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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

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

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RECOMMENDATION ITU-R M.2030

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

(Questions ITU-R 217-2/4 and ITU-R 288/4)

(2012)

Scope

This Recommendation provides a method for use in the initial evaluation of the potential for relevant[1] radio sources other than in the radionavigation-satellite service (RNSS) to cause pulsed interference[2] to a radionavigation-satellite system or network operating in the 1 164-1 215 MHz, 1 215-1 300 MHz, and 1 559-1 610 MHz frequency bands. The evaluation method components are a set of equations and a table of recommended parameters and allowable degradation ratios[3] for each frequency band and RNSS receiver type. Although the evaluation method equations are applicable to RNSS receivers in the 1 559-1 610 MHz band, further studies would be needed to determine the necessary table of recommended method parameters and allowable degradation ratios for that frequency band before the evaluation method is completely defined for the 1 559-1 610 MHz band.

The ITU Radiocommunication Assembly,

considering

a) that systems and networks in the radionavigation-satellite service (RNSS) provide worldwide accurate information for many positioning, navigation and timing applications, including safety aspects for some frequency bands and under certain circumstances and applications;

b) that radio transmitters generally emit a level of out-of-band emissions dependent on the conditions of their use;

c) that while Radio Regulations (RR) Appendix 3 specifies the maximum permitted spurious emission power levels, it also notes that in some cases, these levels may not provide adequate protection for receiving stations in space services and more stringent levels might be considered in each individual case in the light of the geographical position of the stations concerned, and that these levels may not be applicable to systems using digital modulation techniques;

d) that the bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz and 5 010-5 030 MHz are also allocated on a primary or secondary basis to other services besides RNSS;

e) that emissions from other RNSS systems and networks, and from other services and sources in the bands allocated for RNSS, as well as unwanted emissions, may cause interference to an RNSS system's or RNSS network's receivers and should be included in an interference evaluation;

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[1] The term "relevant" refers to radio sources that transmit RF pulses or that generate equivalent RF pulses at the RNSS receiver by other means such as, for example, the use of a scanning antenna beam.

[2] Recommendation ITU-R M.1318-1 provides an analysis method for continuous interference sources.

[3] See Annex 1, § 3 for the degradation ratio description and § 4 for more information on the allowable degradation ratio values.

f) that further work is needed to adequately characterize the interference effects on RNSS receivers from emissions of pulsed RF sources operating in and near the bands 1 559-1 610 MHz and 5 010-5 030 MHz,

noting

a) that several ITU-R Recommendations provide technical data and protection criteria for RNSS system and network operations;

b) that Recommendation ITU-R RS.1347 also provides a pulsed interference evaluation methodology for interference to an RNSS receiver from synthetic aperture radars and measurement test results in the band 1 215-1 300 MHz;

c) that Report ITU-R M.2220 provides a method to calculate certain parameters used by this Recommendation along with supporting material and examples,

recognizing

that RR No. 4.5 states “the frequency assigned to a station of a given service shall be separated from the limits of the band allocated to this service in such a way that, taking account of the frequency band assigned to a station, no harmful interference is caused to services to which frequency bands immediately adjoining are allocated”,

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 relevant radio sources other than in the RNSS to an RNSS system or network operating in the bands 1 164-1 215 MHz or 1 215-1 300 MHz;

2 that if the application of this method indicates that there is potential for pulsed interference that would impair the ability of RNSS systems or networks to function, then a more detailed analysis should be performed;

3 that studies should be performed to develop the parameters to be included in the analytic method for the preliminary evaluation of the potential for pulsed interference from relevant radio sources other than in the RNSS to an RNSS system or network operating in the frequency band 1 559-1 610 MHz (see Note).

NOTE – The analytic method equations in Annex 1 are applicable to the 1 559-1 610 MHz band.

