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Recommendation ITU-R RS.2066-1

(03/2024)

RS Series: Remote sensing systems

Protection of the radio astronomy service in the frequency band 10.6-10.7 GHz from unwanted emissions of synthetic aperture radars operating in the Earth exploration-satellite service (active) around 9 600 MHz

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R RS.2066-1

Protection of the radio astronomy service in the frequency band 10.6-10.7 GHz from unwanted emissions of synthetic aperture radars operating in the Earth exploration-satellite service (active) around 9 600 MHz

(2014-2024)

Scope

This Recommendation provides an operational procedure to avoid main-beam to main-beam coupling between Earth exploration-satellite service (EESS) (active) SAR-4 systems when transmitting near 9 600 MHz and radio astronomy service (RAS) stations performing observations in the band 10.6-10.7 GHz in order to avoid damage to the sensitive RAS low noise amplifier.

Keywords

EESS (active), RAS, mitigation

Abbreviations/Glossary

SAR Synthetic Aperture Radar

Related ITU Recommendations/Reports

Recommendation ITU-R RS.2043 – Characteristics of synthetic aperture radars operating in the Earth exploration-satellite service (active) around 9 600 MHz

Report ITU-R RA.2188 – Power flux-density and e.i.r.p. levels potentially damaging to radio astronomy receivers

Report ITU-R RS.2274 – Spectrum requirements for spaceborne synthetic aperture radar applications planned in an extended allocation to the Earth exploration-satellite service around 9 600 MHz

Report ITU-R RS.2308 – Radio frequency compatibility of unwanted emissions from 9 GHz EESS synthetic aperture radars with the Earth exploration-satellite service (passive), space research service (passive), space research service and radio astronomy service operating in the frequency bands 8 400-8 500 MHz and 10.6-10.7 GHz, respectively

The ITU Radiocommunication Assembly,

considering

a) that the frequency band 9 300-9 800 MHz is allocated to EESS (active) on a primary basis;

b) that the frequency band 9 800-9 900 MHz is allocated to EESS (active) on a secondary basis;

c) that the frequency band 10.6-10.7 GHz is allocated to the RAS on a primary basis;

d) that EESS (active) systems operating active radars around 9 600 MHz use high power chirp emissions in the space-to-Earth direction;

e) that radio astronomy stations operating in the frequency band 10.6-10.7 GHz use extremely sensitive low noise amplifiers;

f) that Report ITU-R RA.2188 provides the power flux-density and e.i.r.p. levels potentially damaging RAS low noise amplifiers/front-ends;

g) that the level of interference received by RAS stations from the emissions of EESS (active) systems may, under rare conditions of mainbeam to main beam coupling, reach or exceed the critical levels as given by Report ITU-R RA.2188, *recommends*

1 that, in order to ensure compatibility of EESS SAR with RAS stations, EESS SAR systems operating around 9 600 MHz should avoid, to the maximum possible extent, to illuminate an area around radio astronomy stations. The size of such an area is defined in Annex 1. Annex 2 provides the list of RAS stations capable to operate in the frequency band 10.6-10.7 GHz and which may perform observations during times of illumination;

2 that, in the event that the conditions referred to in *recommends* 1 are not met, the operator of the EESS SAR system should contact the operator of the concerned radio astronomy station at least seven calendar days before an event for EESS SAR routine operations and at least 24 hours for EESS SAR acquisition of images in cases of emergency only such as disaster management in order to coordinate and, if necessary, to agree on mitigation or other preventive measures.

Annex 1

Determination of the protection area surrounding RAS stations

The emission beam contour corresponding to the margin determined by applying Recommendation ITU-R RA.2188 defines the damage zone for a potential boresight-to-boresight coupling of both antenna beams. Such a contour has the shape of an ellipse with a major axis $\delta\theta_h$ in the horizontal and the minor axis $\delta\theta_v$ in the vertical beam direction, thus defining an area where the power level at the RAS station would exceed −18 dBW. The projection onto the Earth's surface provides the dimension of an area of size with an extension of $\pm\delta h$ in the horizontal direction and $\pm\delta v$ in the vertical direction around the radio astronomy station which should be protected. Table 1 provides the parameter range for the avoidance of accidental damage to an RAS receiver[1] with an antenna diameter of 100 m with regard to SAR-4 as described in Recommendation ITU-R RS.2043.

