Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
	)	
Theia Holdings A, Inc.	)	SAT-LOA-20161115-00121
	)	
Application for Authority Launch and Operate a Non-Geostationary Satellite Orbit System in the Fixed-Satellite Service, Mobile-Satellite Service, and Earth Exploration Service	)))))	Call Sign: S2986

RESOLUTION OF PETITION TO DENY OR DEFER

On June 26, 2017, the GPS Innovation Alliance ("GPSIA") petitioned to deny the above-captioned application ("Application") of Theia Holdings A, Inc. ("Theia") to launch and operate a non-geostationary satellite orbit ("NGSO") system that proposed use of the 1215-1300 MHz frequency band for an Earth Exploration Satellite Service ("EESS") active radar (synthetic aperture radar ("SAR")).[1] In the alternative, GPSIA petitioned to defer action on the Application until Theia amended and removed the 1215-1300 MHz frequency band from its system.[2]

On June 1, 2018, Theia requested that the Application be amended to reflect permanent commitments made with respect to its proposed SAR emission in the 1215-1300 MHz band.[3] Specifically, Theia's letter amendment ("Amendment," attached as **Exhibit A**) requests that the

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[1] *See* Petition to Deny or Defer of the GPS Innovation Alliance, IBFS File No. SAT-LOA-20161115-00121 at 1 (filed June 26, 2017) ("*GPSIA Petition*").

[2] *See Id.* at 1.

[3] Letter from Joseph Fargnoli, Chief Technology Officer, Theia Group, Inc., to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-LOA-2016115-00121 (filed June 1, 2018).

Commission adopt certain enumerated measures ("SAR Conditions") to facilitate protection of Radio Navigation Satellite Service ("RNSS")."[4]

Theia's Amendment, if granted in its entirety, addresses the interference concerns raised in the *GPSIA Petition*. Accordingly, conditioned on the Federal Communications Commission's acceptance of Theia's request to amend its application, the concerns raised in the *GPSIA Petition* have been resolved.

Respectfully submitted,

/s/

Mark N. Lewellen
GPS INNOVATION ALLIANCE

Dated: June 1, 2018

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[4] *Id.*, at 2.

June 1, 2018

Via Electronic Filing (IBFS)

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: ***Ex Parte* Presentation**
Application of Theia Holdings A, Inc.
Call Sign S2986
File No. SAT-LOA-20161115-00121

Dear Ms. Dortch:

In connection with the above-referenced application of Theia Holdings A, Inc. ("Theia") for authority to launch and operate a satellite system (the "Theia Application"), Theia submits this letter amending its application and adopting certain measures, enumerated below (the "SAR Conditions"), to mitigate the risk of interference to Radionavigation-Satellite Service ("RNSS") receivers,[1] which might be caused by Theia's L-band (1215-1300 MHz) radar ("SAR") system, FCC Call Sign S2986 (the "SAR System").[2] Based on discussions with the GPS Innovation Alliance ("GPSIA"), Theia believes that the measures in this letter amendment fully address the concerns expressed by the GPSIA in its filings in this proceeding.[3]

The SAR Conditions reference the International Telecommunication Union ("ITU") Annex 8 to Working Party 7C Chairman's Report, PRELIMINARY DRAFT NEW RECOMMENDATION ITU-R RS.[EESS_SAR-RNSS] (hereafter, the "ITU Document"). Because the ITU Document is a draft and subject to change in the future, Theia is providing the current version of the ITU Document in Appendix A to memorialize the specific calculation methods which Theia shall employ to ascertain potential interference parameters relevant to the SAR Conditions.

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[1] RNSS operates pursuant to a primary allocation in the 1215-1300 MHz band. Operations pursuant to the secondary Active Earth Exploration-Satellite Service ("EESS") allocation in the 1215-1300 MHz band, including Theia's proposed SAR system, must ensure non-interference to higher priority RNSS services.

[2] Because the proposed measures in this letter are intended to resolve interference concerns raised in the application proceeding and do not create new or increased frequency conflicts, Theia submits that its proposals should not be treated as a "major amendment" to the application and similarly that its application should not be treated as newly filed. 47 C.F.R. § 25.116. Nonetheless, in an abundance of caution, Theia requests waiver of the FCC's rule in the public interest. *See WAIT Radio v. FCC*, 418 F.2d 1153, 1157 (D.C. Cir. 1969). Theia is submitting this request to address interference concerns, and grant of the waiver request and the Theia Application would facilitate the development of an innovative satellite system that will efficiently deliver next-generation remote sensing-based analytic and information products and services directly to consumers and commercial users, regardless of their location, via affordable terminals.

[3] *See* GPSIA, Petition to Deny or Defer (filed June 26, 2017); GPSIA, Reply to Opposition (July 14, 2017).

Specifically, under the SAR Conditions, Theia shall operate the SAR System as follows:

1. At all times the SAR System shall be operated in a manner, both with respect to an individual SAR and the constellation, including with respect to space-borne L-band radars operated by others, such that the Theia SAR System does not cause harmful interference to RNSS receivers. This operational requirement shall supersede any and all operating metrics of Theia's SAR, including those indicated below.

2. Theia shall operate the SAR System such that, when the calculation of the interference degradation relative to the interference-free noise level to a RNSS receiver is performed according to Equations 1-1 and 1-2 in the ITU Document with NLIM=1, the resulting degradation to a non-blanking RNSS receiver is less than 0.2 dB. An example of a combination of parameters that may be employed to achieve the 0.2 dB requirement is as follows:

    - Peak transmitter power = 37.3 dBW
    - Transmitter antenna gain = 34.9 dB
    - Pulse Width = 12.8 μsec
    - Pulse repetition frequency = 1490 Hz
    - Transmit duty cycle = 1.91 %

An example of the calculation cited using the above parameters is found in Appendix B for blanking and saturation mode receivers.

3. Theia's SAR transmit antenna shall have sufficiently low side-lobes such that the SAR beams from multiple SARs operating nearby each other do not act to create additive interference. An example of a combination of antenna beam parameters that could be employed to achieve this requirement is as follows:

    (a) the main radar beam -1 dB contour is 12.3 km +/- 10% in diameter on the surface of the Earth at nadir, and

    (b) the main radar beam -3 dB contour is 21.2 km +/- 10% in diameter on the surface of the Earth at nadir, and

    (c) at 2.6 degrees angle off of boresight, the antenna gain is less than -60 dB relative to the beam peak on boresight and is monotonically reduced further thereafter.

4. Theia shall not permit more than one of the Theia constellation SARs to illuminate the same region on the Earth's surface at any given time, defined such that the -3 dB contours of any two SAR transmit antenna beams shall (a) never overlap and (b) remain separated by at least 70 km on the Earth's surface at all times.

5. Theia shall proactively work with other space-borne L-band radar operators to avoid illuminating the same region on the Earth's surface in the L-band radar frequencies at any given time in a manner in which interference could become additive between the two L-band radars. In the event that another L-band SAR operator is non-cooperative, Theia shall avoid the entire field of regard of that operator's L-band SAR system, thereby ensuring there shall be no additive interference risk to RNSS receivers in the relevant area.

6. Theia shall employ center frequency diversity, as discussed below, to manage the bandwidth overlap between the SAR System and the GPS L2 signal, limiting the interference degradation to less than 0.2 dB, as calculated relative to the interference-free noise level to a RNSS receiver according to Equations 1-1 and 1-2 in the ITU Document and using the effective pulse-width method with partial overlap, as specified on p. 17 of the ITU Document, with NLIM=2. The interference degradation is a function of the bandwidth of the chirped pulse and the overlap with the L2 signal. The applicable ranges of center frequencies[4] for the Theia SAR for a 28 MHz SAR chirp and a 14 MHz SAR chirp are as follows:

    - 28 MHz SAR chirp: 1243.0 MHz – 1285.0 MHz.
    - 14 MHz SAR chirp: 1241.5 MHz – 1292.0 MHz.

    Thus, for the 28 MHz chirp mode, the bandwidth overlap with the GPS L2 signal would be at most 11.46 MHz (when the center frequency of the Theia SAR is at 1243.0 MHz), resulting in a less than 0.2 dB degradation for all receiver types. An example interference analysis appears in Appendix C.

Theia consents to the adoption of the above-enumerated SAR Conditions as conditions to the grant of the Theia Application.

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[4] The center frequency for a 28 MHz chirped pulse would mean that the chirp starts at the center frequency – 14 MHz and ends at the center frequency + 14 MHz.

Please direct any questions regarding this letter to the undersigned.

Respectfully submitted,

/s/ Joseph Fargnoli

Joseph Fargnoli
Chief Technology Officer
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Enclosures

cc: (via email)
Jose Albuquerque
Karl Kensinger
Stephen Duall

Appendix A

Radiocommunication Study Groups

Source: Document 7C/TEMP/63

Annex 8 to
Document 7C/147-E
13 April 2017
English only

Annex 8 to Working Party 7C Chairman's Report

PRELIMINARY DRAFT NEW RECOMMENDATION ITU-R RS.[EESS_SAR-RNSS]

{Editor's Note: This Annex replaces Annex 10 of 7C/91. The PDNR no longer is intended to be a replacement to Rec. ITU-R RS.1347 and no longer intends to provide a method to evaluate interference into receiving earth stations in the radionavigation-satellite service (space-to-Earth) from scatterometer radar sensors in the Earth exploration-satellite (active) service in the 1 215-1 300 MHz band. This PDNR is described in the Summary statement below.}

{Editor's Note: The bracketed yellow highlighted text is in regards to the use of the unity bandwidth factor in the methodology.}

Summary

This Recommendation presents a methodology for evaluating the interference from spaceborne synthetic aperture radars in the Earth exploration-satellite service (active) (EESS (active)) into receiving earth stations in the radionavigation-satellite service (RNSS) (space-to-Earth) operating in the 1 215-1 300 MHz band. In addition to the methodology for evaluating interference, Annex 1 contains technical characteristics for both EESS spaceborne active sensors and RNSS receiving earth stations. Annex 2 presents examples of the interference analysis methodology for typical spaceborne synthetic aperture radars (SARs) with representative RNSS receivers.

