| **US Radiocommunication Sector** **FACT SHEET** |
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| **Study Group:** USWP 7C | **Document No:** US 7C/27-025NC |
| **Reference:** 7C/41, Annex 4; 7C/529, Annex 1 | **Date:** 12 August 2024 |
| Document Title: Revision to working document toward a preliminary draft new Report ITU-R RS.[AGG\_EESS\_SAR-RNSS], Examples of evaluating and resolving interference into receiving earth stations in the radionavigation-satellite service (space-to-Earth) from multiple spaceborne synthetic aperture radar sensors in the Earth exploration-satellite (active) service in the 1 215-1 300 MHz band |
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| **Purpose/Objective**: The purpose of this document is to revise, as appropriate, the WD toward a preliminary draft new Report on EESS\_SAR-RNSS (Annex 1 to Document 7C/529). |
| **Abstract**: This contribution addresses the WD toward a PDN Report on aggregate EESS\_SAR interference to RNSS receivers. It is necessary to align the text with PDRR M.2305 in WP 4C or make other changes. |
| **Fact Sheet Preparer:** Steve Baruch/GPSIA |

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| **\_\_ September 2024** |
| **English only** |
| United States of America |
| Revisions to Working Document Toward a PRELIMINARY DRAFT NEW Report ITU‑R RS.[AGG\_EESS\_SAR-RNSS] |
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In this contribution, the United States proposes revisions to the working document toward a preliminary draft new Report in Annex 1 to Doc. 7C/529 from the 2019-2023 ITU-R study cycle (carried forward in Annex 4 to Doc. 7C/41) on the subject of aggregate interference from EESS synthetic aperture radar (SAR) instruments to RNSS receivers in the 1 215-1 300 MHz band. As Annex 2 of this report would be fully aligned with the revisions to Report ITU-R M.2305 that is now a PDR Report within WP 4C if the revisions proposed here are accepted, the United States proposes elevation of the status of this report to Preliminary Draft New Report.

**Attachments:** 1

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| ATTACHMENT |
| PRELIMINARY DRAFT NEW REPORT ITU‑R RS.[AgG\_EESS\_SAR-RNSS] |
| Examples of evaluating and resolving interference into receiving earthstations in the radionavigation-satellite service (space-to-Earth) frommultiple spaceborne synthetic aperture radar sensors in the Earthexploration-satellite (active) service in the 1 215-1 300 MHz band |

(Question ITU-R 234/7)

Scope

This Report presents an example of evaluation of the aggregate interference from multiple representative spaceborne synthetic aperture radar (SAR) sensors in the Earth exploration-satellite service (active) (EESS (active)) into representative radionavigation-satellite service (RNSS) receivers in the 1 215-1 300 MHz band, along with study results on resolving potential or actual cases of aggregate interference from EESS (active) SAR sensors at levels that exceed the relevant RNSS degradation allowances. When the studies on EESS (active) scatterometer sensors operating in the 1 215‑1 300 MHz band are complete, relevant material could be included in a revision to this ITU-R Report.

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](http://www.itu.int/rec/R-REC-RS.1347/en) | 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 RS.2165-0 | Evaluation of the potential for pulsed interference from new spaceborne synthetic aperture radar sensors in the Earth exploration-satellite (active) service to radionavigation-satellite service receivers in the 1 215-1 300 MHz band |
| Report ITU-R RS.2537-0 | Evaluation of the potential for pulsed interference from new spaceborne synthetic aperture radar sensors in the Earth exploration-satellite (active) service to radionavigation-satellite service receivers in the 1 215-1 300 MHz band |
| Recommendation [ITU-R M.1318](http://www.itu.int/rec/R-REC-M.1318/en)-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](https://www.itu.int/rec/R-REC-M.1787)-4  | 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](http://www.itu.int/rec/R-REC-M.1901/en)-3 | 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](http://www.itu.int/rec/R-REC-M.1902/en)-2 | 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](http://www.itu.int/rec/R-REC-M.2030/en)-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 |
| Recommendation [ITU-R RS.2105](http://www.itu.int/rec/R-REC-RS.2105/en)-2 | Typical technical and operational characteristics of Earth exploration-satellite service (active) systems using allocations between 432 MHz and 238 GHz |
| Report [ITU-R M.2220](http://www.itu.int/pub/R-REP-M.2220)-1 | 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  |
| Report [ITU-R M.2305](https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2305-2014-PDF-E.pdf)[-1] | Consideration of aggregate radio frequency interference event potentials from multiple Earth exploration-satellite service systems on radionavigation-satellite service receivers operating in the 1 215-1 300 MHz frequency 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 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.

