Radiocommunication Study Groups

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International Amateur Radio Union

MATERIAL FOR A REVISION TO REPORT ITU-R M.2513-0

Studies regarding the protection of the primary radionavigation-satellite service (space-to-Earth) by the secondary amateur and amateur-satellite services in the frequency band 1 240-1 300 MHz

Introduction

Published Report ITU-R M.2513-0 details studies on the potential for interference from the amateur and amateur-satellite service applications in the range 1 240-1 300 MHz and terrestrial RNSS receivers operating in the same frequency range. However, those studies are based on static minimum coupling loss estimations with no deployment simulations.

The IARU believes that further simulations are required to properly quantify the potential for interference into a population of terrestrial RNSS receivers and thereby develop proportionate guidance for the ongoing use of the band by the amateur services.

This work was originally proposed for consideration in ITU-R WP 5A and is identified in the liaison to WP 4C in Document 4C/408.

Proposal

Working Party 4C is invited to take into account the study provided in Attachment 1 which is extracted from Document 4C/408 with additional revisions (track changes shown) to account for comments received during presentation of the study in WP 5A. These revisions are highlighted below. WP 4C is therefore invited to revise the Report ITU-R M.2513-0 accordingly by adding the proposed simulation as Annex 9 with a corresponding new Section 10.4. Attachment 2 provides a short text for section 10.4.

With this study incorporated the revised Report ITU-R M.2513-0 can be finalised as a Draft New Revision to Report ITU-R M.2513-0.

Description of the Study

The study consists of a number of Monte Carlo style simulations to assess the percentage of RNSS receivers around a transmitting amateur radio station that might suffer interference above the protection threshold given by Recommendation ITU-R M.1902-2 for the RNSS system operating in the E6 band. The simulation areas are based on the densities of amateur radio stations provided by WP 5A and reported in section 6 of the Report ITU-R M.2513-0. Both narrow band and broadband amateur radio emissions are considered. The simulation areas are populated with many thousands of RNSS receivers reflecting the expected ubiquitous deployment that are either fixed or mounted on vehicles.

Statistics are collected on the number of receivers that might suffer interference above the relevant threshold and compared to the overall population of receivers in the simulation area.

Revisions to the study as presented in Document 4C/408

During the presentation in WP 5A some questions were raised, and clarifications sought. The following aspects have been addressed in the text in Annex 1:

1) The study only addresses one RNSS system in the E6 band.

2) The number of simulated receivers in each scenario.

3) Additional results for a range of RNSS antenna gain assumptions.

4) Text clarifications.

Attachment 1: **ANNEX 9:** Assessing the impact of certain amateur station emissions on a deployment simulation of a large number of co-frequency RNSS (space-to-Earth) receivers in the E6 band.

Attachment 2: Text for section 10.4

ATTACHMENT 1

Annex 9

Assessing the impact of certain amateur station emissions on a deployment simulation of a large number of one type of co-frequency RNSS (space-to-Earth) receivers in the E6 band.

1 Introduction

This study aims to quantify the extent of interference occurring between a station of the amateur service and a population of RNSS receivers around that station. Simulations assuming the following scenarios have been carried out:

a) Fixed narrow band amateur “Home” station and static RNSS receivers in fixed locations where the number of receivers is based on the population density and an estimated RNSS receiver “ownership” factor.

b) Fixed narrow band amateur “Home” station and mobile RNSS receivers, on board moving cars.

c) Fixed broadband amateur “Home” station (ATV) and mobile RNSS receivers, on board moving cars.

d) Fixed narrow band amateur “Permanent” station (e.g. voice repeater output channel) and mobile RNSS receivers, on board moving cars.

e) Fixed broadband amateur “Permanent” station (e.g. ATV repeater output channel) and mobile RNSS receivers, on board moving cars.

Each simulation calculates the signal level received by the individual RNSS receivers from an amateur station transmitter. The simulation area depends upon the amateur station density and the number of RNSS receivers placed in the area is based on assumptions about the population and ownership factor.

