CEPT ECC
Electronic Communications Committee SE40

SE40 (meeting #79)

Webmeeting, 17-19 January 2023

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Source: IARU R1

Subject: Probabilistic studies for WI39

Group membership required to read? (Y/N) N

Summary:

Monte Carlo style simulations are presented for a number of amateur transmitter and RNSS receiver scenarios as laid out in this contribution.

Proposal:

SE40 is invited to consider the proposed studies for the WI39 working document given in the Annex 1. The study is proposed as a new section in the draft WI39 report.

Background:

During SE40 meeting #78 it was commented several times that no statistical interference studies had been provided. The meeting was therefore tasked to consider this and how it might be reflected in the report. In this contribution the IARU has provided a statistical Monte Carlo style analysis for inclusion in the WI39 report.

ANNEX 1:

1 PROBALISTIC STUDY

This study aims to assess the probability of interference occurring between a radio amateur station and a population of RNSS receivers around that station. The following scenarios have been considered:

a) Fixed 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 amateur ”Home” station and mobile RNSS receivers, onboard moving cars.
c) Fixed amateur ”Permanent” station (repeater output channel) and mobile RNSS receivers, onboard moving cars.

Each simulation run calculates the signal level received at 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. The simulation is repeated many times until the results converge and stabilise.

In case a) above the RNSS receivers remain fixed but are re-positioned for each run of the simulation. In cases b) and c), 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 statisitics of the impacted receivers can be collated. In the case of the mobile receivers the amount of time as a percentage of the simulation time can be evaluated also.

Initially a static (non-Monte-Carlo) simulation is carried out as a check to validate the parameter assumptions for both the amateur station and the RNSS receivers. In this test case the locations of the amateur and RNSS receivers remains fixed between simulation runs.

1.1 VALIDATION AND STATIC (NON-MONTE-CARLO) SIMULATION

Initially a static (non-Monte-Carlo) simulation is carried out as a check to validate the parameter assumptions for both the amateur station and the RNSS receivers. In this test case the locations of the amateur and RNSS receivers remains fixed between simulation runs.

1.1.1 Protection Distance Validation

The following parameters were assumed:

- Resolution: 500 meters (grid step size)
- P1546 Propagation model (Matlab code provided by ITU (v14 11APR19 Ivica Stevanovic, OFCOM) as available online November the 8th, 2022)
- P.1546 ‘area’ parameter ‘rural’
- P.1546 clutter height: 10m
- Power: 100 Watts
- Antenna: directional, 18 dBi
- Antenna directivity simulated according to Rec. ITU-R F.1336-5; 4.1
- Transmitter frequency: 1297 MHz
- Effective height of the amateur station antenna: 12 meters

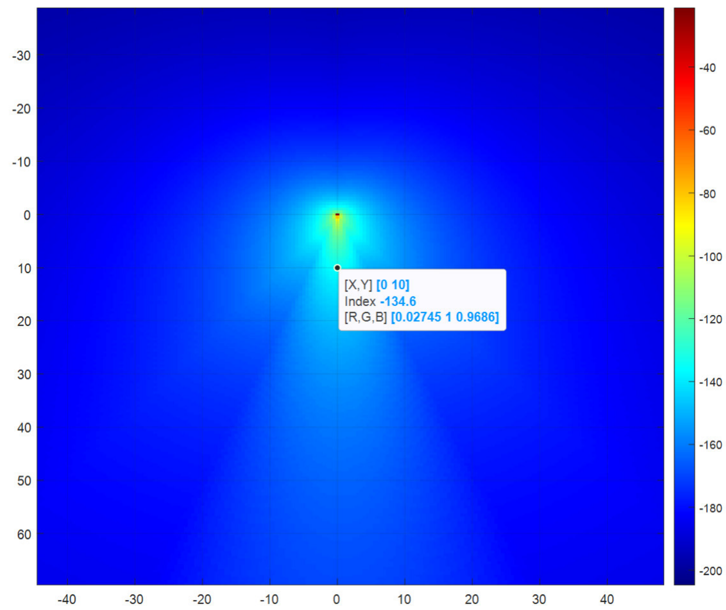

Figure zzz: Static simulation result

In front of the amateur station antenna, in the main lobe: the level is above -134.6 dBW up to 10 km.

1.2 FIXED HOME STATION AND FIXED RNSS RECEIVER SIMULATION

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.

1.2.1 Simulation areas and propagation model parameters

The amateur station density assumed in all simulations:

- Average Home Station and Portable station density = 1 stn / 5000 km^2
- Minimum Home Station and Portable station density = 1 stn / 16,700 km^2
- Maximum Home Station and Portable station density = 1 stn / 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:

- P1546 Matlab code provided by ITU (v14 11APR19 Ivica Stevanovic, OFCOM) as available online November the 8th, 2022.
- Location variability: 50%
- Required percentage time: 1%

1.2.2 Population Density

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

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.

Figure [x]: Population density data extract for France

Three different types of densities are identified:

1. "rural", typically Bourgogne, with a density of 58 habitants / km^2
2. "Urban": Paris & direct suburbs (Ile de France), 1022 habitants / km^2
3. "Average": France average is 119 habitants / km^2

1.2.3 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: 1297 MHz
- Transmitter Antenna gain: 18 dBi
- Transmitter power: 100 Watts
- Effective height of the amateur station antenna: 12 meters
- Receiver antenna height: 1.5 meter
- Receiver max interference threshold: -134.5 dBW
- Receiver antenna gain: -6 dBi, omnidirectional.
- P1546 'area' parameter : Rural, urban and dense urban
- P1546 clutter height: 10m, 20m and 30m (according to the area parameter).
- 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*** is defined as: (Simulation area) * (Population density) * (Use ratio)

1.2.4 Simulation Method

At each iteration step, 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 ITU-R Recommendation 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 impact rate (%) is then defined as **100 * (m / N)**.

