation free from detrimental interference would be precluded. The width of this precluded zone would increase with the number of interfering satellites in the orbit, and could, in principle, cover the whole sky. The effective number of interfering satellites will depend upon whether the interfering signals are spot beams from the satellites' transmitting antennas or are more widely radiated. Spurious emissions not widely separated from the satellite's transmitter frequency are likely directed by the antennas in a way similar to that of the intended signals.

FIGURE 1
Projection of geostationary-satellite orbit on to the celestial sphere



4.2 Non-geostationary satellites

The potential for interference detrimental to the RAS from non-geostationary low-Earth orbit satellites is due to their operation in large numbers, which make it possible for many of them to be simultaneously above the horizon at a radio observatory, and in line-of-sight with the radio telescope antenna. This factor leads to a situation where the radio telescope antenna can receive unwanted emissions from those visible non-geostationary low-Earth orbit satellites through many near and far side lobes of the antenna beam, and also through the main beam. The interference problem is exacerbated by the continually changing directions of arrival of the interfering signals, and the need for the radio telescope antenna to track the celestial source under observation. Multiple inputs of strong signals may drive the operating point of the receiver into a non-linear region, resulting in the generation of intermodulation products.

The impact of unwanted emissions produced at radio astronomy sites by a constellation of satellites in (low) non-geostationary orbits may be determined using the epfd methodology described in Recommendation ITU-R S.1586 – Calculation of unwanted emission levels produced by a non-geostationary fixed-satellite service system at radio astronomy sites, or Recommendation ITU-R M.1583 – Interference calculations between non-geostationary mobile-satellite service or radionavigation-satellite service systems and radio astronomy telescope sites, and the antenna gains given in Recommendation ITU-R RA.1631.

These Recommendations may be used to determine the percentage of data loss during observations made at a particular radio astronomy site due to interference from a given satellite system. The acceptable percentage of data loss is defined in Recommendation ITU-R RA.1513.