TABLE 1

Parameters for the avoidance of accidental damage to RA receivers

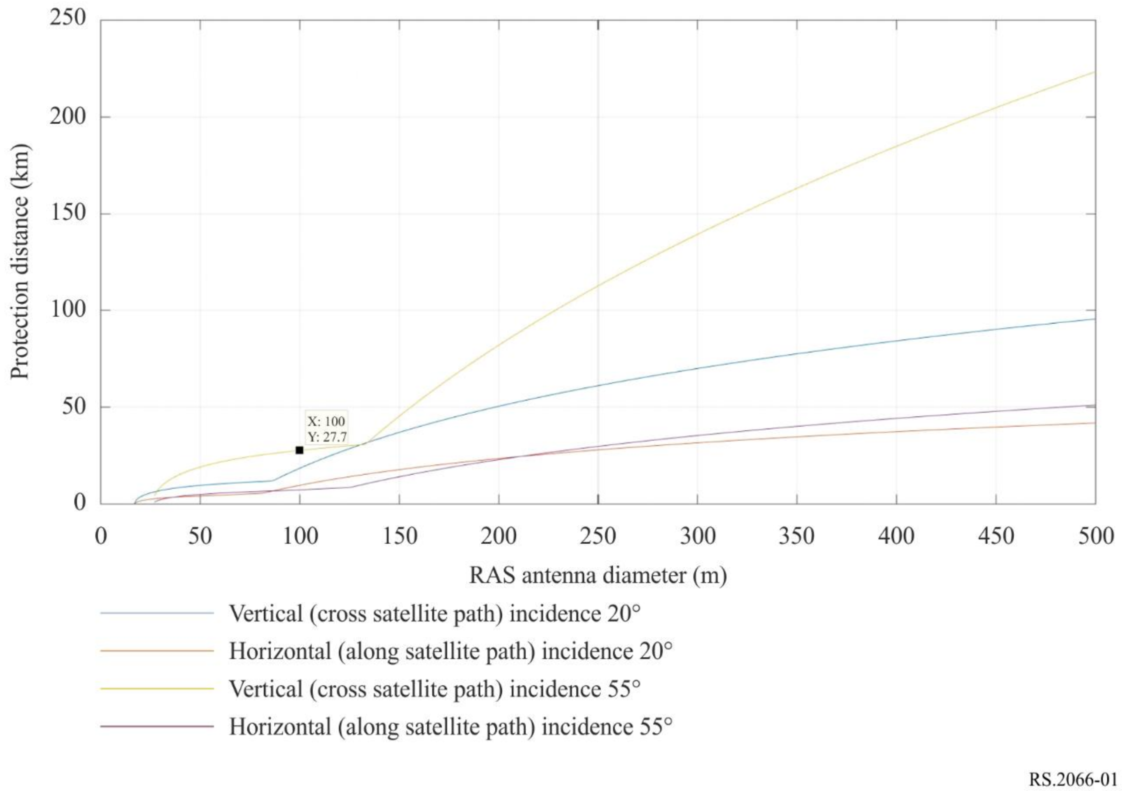
Incident angle Φ	**Horizontal offset angle $\delta\theta_h$**	**Vertical offset angle $\delta\theta_v$**	**Horizontal separation (km) δh**	**Vertical separation (km) δv**
20°	1.02°	1.8°	9.6	18.2
55°	0.5°	1.1°	7.4	28.1

[1] In the vertical direction, there is an asymmetry of 5.6% for $\delta\theta_v$ and δv between inner and outer off-set angles and distances which has been neglected. Only the larger outer value has been listed. The ground projections of the margin contours which are distorted ellipses were approximated by rectangles.

Figure 1 provides the size of the area around the RAS station to be protected, depending on the RAS antenna diameter and the incidence angle. It can be seen that there is no constraint for RAS stations having an antenna diameter less than 17 m, and that the maximum separation distance from the RAS station is 28 km for most RAS stations.