PRELIMINARY DRAFT NEW
RECOMMENDATION ITU-R RS.[EESS_SAR-RNSS]

Method to evaluate interference into receiving earth stations in the radionavigation-satellite service (space-to-Earth) from spaceborne synthetic aperture radar sensors in the Earth exploration-satellite (active) service in the 1 215-1 300 MHz band

(Question ITU-R 234/7)

Scope

This Recommendation presents a general methodology for performing a preliminary interference evaluation of Earth exploration-satellite service (active) (EESS (active)) spaceborne synthetic aperture radars (SARs) with the receiving earth stations in the radionavigation-satellite service (RNSS) (space-to-Earth) operating in the 1 215-1 300 MHz band. This Recommendation has not been evaluated for application to RNSS (space-to-space) receivers on board spacecraft. Along with the preliminary evaluation method, Annex 1 contains technical characteristics for typical EESS spaceborne SARs and RNSS receiving earth stations. Annex 2, presents examples of the interference analysis methodology for typical spaceborne SARs with representative RNSS receivers.

{Editor's note: Administrations are encouraged to make proposals for the following three sub-sections.}

Keywords

EESS, pulsed RF interference, RNSS, spaceborne active sensor, spaceborne synthetic aperture radar, scatterometer.

Abbreviations Glossary

GPS – (NAVSTAR) Global Positioning System

GLONASS – Global Navigation Satellite System

QZSS – Quasi-Zenith Satellite System

SAR – Synthetic Aperture Radar

SBAS – Satellite-Based Augmentation System

Related ITU Recommendations, Reports

Recommendation ITU-R RS.1347-0	Feasibility of sharing between radionavigation-satellite service receivers and the Earth exploration-satellite (active) and space research (active) services in the 1 215-1 260 MHz band
Recommendation ITU-R M.1318-1	Evaluation model for continuous interference from radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz and 5 010-5 030 MHz bands

Recommendation ITU-R M.1787-1	Description of systems and networks in the radionavigation-satellite service (space-to-Earth and space-to-space) and technical characteristics of transmitting space stations operating in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz
Recommendation ITU-R M.1901-1	Guidance on ITU-R Recommendations related to systems and networks in the radionavigation-satellite service operating in the frequency bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz, 5 000-5 010 MHz and 5 010-5 030 MHz
Recommendation ITU-R M.1902-0	Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) operating in the band 1 215-1 300 MHz
Recommendation ITU-R M.2030-0	Evaluation method for pulsed interference from relevant radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz frequency bands
Report ITU-R M.2220-0	Calculation method to determine aggregate interference parameters of pulsed RF systems operating in and near the frequency bands 1 164-1 215 MHz and 1 215-1 300 MHz that may impact radionavigation satellite service airborne and ground-based receivers operating in those bands

The ITU Radiocommunication Assembly,

considering

a) that sharing studies have shown compatibility between certain typical Earth exploration-satellite service (active) (EESS (active)) spaceborne sensors and certain radionavigation-satellite service (RNSS) receivers in the acquisition and tracking phases;

b) that an appropriate analytic method would facilitate evaluation of the potential for pulsed interference from an EESS (active) sensor to an RNSS system or network (space-to-Earth) operating in the frequency band 1 215-1 300 MHz,

recognizing

a) that the RNSS (space-to-Earth) and (space-to-space) is allocated on a primary basis in the 1 215-1 300 MHz frequency band;

b) that the EESS (active) is allocated on a primary basis in the 1 215-1 300 MHz frequency band subject to the limitations of certain Radio Regulations (RR) including Nos. **5.332** and **5.335A**;

c) that synthetic aperture radar (SAR) is one type of EESS (active) spaceborne sensor;

d) that several Recommendations, including ITU-R M.1901, ITU-R M.1902, and ITU-R M.1787, provide technical and operational characteristics and protection criteria for RNSS system and network operations;

e) that Recommendation ITU-R M.2030 and Report ITU-R M.2220 provide, respectively, a general method for analysing the potential for pulsed radio frequency interference to RNSS receivers and a means of characterizing the received pulsed emissions from potential interference sources,

noting

that for scatterometers in the EESS (active) service that would operate in the 1 215-1 300 MHz frequency range, the applicable methodology and example application thereof remains under study in the ITU-R,[1]

recommends

1 that the analytic method in Annex 1 to this Recommendation should be used for the preliminary evaluation of the potential for pulsed interference from an EESS (active) SAR sensor to an RNSS system or network (space-to-Earth) operating in the frequency band 1 215-1 300 MHz (see Note 1);

2 that if the application of the method in Annex 1 indicates exceedance of the protection criteria for receiving earth stations in RNSS (space-to-Earth) systems or networks, –then a more detailed analysis should be performed (see Note 1);

3 that cases where a more detailed analysis is needed (per *recommends* 2) should be addressed between administration(s) of the operators of the intended EESS (active) sensor and administrations of the affected RNSS systems and networks, taking into account operational parameters of the EESS (active) SAR sensor, detailed RNSS receiver characteristics, and any other relevant factors.

NOTE 1 – The evaluation of the potential for pulsed interference from an EESS (active) sensor in *recommends 1* and *2* does not apply without specific consideration of the cumulative impact of multiple spaceborne active sensors that simultaneously illuminate the RNSS receivers, wherever relevant. One means of mitigating the potential simultaneous illumination of the same point on the Earth’s surface from multiple spaceborne active sensors is through operational coordination of such sensors.

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[1] When the studies are complete, relevant material could be included in a revision to this Recommendation and/or in an ITU-R Report. In the meantime, the potential for harmful interference from scatterometers into RNSS systems or networks should be assessed on a case-by-case basis between operators using mutually-agreed parameters and criteria.

ANNEX 1

Technical characteristics of EESS (active) spaceborne synthetic aperture radar sensors and receiving earth stations in the RNSS and a general analytic method to evaluate the potential for pulsed radio frequency interference to receiving earth stations in the RNSS in the 1 215-1 300 MHz band

1 Introduction

The 1 215-1 300 MHz frequency band is allocated to the radionavigation-satellite service (RNSS) (space-to-Earth) and is used by many types of RNSS earth station receivers, some of which are described in section 3 of this Annex. The 1 215-1 300 MHz band is also allocated on a primary basis to the EESS (active) for spaceborne active microwave sensors subject to the limitations of Radio Regulations Nos. **5.332** and **5.335A**. The types of spaceborne active sensors requiring use of this band include synthetic aperture radars (SAR) and scatterometers.

This Annex presents characteristics of spaceborne active sensors (Section 2) and characteristics of RNSS earth station receiver systems (Section 3) found in Recommendation ITU-R M.1902 for use in evaluating interference from systems in the EESS (active) into systems in the RNSS. It also includes in Section 4 a general analytic evaluation method for pulsed radio frequency interference (RFI) from spaceborne active sensors to RNSS receivers along with pulsed RFI protection criteria for RNSS receivers.[2]

2 Technical characteristics of EESS spaceborne active sensors

The technical characteristics for six spaceborne active sensors which are designed to use the 1 215-1 300 MHz band are given in Table 1-1. The antenna gain pattern equations for standard SAR1 through SAR6 are given in Tables 1-2 through 1-6 respectively. The parameters of these systems offer a range of possible characteristics to use as representative for operational SARs. The characteristics chosen in this analysis are those which would result in the worst-case interference to a RNSS receiver considered. Per *recommends* 2, if exceedance of the protection criteria is found, subsequent more detailed analysis should also consider the in-orbit operational modes of the SAR active sensor to determine if the sensor is able to operate with the combination of parameters used in the preliminary analysis.

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[2] Note that the set of RNSS receivers whose characteristics are provided in Recommendation ITU-R M.1902 does not include every type of RNSS receiver that may be deployed in this band. Additional studies are required to determine the potential of interference from EESS (active) systems into other RNSS receiver types.

TABLE 1-1

Technical characteristics of spaceborne synthetic aperture radars in the 1 215-1 300 MHz band

Parameters	**Standard SAR1**	**Standard SAR2**	**Standard SAR3**	**Standard SAR4**	**Standard SAR5**	**Standard SAR6**
Type of Orbit	Sun-synchronous	Sun-synchronous	Sun-synchronous	Sun-synchronous	Sun-synchronous	Sun-synchronous
Altitude, km	400	568	757	628	628	628
Inclination, degrees	57	97.7	98	97.9	97.9	97.9
Eccentricity	circular	circular	circular	Circular	Circular	Circular
Ascending node	NSS	6:00	18:00	12:00	12:00	12:00
Transmit peak power (W)	3 200	1 200	3 200	3 950	6 120	6 120
Antenna type	Planar array 2.9 m × 12.0 m	Planar array 2.2 m × 12.0 m	Offset-feed parabolic 15 m diameter, linear array feed	Planar array 2.9 m × 6.0 m	Planar array 2.9 m × 9.9 m	Planar array 2.9 m × 9.9 m
Antenna peak transmit gain, dBi	36.4	33	35	34.7	36.6	36.6
e.i.r.p. (peak), dBW	71.5	63.8	68.4	70.7	74.5	74.5
Antenna elev. beamwidth, degrees[3]	4.9	6	20.9	4.3	4.6	4.6
Antenna azimuth beamwidth, degrees	1	1	0.89	2.1	1.3	1.3
RF centre frequency, MHz	1 257.5	1 257.5	1 215-1 300	1 257.5	1 236.5, 1 257.5, 1 278.5, selectable	1 236.5, 1 257.5, 1 278.5, selectable
Polarization	Dual linear H and V	Linear H	Dual/quad, linear H and V	H and V	H and V	H, V, Circular and 45 degrees linear
Pulse modulation	Linear FM	Linear FM	Linear FM	Linear FM	Linear FM	Linear FM
RF bandwidth, maximum, MHz4	40	15	78	84	14, 28	28

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[3] The values in Table 1-1 are the minimum requirement for the –3 dB beamwidth. See Table 1-5 and Table 1-6 for antenna pattern equations to be used in interference analysis.

