RECOMMENDATION ITU-R RA.517-3*

Protection of the radio astronomy services from transmitters operating in adjacent bands

(Question ITU-R 145/7)

(1978-1982-1992-2003)

The ITU Radiocommunication Assembly,

considering

a) the value of the scientific results achieved by the radio astronomy service (RAS) through the exploration of the Universe;

b) the need for interference-free bands at intervals throughout the radio spectrum in order that radio astronomy measurements can be made;

c) the levels of detrimental interference to the RAS given in Annex 1 to Recommendation ITU-R RA.769;

d) 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;

e) the desire on the part of both active and passive users of the radio-frequency spectrum to operate in harmony without mutual interference as evidenced by the provisions of the Radio Regulations (RR);

f) that in some cases the RR do not provide protection required by radio astronomy from transmitters operating in frequency bands adjacent to a band allocated to the RAS which may cause detrimental interference due to the unwanted emissions of these transmitters;

g) the difficulties currently being experienced by radio services in the design and utilization of transmitters to operate in frequency bands adjacent to a band allocated to the RAS, in such a manner as to afford adequate protection from detrimental interference to the radio astronomy service (see Annex 1);

h) the possible future increase in the level of usage of frequency bands adjacent to bands allocated to the RAS, particularly by airborne and satellite transmitters;

j) that it is incumbent on both active and passive radio services to find means to minimize detrimental interference, acting both separately and in cooperation with each other, with due consideration for the efficient use of the radio-frequency spectrum,

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* 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 Recommendation 66.

recommends

1 that in order to reduce detrimental interference to the RAS, all practical, technical means, for example, the use of filters in transmitters to confine emissions to the allocated band, and in radio astronomy receivers to avoid sensitivity to signals outside the allocated band, should be adopted to the maximum practicable extent;

2 that when frequencies are assigned to a station in a service operating in a band adjacent to one allocated on a primary basis to RAS, attempts should be made to limit the edge of the necessary band adjacent to the radio astronomy band, so that the power radiated within this band should produce no detrimental interference to a station of that service;

3 that when future frequency assignments are made by administrations in bands adjacent to those allocated to RAS, account should be taken, to the maximum extent practicable, of the special risk of interference to radio astronomy observations from space-to-Earth and airborne transmissions, within the adjacent bands;

4 that taking into account § 1, 2 and 3 above, practical solutions to limit interference to the RAS due to out-of-band emissions to below the detrimental level be sought by administrations, individually and if necessary in cooperation.

Annex 1

Interference to the RAS from transmitters in adjacent bands

1 Introduction

The sensitivity limit of most radio astronomy observations is at a pfd level far below that used for reception of radiocommunication signals. Detrimental interference and protection criteria for frequency sharing between RAS and other services are discussed in Annex 1 to Recommendation ITU-R RA.769; in Tables 1, 2 and 3 of the latter, the sensitivity limits are listed for different frequencies. However, as a consequence of the sensitivity of radio astronomy observations, interference can occur from transmitters which do not share the same band. This may be classified as band-edge interference and interference from harmonic and intermodulation signals. (Interference to the RAS from spurious emissions is treated in Recommendation ITU-R RA.611. The case of protection of the RAS from unwanted emissions resulting from application of wideband digital modulation is treated in Recommendation ITU-R RA.1237.)

Interference problems in a radio astronomy receiver, by a transmitter operating in an adjacent band, can arise by three mechanisms. It can occur if the sensitivity of the radio astronomy receiver to signals outside the radio astronomy band is not sufficiently low. This may be due to the practical limitations on the fall-off of receiver gain at the band edges. Secondly, non-linear effects in the receiver may, in the presence of two or more strong signals at frequencies near the edge of the receiver passband, give rise to intermodulation products falling within the radio astronomy band. Thirdly, interference may arise through unwanted emission by the transmitter (modulation sidebands, phase-noise in oscillators, etc.) falling within the radio astronomy band. In dealing with band-edge interference, the problem common to both transmitting and receiving services is the design of filters which will adequately suppress the unwanted energy without introducing unacceptable modifications, e.g. attenuation or phase distortion, into the wanted signals. Cases of possible band-edge interference, from 13.36 MHz to 275 GHz, as per RR Article 5, are listed in Table 1.