Each EESS (active) SAR sensor is assessed on an individual basis for potential interference into RNSS receivers using the approach described in Recommendation ITU-R M.2030, and in Recommendation ITU-R RS.2165 and the companion report (Report ITU-R RS.2537). This means that any individual EESS (active) SAR sensors contributing to aggregate interference to RNSS receivers would have applied the methodology in Recommendation ITU-R RS.2165. This Report contains material that may be useful for evaluation of aggregate pulsed interference from planned and future EESS (active) SAR sensors to RNSS receivers in the 1 215‑1 300 MHz band.

Annex 1 contains representative technical characteristics for EESS spaceborne active SAR sensors and characteristics (including protection criteria) of RNSS receiving earth stations based on Recommendation ITU-R M.1902. Individual EESS (active) SAR sensors contributing to aggregate interference to RNSS receivers would have applied the methodology in Recommendation ITU-R RS.2165 before being brought into use.[[1]](#footnote-1) Annex 2 presents examples of evaluating the aggregate pulsed radio frequency interference from several spaceborne synthetic aperture radars (SARs) provided in Annex 1 with representative RNSS receivers.

Annex 1

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

# 1 Introduction

This Annex presents characteristics of representative spaceborne SARs (section 2) and characteristics of some RNSS earth station receiver types (section 3) based on Recommendation ITU-R M.1902-2. It also includes in section 4 the methodology of Recommendation ITU-R M.2030 for evaluating pulsed radio frequency interference (RFI) from spaceborne SARs to RNSS receivers along with pulsed RFI protection criteria for RNSS receivers.[[2]](#footnote-2)

In addition, it must be noted that the evaluation of the potential for pulsed interference from an EESS (active) sensor to an RNSS receiver should also consider the cumulative impact of multiple spaceborne active sensors that may simultaneously illuminate the RNSS receivers. One means of mitigating the potential aggregate interference from multiple spaceborne active sensors is through operational collaboration by EESS (active) operators of such sensors.

# 2 Representative technical characteristics of EESS spaceborne SARs

The technical characteristics for six spaceborne SARs which operate in 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 that are representative for operational SARs. The characteristics chosen for the analysis in this Report are those which would result in the worst-case interference to the considered RNSS receiver.

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[SAR-B1] | Standard SAR4[SAR-B2] | Standard SAR5[SAR-B2] | Standard SAR6[SAR-B2] |
| --- | --- | --- | --- | --- | --- | --- |
| 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 array2.9 m × 12.0 m | Planar array2.2 m × 12.0 m | Offset-feed parabolic 15 m diameter, linear array feed | Planar array2.9 m × 6.0 m | Planar array2.9 m × 9.9 m | Planar array2.9 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]](#footnote-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, MHz[[4]](#footnote-4) | 40 | 15 | 78 | 84 | 14, 28 | 28 |
| 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 0.3828 MHz: 0.42 to 0.76 | 0.65 to 1.56 |
| Transmit duty cycle, %[[5]](#footnote-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 |

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*() (dBi) as a function ofoff-axis angle  (degrees) | Angle range |
| Vertical(elevation) | *Gv* (*v* )  36.4 – 0.478(*v* )2*Gv* (*v* )  33.8 – 1.0 *v**Gv* (*v* )  –11 | 0   ׀*v* ׀  3.6 3.6 ≤  ׀ ׀  45 ׀*v* ׀ ≥  45 |
| Horizontal(azimuth) | *Gh* (*h* )  0.0 – 19.6(*h*)2*Gh* (*h* )  –24.5 – 0.47 *h**Gh* (*h* )  –30.5  | 0  ׀*h* ׀  1.131.13 ≤  ׀*h* ׀  12.7  ׀*h* ׀≥  12.7 |
| Beam pattern | *G*()  {*Gv* (*v* )  *Gh* (*h* ), –11} max | – |