[4] NOTE – The “Maximum RF bandwidth” value shown is the *occupied bandwidth* for SAR4, SAR5 and SAR6, while for SAR1, SAR2 and SAR3 it is the *resolution bandwidth*.

Parameters	**Standard SAR1**	**Standard SAR2**	**Standard SAR3**	**Standard SAR4**	**Standard SAR5**	**Standard SAR6**
RF pulse width, µsec	33.8	35	78	43-71	37-67	18-43
Pulse repetition frequency maximum, Hz	1 736	1 607	2 400	1 620-2 670	1 050-1 860	1 550-3 640
Transmit average power, W	187.8	67.5	598.4	454.3	428.4	428.4
e.i.r.p. average, dBW	59.1	51.3	61.2	61.3	62.9	62.9
Chirp rate, MHz/µs				1.18 to 1.95	14 MHz: 0.21 to 0.38 28 MHz: 0.42 to 0.76	0.65 to 1.56
Transmit duty cycle, %[5]	5.87	5.62	18.7	11.5	7	6.8
Azimuth scan rate, rpm	0	0	0	0	0	0
Antenna beam transmit look angle, degrees	20-55	35	30	7.2 to 59	7.2 to 59	7.2 to 59
Antenna beam transmit azimuth angle, degrees	0	0	0	±3.5	0	0
NOTE	Transmits beam orthogonal to flight path (az angle of 0 degrees) at selectable look angle 20 to 55 degrees	Transmits beam orthogonal to flight path (az angle of 0 degrees) at fixed look angle 35 degrees	Transmits wide beam in elevation, receives with multiple narrow beams in elevation during receive interval.	Transmits beam orthogonal to flight path (azimuth angle of ±3.5 degrees for spotlight SAR observation) at selectable look angle 7.2 to 59 degrees	Transmits beam orthogonal to flight path (azimuth angle of 0 degrees; ScanSAR) at selectable look angle 7.2 to 59 degrees	Transmits beam orthogonal to flight path (azimuth angle of 0 degrees; Strip map SAR) at selectable look angle 7.2 to 59 degrees

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[5] NOTE – For a given EESS transmitter, the transmit duty cycle value is fixed across the range of PRF values shown above. This is done by reducing the RF pulse-width as the PRF is increased.

All six spaceborne SARs in Table 1-1 transmit linear FM pulses with pulse widths and pulse repetition frequencies as shown in the table resulting in a range of pulse-to-pulse, or static, duty cycle values from 5% to 18.7%. They transmit on antenna beams orthogonal to the flight path (azimuth angle of 0 degrees) at either a selectable look angle for the pass or at a fixed look angle for the mission.

TABLE 1-2

Standard SAR1 antenna gain equations

Pattern	**Gain $G(\theta)$ (dBi) as a function of off-axis angle θ (degrees)**	**Angle range**
Vertical (elevation)	$G_v(\theta_v) = 36.4 - 0.478(\theta_v)^2$ $G_v(\theta_v) = 33.8 - 1.0\ \theta_v$ $G_v(\theta_v) = -11$	$0° < \lvert\theta_v\rvert < 3.6°$ $3.6° \leq \lvert\theta\rvert < 45°$ $\lvert\theta_v\rvert \geq 45°$
Horizontal (azimuth)	$G_h(\theta_h) = 0.0 - 19.6(\theta_h)^2$ $G_h(\theta_h) = -24.5 - 0.47\ \theta_h$ $G_h(\theta_h) = -30.5$	$0° < \lvert\theta_h\rvert < 1.13°$ $1.13° \leq \lvert\theta_h\rvert < 12.7°$ $\lvert\theta_h\rvert \geq 12.7°$
Beam pattern	$G(\theta) = \{G_v(\theta_v) + G_h(\theta_h), -11\}$ max	-

TABLE 1-3

Standard SAR2 antenna gain equations

Pattern	**Gain $G(\theta)$ (dBi) as a function of off-axis angle θ (degrees)**	**Angle range**
Vertical (elevation)	$G_v(\theta_v) = 33.0 - 0.320(\theta_v)^2$ $G_v(\theta_v) = 30.4 - 0.818\ \theta_v$ $G_v(\theta_v) = -11$	$0° < \lvert\theta_v\rvert < 4.4°$ $4.4° \leq \lvert\theta_v\rvert < 50.6°$ $\lvert\theta_v\rvert \geq 50.6°$
Horizontal (azimuth)	$G_h(\theta_h) = 0.0 - 19.6(\theta_h)^2$ $G_h(\theta_h) = -24.5 - 0.47\ \theta_h$ $G_h(\theta_h) = -30.5$	$0° < \lvert\theta_h\rvert < 1.13°$ $1.13° \leq \lvert\theta_h\rvert < 12.7°$ $\lvert\theta_h\rvert \geq 12.7°$
Beam pattern	$G(\theta) = \{G_v(\theta_v) + G_h(\theta_h), -11\}$ max	-

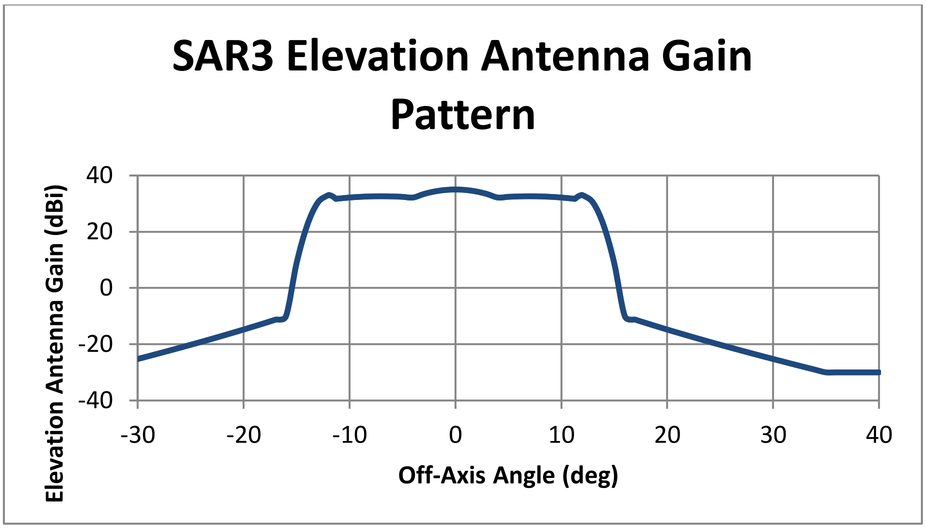
TABLE 1-4

Standard SAR3 antenna gain equations

Pattern	Gain $G(\theta)$ (dBi) as a function of off-axis angle θ (degrees)	Angle range
Vertical (elevation)	$G_v(\theta_v) = 35.0 - 0.18(\theta_v)^2$	$\lvert\theta_v\rvert < 4.0°$
	$G_v(\theta_v) = 32.6 - 0.05(\lvert\theta_v\rvert - 7)^2$	$4.0° \le \lvert\theta_v\rvert < 11.3°$
	$G_v(\theta_v) = 33.0 - 2.69(\lvert\theta_v\rvert - 12)^2$	$11.3° \le \lvert\theta_v\rvert < 16.0°$
	$G_v(\theta_v) = 15.0 - 20.8 \log(\lvert\theta_v\rvert) - 0.68(\lvert\theta_v\rvert - 16)$	$16.0° \le \lvert\theta_v\rvert < 35.0°$
	$G_v(\theta_v) = -30$	$\lvert\theta_v\rvert \ge 35°$
Horizontal (azimuth)	$G_h(\theta_h) = 0.0 - 15.0(\theta_h)^2$	$\lvert\theta_h\rvert < 1.1°$
	$G_h(\theta_h) = -18.0$	$1.1° \le \lvert\theta_h\rvert < 1.7°$
	$G_h(\theta_h) = -13.55 - 23 \log \lvert\theta_h\rvert$	$1.7° \le \lvert\theta_h\rvert < 10.0°$
	$G_h(\theta_h) = -36.5$	$\lvert\theta_h\rvert \ge 10.0°$
Beam pattern	$G(\theta) = \{G_v(\theta_v) + G_h(\theta_h)\}$	