Annex 1

Analytic method for the preliminary evaluation of the potential for pulsed interference from relevant radio sources other than in the RNSS to an RNSS system or network operating in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz

1 Introduction

An evaluation model for continuous RF interference[4] (RFI) to RNSS receivers has been developed in Recommendation ITU-R M.1318-1, but ITU-R has also recognized the need to address pulsed RF interference. This Annex derives from basic concepts a general pulsed RFI evaluation method for use with RNSS receivers. Report ITU-R M.2220 contains background material and a methodology to calculate composite pulsed interference parameters used in the interference evaluation. Section 2 below provides some background and describes RFI degradation equations for two basic types of RNSS receivers. Section 3 describes how the degradation equations could be used to assess the impact of additional pulsed RFI. Section 4 lists recommended baseline RFI method parameters and allowable degradation ratios for the pulsed RFI evaluation.

2 Characterization of pulsed RFI effects on RNSS receivers

Studies by two aviation standards organizations[5] have shown that the highest levels of pulsed RFI impacting RNSS air-navigation receivers operating in the 1 164-1 215 MHz band at or above Flight Level 200 (6 096 m above mean sea level (MSL)) occur in several localized regions around the world. Those studies have developed a model of a general RNSS receiver signal processing method used to mitigate strong pulsed RFI and an associated equation[6] to express the amount of degradation to the post-correlator signal quality measure ($C/N_{0,EFF}$) of that receiver. One study[7] also developed the comparable degradation equation for conventional receivers without special pulsed RFI mitigation. Both degradation equations handle continuous RFI present along with the pulsed RFI. As such, they can be useful for determining RFI protection criteria as well as for analysing the effects of any new pulsed or continuous RFI beyond an initial baseline case. Sections 2.1 and 2.2 below describe details of the RFI degradation equations.

2.1 Effective noise density calculation method (receiver pulse blanking)

An effective means for mitigating strong pulsed RFI in, for example, an air navigation receiver, is the pulse blanker. One aspect of the blanker is that pulsed RFI signals with peak power levels below the blanker threshold combine with the receiver noise and the un-blanked components of the continuous RFI. The other main aspect is that the blanker "zeros" the signal and noise into the

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[4] Continuous interference is used here to mean interference from sources of fairly constant power that is generally present at all times. This is distinguished from pulsed interference which requires an analysis based on pulse duration, peak power and duty cycle.

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

[6] SC-159, "Assessment of radio frequency interference relevant to the GNSS L5/E5A frequency band", RTCA Document No. RTCA/DO-292, Washington, DC, 29 July 2004, Section 2.6.2.3.

[7] *ibid* RTCA/DO-292, Appendix D.2.2.

correlators during the time duration of strong pulses with power levels above the blanker threshold. The equation described below estimates an effective noise-plus-interference density ($N_{0,EFF}$) at the output of the signal correlators due to the pulse blanker. $N_{0,EFF}$ is quite general and can be applied to all RFI environments for an RNSS receiver because the equation input variables quantify the RFI environment as it changes. The effective post-correlator noise-plus-interference density, $N_{0,EFF}$, is defined as:

$$N_{0,EFF} = \frac{N_0}{(1 - PDC_B)}\left(1 + \frac{I_{0,WB}}{N_0} + R_I\right) \tag{1}$$

where:

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

In the above equations:

R_I: is the post-correlator power density ratio of total aggregate below-blanker threshold average pulsed RFI to receiver thermal noise (unitless ratio)

PDC_B: (pulse duty cycle of the blanker) is the net aggregate duty cycle of all pulses exceeding the blanker threshold (unitless fraction)

N_0: is the RNSS receiver system thermal noise power spectral density in W/Hz (= kT_{sys})

$I_{0,WB}$: is the total wideband equivalent continuous RFI power spectral density (W/Hz) for the particular RNSS receiver application[8]

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

P_i: is the received peak power (W) of the i-th pulse source (referenced to antenna output) with peak level below the blanker threshold

dc_i: is the duty cycle (unitless fraction) of the i-th below-blanker pulse source

N: is the total number of emitters that generate received pulses with peak level below the blanker threshold.