In case a) above the RNSS receivers remain fixed but are re-positioned for each run of the simulation. In the remaining cases b) to e) the mobile RNSS receivers are moved between each set of calculations according to a vehicle speed and trajectory across the simulation area. For each simulation run a new set of vehicle starting positions and speed assignments are made.

The received levels are compared to the protection criteria and if above this level the receiver is labelled ”impacted” so that the statistics of the impacted receivers can be collated to determine the mean percentage of impacted receivers from the simulation population.

2 Fixed Home Station and Fixed RNSS Receiver Scenario

In this simulation fixed amateur home stations and fixed RNSS receivers are considered. The number of receivers is based on the population density and an estimated “ownership” factor. RNSS receivers are considered to be in fixed locations and the number of receivers is based on the population density and an estimated RNSS receiver “ownership” factor.

2.1 Simulation areas and propagation model parameters

The amateur station densities are determine the simulation areas from a range from 0.00006 to 0.0016 stations/km^2 with an average of 0.0002 stations/km^2.

The amateur station density assumed in all simulations:

- Average Home Station and Portable station density = 1 station / 5 000 km^2
- Minimum Home Station and Portable station density = 1 station / 16,700 km^2
- Maximum Home Station and Portable station density = 1 station / 625 km^2

The simulation area according to each amateur station density:

- Average Home Station and Portable station density = 70 x 70 km
- Minimum Home Station and Portable station density = 130 x 130 km
- Maximum Home Station and Portable station density = 25 x 25 km

~~The propagation model parameters are:~~

- ~~Recommendation ITU-R P.1546 Matlab code provided by ITU. Latest update (3rd May 2019) is available from https://www.itu.int/md/R15-WP3K-C-0289/en.~~
- ~~Location variability: 50%~~
- ~~Required percentage time: 1%~~

Commented [BL1]: Moved to section 2.3 below.

2.2 Population Density

The study was based on population data for France, based on National Institute for Statistics (INSEE):

FIGURE 1

Population density data extract for France

Population par région

	Estimations de population au 1er janvier 2020[1] en milliers	Variation annuelle moyenne 20/12 en %			Densité moyenne au 1er janvier 2020 en hab/km²	
		Totale	Due au solde naturel	Due au solde apparent des entrées et des sorties[2]		
Auvergne-Rhône-Alpes	8 032.4	0.5	0.3	0.2	115	
Bourgogne-Franche-Comté	2 783.0	-0.2	0.0	-0.2	58	< mini
Bretagne	3 340.4	0.4	0.0	0.4	123	
Centre-Val de Loire	2 559.1	0.0	0.1	-0.1	65	
Corse	344.7	1.1	-0.1	1.2	40	
Grand Est	5 511.7	-0.1	0.1	-0.2	96	
Hauts-de-France	5 962.7	0.0	0.3	-0.3	187	
Île-de-France	12 278.2	0.4	0.9	-0.5	1 022	< maxi
Normandie	3 303.5	-0.1	0.1	-0.2	110	
Nouvelle-Aquitaine	6 000.0	0.4	-0.1	0.5	71	
Occitanie	5 924.9	0.6	0.1	0.5	81	
Pays de la Loire	3 801.8	0.6	0.2	0.4	119	
Provence-Alpes-Côte d'Azur	5 055.7	0.3	0.2	0.1	161	
France métropolitaine	**64 898.0**	**0.3**	**0.3**	**0.0**	**119**	< average
Guadeloupe	376.9	-0.8	0.4	-1.2	221	
Guyane	290.7	2.4	2.4	0.0	3	
La Réunion	860.0	0.4	1.1	-0.7	343	
Martinique	358.7	-1.0	0.2	-1.2	318	
Mayotte	279.5	nd	nd	nd	747	
France y c. Mayotte	**67 063.7**	**nd**	**nd**	**nd**	**106**	
France hors Mayotte	**66 784.2**	**0.3**	**0.3**	**0.0**	**106**	

nd : donnée non disponible.