FIGURE 1-1

a) Standard SAR3 antenna elevation transmit gain pattern model



b) Standard SAR3 antenna azimuth transmit gain pattern model

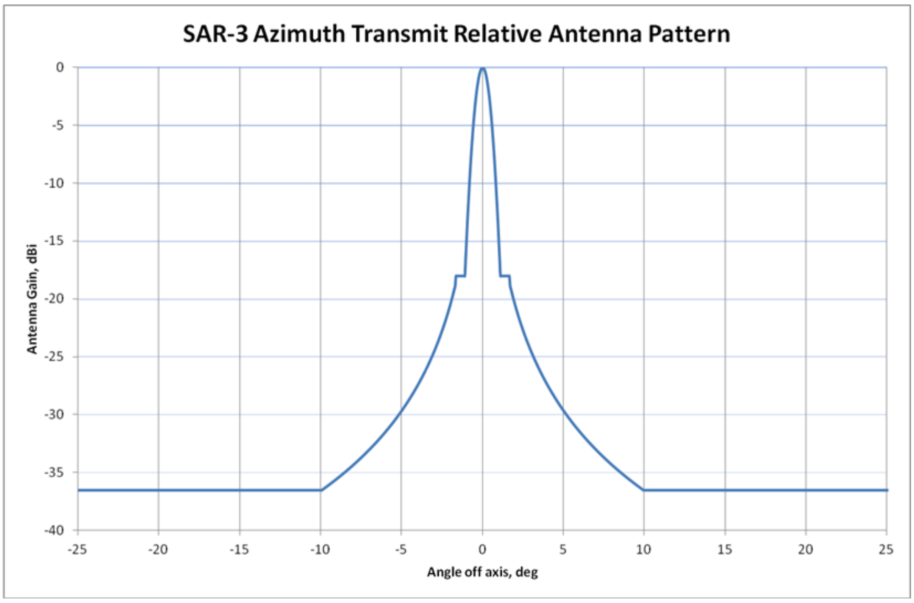


TABLE 1-5

Standard SAR4 antenna gain equations

Pattern	**Gain $G(\theta)$ (dBi) as a function of off-axis angle θ (degrees)**	**Angle range**
Vertical (elevation)	$G_v(\theta_v) = 0.0 - 0.38(\theta_v)^2$ $G_v(\theta_v) = 0.0 - 0.544\theta_v - 8.5$ $G_v(\theta_v) = -22.0$	$0° < \lvert\theta_v\rvert < 5.5°$ $5.5° \leq \lvert\theta_v\rvert < 24.75°$ $\lvert\theta_v\rvert \geq 24.75°$
Horizontal (azimuth)	$G_h(\theta_h) = 34.7 - 2.7(\theta_h)^2$ $G_h(\theta_h) = 34.7 - 0.95\,\theta_h - 10.65$ $G_h(\theta_h) = 34.7 - 23.0$ $G_h(\theta_h) = 34.7 - 23.0 - 35\log(\theta_h/38)$ $G_h(\theta_h) = 34.7 - 36.1$	$0° < \lvert\theta_h\rvert < 2.17°$ $2.17° \leq \lvert\theta_h\rvert < 13.0°$ $13.0° \leq \lvert\theta_h\rvert < 38.0°$ $38.0° \leq \lvert\theta_h\rvert < 90.0°$ $\lvert\theta_h\rvert \geq 90.0°$
Beam pattern	$G(\theta) = G_v(\theta_v) + G_h(\theta_h)$	–
Note	These equations cover the worst case envelope patterns with the maximum electric beam steering angle range in both elevation and azimuth directions. As the result, these equations contain some margins against actual antenna patterns. Therefore, the –3 dB beamwidth derived from these equations can be slightly different from the beamwidth (–3 dB) specified in Table 1-1.	

TABLE 1-6

Standard SAR5 and SAR6 antenna gain equations

Pattern	Gain $G(\theta)$ (dBi) as a function of off-axis angle θ (degrees)	Angle range
Vertical (elevation)	$G_v(\theta_v) = 0.0 - 0.30(\theta_v)^2$ $G_v(\theta_v) = 0.0 - 0.69\,\theta_v - 7.24$ $G_v(\theta_v) = -26.0$	$0° < \lvert\theta_v\rvert < 6.20°$ $6.20° \le \lvert\theta_v\rvert < 27.00°$ $\lvert\theta_v\rvert \ge 27.00°$
Horizontal (azimuth)	$G_h(\theta_h) = 36.6 - 7.0(\theta_h)^2$ $G_h(\theta_h) = 36.6 - 1.43\,\theta_h - 12.83$ $G_h(\theta_h) = 36.6 - 25.0$ $G_h(\theta_h) = 36.6 - 25.0 - 34\log(\theta_h/40)$ $G_h(\theta_h) = 36.6 - 36.98$	$0° < \lvert\theta_h\rvert < 1.46°$ $1.46° \le \lvert\theta_h\rvert < 8.47°$ $8.47° \le \lvert\theta_h\rvert < 40.0°$ $40.0° \le \lvert\theta_h\rvert < 90.0°$ $\lvert\theta_h\rvert \ge 90.0°$
Beam pattern	$G(\theta) = G_v(\theta_v) + G_h(\theta_h)$	-
Note	These equations cover the worst case envelope patterns with the maximum electric beam steering angle range in both elevation and azimuth directions. As the result, these equations contain some margins against actual antenna patterns. Therefore, the –3 dB beamwidth derived from these equations can be slightly different from the beamwidth (–3 dB) specified in Table 1-1.	

3 Characteristics of RNSS receiver systems

The following ITU-R documents provide the characteristics and description of the several systems to be used in assessing compatibility between RNSS earth station receiver systems and other services in the frequency band 1 215-1 300 MHz:

– Recommendation ITU-R M.1902 "Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) operating in the band 1 215-1 300 MHz";

– Recommendation ITU-R M.1787 "Description of systems and networks in the radionavigation-satellite service (space-to-Earth and space-to-space) and technical characteristics of transmitting space stations operating in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz".

In addition, the following Recommendation gives definitions for receiver and signal parameters used in the above set of RNSS characteristics Recommendations.

– Recommendation ITU-R M.1901 "Guidance on ITU-R Recommendations related to systems and networks in the radionavigation-satellite service operating in the frequency bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz, 5 000-5 010 MHz and 5 010-5 030 MHz."

The RNSS receivers may encounter both pulsed and continuous interference[6] during both signal acquisition and tracking phases. In the case of potential interference from the SAR spaceborne active sensors included in Table 1-1 above, the interference falls into the category of pulsed interference. Pulsed interference can affect an RNSS receiver in two ways: either by causing receiver saturation, or by causing receiver front-end burnout. The principle interference effect is that the pulsed interference causes saturation in the receiver. This occurs when a signal level is received that is strong enough to cause gain reduction or saturation at some point in the receiver. When this saturation occurs, the relatively low-level desired signal would be blocked during the transmission pulse period and any recovery time that is necessary for the RNSS receiver. However, if this period of lost signal is short enough, there should be no appreciable impact on the performance of the receiver.

The other possible interference effect occurs when either the peak or average RF power level is high enough to cause receiver front-end component damage. The relevant technical characteristics for the three RNSS systems are summarized in Table 1-7. The saturation power level (receiver input compression level) and the input survival power level are also given in Table 1-7.

A pulsed signal received power level that is below the input compression level of an RNSS receiver is assumed to have less detrimental effect on the performance of the receiver if the spaceborne active sensor transmitted pulse width is relatively short compared to the RNSS information bit length and the spaceborne active sensor transmitter duty cycle is low. This lessor detrimental impact is in comparison to pulsed signals with longer durations and/or higher duty cycle. See Section 4 for more details.

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[6] *Pulsed interference* results from RF transmitted signals that are modulated on/off at some *pulse repetition frequency* (usually identified in Hz). The duration of the “on” period is called the *pulse duration* (given in units of time, e.g. microsec). The product of the pulse duration and the pulse repetition frequency is the *pulse duty cycle* (a unit-less quantity). An interference signal is considered *pulsed RFI* if the pulse duration is much shorter than the integration time of a victim receiver. On the other hand, *continuous* RFI is used here to mean interference from sources of fairly constant power that is generally present at all times.

TABLE 1-7

Technical characteristics for RNSS receivers (space-to-Earth) operating in the band 1 215-1 300 MHz

Parameters (units)	**Indoor positioning**	**General purpose**	**Air navigation receiver (Note 1)**	**Indoor positioning**	**General purpose**	**SBAS ground reference receiver**	**High-precision semi-codeless receiver**	**High-precision receiver using L2C**	**Other**
Carrier frequencies (MHz)	1 227.6 ± 12		1 246 + 0.4375*K ± 5.11, where K= -7,…, +6 (Note 2)			1 227.6 ± 15.345			1 278.75 ± 21
Pre-correlator filter 3 dB bandwidth (MHz)	2		20			20.46			50
Receiver System Noise Temperature (K)	645		400	645	645	513			645
Polarization	RHC		RHC			RHC			RHC
Maximum antenna gain (dBi)	6	6	7 (Note 3)	6	6	–2 (Note 4)	3	3	6
Receiver input survival level (average) (dBW)	–20	–20	–1	–20	–20	–20	#	#	–20
Receiver input survival level (peak) (dBW)						–10 (Note 6)	#	#	#
Receiver input compression level (dBW)	–70	–70	–80	–70	–70	–135 (Note 5)	#	#	–70
Overload recovery time (s)	30×10^{-6}	30×10^{-6}	(1 to 30) $\times 10^{-6}$	30×10^{-6}	30×10^{-6}	1.0×10^{-6}	#	#	30×10^{-6}

NOTE 1 – Given values represent typical characteristics of receivers. Under certain conditions, more rigid values for some parameters could be required (e.g. recovery time after overload, threshold values of aggregate interference, etc.).

NOTE 2 – This receiver type operates on several RNSS signal carrier frequencies simultaneously. The carrier frequencies are defined by f_c (MHz) = 1 246.0 + 0.4375*K, where K = −7 to +6.

NOTE 3 – Minimum receiver antenna gain at 5 degrees elevation angle is –4.5 dBi.

NOTE 4 – The listed maximum upper hemisphere gain value applies for 30° elevation. The maximum upper-hemisphere gain value at 0° elevation (i.e. at the horizon) = –5 dBic and at zenith = +5 dBic.

NOTE 5 – The input compression level is for power in a 1-MHz bandwidth.

NOTE 6 – The survival level is the peak power level for a pulsed signal with a 10% maximum duty factor.

Pulse response parameters for these receiver types are subject to further study in conjunction with ITU-R work on a general pulsed RFI evaluation method.

4 Analytic evaluation method for pulsed RFI from spaceborne SARs to RNSS receivers

4.1 Assessment of potential for RNSS receiver damage or saturation

The first step in analysing the interference potential from a spaceborne SAR to a RNSS receiver is to determine if the peak signal power from the spaceborne active sensor is great enough to cause front-end component damage within the RNSS receiver. The maximum interfering signal power levels received from a spaceborne active sensor occur when an RNSS receiver is located in the main beam of the spaceborne active sensor antenna (no RNSS receiver filtering assumed). The peak interfering signal power levels from active sensors into an RNSS receiver may be calculated using a template shown in Table 1-8. The calculations assume co-frequency operation. The template is applied to each of the RNSS receiver types and the results are first compared with the particular receiver input survival levels listed in Table 1-7 to assure none exceed the limits.