Table 1-3

Standard SAR2 antenna gain equations

|  |  |  |
| --- | --- | --- |
| Pattern | Gain *G*() (dBi) as a function ofoff-axis angle  (degrees) | Angle range |
| Vertical(elevation) | *Gv* (*v* )  33.0 – 0.320(*v* )2*Gv* (*v* )  30.4 – 0.818 *v**Gv* (*v* )  –11 | 0   ׀*v*׀   4.4 4.4 ≤  ׀*v* ׀  50.6  ׀*v*  ׀≥  50.6 |
| Horizontal(azimuth) | *Gh* (*h* )  0.0 – 19.6(*h*)2*Gh* (*h* )  –24.5 – 0.47 *h**Gh* (*h* )  –30.5  | 0   ׀*h* ׀  1.131.13 ≤  ׀*h* ׀  12.7  ׀*h* ׀≥  12.7 |
| Beam pattern | *G*()  {*Gv* (*v* )  *Gh* (*h* ), –11} max | – |

Table 1-4

Standard SAR3 antenna gain equations

|  |  |  |
| --- | --- | --- |
| Pattern | Gain *G*() (dBi) as a function ofoff-axis angle  (degrees) | Angle range |
| Vertical(elevation) | *Gv* (*v* )  35.0 – 0.18 (*v* )2*Gv* (*v* )  32.6 – 0.05 ( ׀*v* ׀ -7)2*Gv* (*v* )  33.0 – 2.69 ( ׀*v* ׀ -12)2*Gv* (*v* )  15.0 – 20.8 log ( ׀*v* ׀) – 0.68 ( ׀*v* ׀-16)*Gv* (*v* )  –30 | ׀*v* ׀  4.0 4.0 ≤   ׀*v* ׀  11.311.3 ≤    ׀*v* ׀  16.016.0 ≤    ׀*v* ׀  35.0׀*v* ׀ ≥  35 |
| Horizontal(azimuth) | *Gh* (*h* )  0.0 – 15.0 (*h*)2*Gh* (*h* )  –18.0*Gh* (*h* )  –13.55 – 23 log  ׀*h* ׀ *Gh* (*h* )  –36.5  | ׀*h* ׀  1.11.1 ≤  ׀*h* ׀  1.71.7 ≤  ׀*h* ׀  10.0  ׀*h* ׀≥  10.0 |
| Beam pattern | *G*()  {*Gv* (*v* )  *Gh* (*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*() (dBi) as a function ofoff-axis angle  (degrees) | Angle range |
| Vertical(elevation) | *Gv* (*v* )  0.0 – 0.38(*v* )2*Gv* (*v* )  0.0 – 0.544*v*  -8. 5*Gv* (*v* )  –22.0 |   0   ׀*v* ׀  5.5 5.5 ≤  ׀*v* ׀  24.75  ׀*v*  ׀≥  24.75 |
| Horizontal(azimuth) | *Gh* (*h* )  34.7 – 2.7(*h*)2*Gh* (*h* )  34.7 – 0.95 *h* - 10.65*Gh* (*h* )  34.7 - 23.0*Gh* (*h* )  34.7 - 23.0 - 35log(*h* /38)*Gh* (*h* )  34.7 - 36.1 |   0   ׀*h* ׀  2.172.17 ≤  ׀*h* ׀  13.013.0 ≤  ׀*h* ׀  38.038.0 ≤  ׀*h* ׀  90.0  ׀*h* ׀ ≥  90.0 |
| Beam pattern | *G*()  *Gv* (*v* )  *Gh* (*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*() (dBi) as a function ofoff-axis angle  (degrees) | Angle range |
| --- | --- | --- |
| Vertical(elevation) | *Gv* (*v* )  0.0 – 0.30(*v* )2*Gv* (*v* )  0.0 – 0.69 *v*  -7.24*Gv* (*v* )  –26.0 |   0   ׀*v* ׀  6.206.20 ≤  ׀*v* ׀  27.00  ׀*v* ׀≥  27.00 |
| Horizontal(azimuth) | *Gh* (*h* )  36.6 - 7.0(*h*)2*Gh* (*h* )  36.6 - 1.43 *h* - 12.83*Gh* (*h* )  36.6 - 25.0*Gh* (*h* )  36.6 - 25.0 - 34 log(*h* /40)*Gh* (*h* )  36.6 - 36.98 |   0   ׀*h* ׀   1.461.46 ≤  ׀*h* ׀  8.478.47 ≤  ׀*h* ׀  40.040.0 ≤  ׀*h* ׀  90.0  ׀*h* ׀≥  90.0 |
| Beam pattern | *G*()  *Gv* (*v* )  *Gh* (*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 receivers