2 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 geostationary or non-geostationary orbit, and the number of satellites in the system under consideration that are above the horizon at the radio observatory.

2.1 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 cause troublesome sources of interference to radio astronomy observations. The radius of the GSO orbit is approximately 6.6 times the radius of the Earth. At that 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 GSO satellite belt in celestial coordinates as seen from the latitudes of some 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.

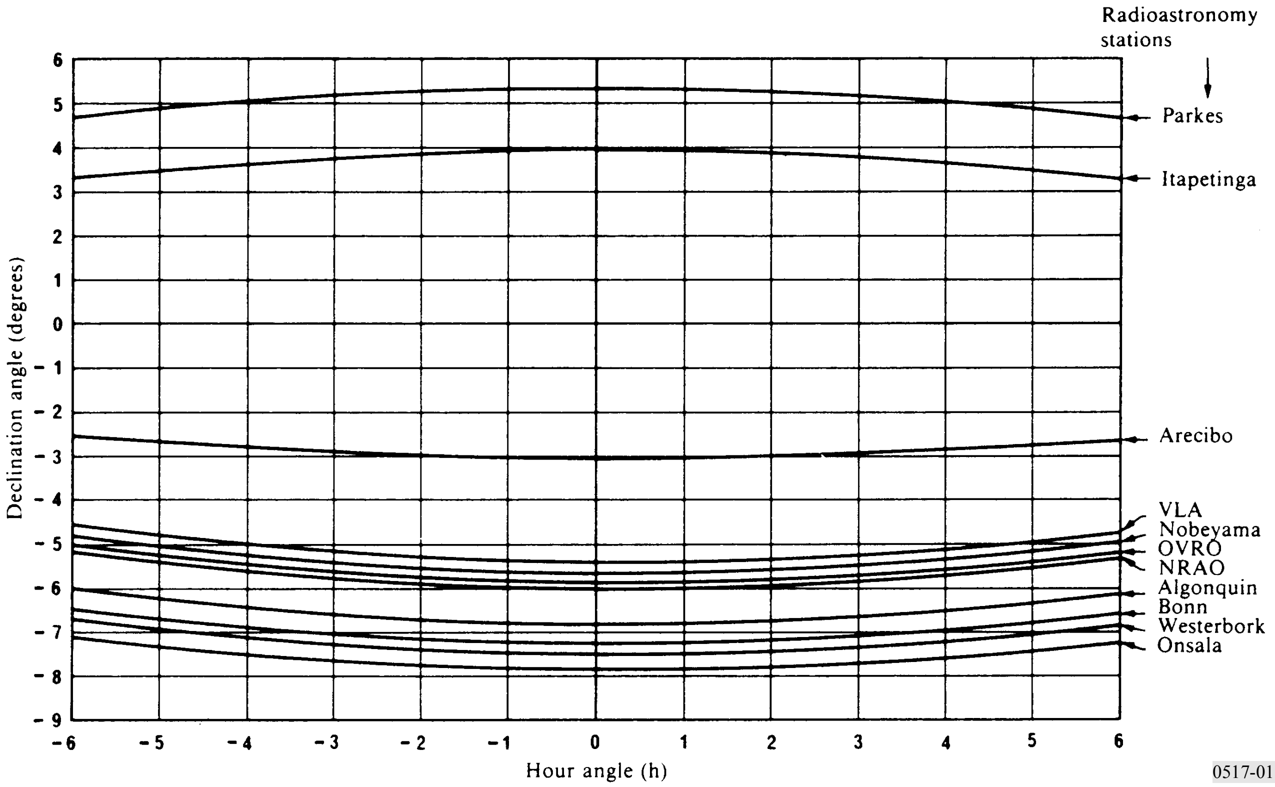
Detrimental thresholds for interference to radio astronomy are given in Annex 1 to Recommendation ITU-R RA.769. Listed there is the level, in each radio astronomy band, of the power into the receiver that is just sufficient to cause detrimental interference. Also listed are the pfd (dB(W/m^2)) causing detrimental 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 sources, the situation is different.