As defined above, $N_{0,EFF}$ combines all the pulsed RFI effects on thermal noise density, wideband continuous RFI density, and RNSS signal loss.[9] All noise and interference parameters in equations (1) and (2) are referenced to the receive system passive antenna terminals. Note in equation (1) that without the pulsed RFI (i.e. R_I and $PDC_B = 0$), the $N_{0,EFF}$ equation reduces to the simpler expression used in continuous RNSS RFI analyses ($N_{0,EFF} = N_0 + I_{0,WB}$).

The aggregate pulsed RFI parameter, PDC_B, is built out of components from the separate heterogeneous pulsed tranmitter systems "*a*", "*b*" and "*c*" as follows:

$$PDC_B = 1 - (1 - PDC_a)(1 - PDC_b)(1 - PDC_c) \tag{3}$$

where:

PDC_a: above-blanker threshold pulse duty cycle for system "*a*" pulses (e.g. Distance Measuring Equipment/Tactical Air Navigation (DME/TACAN))

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8 See Report ITU-R M.2220 for more details about this parameter.

9 See Report ITU-R M.2220 for more details on $N_{0,EFF}$.

PDC_b: above-blanker threshold pulse duty cycle for system "*b*" pulses (e.g. a Communication Navigation Identification (CNI) system); and

PDC_c: above-blanker threshold pulse duty cycle for system "*c*" pulses (e.g. Aeronautical Radionavigation Service/Air Traffic Control (ARNS/ATC)).

For each individual source, *i*, of a system, *x*, the above-blanker threshold pulse duty cycle $PDC_{x,i}$ is given in general by:

$$PDC_{x,i} = (PW_{x,i} + \tau_{REC}) \cdot PRF_{x,i} \tag{3a}$$

where:

$PW_{x,i}$: is the effective received above-blanker threshold pulse width (s)

τ_{REC}: is the receiver overload recovery time (s); and

$PRF_{x,i}$: is the pulse repetition rate (Hz).

The aggregate pulsed RFI parameter R_I is built out of components from the separate heterogeneous pulsed transmitter systems "*a*", "*b*" and "*c*" as follows:

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

where R_a, R_b and R_c are the below-blanker signal-to-receiver noise density ratio 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 pulse duty cycle of an individual source, *j*, of a system, *y* for below-blanker threshold received pulses, $dc_{y,j}$, is defined by:

$$dc_{y,j} = PW_{y,j} \cdot PRF_{y,j} \tag{4a}$$

where the equation right side terms are defined similar to (3a) except they are with respect to below-blanker threshold pulse characteristics.

2.2 Effective noise density calculation (receiver pulse saturation)

Certain RNSS receivers operating in the RNSS bands in, for example, ground-based applications may not be subjected to large amounts of in-band and adjacent band pulsed RFI as air navigation or similar receivers are. As such, they may not contain pulse blanking circuitry as described in § 2.1 above but rather will be saturated briefly by RFI pulses from a nearby source. The presence of pulsed RFI reduces the amount of continuous RFI that the RNSS receiver can tolerate. 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, $N_{0,EFF}$, as:

$$N_{0,EFF} = \frac{N_0 \cdot \left(1 + \frac{I_{0,WB}}{N_0} + R_I\right)\left(1 + \frac{N_{LIM}{}^2 \cdot PDC_{LIM}}{(1 - PDC_{LIM})}\right)}{(1 - PDC_{LIM})} \tag{5}$$

where:

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

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

PDC_{LIM}: aggregate fractional duty cycle of the saturating RFI pulses (unitless)

R_I: ratio (unitless) of aggregate below-saturation average pulse RFI power density to N_0; and

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

All the noise and interference terms in equation (5) are referenced to the receive system passive antenna terminals. The parameter N_{LIM} is a receiver parameter that is determined by the A/D conversion implementation. For the simplest hard-limiting RNSS receiver (with a "1-bit" quantizer), N_{LIM} = unity. Since, in that case, the receiver limits on noise, the RFI parameter R_I is essentially zero. In more general cases, R_I is related to the receiver A/D saturation level and the peak power and pulse duty cycle of below-saturation RFI pulses with the same definition form as in equation (2). As in equation (1), the terms PDC_{LIM} and R_I represent aggregate values for the pulsed RFI sources involved. Note also that when no pulsed RFI is present, the RFI parameters, PDC_{LIM} and R_I are zero and equation (5) reduces to $N_{0,EFF} = N_0 + I_{0,WB}$, a familiar definition for continuous RFI analysis.