1. Résultats provisoires arrêtés fin 2019.

2. Le solde apparent des entrées et des sorties est calculé comme la différence entre la variation de population et le solde naturel.

Sources : IGN ; Insee, estimations de population, code officiel géographique.

Three different population densities are identified:

1 "Rural", typically Bourgogne, with a density of 58 inhabitants / km^2

2 "Dense Urban": Paris & direct suburbs (Ile de France), 1022 inhabitants / km^2

3 "~~Average~~Urban": France average is 119 inhabitants / km^2

The potential number of RNSS receivers (*N*) = (Simulation area) * (Population density) * (Use ratio).

Assuming a RNSS receiver use ratio of just 10% of the population produces sufficient receiver numbers for a valid simulation. See Table 1.

TABLE 1

Number of RNSS receivers placed in each simulation area.

	Minimum amateur station density	Average amateur station density	Maximum amateur station density
Rural	96,860	29,000	3,625
Urban	198,730	59,500	7,438
Dense Urban	1,706,740	511,000	63,874

2.3 Propagation Model

Recommendation ITU-R P.1546 Matlab code provided by ITU. Latest update (3rd May 2019) is available from https://www.itu.int/md/R15-WP3K-C-0289/en.

- Location variability: 50%
- Required percentage time: 1%

2.34 Simulation Parameters

The following parameters were assumed for the amateur home station and the RNSS receivers:

- ~~Average, minimum and maximum home station density.~~
- ~~Simulation area: According to the station density.~~
- Transmitter frequency: 1 297 MHz
- Transmitter Antenna gain: 18 dBi
- Transmitter power: 150 Watts
- Effective height of the amateur station antenna: 12 meters
- Receiver antenna height: 1.5 meters
- Narrow band receiver max interference threshold: –134.5 dBW (Ref: ITU-R M.1902-2, Table 1, System 3b).
- Receiver antenna gain: –6 dBi, 0 dBi and 3 dBi omnidirectional.
- Polarisation Loss = 3 dB
- Rec. ITU-R P.1546 'area' parameter: rural, urban and dense urban
- Rec. ITU-R P.1546 representative clutter height around the receiver: Typical values recommended for variable R2 in the ITU-R Matlab code: 10 m, 20 m and 30 m (according to rural, urban or dense urban area parameter respectively).
- Location variability: 50%
- Required percentage time: 1%
- Use ratio: 10% of the population is using the RNSS receiver at simulation time.

The potential number of victim receivers (***N***) = (Simulation area) * (Population density) * (Use ratio)

2.45 Simulation Method

At each simulation iteration step (one run), the victim receivers are randomly placed in the simulation area. The (x, y) coordinates of each receiver are initialized from two distinct random uniform distributions.

For each receiver we compute:

- Distance to the transmitter,
- Angle to the main lobe of the transmitter antenna.

From the angle to the main lobe, the antenna gain is estimated according to Recommendation ITU-R F.1336-5. Then the received level is computed as:

- Received level = (transmitter power) + (transmitter antenna gain) + (receiver antenna gain) - (path loss)

Where the path loss value is provided by the ITU-R P.1546 Matlab code.

Each time the received level is above the RNSS receiver interference threshold the receiver is counted as "**impacted**".

At the end of one simulation step, we have ***m*** receivers impacted from a potential number of victim receivers ***N***.

The percentage of impacted receivers from the simulation step is then defined as (***m*** / ***N***) * 100.

The simulation is performed 1 000 times and ends with 1 000 distinct values for the percentage of impacted receivers. From these the mean percentage of impacted RNSS receivers can be calculated.