TABLE 1-8

Maximum RNSS received RFI power calculation template

Parameters (units)	SAR1	SAR2	SAR3	SAR4	SAR5	SAR6
Centre frequency (MHz)[7]	1 257.5	1 257.5	1 215.0- 1 300.0	1 257.5	1 215.0- 1 300.0	1 215.0- 1 300.0
Peak transmitter power (dBW)	35.1	30.8	35.1	36.0	37.9	37.9
Transmitter antenna gain (dB)	36.4	33.0	33.4	34.7	36.6	36.6
Distance (km)	427.5	710.8	898.5	637.8	636.65	639.53
Free space loss (dB)	147.0	151.5	153.4	150.5	150.5	150.6
Receive antenna gain (dB)	–	–	–	–	–	–
*Polarization mismatch loss (dB)	1.46	1.46	1.46	1.46	1.46	0.0**
Max. received RFI power (peak) (dBW)	–	–	–	–	–	–
Receiver input compression point (dBW)	–	–	–	–	–	–
Receiver input survival level (dBW)						

* Polarization mismatch loss is defined in section 2.3.3 of Appendix **8 (Rev.WRC-03)** of the Radio Regulations.

** SAR6 capable of transmitting the circular polarization (RHCP or LHCP is selectable by command), so the worst case polarization loss for the RHCP receive antenna is assumed to be 0.0 dB.

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[7] Centre frequency of active sensor can vary within the given range. For calculation of free space loss, a centre frequency of 1 250 MHz is assumed. For sensor waveforms which overlap a particular RNSS receiver –3 dB RF bandwidth, the loss at the RNSS signal centre frequency should be used instead.

Then, if the results from the assessment template indicate the peak received pulsed power from the spaceborne active sensor is below the survival level but above a level of 15 dB below the RNSS receiver input compression point, the RNSS receiver degradation ratio should be computed as described in § 4.2.

4.2 Assessment of potential for RNSS receiver performance degradation

RNSS receivers operating in the 1 215-1 300 MHz band are subjected to continuous interference from a variety of sources, including RNSS space stations. In addition, they are subjected to in-band and adjacent band pulsed RF interference from radiolocation radars and ARNS transmitters as well as spaceborne EESS active sensors. The presence of continuous RFI from other sources reduces the amount of pulsed RFI that the RNSS receiver can tolerate. The presence of an existing baseline amount of pulsed RFI reduces the amount of additional pulsed RFI that the RNSS receiver can tolerate from a new source. The amount of pulsed RFI to be considered depends on the number of pulsed sources within the radio horizon of the RNSS receive antenna.

Studies initially performed by two aviation standards organizations[8] that were further refined within the ITU-R have resulted in an analysis method that addresses the combined effects of pulsed and continuous RFI on RNSS receivers. The method accounts for a range of RNSS receiver implementations from fairly sophisticated, pulse-blanking (for high duty cycle pulsed RFI) to simple hard-limiting receivers (suitable for lower duty cycle pulsed RFI).

4.2.1 RNSS receiver effective noise density general formula

The effects of both pulsed and continuous RFI for a saturating RNSS receiver can be quantified by defining an effective post-correlator noise power spectral density, $N_{0,EFF}$, which combines all the pulsed RFI effects on thermal noise density, wideband continuous RFI density, and RNSS signal loss. It is given by:

$$N_{0,EFF} = \frac{N_0\left[\left(1+\frac{I_{0,WB}}{N_0}+R_I\right)\left(1+\frac{{N_{LIM}}^2 PDC}{(1-PDC)}\right)\right]}{(1-PDC)} \tag{1-1}$$

where:

$$R_I = \left(\frac{1}{N_0 \times BW}\right)\sum_{i=1}^{N} P_i \times dc_i \tag{1-2}$$

In the above equations:

N_0: receive system thermal noise power spectral density in Watts/Hz (= kT_{SYS});

PDC: fractional duty cycle (unitless ratio) of all pulses exceeding the specific peak power threshold (blanking or saturation);

R_I: ratio (unitless) of average power density of below-threshold pulsed RFI to receiver thermal noise spectral density, N_0;

$I_{0,WB}$: total wideband equivalent continuous RFI power spectral density (Watts/Hz);

N_{LIM}: ratio (unitless) of receiver analogue-to-digital (A/D) saturation level to 1σ noise voltage established by automatic gain control (AGC);

BW: is the pre-correlator RF/IF bandwidth (Hz);

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[8] RTCA, headquartered in the United States, and EUROCAE in Europe.

P_i: the received peak power (Watts) of the *i*-th pulsed RFI source (referenced to antenna output) with peak level below the specific threshold;

dc_i: the *i*-th below-threshold pulse source duty cycle (unitless ratio); and

N: the number of pulsed emitters with signals below the specific peak power threshold (blanking or saturation).

All the noise and interference terms in equations (1-1) and (1-2) are referenced to the receive system passive antenna terminals. The parameter N_{LIM} is a non-negative receiver parameter that is determined by the A/D conversion implementation (Note that $N_{LIM} = 0$ for a pulse blanking receiver). For the simplest RNSS receiver with a "1-bit" quantizer (hard-limiting), N_{LIM} = unity.

The total pulsed RFI parameter, *PDC*, is built out of components from the separate heterogeneous pulsed tranmitter systems (or individual sources) "*a*", "*b*" and "*c*" as follows:

$$PDC = 1 - \left(1 - PDC_a\right)\left(1 - PDC_b\right)\left(1 - PDC_c\right) \tag{1-3}$$

where:

PDC_a: above- threshold pulse duty cycle for system "*a*" pulses (e.g. radiolocation);

$PDC_{b:}$ above- threshold pulse duty cycle for system "*b*" pulses (e.g. ARNS); and

PDC_c: above-r threshold pulse duty cycle for system "*c*" pulses (e.g. EESS).

The total pulsed RFI parameter, R_I , is built out of components from the separate heterogeneous pulsed tranmitter systems (or individual sources), for example, "*a*", "*b*" and "*c*" as follows:

$$R_I = R_a + R_b + R_c \tag{1-4}$$

where R_a, R_b, and R_c are the below-threshold average pulse power density ratios for systems "*a*", "*b*" and "*c*" respectively. These ratios are calculated without regard to the presence of any other pulses that overlap in time from the various individual pulsed RFI sources.

The pulsed RFI parameter, PDC_j, for strong (above-threshold) pulses from a given (j-th) source is:

$$PDC_j = \left(PW_{j,eff} + \tau_r\right)PRF_j \tag{1-5}$$

where $PW_{i,eff}$ and PRF_j are, respectively, the effective pulse width (in seconds) and pulse repetition frequency (Hz) for the j-th RFI source, and τ_r is the RNSS receiver overload recovery time (in seconds). Similarly, the duty cycle, dc_k, for weak (below-threshold) pulses from the k-th RFI source, used in computing the pulsed RFI parameter R_k, for that source is determined by:

$$dc_k = PW_{\mathrm{k,eff}} PRF_k \tag{1-6}$$

Intra-pulse frequency chirp is typically employed by the spaceborne active sensors considered in this Recommendation. In some cases the chirp may be wide enough that a portion of the full transmit pulse width falls outside the RNSS receiver passband and does not impact receiver performance. In equations (1-5) and (1-6) the effective pulse width, PW_{eff}, is related to the full RFI source transmit pulse width, PW, by $PW_{eff} = PW \cdot (\Delta f / Chirpwidth)$, where Δf is the portion of the full chirp width that falls within the receiver pre-correlation passband[9](see Table 1-7)[10].

{Editor's note: Further study is needed to address the appropriateness of the worst-case assumption for preliminary evaluation in footnote 10~~11~~ (currently applicable to GLONASS receivers in Table 1-9) and whether it should also apply to other RNSS receivers such as those listed in Rec. ITU-R M.1902.}

{One administration submitted additional text for Annex 2 Section 3.2 in relation to an example with the worst-case bandwidth assumption. To address concerns raised by others, WP 7C decided to move the text here to Annex 1 and shorten it to read as follows. [It should be noted that a bandwidth greater than the pre-correlator –3 dB filter bandwidth of RNSS receivers has to be taken into consideration. However, this value should not be greater than the RF –3 dB filter bandwidth which is contained in Recommendation ITU-R M.1902.]}

4.2.2 RNSS receiver performance degradation computation

Define the baseline environment to have pulsed RFI present (i.e.; baseline PDC and/or $R_I > 0$). If an additional pulse source group Y is introduced, the new composite RNSS pulsed RFI parameters, PDC_{base+Y} and R_{I+Y}, can be defined by extension of (1-3) and (1-4) as:

$$(1-PDC_{base+Y}) = (1-PDC_{base})(1-PDC_Y) \quad \text{and} \quad R_{I+Y} = R_I + R_Y$$

where PDC_{base} and R_I represent the baseline environment pulsed RFI parameters and PDC_Y and R_Y represent the additional source group pulsed RFI parameters. The degradation ratio is then defined by extension using Equation (1-1) as:

---

[9] When $PW_{EFF} = 0$ due to zero bandwidth overlap ($\Delta f = 0$), the associated PDC is identically 0.

[10] Report ITU-R M.2220 does not indicate the RNSS receiver bandwidth associated with the necessary attenuation level for the pre-correlator filter that should be used to calculate the overlap bandwidth factor ($\Delta f / Chirpwidth$). This level depends on the technical implementation of RNSS receivers. Because this information is lacking, a worst-case assumption is used for GLONASS air navigation receivers in Table 1-9. For those receivers lacking sufficient information, a unity overlap bandwidth factor value should be used in equations (1-5) and (1-6) for EESS SAR preliminary evaluations in Section 3.2 of Annex 2. [However, any increase of the estimation of interference from spaceborne active sensors resulting from the use of a unity overlap bandwidth factor should be taken into account by administrations when performing the more detailed analysis as specified in *recommends* 3.]