The individual source saturated pulse duty cycle, $PDC_{LIM,j}$, making up the aggregate duty cycle is defined in the same form as equation (3a) except with respect to the receiver input saturation level (approximated by the tabulated receiver input compression level). The individual source below-saturation duty cycle is defined in the same form as equation (4a).

Given a maximum value for $N_{0,EFF}$ and the set of pulsed RFI parameters, equation (5) can be solved for the allowable aggregate continuous wideband power spectral density for the non-RNSS interference component.

2.3 Usage limits for effective noise power spectral density ($N_{0,EFF}$) equations

For RFI pulse width values from 0.1 to 1 000 microseconds, the $N_{0,EFF}$ defining equations described in §§ 2.1 and 2.2 above have been shown to properly represent the pulsed RFI effect on RNSS receivers operating in signal tracking mode in the 1 164-1 215 MHz and 1 215-1 300 MHz bands. For some RNSS receivers operating in the signal acquisition mode, the equations also properly represent the pulsed RFI effect over the same RFI pulse width range as long as associated pulse duty cycles remain moderate.

For certain RNSS receivers operating in the acquisition mode with short integration time (about 1-2 ms), the equations in §§ 2.1 and 2.2 may not properly represent the pulsed RFI effect over the same RFI pulse width range at high pulse duty cycles (including the 1 559-1 610 MHz band). Thus further study is needed to determine the usage limits for high duty cycle and long interference pulse width and verify the equation predictions.

3 Pulsed RFI evaluation method concepts

The combined effects of pulsed and continuous RFI on two basic types of RNSS receivers are described in § 2 above. The combined RFI effect is captured in the form of an effective noise-plus-interference power spectral density, $N_{0,EFF}$, for the RNSS receiver. The received RFI is characterized by the three RF source related parameters described above (the pulsed parameters, PDC and R_I, and the continuous parameter, ($I_{0,WB}/N_0$)). As noted in the definitions above, the term, $I_{0,WB}$, is used to represent the total wideband equivalent continuous RFI power spectral density present at the RNSS receive antenna. To minimize the complexity of the pulsed RFI analysis, the $I_{0,WB}$ term is assumed to be a fixed value representing the baseline condition.

Certain receiver technical characteristics are also involved both directly (e.g. N_0, the receiver system thermal noise power spectral density) and indirectly. The effect of added pulsed RFI to a predetermined baseline can be determined in terms of a ratio of the $N_{0,EFF}$ with the new source included, $N_{0,EFF\text{-}New}$, to the baseline value for $N_{0,EFF}$.

3.1 Additional pulsed RFI to a pulse blanking RNSS receiver (case 1)

Define the baseline $N_{0,EFF}$ (assuming non-zero pulsed RFI present) using equations (1) and (2) as:

$$N_{0,EFF} = \frac{N_0}{(1-PDC_B)}\left(1+\frac{I_{0,WB}}{N_0}+R_I\right) \text{ with } R_I = \left(\frac{1}{N_0 \times BW}\right)\sum_{i=1}^{N} P_i \times dc_i$$

where, by equations (3) and (4), $(1-PDC_B) = (1-PDC_a)(1-PDC_b)(1-PDC_c)$ and $R_I = R_a + R_b + R_c$ from baseline pulsed source groups a, b, and c.