FIGURE 1

Size of the area around RAS stations to be protected assuming EESS SAR-4 characteristics



More generally, for a given incident angle *i*, the distance between the SAR satellite and the acquisition area is given by:

$$d = \sqrt{(\mathrm{r} + h)^2 - \mathrm{r}^2 * \sin^2(i)} - \mathrm{r} * \cos(i)$$

where:

r: Earth radius (km)

i: incidence angle (°)

h: SAR altitude (km).

The corresponding angle between the nadir and the acquisition area in the vertical plane is given by:

$$\theta_v = \operatorname{asin}\left(\frac{\mathrm{r}*\sin(i)}{\mathrm{r}+h}\right)$$

where:

r: Earth radius (km)

i: incidence angle (°)

h: SAR altitude (km).

The maximum gain of the RAS antenna can be derived from the antenna diameter and the frequency using the following equation:

$$G_r = 8.9 + 20\log(\pi D f)$$

where:

D: RAS antenna diameter (m)

f: frequency (GHz).

From these values, the SAR antenna gain limit that allows the received power limit of −18 dBW to be met is given by:

$$Ge = Pr_{limit} + L_p - G_r - P_e$$

where:

Pr_{limit}: received power not to be exceeded (−18 dBW below 20 GHz)

L_p: free space loss (dB)

G_r: RAS maximum antenna gain (dBi)

P_e: SAR peak power (dBW).

Using the horizontal and vertical SAR antenna patterns, it is possible to determine the corresponding offset angles $\delta\theta_h$ and $\delta\theta_v$. From these angles, one can derive the horizontal and vertical separation distances δh and δv.

$$\delta h = \mathrm{r} * \mathrm{asin}\left(\frac{\mathrm{d}\tan(\delta\theta_h)}{\mathrm{r}}\right)$$

where:

r: Earth radius (km)

d: slant range (km)

$\delta\theta_h$: horizontal offset angle (degree).

The slant range between the satellite and the RAS station that meets the received power limit is given by:

$$d + \delta d = (\mathrm{r} + h)\cos(\theta_v + \delta\theta_v) - \sqrt{\mathrm{r}^2 - (\mathrm{r} + h)^2\sin^2(\theta_v + \delta\theta_v)}$$

where:

r: Earth radius (km)

d: slant range between satellite and acquisition area (km)

h: SAR satellite altitude (km)

θ_v: angle between nadir and acquisition area in the vertical plane (°)

$\delta\theta_v$: vertical offset angle (degree).

And also, one can derive the vertical separation distance, δv:

$$\delta v = \mathrm{r}\left(\mathrm{asin}\left(\frac{(d+\delta d)}{\mathrm{r}}\sin(\theta_v + \delta\theta_v)\right) - \mathrm{asin}\left(\frac{d}{\mathrm{r}}\sin(\theta_v)\right)\right)$$

where:

r: Earth radius (km)

d: slant range between satellite and acquisition area (km)

$d+\delta d$: slant range between satellite and RAS station (km)

θ_v: angle between nadir and acquisition area in the vertical plane (°)

$\delta\theta_v$: vertical offset angle (degree).