{Editor's note: The highlighted text above has not been agreed upon, but reflects progress by the concerned administrations toward a potential compromise on the use of the unity bandwidth factor in the methodology. Once there is agreement on this text, it will be used as the basis for replacing the square-bracketed areas in Annex 2.}

$$
N_{0,EFF+Y} \Big/ N_{0,EFF} = \frac{N_0\left(1+\frac{I_{0,WB}}{N_0}+R_{I+Y}\right)\left(1+\frac{N_{LIM}{}^2 PDC_{base+Y}}{\left(1-PDC_{base+Y}\right)}\right)\left(1-PDC_{base}\right)}{N_0\left(1+\frac{I_{0,BW}}{N_0}+R_I\right)\left(1+\frac{N_{LIM}{}^2 PDC_{base}}{\left(1-PDC_{base}\right)}\right)\left(1-PDC_{base+Y}\right)}
$$

$$
= \frac{1}{\left(1-PDC_Y\right)}\left[1+\frac{R_Y}{\left(1+\frac{I_{0,WB}}{N_0}+R_I\right)}\right]\left[1+\left(\frac{N_{LIM}{}^2 PDC_Y}{\left(1-PDC_Y\right)\left[1+PDC_{base}\left(N_{LIM}{}^2-1\right)\right]}\right)\right] \qquad (1\text{-}7)
$$

If in addition, the RNSS receiver is a hard-limiting style, $N_{LIM} = 1$ and $R_I = R_Y \cong 0$, then the degradation ratio in (1-7) simplifies to:

$$
N_{0,EFF+Y} \Big/ N_{0,EFF} = \frac{1}{\left(1-PDC_Y\right)^2} \qquad (1\text{-}7a)
$$

4.2.3 Allowable RNSS receiver degradation and associated model parameters

Table 1-9, taken from Recommendation ITU-R M.2030-0, Annex 1, Table 2, lists baseline model parameters and allowable degradation ratios[11] to be used for a preliminary evaluation of the potential for pulsed interference from an active spaceborne sensor (EESS or SRS) to an RNSS system or network operating in the 1 215-1 300 MHz band. RNSS receiver types in the table are taken from Recommendation ITU-R M.1902. The listed baseline model pulse RFI model parameters, *PDC* and R_I, and continuous parameter, $I_{0,WB}/N_0$, are to be used in the appropriate degradation ratio equation (either (1-7) or (1-7a) as determined by the N_{LIM} parameter). The equation result for the actual degradation ratio in dB ($10 \cdot \log_{10}(N_{0,EFF+Y}/N_{0,EFF})$) is compared to the allowable degradation ratio value in Table 1-9. If the allowable degradation ratio of an RNSS receiver in Table 1-9 is exceeded, then a more detailed analysis of the impact of the pulsed interference should be conducted to determine whether or not the pulsed interference is acceptable to the victim RNSS receiver.

Report ITU-R M.2220 provides a methodology for computing received pulsed RFI model parameters, *PDC* and R_I for both baseline and new pulsed sources and background on the continuous parameter, $I_{0,WB}/N_0$. Computation examples are given in Section 4 of that Report.

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[11] The allowable degradation ratio is the upper limit for the RFI effect of new planned pulsed sources not in the baseline RFI condition. It is determined from consideration of the overall RFI, including the baseline parameters, that the receiver can tolerate and still meet required performance.

TABLE 1-9

Baseline pulsed RFI model parameters and allowable degradation ratios for RNSS receivers (space-to-Earth) operating in the band 1 215-1 300 MHz *

Receiver type	**N_{LIM} (unitless) (Note 1)**	**Baseline PDC (unitless) (Note 2)**	**Baseline R_I (unitless) (Note 2)**	**Baseline $I_{0,WB}/N_0$ ratio (unitless)**	**Allowable degradation ratio for pulsed sources (dB) (Note 3)**
SBAS[12] ground reference receiver	1	0.0793 (Note 4)	0	0.3925	0.2
High-precision semi-codeless receiver	2	0.0765 (Note 4)	0	0.3983	0.2
Air navigation receiver (FDMA)	1	0.1327 (Note 4)	0	0.455	0.1
Air navigation receiver (FDMA)	1	0.1723 (Note 5)	0	0.455	0.1

* Parameter values for other RNSS receiver types are yet to be developed. The degradation ratio equations in section 4.2 of this annex can be used to predict the general nature of the pulsed interference effects on RNSS receiver types for which no parameters are listed.

NOTE 1 – A receiver with pulse blanking has an N_{LIM} value of zero.

NOTE 2 – The parameters for the baseline pulsed sources given in this table are considered to be the worst-case values. It is expected that, in most actual environments, there may be various types of pulsed interference sources with lower individual values for PDC and the therefore the aggregate baseline pulsed interference PDC would be less than given in the table. These actual conditions should be taken into account when performing the detailed analysis requested by *recommends* 2.

NOTE 3 – The allowable degradation ratio for new pulsed sources not in the baseline RFI condition requires consideration of the cumulative impact on an RNSS receiver from multiple pulsed sources that simultaneously illuminate the RNSS receiver.

NOTE 4 – Based on a 1 microsecond overload recovery time.

NOTE 5 – Based on a 30 microsecond overload recovery time.

5 Summary

Annex 1 presented characteristics of spaceborne active sensors and characteristics and pulsed RFI protection criteria for RNSS earth station receiver systems to be used in evaluating interference from systems in the EESS (active) into systems in the RNSS. Annex 1 also presented a general analytic evaluation method for pulsed RFI from spaceborne active sensors to RNSS receiver systems.

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[12] Satellite-based augmentation system (SBAS) ground reference receiver, a semi-codeless type receiver.

ANNEX 2

Analytic method application examples to evaluate the potential for spaceborne synthetic aperture radars pulsed radio frequency interference to RNSS Earth station receivers operating in the 1 215-1 300 MHz band

1 Introduction

The 1 215-1 300 MHz frequency band is allocated to the radionavigation-satellite service (RNSS) and is used by several systems including the Navstar Global Positioning System (GPS), the Global Navigation Satellite System (GLONASS-M), Galileo, QZSS, and COMPASS. The 1 215-1 300 MHz band is allocated on a primary basis to the EESS (active) for spaceborne active microwave sensors.

The types of active sensors requiring use of this band include the synthetic aperture radar (SAR) and scatterometers. This annex presents the worst-case interference evaluation analyses of some typical spaceborne SARs for three RNSS receivers and presents a performance degradation evaluation analysis example between a SAR and the GPS SBAS ground reference receiver and between a SAR and the GLONASS receiver.

2 RNSS received power damage and compression level example calculations

The levels for spaceborne active sensor maximum peak or average power at the receiver input of an RNSS receiver are likely to be well below the –20 to –1 dBW levels that would cause front end burnout. Thus, the emissions from a spaceborne active sensor will likely not cause burnout or damage to a RNSS receiver. The interfering signal level at the RNSS receiver input which will compress the receiver and cause a temporary loss of signal is –80 to –70 dBW in all cases except for the GPS SBAS ground reference receiver for which the level is –135 dBW. As an example, the worst-case received peak power configuration for three types of receivers is depicted as follows:

– CDMA (QZSS) indoor positioning receiver: Table 2-1;

– (GPS) SBAS ground reference receiver: Table 2-2;

– GLONASS air navigation receiver: Table 2-3.

TABLE 2-1

Maximum received peak RFI power for CDMA (QZSS) indoor positioning receivers

Parameters (units)	SAR1	SAR2	SAR3	SAR4	SAR5	SAR6
Centre frequency (MHz)[13]	1 257.5	1 257.5	1 215.0- 1 300.0	1 257.5	1 215.0- 1 300.0	1 215.0- 1 300.0
Peak transmitter power (dBW)	35.1	30.8	35.1	36.0	37.9	37.9
Transmitter antenna gain (dB)	36.4	33.0	33.4	34.7	36.6	36.6
Distance (km)	427.5	710.8	898.5	637.8	636.65	639.53
Free space loss (dB)	147.0	151.5	153.4	150.5	150.5	150.6
Receiver antenna gain (dB)	6.0	6.0	6.0	6.0	6.0	6.0

---

[13] Centre frequency of active sensor can vary within the given range. For calculation of free space loss, a centre frequency of 1 250 MHz is assumed.

Polarization mismatch loss (dB)**	1.46	1.46	1.46	1.46	1.46	0.0*
Maximum received interference \power (peak) (dBW)	–70.96	–83.16	–80.44	–75.29	–71.48	–70.05
Receiver input compression level (dBW)	–70	–70	–70	–70	–70	–70
Receiver input survival level (dBW)	–20	–20	–20	–20	–20	–20

* SAR6 capable of transmitting the circular polarization (RHCP or LHCP is selectable by command), so the worst-case polarization loss for the RHCP receive antenna is assumed to be 0.0 dB.

** Polarization mismatch loss is defined in Section 2.3.3 of Appendix **8 (Rev.WRC-03)** of the Radio Regulations.

Since all the cells in the Table 2-1 row of maximum received interference peak power values are below the receiver input survival level, these representative systems do not exceed the allowable interference criteria from a peak power standpoint with the QZSS indoor positioning receiver. However, since all but one of the maximum received peak power results are within 15 dB of the QZSS receiver input compression level, further interference evaluation analysis using the method of Annex 1 section 4.2 is warranted.

TABLE 2-2

Maximum received peak RFI power for (GPS) SBAS ground reference receivers

Parameters (units)	**SAR1**	**SAR2**	**SAR3**	**SAR4**	**SAR5**	**SAR6**
Centre frequency (MHz)[14]	1 257.5	1 257.5	1 215.0- 1 300.0	1 257.5	1 215.0- 1 300.0	1 215.0- 1 300.0
Peak transmitter power (dBW)	35.1	30.8	35.1	36.0	37.9	37.9
Transmitter antenna gain (dB)	36.4	33.0	33.4	34.7	36.6	36.6
Distance (km)	427.5	710.8	898.5	637.8	636.65	639.53
Free space loss (dB)	147.0	151.5	153.4	150.51	150.5	150.6
Receiver antenna gain (dB)	–2.0	–2.0	–2.0	–2.0	–2.0	–2.0
Polarization mismatch loss (dB)**	1.46	1.46	1.46	1.46	1.46	0.0*
Maximum received interference \power (peak) (dBW)	–78.96	–91.16	–88.36	–83.29	–79.48	–78.05
Receiver input compression level (dBW)	–135	–135	–135	–135	–135	–135
Receiver input survival level (dBW)	–10	–10	–10	–10	–10	–10

* SAR6 capable of transmitting the circular polarization (RHCP or LHCP is selectable by command), so the worst case polarization loss for the RHCP receive antenna is assumed to be 0.0 dB.