If an additional pulsed source (or source group) Y is introduced, then by extension:

$$(1–PDC_{B+Y}) = (1–PDC_a)(1–PDC_b)(1–PDC_c)(1–PDC_Y) = (1–PDC_B)(1–PDC_Y) \text{ and}$$

$$R_{I+Y} = R_a + R_b + R_c + R_Y = R_I + R_Y$$

Also by similarity,

$$N_{0,EFF+Y} = \frac{N_0}{(1-PDC_{B+Y})}\left(1+\frac{I_{0,WB}}{N_0}+R_{I+Y}\right)$$

The RFI degradation relative to the baseline can be computed as the ratio $N_{0,EFF+Y} / N_{0,EFF}$:

$$N_{0,EFF+Y} / N_{0,EFF} = \frac{(1-PDC_B)\left(1+\frac{I_{0,WB}}{N_0}+R_I+R_Y\right)}{(1-PDC_{B+Y})\left(1+\frac{I_{0,WB}}{N_0}+R_I\right)} = \frac{1}{(1-PDC_Y)}\left[1+\frac{R_Y}{\left(1+\frac{I_{0,WB}}{N_0}+R_I\right)}\right] \quad (6)$$

Note that both PDC_Y and R_Y are estimated using the RNSS receiver input compression level as power reference point (upper bound to the blanker threshold). The duty cycle calculation of above-blanker threshold pulses (PDC_Y) makes use of the receiver overload recovery time as described in equation (3a).

3.2 Additional pulsed RFI to a saturating RNSS receiver (case 2)

3.2.1 Saturating RNSS receiver – non-zero baseline pulsed RFI (case 2a)

In this sub-case pulsed RFI is assumed to be present in the baseline environment (i.e. baseline *PDC* and/or $R_I > 0$). If an additional saturating pulse source group Y is introduced, the new composite RNSS pulsed RFI parameters, PDC_{LIM+Y} and R_{I+Y}, can be defined similar to Case 1 as:

$$(1–PDC_{LIM+Y}) = (1–PDC_{LIM})(1–PDC_Y) \text{ and } R_{I+Y} = R_I + R_Y$$

where PDC_{LIM} and R_I represent the baseline environment pulsed RFI parameters and PDC_Y and R_Y represent the additional source group pulsed RFI parameters. Similar to Case 1, the degradation ratio is then defined by extension using equation (5) as:

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

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

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 simplifies to:

$$
\frac{N_{0,EFF+Y}}{N_{0,EFF}} = \frac{1}{(1-PDC_Y)^2} \tag{7a}
$$

3.2.2 Saturating RNSS receiver – zero baseline pulsed RFI (case 2b)

For the sub-case when no pulsed RFI is assumed in the baseline environment (i.e. baseline *PDC* and $R_I = 0$) and a saturating pulse source group Y is introduced (pulsed RFI parameters PDC_Y and R_Y), then the degradation ratio is defined as:

$$
\begin{aligned}
\frac{N_{0,EFF+Y}}{N_{0,EFF}} &= \frac{N_0\left(1+\frac{I_{0,WB}}{N_0}+R_Y\right)\left(1+\frac{N_{LIM}{}^2\cdot PDC_Y}{(1-PDC_Y)}\right)}{N_0\left(1+\frac{I_{0,WB}}{N_0}\right)(1-PDC_Y)} \\
&= \frac{1}{(1-PDC_Y)}\left[1+\frac{R_Y}{\left(1+\frac{I_{0,WB}}{N_0}\right)}\right]\left(1+\frac{N_{LIM}{}^2\cdot PDC_Y}{(1-PDC_Y)}\right)
\end{aligned} \tag{8}
$$

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

$$
\frac{N_{0,EFF+Y}}{N_{0,EFF}} = \frac{1}{(1-PDC_Y)^2}
$$

4 Allowable degradation ratios and associated evaluation method parameters

Table 1 lists baseline method parameters and allowable degradation ratios[10] to be used for a preliminary evaluation of the potential for pulsed interference from relevant radio sources other than in the RNSS to an RNSS system or network operating in the 1 164-1 215 MHz band. RNSS receiver types in the table are taken from Recommendation ITU-R M.1905. If the analysis of an additional pulsed interference source gives a degradation ratio value in dB

[10] 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.