Annex 2

List of radio astronomy stations capable of operating in the band 10.6-10.7 GHz

Region 1

Country	Name	N latitude	E longitude	Antenna size[2]
Belgium	Humain	50° 11' 30"	05° 15' 27"	64 m
Finland	Metsahövi	60° 13' 04"	24° 23' 37"	13.7 m, 13.2 m
France	Nancay	47° 23' 00"	02° 12' 00"	16 × 1.1 m
Germany	Effelsberg	50° 31' 29"	06° 53' 03"	100 m
	Stockert	50° 34' 10"	06° 43' 19"	10 m
	Wettzell	49° 08' 41"	12° 52' 40"	20 m, 2 × 13.2 m
Italy	Matera	40° 38' 58.2"	16° 42' 14.45"	20 m, 13.2 m
	Medicina	44° 31' 14"	11° 38' 49"	32 m, 2.4 m
	Noto	36° 52' 33"	14° 59' 20"	32 m
	Sardinia	39° 29' 34"	09° 14' 42"	64 m
Latvia	Ventspils	57° 33' 12"	21° 51' 17"	32 m
Norway	Ny Ålesund	78° 55' 45"	11° 52' 15"	2 × 13.2 m
Portugal				
	Santa Maria	36° 59' 07"	–25° 07' 33"	13 m
Russia	Badari	51° 46' 10"	102° 14' 00"	32 m, 13.2 m
	Kaliazyn	57° 13' 22"	37° 54' 01"	64 m
	Pushchino	54° 49' 20"	37° 37' 53"	22 m
	Svetloe	60° 31' 56"	29° 46' 54"	32 m, 13.2 m
	Zelenchukskaya	43° 49' 34"	41° 35' 12"	32 m, 13.2 m
South Africa	Hartebeesthoek	–25° 53' 22"	27° 41' 05"	26 m, 13.2 m
	MeerKAT	–30° 43' 16"	21° 24' 40"	64 × 13.5 m
	SKA1-MID	–30° 42' 47"	21° 26' 38"	133 × 15 m
Spain	Gran Canaria	28° 01' 34"	–15° 40' 16"	13.2 m
	Robledo	40° 25' 38"	–04° 14' 57"	70 m, 34 m
	Tenerife	28° 18' 00"	–16° 30' 35"	12 m
	Yebes	40° 31' 27"	–03° 05' 13"	40 m, 13.2 m
Sweden	Onsala	57° 23' 45"	11° 55' 35"	20 m, 25 m, 2 × 13.2 m
Switzerland	Bleien	47° 20' 24"	08° 06' 42"	5 m, 7 m
	Zurich	47° 22' 40.8"	08° 33' 03"	5 m

[2] In this column, X m means antenna of X metres diameter and Y × X m means Y antennas of X metre diameter.

Country	Name	N latitude	E longitude	Antenna size[2]
Turkey	Kayseri	38° 42' 37"	35° 32' 43"	13 m
UK	MERLIN Cambridge	52° 10' 01"	00° 02' 14"	32 m
	MERLIN Knockin	52° 47' 25"	–02° 59' 50"	25 m
	MERLIN Darnhall	53° 09' 23"	–02° 32' 09"	25 m
	MERLIN Jodrell Bank	53° 14' 07"	–02° 18' 23"	26 m
	MERLIN Pickmere	53° 17' 19"	–02° 26' 44"	25 m
	MERLIN Defford	52° 06' 02"	–02° 08' 40"	25 m

List of radio astronomy stations capable of operating in the band 10.6-10.7 GHz

Region 2

Country	Name	N latitude	E longitude	Antenna size[3]
Brasil	Itapetinga	–23° 11' 05"	–46° 33' 28"	14 m
Canada	Algonquin Radio Obsy	45° 57' 19"	–78° 04' 23"	46 m
Chile	ALMA	–23° 01' 09"	–67° 45' 12"	54 × 12 m, 12 × 7 m
Mexico	INAOE RT5	18° 59' 04"	–97° 18' 32"	50 m
USA	Allen Telescope Array (ATA), Hat Creek Radio Observatory	40° 49' 03"	–121° 28' 24"	42 × 6 m
	Arecibo	18° 20' 39"	–66° 45' 10"	305 m
	Goddard Geophysical and Astronomic Observatory (GGAO)	39° 01' 19"	–76° 49' 37"	12 m
	Goldstone Deep Space Communications Complex (GDSCC)	35° 25' 33"	–116° 53' 22"	70.3 m
	Robert C. Byrd Telescope, Green Bank Observatory	38° 25' 59"	–79° 50' 23"	100 m
	Westford Radio Telescope, Haystack Observatory	42° 36' 47"	–71° 29' 38"	18.3 m
	Kōkeʻe Park Geophysical Observatory (KPGO)	22° 07' 34"	–159° 39' 54"	20 m, 12 m
	Jansky Very Large Array (JVLA)	33° 58' 22" to 34° 14' 56"	–107° 24' 40" to –107° 48' 22"	27 × 25 m
	McDonald Geodetic Observatory (MGO)	30° 40' 48"	–104° 01' 26"	12 m
	VLBA Brewster, WA	38° 25' 59"	–79° 50' 23"	25 m

[3] In this column, X m means antenna of X metres diameter and Y × X m means Y antennas of X metres diameter.