2.56 Simulation Results

Mean percentage of fixed RNSS receivers within the simulation area impacted by one static amateur station operating as defined above:

TABLE 12

Mean Percentage of impacted fixed RNSS receivers and Standard Deviation

a) RNSS Receiver Antenna Gain = -6 dBi

	Minimum amateur station density		**Average amateur station density**		**Maximum amateur station density**	
Area setting and population density	**% Impacted RNSS Rx**	**Standard Deviation**	**% Impacted RNSS Rx**	**Standard Deviation**	**% Impacted RNSS Rx**	**Standard Deviation**
Rural	0.06%	0.01%	0.20%	0.03%	1.62%	0.21%
Urban	0.02%	0.004%	0.08%	0.01%	0.65%	0.09%
Dense urban	0.02%	0.001%	0.06%	0.001%	0.45%	0.02%

b) RNSS Receiver Antenna Gain = 0 dBi

	Minimum amateur station density		Average amateur station density		Maximum amateur station density	
Area setting and population density	**% Impacted RNSS Rx**	**Standard Deviation**	**% Impacted RNSS Rx**	**Standard Deviation**	**% Impacted RNSS Rx**	**Standard Deviation**
Rural	0.118%	0.011%	0.396%	0.039%	3.177%	0.306%
Urban	0.048%	0.005%	0.161%[1]	0.017%	1.287%	0.134%
Dense urban	0.033%	0.001%	0.111%	0.005%	0.889%	0.037%

c) RNSS Receiver Antenna Gain = 3 dBi

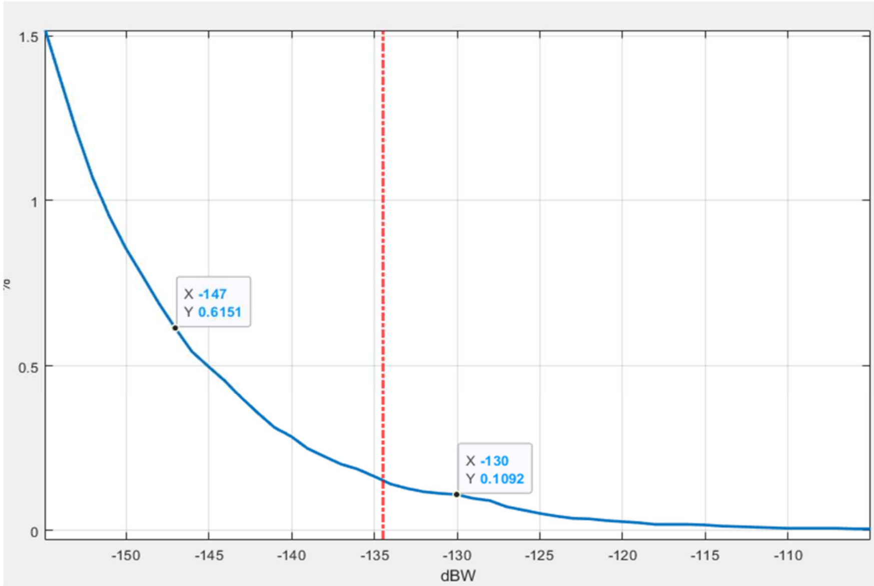
	Minimum amateur station density		Average amateur station density		Maximum amateur station density	
Area setting and population density	**% Impacted RNSS Rx**	**Standard Deviation**	**% Impacted RNSS Rx**	**Standard Deviation**	**% Impacted RNSS Rx**	**Standard Deviation**
Rural	0.163%	0.013%	0.544%	0.043%	4.385%	0.35%
Urban	0.067%	0.006%	0.224%[1]	0.019%	1.779%	0.154%
Dense urban	0.047%	0.002%	0.157%	0.005%	1.249%	0.042%

~~Note 1: The "% impacted" figures in bold can also be identified in the Figure 2 below.~~

Based on the amateur home station and fixed RNSS receiver scenario for the average amateur station density and the urban environment, Figure 2 shows the ~~%~~percentage of impacted receivers having a signal "**greater or equal than x dBW**".

FIGURE 2

The percentage of impacted receivers having a signal greater than or equal to x dBW



~~Based on the amateur home station and fixed RNSS receiver scenario for the average amateur station density and the urban environment, Figure 2 shows the % of impacted receivers having a signal **"greater or equal than x dBW"**.~~

For the average amateur home station density simulation and the urban environment, the protection threshold can be modified accordingly depending on the RNSS antenna gain to read off the impacted percentage of receivers on the y-axis.