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

– Recommendation ITU-R М.1902-2 – *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 М.1787-4 *– 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 М.1901-3 – *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]](#footnote-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 principal 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 RNSS systems are summarized in Table 1-7. The saturation power level (receiver input saturation 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 saturation 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.

TABLE 1-7

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

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 3a | 3b | 4 | 5 | 6 |
| Parameter | SBAS ground reference receiver\* | High-precision semi-codeless receiver\* | High-precision receiver using L2C\* | High-precision receiver using B3 and B3A | High-accuracy and authentication receiver using E6-BC/L6 | Air-navigation receiver(Note 10) | Indoor positioning | General purpose  |
| Signal frequency range (MHz) | 1 227.6 ± 15.345 | 1 227.6 ± 15.345 | 1 227.6 ± 15.345 | 1 268.52 ± 12 | 1 278.75 ± 21 | 1 246 + 0.4375\**K* ± 5.11,where*K* = –7, …, +6(Note 8) | 1 248,06 ± 7.7 | 1 227.6 ± 12 | 1 246 + 0.4375\**K* ± 5.11where *K* = –7, .., +6 | 1 248,06 ± 7.7 | 1 268.52 ± 12 | 1 227.6 ± 12 | 1 246 + 0.4375\**K* ± 5.11where *K*= –7,..,+6 | 1 248,06 ± 7.7 | 1 268.52 ± 12 |
| Maximum receiver antenna gain in upper hemisphere (dBi) | –2.0 circular (Note 3) | 3.0 circular | 3.0 circular | 3.0 circular | 3 circular | 7 circular (Note 11) | 6 | 3 | 6 | 3 |
| Maximum receiver antenna gain in lower hemisphere (dBi) | –5.0 circular (see Note 3) | –7 linear (< 10° elev.) | –7 linear (< 10° elev.) | –7 linear (< 10° elev.) | –6 circular (Note 15) | –10 circular | 6(Note 12) | –9 | 6(Note 12) | -10 |
| RF filter 3 dB bandwidth (MHz) | 24.0 | 24.0 | 24.0 | 24.0 | 40.92(Note 18) | 42.0(Note 18) | 30 | 32 | 30 | 24 | 32 | 30 | 24 |
| Pre-correlation filter 3 dB bandwidth (MHz) | 20.46 | 20.46 | 20.46 | 20.46 | 40.92(Note 18) | 42.0(Note 18) | 20 | 25 | 2 | 20 | 25 | 20.46 | 2 | 20 | 25 | 20.46 |
| Receiver system noise temperature (K) | 513 | 513 | 513 | 513 | 722(Note 18) | 645(Note 18) | 400 | 645 | 330 | 645 | 330 |
| ***Thresholds for continuous interference*** |
| Tracking mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW) | –137.5 (P(Y))(Note 1) | –137.4 (P(Y))(Note 1) | –151.4 (Note 1) | –157.4(Note 2) | –134.5(Note 16) | –149 (Note 1) (Note 9) | –193(Note 1) | –193(Note 2) | –158(Note 1) | -150(Note 2) |
| Acquisition mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW) | See Note 4 | See Note 5 | –157.4 (Note 1) | –157.4(Note 2) | See Note 17 | –155 (Note 1) (Note 9) | –199(Note 1) | –199(Note 2) | −164(Note 1) | -156(Note 2) |