Country	Name	N latitude	E longitude	Antenna size[3]
	VLBA Fort Davis, TX	30° 38' 06"	–103° 56' 41"	25 m
	VLBA Hancock, NH	42° 56' 01"	–71° 59' 12"	25 m
	VLBA Kitt Peak, AZ	31° 57' 23"	–111° 36' 45"	25 m
	VLBA Los Alamos, NM	35° 46' 30"	–106° 14' 44"	25 m
	VLBA Mauna Kea, HI	19° 48' 05"	–155° 27' 20"	25 m
	VLBA North Liberty, IA	41° 46' 17"	–91° 34' 27"	25 m
	VLBA Owens Valley, CA	37° 13' 54"	–118° 16' 37"	40 m, 5 × 2 m, 8 × 2 m, 2 × 27 m
	VLBA Pie Town, NM	34° 18' 04"	–108° 07' 09"	25 m
	VLBA St. Croix, VI	17° 45' 24"	–64° 35' 01"	25 m

List of radio astronomy stations capable of operating in the band 10.6-10.7 GHz

Region 3

Country	Name	N latitude	E longitude	Antenna size[4]
Australia	Parkes	–33° 00' 00"	148° 15' 44"	64 m
	Katherine	–14° 22' 30"	132° 09' 07"	12 m
	Mopra	–31° 16' 04"	149° 05' 58"	22 m
	ATCA (Narrabri)	–30° 18' 47"	149° 33' 52"	6 × 22 m
	Tidbinbilla	–35° 24' 18"	148° 58' 59"	70 m, 34 m
	Hobart (Mt. Pleasant)	–42° 48' 18"	147° 26' 21"	26 m, 12 m
	Ceduna	–31° 52' 05"	133° 48' 37"	30 m
	Yarragadee	–29° 02' 47"	115° 20' 48"	12 m
China	Miyun	40° 33' 29"	116° 58' 37"	50 m
	Sheshan	31° 05' 58"	121° 11' 59"	25 m, 13 m
	Nanshan	43° 28' 16"	87° 10' 40"	26 m, 13.2 m
	Tianma	31° 05' 13"	121° 08' 00"	65 m, 13 m
	CSRH	42° 12' 31"	115° 14' 45"	60 × 2 m
	QTT	43° 36' 04"	89° 40' 57"	110 m
France	Tahiti	−17° 31' 05"	−149° 26' 13"	12 m
Japan	Nobeyama	35° 56' 40"	138° 28' 21"	45 m
	VERA-Mizusawa	39° 08' 01"	141° 07' 57"	20 m, 10 m
	VERA-Iriki	31° 44' 52"	130° 26' 24"	20 m
	VERA-Ogasawara	27° 05' 31"	142° 13' 00"	20 m
	VERA-Ishigakijima	24° 24' 44"	124° 10' 16"	20 m

4 In this column X m means antenna of X meters diameter and Y × X m means Y antennas of X meter diameter.

Country	Name	N latitude	E longitude	Antenna size[4]
	Ishioka	36° 12' 33''	140° 13' 08''	13.2 m
	Kashima	35° 57' 21''	140° 39' 36''	34 m
	Usuda	36° 07' 57''	138° 21' 46''	64 m
	Ibaraki	36° 41' 51''	140° 41' 32''	32 × 2 m
	Gifu	35° 28' 03''	136° 44' 14''	11 m
	Yamaguchi	34° 12' 58''	131° 33' 26''	32 m
	Tsukuba-NICT	36° 03' 33''	140° 08' 05''	1.6 m
	Koganei-NICT	35° 42' 37''	139° 29' 17''	2.4 m, 11 m
Korea	KSWC (Jeju)	33° 25' 40''	126° 17' 45''	1.8 m
	SGOC (Sejong)	36° 31' 22''	127° 18' 12''	22 m
	K-SRBL	36° 23' 54''	127° 22' 31''	2.1 m
	KVN-Yonsei	37° 33' 55''	126° 56' 27''	21 m
	KVN-Ulsan	35° 32' 44''	129° 14' 59''	21 m
	KVN-Tamna	33° 17' 21''	126° 27' 34''	21 m
New Zealand	Warkworth	–36° 25' 59''	174° 39' 52''	30 m, 12 m

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