** Polarization mismatch loss is defined in section 2.3.3 of Appendix **8 (Rev.WRC-03)** of the Radio Regulations.

Since all the cells in the Table 2-2 row of maximum received interference peak power values are below the receiver input survival level, these representative systems do not exceed the allowable interference criteria from a peak power standpoint with the SBAS ground reference receiver.

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[14] Centre frequency of active sensor can vary within the given range. For calculation of free space loss, a centre frequency of 1 250 MHz is assumed.

However, since all of the maximum received peak power results are well above the receiver input compression level, further interference evaluation analysis using the method of Annex 1 section 4.2 is needed. Section 3 below contains an example calculation.

TABLE 2-3

Maximum received peak RFI power for (GLONASS) air navigation receivers

Parameters (units)	**SAR1**	**SAR2**	**SAR3**	**SAR4**	**SAR5*****	**SAR6*****
Centre frequency (MHz)	1 257.5	1 257.5	1 250	1 257.5	1 250	1 250
Peak transmitter power (dBW)	35.1	30.8	35.1	36.0	37.9	37.9
Transmitter antenna gain (dB)	36.4	33.0	33.4	34.7	36.6	36.6
Distance (km)	427.5	710.8	898.5	637.8	636.65	639.53
Free space loss (dB)	147.0	151.5	153.4	150.51	150.5	150.6
Receiver antenna gain (dB)	7.0	7.0	7.0	7.0	7.0	7.0
Polarization mismatch loss (dB)**	1.46	1.46	1.46	1.46	1.46	0.0*
Maximum received interference\power (peak) (dBW)	–69.96	–82.16	–79.36	–74.29	–70.48	–69.05
Receiver input compression level (dBW)	–80	–80	–80	–80	–80	–80
Receiver input survival level (dBW)	-1	-1	-1	-1	-1	-1

* : SAR6 capable of transmitting the circular polarization (RHCP or LHCP is selectable by command), so the worst-case polarization loss for the RHCP receive antenna is assumed to be 0.0 dB.

** : Polarization mismatch loss is defined in section 2.3.3 of Appendix **8 (Rev.WRC-03)** of the Radio Regulations**.**

*** : The peak power is worst-case analysis, because the size of antenna aperture for SAR 5 and 6 will be small in actual.

Since all the cells in the Table 2-3 row of maximum received interference peak power values are below the receiver input survival level, these representative systems do not exceed the allowable interference criteria from a peak power standpoint with the GLONASS receiver. However, since almost all of the maximum received peak power results are above the receiver input compression level, further interference evaluation analysis using the method of Annex 1 section 4.2 is needed. Section 3 below contains an example calculation.

3 RNSS receiver performance degradation calculation examples using the analytic evaluation method

3.1 SBAS ground reference receiver pulsed RFI evaluation case

One pulsed RFI analysis case chosen to illustrate the use of the analytic evaluation method is of an SBAS ground reference receiver illuminated by a single EESS SAR5 active sensor. The SBAS receiver is also assumed to be near a ground-based surveillance radar that produces a baseline pulsed RFI condition below the receiver's tolerance limit. Normally a dynamic link analysis would be done to find the actual time profile of peak received SAR5 power. The dynamic analysis would involve orbital simulation together with the satellite radiated power pattern and the RNSS receiver receive antenna pattern.

For this simpler example, however it is assumed that for a certain nominal time period (at least a few minutes), the received SAR 5 peak power is sufficiently above the SBAS ground reference receiver input compression level so that the SBAS receiver is saturated during the pulse duration. With that worst-case assumption, the analytic method in Annex 1 Section 4.2 can be applied to find the SBAS receiver pulsed RFI degradation.

3.1.1 Computation of the received effective pulsed RFI duty cycle parameter, PDC_{LIM}

The received peak SAR5 received power effective pulsed RFI duty cycle ($\mathrm{PDC}_{\mathrm{LIM}}$) is computed for the various SAR 5 modes using the Annex 1 section 2 equation (2-1):

$$PDC_{LIM,5} = \left(PW_{\mathrm{SAR5,eff}} + \tau_{\mathrm{r}}\right) PRF_{SAR5} \, ;$$

where:

$$PW_{SAR5,eff} = PW_{SAR5} \cdot \left(\frac{\Delta f}{Chirpwidth} \right)$$

From Annex 1, Table 1-1, it is noted that the; transmit pulse width (PW_{SAR5}) and pulse repetition frequency (PRF_{SAR5}) vary over a stated range such that the transmit duty cycle is a constant (7%). The chirp width has 2 values (14 and 28 MHz) and the chirp centre frequency has 3 values (1 236.5, 1 257.5, and 1 278.5 MHz). For this example, the effective received pulsed RFI duty cycle is computed for each centre frequency and chirp width (showing the SBAS receiver filtering effect) and two combinations of transmit pulse width and PRF. The assumed SBAS receiver recovery time (τ_R) for this example is 1.0 µsec and the SBAS receiver pre-correlator filter bandwidth is 20.5 MHz (rectangular) [15] centred at 1 227.6 MHz. Tables 2-4 and 2-5 show the results for the 14 MHz and 28 MHz chirp width cases, respectively.

TABLE 2-4

SBAS ground reference receiver effective received pulse width and PDC for 14 MHz chirp width

Centre Freq. (MHz)	Tx PRF (Hz)	Tx PW (µsec)	BW Overlap Ratio	Eff. PW (µsec)	PDC (%)
1 236.5	1 050	66.67	0.5964	39.760	4.280
	1 860	37.63	0.5964	22.445	4.361
1 257.5	1 050	66.67	0	0	0
	1 860	37.63	0	0	0
1 278.5	1 050	66.67	0	0	0
	1 860	37.63	0	0	0

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[15] This bandwidth value is the estimated rectangular equivalent determined from the receiver design. It is slightly larger than the pre-correlator 3 dB bandwidth in Annex 1, Table 1-7.

TABLE 2-5

SBAS ground reference receiver effective received pulse width and PDC for 28 MHz chirp width

Centre Freq. (MHz)	Tx PRF (Hz)	Tx PW (µsec)	BW Overlap Ratio	Eff. PW (µsec)	PDC (%)
1 236.5	1 050	66.67	0.5482	36.548	3.942
	1 860	37.63	0.5482	20.632	4.023
1 257.5	1 050	66.67	0	0	0
	1 860	37.63	0	0	0
1 278.5	1 050	66.67	0	0	0
	1 860	37.63	0	0	0

3.1.2 SBAS ground reference receiver pulsed RFI degradation computation

The pulsed RFI degradation ratio for the SBAS receiver is computed from the PDC values in Tables 2-4 and 2-5 by using equation (1-7a)[16] from Annex 1 section 4.2.2. The computation result is to be compared with an allowable degradation ratio limit (in dB) from Annex 1, Table 1-9. Using equation (1-7a) in logarithmic form for the largest PDC value (0.04361) for 14 MHz chirp centred at 1 236.5 MHz from Table 2-4, the degradation ratio in dB is 10 log ($N_{0,EFF+Y}/N_{0,EFF}$) = -20log(1-PDC) = **0.387 dB**. Similarly, the smallest PDC (0.03942) for 28 MHz chirp produces a **0.349 dB** degradation ratio. Since both these results exceed the allowable degradation ratio limit of 0.2 dB, the preliminary evaluation shows SAR5 defined waveforms with 14 or 28 MHz chirp width at the 1 236.5 MHz centre frequency exceed the allowable interference criteria for the SBAS ground reference receiver. Therefore a more detailed analysis should be performed. However, the preliminary analysis shows SAR5 defined waveforms at the higher two centre frequencies do not interfere since they do not overlap the SBAS receiver passband.

3.2 GLONASS receiver pulsed RFI evaluation cases

In this example a single EESS SAR5 active sensor illuminates one GLONASS receiver. Normally a dynamic link analysis would be done to find the actual time profile of peak received SAR5 power. The dynamic analysis would involve orbital simulation together with the satellite radiated power pattern and the RNSS receiver receive antenna pattern. For this simpler example, however it is assumed that for a certain nominal time period (at least a few minutes), the received SAR 5 peak power is sufficiently above the GLONASS receiver input compression level so that the GLONASS receiver is saturated during the pulse duration. With that basis, the analytic method in Annex 1 section 4.2 can be applied to find the GLONASS receiver pulsed RFI degradation.

3.2.1 Computation of the received effective pulsed RFI duty cycle parameter, PDC_{LIM}

As it was said in Annex 1 section 4.2.2, the estimation results depend on the pre-correlator filter bandwidth of RNSS receiver. [Report ITU-R M.2220 does not indicate the RNSS receiver bandwidth associated with the necessary attenuation level for the pre-correlator filter that should be used to calculate the overlap bandwidth factor (*Δf/Chirpwidth*). This level depends on technical implementation of RNSS receivers. Because this information is lacking, a worst-case assumption may be used for GLONASS air navigation receivers in Table 1-~~10~~ 9. However, since the

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[16] Equation (1-7a) is used since the SBAS ground reference receiver N_{LIM} value = 1 (Table 1-9).

methodology used in this analysis is using worst-~~-~~case parameters, the additional overestimation of the interference from spaceborne active sensors due to the use of unity overlap bandwidth factor~~,~~ should be noted when evaluating the results of the analysis. ~~Currently it is not clear at what level the pre-correlator filter bandwidth of RNSS receiver shall be estimated in case of pulsed interference impact. In addition there is no certainty that such approach is applicable for all RNSS receiver types.~~]*{Editor's Note: The highlighted text above is not agreed. Once there is agreement on the unity-bandwidth factor text in Note 10 of Annex 1, the agreed text will be used as the basis for replacing or revising the highlighted text above.}* Taking into account these circumstances, the following formula is used to define the worst-case pulse duty cycle for GLONASS system with respect to the pulsed interference from SAR signals:

*PDC = (SAR pulse width + RNSS recovery time) * SAR pulse repetition frequency.*

Values of the SAR5 pulse width and SAR5 pulse repetition frequency are presented in Annex 1, Table 1-1. There are GLONASS receivers with 1µs as well as 30µs of overload recovery time operating at the moment. Thus, both of these cases are presented in this example. The results of computation of the received PDC for the GLONASS receiver are presented in Table 2-6.