TABLE 1 (*end*)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 3a | 3b | 4 | 5 | 6 |
| Parameter | SBAS ground reference receiver\* | High-precision semi-codeless receiver\* | High-precision receiver using L2C\* | High-precision receiver using B3 and B3A | High-accuracy and authentication receiver usingE6-BC/L6 | Air-navigation receiver(Note 10) | Indoor positioning | General purpose  |
| Tracking mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz)) | –147.5 (P(Y))(Note 1) | –147.4 (P(Y))(Note 1) | –147.4(Note 1) | –147.4(Note 2) | –140(Note 16) | –140 (Note 1) (Note 9) | –150(Note 1) | –145(Note 2) | –139(Note 1) | -140(Note 2) |
| Acquisition mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz))  | See Note 4 | See Note 5 | –147.4(Note 1) | –147.4(Note 2) | See Note 17 | –146 (Note 1) (Note 9) | –156(Note 1) | –151(Note 2) | –145(Note 1) | -146(Note 2) |
| ***Thresholds for pulsed interference (see Note 14)*** |
| Receiver input saturation level (dBW) (Note 14) | –135.0 (Note 6)(Note 13) | –120(Note 6) | –120(Note 6) | –120(Note 6) | –120(Note 6)  | –80 | –70 | –100 | –70 | –100 |
| Receiver survival level (dBW) (Note 14) | −10.0 (Note 7) | –20 | –20 | –20 | –20 | −1 | −20 | –17 | −20 | –17 |
| Overload recovery time (s) (Note 14) | 1.0 × 10−6 | 1.0 × 10−6  | 1.0 × 10−6  | 1.0 × 10−6 | 1.0 × 10−6 | (1 to 30) × 10−6 | 30 × 10−6 | 30 × 10−6 |
| *Notes to Table 1:*\* These columns cover characteristics and thresholds for RNSS receivers that operate in the 1 215-1 300 MHz band. (Receivers of this type operate with the signals described in Annex 2 to Recommendation ITU‑R М.1787.) For characteristics and protection criteria for the receiver operation in the bands 1 559‑1 610 MHz and/or 1 164‑1 215 MHz, refer also to the associated table columns in Recommendations ITU‑R M.1903 and/or ITU‑R M.1905, respectively.Note 1: For P(Y) signal processing, including that using semi-codeless techniques, narrow-band interference is considered to have less than a 100 kHz bandwidth and wideband interference has greater than a 1 MHz bandwidth. For L2C signal processing, narrow-band interference is considered to have less than a 1 kHz bandwidth and wideband interference has greater than a 1 MHz bandwidth. For FDMA and CDMA (carrier frequency 1 248.06 MHz) signals processing, narrow-band continuous interference is considered to have less than a 1 kHz bandwidth, and wideband continuous interference is considered to have greater than a 500 kHz bandwidth. Thresholds for interference bandwidths between 100 kHz (for P(Y)) or 1 kHz (for L2C and FDMA/CDMA (carrier frequency 1 248.06 MHz)) to 1 MHz (or for FDMA to 500 kHz) are undefined and may require further study.Note 2: Narrow-band continuous interference is considered to have a bandwidth less than 700 Hz. Wideband continuous interference is considered to have a bandwidth greater than 1 MHz. Thresholds for interference bandwidths between 700 Hz and 1 MHz may require further study.Note 3: The listed maximum upper hemisphere gain value applies for 30° elevation (i.e. maximum expected RFI arrival angle). The listed maximum lower hemisphere gain value applies for 5° elevation.Note 4: Signal acquisition is performed using the L1 C/A signal. See the appropriate acquisition threshold row in Recommendation ITU‑R M.1903 Annex 2, Table 2‑2, “SBAS Ground Reference Receiver” column.Note 5: Signal acquisition is performed using the L1 C/A signal. See the appropriate acquisition threshold row in Recommendation ITU‑R M.1903 Annex 2, Table 2‑2, “High-precision” column.Note 6: These receiver input saturation levels apply over the corresponding RF filter 3-dB bandwidth.Note 7: This survival level is the peak power level for a pulsed signal with a 10% maximum duty factor.Note 8: This receiver type operates on several RNSS signal carrier frequencies simultaneously. The carrier frequencies are defined by *fc* (MHz) = 1 246.0 + 0.4375 *K*, where *K* = − 7 to + 6.Note 9: This threshold should account for the aggregate power of all interference. The threshold value does not include any safety margin.Note 10: 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 11: Minimum receiver antenna gain at 5 degrees elevation angle is −5.5 dBiс.Note 12: Because the antenna in some RNSS receiver applications could potentially be pointed in almost any direction, the maximum antenna gain in the lower hemisphere could (under worst-case conditions) be equal to that for the upper hemisphere.Note 13: This receiver input saturation level is for power in a 1 MHz bandwidth. Note 14: The values in these rows are to be used for assessment of interference from pulsed sources in conjunction with the methodology Note 15: The maximum lower hemisphere gain value applies for 5° elevation angle.Note 16: Narrow-band continuous interference is considered to have a bandwidth less than 128 kHz. Wideband continuous interference is considered to have a bandwidth greater than 1 MHz. Thresholds for interference with a bandwidth between 128 kHz and 1 MHz may require further study. Note 17: For E6-BC, signal acquisition is performed using the E1-BC signal. See the appropriate acquisition threshold row in Recommendation ITU‑R M.1903 Annex 2, Table 2‑2, “High-precision” column. For L6 signal, some receivers perform signal acquisition using the signals in L1 band and other receivers are expected to have 6 dB smaller threshold for the acquisition mode than for the tracking mode. Note 18: Bandwidth of 40.92 MHz is for E6-BC receiver and that of 42.0 MHz is for L6 receiver. Noise temperature of 722 K is for E6-BC receiver and that of 645 K is for L6 receiver. |