If we assume that the RAS 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 detrimental interference level 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 beamed by the satellites’ transmitting antennas or are more widely radiated.

Out-of-band emission that is not widely separated from the satellite's transmitter frequency is likely to be 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



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2.2 Non-GSO satellites

The potential for detrimental interference from non-GSO 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-GSO 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-GSO 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 lost encountered during observations made at a particular radio astronomy site due to interference from a given satellite system. The acceptable percentage of data lost is defined in Recommendation ITU-R RA.1513.

TABLE 1

Services in adjacent bands which could cause detrimental interference to the RAS*

Band allocated to the RAS on primary basis	Adjacent bands	Adjacent-band services [(1)]
13.36-13.41 MHz	13.26-13.36 MHz	AERONAUTICAL MOBILE (R)
	13.410-13.570 MHz	Mobile except aeronautical mobile (R)
25.55-25.67 MHz	25.210-25.550 MHz	MOBILE except aeronautical mobile
	25.67-26.10 MHz	BROADCASTING
73-74.6 MHz *(Region 2)*	72-73 and 74.6-74.8 MHz	MOBILE
150.05-153 MHz *(Region 1)*	148-150.05 MHz	MOBILE-SATELLITE (Earth-to-space)
	149.9-150.05 MHz	RADIONAVIGATION-SATELLITE
	146-149.9 and 153-154 MHz	MOBILE except aeronautical mobile (R)
	153-154 MHz	Meteorological Aids
322-328.6 MHz	235-322 MHz	MOBILE, including satellite
	328.6-335.4 MHz	AERONAUTICAL RADIONAVIGATION
406.1-410 MHz	400.15-406 MHz	METEOROLOGICAL AIDS
	401-406 and 410-430 MHz	Mobile except aeronautical mobile
	406-406.1 MHz	MOBILE-SATELLITE (Earth-to-space)
	410-420 MHz	SPACE RESEARCH (space-to-space)
608-614 MHz *(Region 2)*	470-608 and 614-890 MHz	BROADCASTING
	614-806 MHz	Mobile
1 400-1 427 MHz	1 350-1 400 MHz	MOBILE *(Region 1)* and RADIOLOCATION
	1 427-1 429 MHz	SPACE OPERATION (Earth-to-space) and MOBILE except aeronautical mobile
	1 429-1 452 MHz	MOBILE *(Regions 2 and 3)* except aeronautical mobile *(Region 1)*
1 610.6-1 613.8 MHz	1 559-1 610 MHz	RADIONAVIGATION-SATELLITE (space-to-Earth) (space-to-space)
	1 559-1 626.5 MHz	AERONAUTICAL RADIONAVIGATION
	1 610-1 660.5 MHz	MOBILE-SATELLITE (Earth-to-space)
	1 610-1 626.5 MHz	RADIODETERMINATION-SATELLITE (Earth-to-space), (Primary Region 2, Secondary Region 3)
	1 613.8-1 626.5 MHz	Mobile-satellite (space-to-Earth)
1 660-1 670 MHz	1 610-1 660.5 MHz	MOBILE-SATELLITE (Earth-to-space)
	1 668.4-1 690 MHz	METEOROLOGICAL AIDS
	1 670-1 690 MHz	METEOROLOGICAL-SATELLITE (space-to-Earth)

TABLE 1 (*continued*)