($10\log_{10}(N_{0,EFF+Y}/N_{0,EFF})$) that exceeds the allowable degradation ratio of an RNSS receiver in Table 1, then a more detailed analysis of the impact of the additional pulsed interference may be required to determine whether or not the new interference is acceptable to the victim RNSS receiver. The listed baseline pulse RFI method parameters, *PDC* and R_I, and continuous parameter, $I_{0,WB}/N_0$, are to be used in the appropriate degradation ratio equation (equation 6 for pulse-blanking RNSS receivers (N_{LIM} =0), or equation 7, 7a, or 8 for saturating RNSS receivers ($N_{LIM} \geq 1$)). The pulse parameters for the new pulsed RFI source (or source group) in the degradation equations may be computed using a method described in Report ITU-R M.2220.

TABLE 1

Baseline pulsed RFI method parameters and allowable degradation ratios for RNSS receivers (space-to-Earth) operating in the band 1 164-1 215 MHz*

Receiver type	N_{LIM} (unitless) (Note 4)	Baseline *PDC* (unitless)	Baseline R_I (unitless)	Baseline $I_{0,WB}/N_0$ ratio (unitless)	Allowable degradation ratio for pulsed sources (dB) (Notes 2, 3)
Air navigation receiver #1 (CDMA) (Notes 1, 5)	0	0.6527	0.9628	1.0551	0.1
Air-navigation receiver # 2 (FDMA) (Notes 1, 5)	1	0.6527	0.9628	0.455	0.1
High precision (CDMA) (Note 5)	2	0.0941	0	0.5012	0.2
High precision (FDMA) (Note 5)	2	0.0941	0	0.5012	0.2

* Parameter values for other RNSS receiver types are yet to be developed. The degradation ratio equations in § 3 of this Annex can be used to predict the general nature of the pulsed interference effects on RNSS receivers for which no parameters are listed.

NOTE 1 – The listed baseline parameters are for the high altitude U.S. hotspot case that includes existing DME/TACAN, CNI, and ARNS/ATC pulsed sources. The degradation limit applies to the effect from a new non-aeronautical pulsed source or source group.

NOTE 2 – Unwanted emissions from continuous sources, to which Recommendation ITU-R M.1318-1 applies, will not affect the allowable degradation ratio for pulsed sources.

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

NOTE 5 – Based on a 1 microsecond overload recovery time.

Table 2 gives similar listings for the frequency band 1 215-1 300 MHz. RNSS receiver types in the table are taken from Recommendation ITU-R M.1902. Similar to the process for Table 1, the listed baseline model pulse RFI parameters, *PDC* and R_I, and continuous parameter, $I_{0,WB}/N_0$, are to be used in the appropriate degradation ratio equation (equation 6 for pulse-blanking RNSS receivers (N_{LIM} =0), or equation 7, 7a, or 8 for saturating RNSS receivers ($N_{LIM} \geq 1$)). The equation result for the actual degradation ratio is compared to the allowable degradation ratio value in Table 2.

TABLE 2

Baseline pulsed RFI method 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[11] 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 § 3 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 NLIM 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.

The degradation ratio equations in § 3 of this Annex can also be used to predict the general nature of the pulsed interference effects on RNSS receivers operating in the 1 559-1 610 MHz frequency band. However, the table of recommended evaluation method parameters and allowable degradation limits for the 1 559-1 610 MHz band, necessary to perform pulsed interference impact evaluations, has yet to be developed. The starting point for that development can be the basic method described in Report ITU-R M.2220 as adapted to determine aggregate interference parameters of pulsed RF systems in and near the 1 559-1 610 MHz band while accounting for the continuous interference sources in and near that frequency band.

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[11] Satellite-based augmentation system (SBAS).

Annex 2

Application examples of the pulsed RFI analytic evaluation method

This Annex presents two examples of applying the Annex 1 analytic evaluation method to determine the pulsed interference impact from the same new pulsed RF source on two different RNSS receiver types operating in the 1 215-1 300 MHz frequency band.