ANNEX 2

Example of evaluating the aggregate pulsed radio frequency interference from multiple EESS (active) spaceborne synthetic aperture radars
to RNSS earth station receivers operating in the 1 215-1 300 MHz band

# 1 Introduction

In the evaluation of the pulsed interference impact from spaceborne synthetic aperture radars in the EESS to RNSS receivers, it may become necessary to take into account the aggregate impact of several spaceborne active sensors that simultaneously interfere with one RNSS receiver.

This annex provides an example of calculating the aggregate interference from multiple EESS (active) SAR sensors operating simultaneously over the same territory.

# 2 Example of evaluating the aggregate pulsed radio frequency interference from multiple spaceborne synthetic aperture radars

As an example, consider the impact of interference from the SAR1 system (Table 1-1 of Annex 1 of this Report) on an SBAS receiving RNSS earth station from Column 1 to Table 1-7. The characteristics of SAR1 are presented in Table 2-1 below.

table 2-1

Technical characteristics of SAR1

| Parameter | Value |
| --- | --- |
| RF centre frequency, MHz  | 1 257.5 |
| RF bandwidth, maximum, MHz  | 40 |
| RF pulse width, µs  | 33.8 |
| Pulse repetition frequency maximum, Hz  | 1 736 |

The effective pulsed RFI duty cycle (*PDCLIM*) is computed for SAR 1 using the Annex 1 equation (2‑1) of the Report:

 $PDC\_{LIM}=(PW\_{SAR1,EFF}+τ\_{r})PRF\_{SAR1}$

where:

 $PW\_{SAR1,EFF}=PW\_{SAR1}(\frac{∆f}{Chirpwidth})$

The assumed SBAS receiver recovery time (*τr*) is 1.0 µs and the SBAS receiver pre-correlator filter bandwidth is 20.5 MHz centred at 1 227.6 MHz. Considering this *PDCLIM* for SAR1 is the following:

 $PDC\_{LIM, SAR1}=0.00225$

Using equation (1-7a) from Annex 1 of this Report, the degradation ratio of the pulsed interference caused by SAR1 to SBAS receiver is the following:

 $^{N\_{0, EFF+Y}}/\_{N\_{0, EFF}}= \frac{1}{(1-PDC\_{Y})^{2}}≈1.0045$

Or in logarithmic form 10⋅log10(*N*0*,EFF+Y/N*0*,EFF*) = 0.019 dB.