3 Fixed Amateur Home Station and Mobile RNSS Receivers Scenario

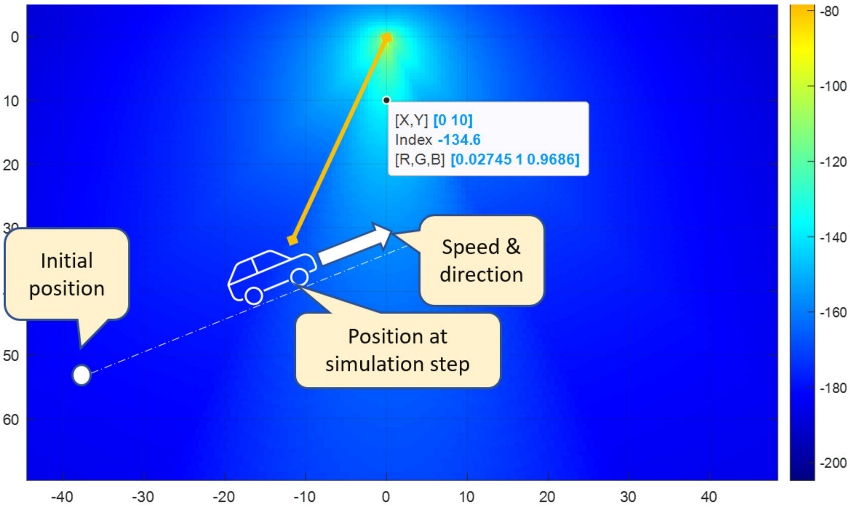
In this section the impact on moving RNSS receivers located in cars is considered. Both the amateur service narrow band emission and amateur service broadband emission with the appropriate interference threshold value are considered.

3.1 Simulation Method

The first simulation step selects random locations for each car according to the vehicle density and simulation area, assigning them a random speed (from 10 to 50 km/h in urban area) and a random direction. Each car then moves along the selected heading for 15 minutes (maximum assumed amateur transmission duration). Every 5 seconds (180 individual time steps in 15 minutes), the received level is computed and compared to the RNSS receiver maximum interference threshold.

FIGURE 3

Mobile RNSS receiver simulation scenario



At the end of each simulation step we compute:

The percentage of "impacted" RNSS receivers that have faced interference above the protection threshold.

This process is repeated 100 times and the mean percentage and standard deviation are calculated and presented in the results.

3.2 Narrow Band Amateur Home Station

3.2.1 Simulation parameters

The same section 2.3 4 simulation parameters were used here with RNSS antenna gain = -6dBi, 0dBi and 3dBi. The following vehicular assumptions were made:

- Car density: 330 vehicles/km^2 (according to ECC Report 351 for the urban case)
- Percentage of cars having an active RNSS receiver during the simulation: 50%
- Speed distribution: uniform, from 5 to 50 km/h,
- Simulated drive path duration for each simulation step: 15 minutes,
- Time step for the drive path: 5 seconds, leading to 180 steps for 15 minutes.

Note: In this simulation, if a RNSS receiver moves outside of the simulation area, it turns around back into the area. Thus the number of RNSS receivers inside the simulation remains constant.

TABLE 3

Number of mobile RNSS receivers placed in each simulation area.

Minimum amateur station density	Average amateur station density	Maximum amateur station density
2,755,500	825,000	103,125

3.2.2 Simulation Results

Mean percentage of mobile RNSS receivers impacted by one fixed narrowband amateur home station:

TABLE 24

Narrow Band Amateur Home Station: Mean Percentage of impacted mobile RNSS receivers and Standard Deviation

a) RNSS Receiver Antenna Gain = -6dBi

	Minimum amateur station density		Average amateur station density		Maximum amateur station density	
Area Setting Parameter	% Impacted RNSS Rx	Standard Deviation	% Impacted RNSS Rx	Standard Deviation	% Impacted RNSS Rx	Standard Deviation
Rural	0.15%	0.002%	0.50%	0.008%	3.94%	0.058%
Urban	0.079%	0.001%	0.27%	0.006%	2.10%	0.046%
Dense urban	0.06%	0.0015%	0.21%	0.0047%	1.67%	0.038%

b) RNSS Receiver Antenna Gain = 0 dBi

	Minimum amateur station density		Average amateur station density		Maximum amateur station density	
Area setting and population density	% Impacted RNSS Rx	Standard Deviation	% Impacted RNSS Rx	Standard Deviation	% Impacted RNSS Rx	Standard Deviation
Rural	0.24%	0.003%	0.81%	0.01%	6.375%	0.077%
Urban	0.123%	0.002%	0.425%	0.007%	3.33%	0.057%
Dense urban	0.096%	0.002%	0.332%	0.006%	2.60%	0.051%

c) RNSS Receiver Antenna Gain = 3 dBi

	Minimum amateur station density		Average amateur station density		Maximum amateur station density	
Area setting and population density	% Impacted RNSS Rx	Standard Deviation	% Impacted RNSS Rx	Standard Deviation	% Impacted RNSS Rx	Standard Deviation
Rural	0.302%	0.003%	1.04%	0.01%	8.163%	0.08%
Urban	0.156%	0.003%	0.537%	0.009%	4.21%	0.065%
Dense urban	0.12%	0.002%	0.417%	0.008%	3.285%	0.055%

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3.3 Broadband Amateur Home Station

3.3.1 Simulation Parameters

The same simulation parameters and vehicular assumptions were used as detailed in section 3.2.1 but in this case using the RNSS receiver broadband interference threshold:

For the amateur service broadband emission:

- Broadband emission bandwidth: 2 MHz (DATV signal)
- Broadband RNSS receiver max interference threshold: –140 dBW/MHz (Ref: ITU-R M.1902-2, Table 1, System 3b).

3.3.2 Simulation Results

Mean percentage of mobile RNSS receivers impacted by one fixed broadband amateur home station:

TABLE 35

Broadband Amateur Home Station: Mean Percentage of impacted mobile RNSS receivers and Standard Deviation

	Average amateur station density	
Area Setting Parameter	**% Impacted RNSS Rx**	**Standard Deviation**
Rural	0.612%	0.008%
Urban	0.325%	0.006%
Dense urban	0.26%	0.01%

4 Permanent Amateur Station and Mobile RNSS Receivers Scenario

In this simulation, the amateur station parameters are changed to those appropriate for a fixed permanent station (repeater station output channel) and the impact on moving RNSS receivers located in cars is considered from both a narrow band amateur emission and a broadband amateur emission.

4.1 Simulation Method

The same simulation method was followed as used in the ~~fixed amateur home station and~~ mobile RNSS receiver scenario in section 3.1.

4.2 Narrow Band Amateur Permanent Station

4.2.1 Simulation Parameters

The following parameters identified in section ~~5~~ 6 of the main report were assumed for the amateur permanent station and the RNSS receivers:

- Average permanent station density = 1 station / 3 333 km^2
- Simulation area: According to the station density = 58 x 58 km
- Transmitter frequency: 1 297 MHz
- Transmitter e.i.r.p.: 25 Watts

- Effective height of the amateur station antenna: 25 meters
- Receiver antenna height: 1.5 meter
- Narrow band receiver max interference threshold: –134.5 dBW (Ref: ITU-R M.1902-2, Table 1, System 3b).
- Receiver antenna gain: –6 dBi, omnidirectional.
- Rec. ITU-R P.1546 'area' parameter: Rural, Urban and Dense Urban
- Rec. ITU-R P.1546 clutter height: 10 m, 20 m and 30 m (according to the rural, urban or dense urban area parameter respectively)
- Location variability: 50%
- Required percentage time: 1%

Vehicular assumptions:

- Car density: 330 vehicles/km^2
- Percentage of cars having an active RNSS receiver during the simulation: 50%
- Number of mobile RNSS receivers placed in the simulation area = 549,945.
- Speed distribution: uniform, from 5 to 50 km/h,
- Simulated drive path duration for each simulation step: 15 minutes,

Time step for the drive path: 5 seconds, leading to 180 steps for 15 minutes.