Band allocated to the RAS on primary basis	Adjacent bands	Adjacent-band services [(1)]
2 690-2 700 MHz	2 670-2 690 MHz	MOBILE-SATELLITE (Earth-to-space)
	2 500-2 690 MHz	FIXED-SATELLITE (Regions 2 and 3) and MOBILE except aeronautical mobile
	2 700-2 900 MHz	AERONAUTICAL RADIONAVIGATION
	2 700-3 300 MHz	Radiolocation
4 990-5 000 MHz	4 800-4 990 MHz	MOBILE
	5 000-5 250 MHz	AERONAUTICAL RADIONAVIGATION
	5 010-5 030 MHz	RADIONAVIGATION SATELLITE
10.6-10.7 GHz	8.5-10.6 GHz	Radiolocation/RADIOLOCATION
	10.5-10.6 GHz	MOBILE
	10.7-11.7 GHz	FIXED-SATELLITE (space-to-Earth in all Regions; also, Earth-to-space in Region 1)
	10.7-12.1 GHz	MOBILE except aeronautical mobile
15.35-15.4 GHz	14.5-15.35 GHz	MOBILE Space research
	15.4-15.43 GHz	AERONAUTICAL RADIONAVIGATION
22.21-22.5 GHz	22-22.21 GHz	MOBILE except aeronautical mobile
	22.5-23.6 GHz	MOBILE
23.6-24 GHz	22.5-23.6 GHz	MOBILE
	24-24.05 GHz	AMATEUR (secondary till 24.25 MHz)
	24.05-24.25 GHz	AMATEUR-SATELLITE
31.3-31.8 GHz	31-31.3 GHz	MOBILE
	30-31.3 GHz	Standard frequency and time signal-satellite (space-to-Earth)
	31-31.3 GHz	Space research
	31.8-33.4 GHz	RADIONAVIGATION
	31.8-32.3 GHz	SPACE RESEARCH (deep space) (space-to-Earth)
42.5-43.5 GHz	37.5-42.5 GHz	FIXED-SATELLITE (space-to-Earth)
	40.5-42.5 GHz	BROADCASTING-SATELLITE BROADCASTING Mobile
	43.5-47 GHz	MOBILE MOBILE-SATELLITE RADIONAVIGATION RADIONAVIGATION-SATELLITE
76-77.5 GHz	66-76 GHz	MOBILE
	71-76 GHz	FIXED-SATELLITE (space-to-Earth)
	74-76 GHz	BROADCASTING BROADCASTING-SATELLITE Space research (space-to-Earth)
	77.5-78 GHz	AMATEUR AMATEUR-SATELLITE
	77.5-79 GHz	Space research (space-to-Earth)

TABLE 1 (*end*)

Band allocated to the RAS on primary basis	**Adjacent bands**	**Adjacent-band services** [(1)]
79-94 GHz	78-79 GHz	RADIOLOCATION Amateur Amateur-satellite
	77.5-79 GHz	Space research (space-to-Earth)
94.1-116 GHz	92-94.1 GHz	RADIOLOCATION
	94-94.1 GHz	SPACE RESEARCH (active) EARTH EXPLORATION-SATELLITE (active)
	116-122.25 GHz	INTER-SATELLITE
130-134 GHz	123-130 GHz	FIXED-SATELLITE (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) RADIONAVIGATION RADIONAVIGATION-SATELLITE
	134-136 GHz	AMATEUR AMATEUR-SATELLITE
136-158.5 GHz	134-136 GHz	AMATEUR AMATEUR-SATELLITE
	158.5-164 GHz	FIXED-SATELLITE (space-to-Earth) MOBILE MOBILE-SATELLITE (space-to-Earth)
164-167 GHz	158.5-164 GHz	FIXED-SATELLITE (space-to-Earth) MOBILE MOBILE-SATELLITE (space-to-Earth)
	167-174.8 GHz	MOBILE
	167-182 GHz	INTER-SATELLITE
	167-174.5 GHz	FIXED-SATELLITE (space-to-Earth)
182-185 GHz	167.5-182 GHz	INTER-SATELLITE
	185-190 GHz	INTER-SATELLITE
200-231.5 GHz	191.8-200 GHz	INTER-SATELLITE MOBILE MOBILE-SATELLITE RADIONAVIGATION RADIONAVIGATION-SATELLITE
	231.5-235 GHz	MOBILE Radiolocation
241-248 GHz	238-241 GHz	MOBILE RADIOLOCATION
	248-250 GHz	AMATEUR AMATEUR-SATELLITE
250-275 GHz	248-250 GHz	AMATEUR AMATEUR-SATELLITE

* To keep the Table tractably small and comprehensible, fixed and mobile (except aeronautical mobile) services have not been included in the Table. Similarly, only bands where the RAS has primary status are considered.

[(1)] The category of service of these allocations is shown in conformity with RR provisions.