TABLE 2-6

GLONASS receiver PDC calculation results

Overload recovery time. (µsec)	Tx PRF (Hz)	Tx PW (µsec)	PDC (%)
1	1 050	67	7.14
	1 860	37	7.07
30	1 050	67	10.18
	1 860	37	12.46

3.2.2 GLONASS receiver pulsed RFI degradation computation

The pulsed RFI degradation ratio for the GLONASS receiver is computed from the PDC values in Table 2-6 by using equation (1-7a)[17] from Annex 1 section 4.2.2. The computation result is to be compared with an allowable degradation ratio limit (in dB) from Annex 1, Table 1-10. Using equation (1-7a) in logarithmic form for the largest PDC value (0.1246) for the case of 30µs overload recovery time from Table 2-6, the degradation ratio in dB is 10 log ($N_{0,EFF+Y}/N_{0,EFF}$) = –20log(1-PDC) = 1.16 dB. Additionally, for the largest PDC value (0.07144) for the case of 1µs overload recovery time, the degradation ratio is 0.64 dB. [Since both of these results exceed the limit of 0.1 dB, the worst-case preliminary evaluation additionally including the use of the unity overlap bandwidth factor shows that SAR5 ~~are~~ exceeds the allowable interference criteria~~not compatible with~~ for the GLONASS receiver.] *{Editor's Note: The highlighted text above is not agreed. Once there is agreement on the unity-bandwidth factor text in Note 10 of Annex 1, the agreed text will be used as the basis for revising the highlighted text above.}* Therefore, a more detailed analysis should be performed.

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[17] Equation (1-7a) is used since the Air navigation receiver N_{LIM} value = 1 (see Table 1-9).

3.2.3 Results of PDC and receiver pulsed RFI degradation computation for GLONASS receiver from all types of active sensors

The calculation results of PDC and pulsed RFI degradation of the GLONASS receiver affected by the six example SAR EESS active sensors are presented in Tables 2-7 and 2-8. These results were obtained by the methodology described in Annex 1 section 4.2. [However, when evaluating these results it should be considered that Report ITU-R M.2220 does not indicate the RNSS receiver bandwidth associated with the necessary attenuation level for the pre-correlator filter that should be used to calculate the overlap bandwidth factor (*Δf/Chirpwidth*), where this factor is constrained to be no greater than 1. This level depends on technical implementation of RNSS receivers. Because this information is lacking, a worst-case assumption was used for GLONASS air navigation receivers in Table 1-9. Since the methodology used in this analysis is using worst-case parameters the use of a unity overlap bandwidth factor, which additionally overestimates the impact of the interference from spaceborne active sensors~~,~~ should be taken into account when evaluating the results of the analysis.] *{Editor's Note: The highlighted text above is not agreed. Once there is agreement on the unity-bandwidth factor text in Note 10 of Annex 1, the agreed text will be used as the basis for replacing or revising the highlighted text above.}*

TABLE 2-7

PDC parameters of certain EESS active sensors and the result of SNR degradation for GLONASS receivers

Receiver type	**Overload recovery time, µsec**	**Active Sensor**	**Standard SAR1**		**Standard SAR2**		**Standard SAR3**	
		Freq. MHz	**1 257.5**		**1 257.5**		**1 257.5**	
Air navigation	1	PDC	0,06	-	0.06	-	0,19	-
		SNR (dB)	-0,54	-	-0,52	-	-1,83	-
	30	PDC	0,11	-	0,10	-	0,26	-
		SNR (dB)	-1,02	-	-0,96	-	-2,61	-
Indoor positioning	30	PDC	0,11	-	0,10	-	0,26	-
		SNR (dB)	-1,02	-	-0,96	-	-2,61	-
General Purpose	30	PDC	0,11	-	0,10	-	0,26	-
		SNR (dB)	-1,02	-	-0,96	-	-2,61	-

TABLE 2-8

PDC parameters of certain EESS active sensors and the result of SNR degradation for GLONASS receivers

Receiver type	**Overload recovery time, µsec**	**Active Sensor**	**Standard SAR4**		**Standard SAR5_PW_min**			**Standard SAR5_PW_MAX**			**Standard SAR6_PW_min**			**Standard SAR6_PW_MAX**		
		Freq. MHz	**centre freq. 1 257.5 MHz**		**centre freq. MHz**			**centre freq. MHz**			**centre freq. MHz**			**centre freq. MHz**		
					1 236.5	**1 257.5**	**1 278.5**	**1 236.5**	**1 258**	**1 278.5**	**1236,5**	**1257,5**	**1278,5**	**1236,5**	**1257,5**	**1278,5**
Air navigation	1	PDC	0.12	0.12	0.07	0.07	–	0.07	0.07	–	0,07	0,07	-	0,07	0,07	-
		SNR (dB)	–1.08	–1.08	–0.64	–0.64	–	–0.64	–0.64	–	-0,62	-0,62	-	-0,61	-0,61	-
	30	PDC	0.19	0.16	0.12	0.12	–	0.10	0.10	–	0,17	0,17	-	0,11	0,11	-
		SNR (dB)	–1.88	–1.55	–1.16	–1.16	–	–0.93	–0.93	–	-1,67	-1,67	-	-1,04	-1,04	-
Indoor positioning	30	PDC	0.19	0.16	0.12	0.12	–	0.10	0.10	–	0,17	0,17	-	0,11	0,11	-
		SNR (dB)	–1.88	–1.55	–1.16	–1.16	–	–0.93	–0.93	–	-1,67	-1,67	-	-1,04	-1,04	-
General Purpose	30	PDC	0.19	0.16	0.12	0.12	–	0.10	0.10	–	0,17	0,17	-	0,11	0,11	-
		SNR (dB)	–1.88	–1.55	–1.16	–1.16	–	–0.93	–0.93	–	-1,67	-1,67	-	-1,04	-1,04	-

4 Summary

Annex 2 presented example applications of the worst-case received power portion of the interference evaluation analysis methodology (Annex 1, Sec. 4.1) between six SAR systems in the EESS (active) and three receivers in the RNSS. It also presented example applications of the pulsed RFI performance degradation evaluation method (Annex 1 Sec. 4.2) to the pulsed RFI effects from several spaceborne active sensors on two RNSS receiver systems.

Appendix B

This appendix uses the equations specified in Appendix A to compute the degradation to both pulse blanking and saturation mode receivers. In both cases N_{LIM}=1 and the same set of parameters are used. Note that it is assumed herein that the pulsed interference is completely inside the victim receiver so densities rather than bandwidths are used.

	Blanking and Saturation Receivers
SAR PW, sec	1.28E-05
RNSS Recovery Time, sec	1.00E-06
PRF	1490
Intrapulse period, sec	0.000671141

Boltzmann's Constant, k	1.38E-23
RNSS NF, dB	2
RNSS Ant Temp, K	290
RNSS Rx Temp, K	169.6190258
RNSS Sys Temp, K	459.6190258
RNSS N_0, W/Hz	6.34E-21

N_0, W/Hz	6.34E-21
$I_{0,WB}$, W/Hz	0
R_I	0
N_{LIM}, Saturating RCVR	1
N_{LIM}, Pulse Blanking RCVR	0
PDC_{LIM}	0.020510193
$N_{0,EFF}$, W/Hz, Sat RCVR	6.61115E-21
$N_{0,EFF}$, W/Hz, Blanking RCVR	6.47556E-21

Degradation, dB, Sat RCVR	**0.180**
Degradation, dB, Blanking RCVR	**0.09**

The data shows that the degradation factors for the saturation mode receivers is less than the ITU threshold of 0.2 dB while the pulse blanking receivers is below the limit of 0.1 dB. Note that the models for pulse blanking receivers are insensitive to N_{LIM} as this is defined as 0, and as such, it is insensitive to whether the pulse overlaps the victim's bandwidth or not. It is assumed, however, that the pulse levels for both receiver types are above threshold based on the main-beam interference scenario.

Appendix C

This appendix is focused upon the high precision semi-codeless class of receivers. For this class, the value of N_{LIM} has been set to 2 and the interfering pulsed emitter (Theia SAR) partially overlaps the victim's RF bandwidth. Since the pulsed emitter only partially overlaps the victim's RF bandwidth, the actual pulse width of the emitter has been converted to the effective pulse width based on the portion that overlaps the RF bandwidth according to the model in the referenced ITU document as:

$$PWeff = PW \cdot (\Delta f \,/\, Chirpwidth)$$

Where Δf is the overlapped bandwidth

	High Precision Semi-Codeless Receivers
SAR PW, sec	1.28E-05
RNSS Recovery Time, sec	1.00E-06
PRF	1490
Intrapulse period, sec	0.000671141

Boltzmann's Constant, k	1.38E-23
RNSS NF, dB	2
RNSS Ant Temp, K	290
RNSS Rx Temp, K	169.6190258
RNSS Sys Temp, K	459.6190258
RNSS N_0, W/Hz	6.34274E-21

N_0, W/Hz	6.34E-21
$I_{0,WB}$, W/Hz	0
R_I	0
N_{LIM}, Saturating RCVR	2

Receiver Bandwidth, MHz	20.48
Chirp Bandwidth, MHz	28
Overlap factor, Δf , MHz	11.4
Effective Pulse Width, PW_{eff} , sec	5.19727E-06
PDC_{LIM}	0.009233936
$N_{0,EFF}$, W/Hz, Sat RCVR	6.64052E-21

Degradation, dB, Semi-codeless RCVR	0.199

It can be seen that when the overlap is set to 11.4 MHz, the effective pulse width drops from about 12.8 microseconds to about 5.2, resulting in a degradation less than the ITU threshold of 0.2 dB. In practice, this degradation will drop further as the overlap decreases.