Note: Again, if a RNSS receiver moves outside of the simulation area, it turns around back into the area. Thus the number of RNSS receivers inside the simulation remains constant.

4.2.2 Simulation Results

Mean percentage of mobile RNSS receivers impacted by one fixed narrow band permanent amateur station:

TABLE 46

Narrow Band Amateur Permanent Station: Mean Percentage of impacted mobile RNSS receivers and Standard Deviation

Area Setting Parameter	% Impacted RNSS Rx	Standard Deviation
Rural	0.24%	0.01%
Urban	0.13%	0.005%
Dense urban	0.1%	0.005%

4.3 Broadband Amateur Permanent Station

4.3.1 Simulation parameters

The same simulation parameters and vehicular assumptions were used as detailed in section 4. 2.1 but in this case using the RNSS receiver broadband interference threshold:

For the amateur service broadband emission:

- Broadband emission bandwidth: 2 MHz (DATV signal)
- Broadband RNSS receiver max interference threshold: –140 dBW/MHz (Ref: ITU-R M.1902-2, Table 1, System 3b).

4.3.2 Simulation Results

Mean percentage of mobile RNSS receivers impacted by one fixed broadband amateur permanent station:

TABLE 57

Broadband Amateur Permanent Station: Mean Percentage of impacted mobile RNSS receivers and Standard Deviation

Area Setting Parameter	% Impacted RNSS Rx	Standard Deviation
Rural	0.68%	0.01%
Urban	0.34%	0.01%
Dense urban	0.26%	0.01%

5 Observations

In the fixed RNSS receivers and static amateur home station case the percentage of impacted receivers in the simulation area population is less than 1% for all the most likely combinations of area setting and amateur station density. One case returns a value of 1.62% but this is considered an unlikely combination of maximum amateur station density and a rural propagation model setting. Generally, the percentage of impacted receivers is higher for the highest amateur station density case but even in the urban setting the percentage is less than 0.5%.

This trend is true also for the mobile RNSS receiver case and the percentages are again higher for the maximum amateur station density case. However in the most likely combinations of area setting and station density, the percentage of impacted receivers in the simulation area population is mostly less than 1%. For an amateur station with an assumed broadband emission, the mean percentage of impacted RNSS receivers for an average amateur station density (based on narrowband station density) remains below 1%.

For the permanent amateur station (narrow band or broadband repeater output channel) and mobile RNSS receiver case only a single average density figure is available. All the mean percentage results for impacted RNSS receivers are less than 1%.

To ensure their statistical validity, the simulations employ a large population of RNSS receivers. The low standard deviation figures provide good confidence in the results. The number of RNSS receivers placed in the simulation area is large enough to obtain a statistically stable result from a reasonable simulation run time.

These results should be considered alongside the operational data estimating the amount of time that amateur stations are actively transmitting. For example, and for narrow band operations this amounts to less than 3% of time across a year.

These simulations do not consider any improvement in interference resilience brought about by frequency offset from the RNSS system centre frequency. In addition, the continuous transmitting time of 15 minutes assumed in the mobile RNSS simulations would be unusually long for a home station although it could be reasonable for a permanent station.

6 Conclusions

This study shows that the percentage of a deployed population of ~~one type of~~E6 Band fixed or mobile RNSS receivers that might suffer interference from either a Home Station or a Permanent Station operating in the amateur service is very low.

ATTACHMENT 2

Proposed text for a new section 10.4

10.4 Impact of Amateur Station Emissions

Using the parameters and operational data in the sections above, simulations have been carried out to assess the impact of certain amateur station emissions on a deployed population of co-frequency RNSS receivers in the E6 band. These simulations are detailed in Annex 9.

This study shows that the percentage of a deployed population of E6 Band fixed or mobile RNSS receivers that might suffer interference from either a Home Station or a Permanent Station operating in the amateur service is very low.

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