1 RNSS receiver operational baseline case description

The two types of RNSS receivers, an SBAS ground reference receiver and some high-precision semi-codeless receivers (1 215-1 300 MHz band) are assumed operating normally in the vicinity of a single pulsed radar system. That radar is assumed to produce pulsed signals within the pre-correlator filter passbands of the two receiver types that fully saturate them. As listed in Annex 1, Table 2, row 2, the baseline radar is assumed to produce the following received pulsed RFI factors:

$$PDC = 0.0765,$$
$$R_I = 0.$$

The SBAS ground reference receiver pertinent parameters are:

$$N_{LIM} = 1.0$$
$$\tau_{REC} = 1.0 \text{ µs.}$$

The High-precision semi-codeless receiver pertinent parameters are:

$$N_{LIM} = 2.0$$
$$\tau_{REC} = 1.0 \text{ µs.}$$

Each is assumed to operate in the simultaneous presence of continuous interference with an I_0/N_0 density ratio from Annex 1, Table 2.

2 Analytic method pulsed RFI degradation ratio calculation examples

A single new pulsed RF transmitter is proposed to be placed into the baseline operational case described above. It is assumed to have sufficiently high peak received power to saturate both RNSS operating receiver types. The proposed transmit pulse parameters for the new source are:

$$PW_Y = 44.0 \text{ µs, and}$$
$$PRF_Y = 500 \text{ Hz.}$$

2.1 SBAS ground reference receiver pulsed RFI degradation ratio calculation

For the SBAS ground reference receiver, the effective saturated received pulse duty cycle to the proposed new source, PDC_Y, from Annex 1, equation (3a) is:

$$PDC_Y = (PW_Y + \tau_{REC}) \cdot PRF_Y = (44 + 1.0) \cdot 500 \cdot 10^{-6} = 0.02250$$

Since the new source pulses fully saturate the receiver,

$$R_Y = 0$$

According to Annex 1 Table 2 for the SBAS ground reference receiver, $N_{LIM} = 1$. Since for the new pulsed RF source, $R_Y = 0$, the pulsed RFI degradation equation is Annex 1 equation (7a). Thus,

$$N_{0,EFF+Y}\big/N_{0,EFF} = \frac{1}{(1 - PDC_Y)^2} = 1/(1 - 0.0225)^2 = \mathbf{1.04657} \text{ (algebraic ratio).}$$

To compare the computed degradation ratio to the allowable degradation factor (0.2 dB) from Annex 1, Table 2, convert the algebraic ratio to dB:

$$10 \cdot \log_{10}(1.04657) = \mathbf{0.198\ dB}$$

Thus the proposed new source produces less than the SBAS ground reference receiver allowable degradation limit by a small margin.

2.2 High-precision semi-codeless receiver pulsed RFI degradation ratio calculation

Since the high-precision semi-codeless receiver is assumed to have the same pulse overload recovery time (1.0 µs) as the SBAS ground reference receiver, the new source saturation received pulse duty cycle is also the same (PDC_Y = 0.0225). Since there are no below-saturation pulses received by the high-precision semi-codeless receiver, $R_Y = 0$ as well. The baseline pulse duty cycle, PDC_{LIM}, from Annex 1, Table 2 is 0.0765. Because the receiver $N_{LIM} = 2$, the pulsed RFI degradation equation to use is Annex 1, equation 7. Thus after substituting PDC_{LIM}, N_{LIM} and R_Y parameter values into the equation and simplifying it, the computed degradation ratio is:

$$N_{0,EFF+Y}/N_{0,EFF} = \{1/(1\text{-}PDC_Y)\} \cdot (1) \cdot \{1+(4 \cdot PDC_Y)/[(1\text{-}PDC_Y)(1+3 \cdot PDC_{LIM})]\}$$

$$= \{1.02302\} \cdot \{1+[0.090/1.20184]\} = \mathbf{1.09963} \text{ (algebraic ratio)}$$

Converting the algebraic ratio to dB yields:

$$10 \cdot \log_{10}(1.099627) = \mathbf{0.413\ dB}$$

Thus, the proposed new pulse source produces more RFI degradation than the high-precision semi-codeless receiver allowable degradation limit of 0.2 dB.