In accordance with Annex 1 Table 1-9, the allowable degradation ratio of SBAS receiver is 10⋅log10(*N*0*,EFF+Y/N*0*,EFF*) = 0.2 dB. Thus, based on the methodology given in Annex 2, SAR1 system meets the SBAS protection criteria.

Suppose that after some time a new SARA system appears, which is identical in characteristics to the SAR1 system, except that the central frequency of the signal will be 1 243.85 MHz. Due to the greater overlap of frequency bands, the effective pulse duration of such a system will be longer. Applying the same equations presented above, it turns out that the value of the effective pulse duty cycle for SARA is:

 $PDC\_{LIM, SARA}=0.0223$

Thus, the degradation ratio of SARA interference impact on the SBAS receiver is 10⋅log10(*N*0*,EFF+Y/N*0*,EFF*) = 0.196 dB. This system also meets the protection requirements of the SBAS receiver, since the degradation does not exceed 0.2 dB.

Now consider the cumulative impact of two SAR1 and SARA systems on the SBAS receiver in question if they operate simultaneously. Using equations (1-3), (1-4), (1-7) and (1-7a) from Annex 1 of this Report, it can be obtained that the degradation for the SBAS receiver with simultaneous operation of SAR1 and SARA will be determined by the following equation:

 $^{N\_{0,EFF+A+B}}/\_{N\_{0,EFF}}=\frac{1}{\left(1-PDC\_{A}\right)^{2}\*\left(1-PDC\_{B}\right)^{2}}$

Or in logarithmic form:

 10⋅log10(*N*0*,EFF+A+B/N*0*,EFF) = −*20⋅log10(1-*PDCA*) - 20⋅log10(1-*PDCB*)

Thus, the degradation of simultaneous pulsed interference impact from new two system is equal to the sum of degradations of the systems while they operate separately.

 10⋅log10(N0,EFF+A+B/N0,EFF) = 10⋅log10(N0,EFF+A /N0,EFF) + 10⋅log10(N0,EFF+B /N0,EFF)

Considering that for SAR1 and SARA systems the degradation is 0.019 dB and 0.196 dB, respectively, the total degradation will be 0.215 dB. This means that with simultaneous exposure to pulse interference from SAR1 and SARA systems, the permissible degradation level for the SBAS receiver will be exceeded.

Thus, taking into account the increasing number of sources of pulsed interference, in order to correctly assess the interference effect of new pulsed systems on RNSS receivers, it is necessary to take into account the current cumulative interference from all operating pulsed systems.

# 3 Summary and proposals

This annex shows that when evaluating the impact of possible pulsed interference from new spaceborne synthetic aperture radars of the EESS on RNSS receivers based on the methodology of Recommendation of ITU-R M.2030 as used in Report ITU-R RS.2537-0, it is necessary to take into account the cumulative simultaneous effect of pulsed interference from multiple sources. The methodology presented in Recommendation ITU-R M.2030 can be used for a preliminary assessment of the impact of pulsed interference to the RNSS receiver.

The issue of possible mechanisms to avoid or mitigate aggregate interference from multiple EESS (active) SAR systems requires further study, taking into account the examples in this Report.

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1. Note that the set of RNSS receivers whose characteristics are provided in Recommendation ITU‑R M.1902-2 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. [↑](#footnote-ref-1)
2. Note that the set of RNSS receivers whose characteristics are provided in Recommendation ITU‑R M.1902-2 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. [↑](#footnote-ref-2)
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. [↑](#footnote-ref-3)
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*. [↑](#footnote-ref-4)
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. [↑](#footnote-ref-5)
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. [↑](#footnote-ref-6)