The simulation is performed over 1000 runs and ends with 1000 distinct values of the "impact rate", as defined previously.

1.2.5 Simulation Results

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

	Amateur Station Density					
Area setting and population density	Minimum		Average		Maximum	
	% Impacted	S. Dev	% Impacted	S. Dev	% Impacted	S. Dev
Rural	0.07%	0.008%	0.24%	0.029%	1.90%	0.228%
Urban	0.03%	0.004%	0.10%	0.011%	0.78%	0.11%
Dense urban	0.02%	0.001%	0.07%	0.003%	0.54%	0.031%

Table [yy]: Percentage of impacted fixed RNSS receivers and Standard Deviation

1.3 FIXED AMATEUR HOME STATION AND MOBILE RNSS RECEIVERS

In this simulation the impact on moving RNSS receivers located in cars is considered.

1.3.1 Simulation parameters

The same simulation parameters were used here with the addition of the following vehicular assumptions:

- Car density: 330 vehicles/km^2 (according to **Draft 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 “wraps around” back into the area. It means that the number of RNSS receivers inside the simulation remains constant.

1.3.2 Simulation Method

The elementary simulation step consists in selecting random locations for the cars 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 heading direction. Each car is then moving along the selected heading direction for 15 minutes (maximum assumed amateur transmission duration). At each time step, the received level is computed and compared to the threshold.

Number of simulations: 100, each simulating 180 individual time steps (15 minutes/5 seconds).

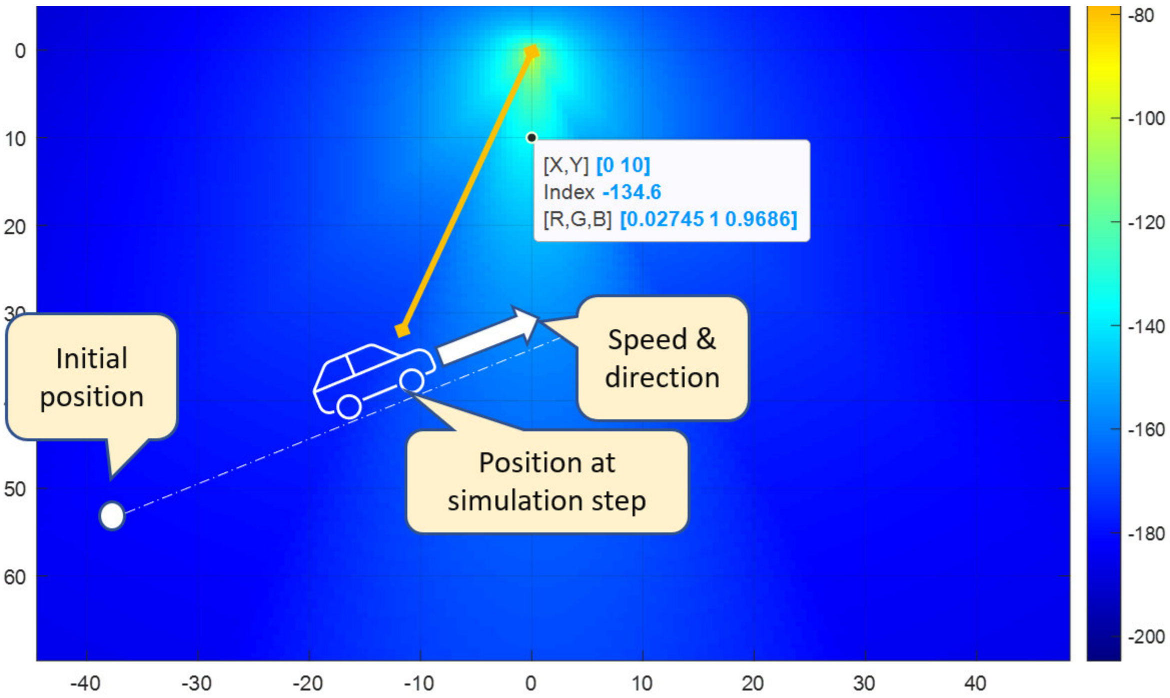

Figure [x]: Mobile RNSS receiver simulation scenario

Then, at the end of each elementary simulation step we compute:

- Number of “impacted” RNSS receivers that have faced interference above the protection threshold,
- For these “impacted” RNSS receivers:
  - The cumulative duration of the interference,
  - The standard deviation

1.3.3 Simulation Results

Percentage of mobile RNSS receivers impacted by one fixed amateur home station

	Amateur Station Density					
Area Setting Parameter	Minimum		Average		Maximum	
	% Impacted	S. Dev	% Impacted	S. Dev	% Impacted	S. Dev
Rural	0.163%	0.003%	0.54%	0.01%	4.33%	0.06%
Urban	0.086%	0.002%	0.29%	0.007%	2.31%	0.045%
Dense urban	0.068%	0.002%	0.23%	0.005%	1.83%	0.037%

Table [xx]: Amateur Home Station and Impacted Mobile RNSS receiver results

When a RNSS receiver is impacted, the percentage of the amateur emission time can be evaluated:

	Amateur Station Density					
Area Setting Parameter	Minimum		Average		Maximum	
	% Time	S. Dev	% Time	S. Dev	% Time	S. Dev
Rural	43.12%	0.43%	43.17%	0.42%	43.15%	0.44%
Urban	32.24%	0.48%	32.1%	0.47%	32.26%	0.54%
Dense urban	28.28%	0.49%	28.22%	0.51%	28.25%	0.50%

Table [yy]: Impacted RNSS receiver time percentage

1.4 PERMANENT AMATEUR STATION (REPEATER OUTPUT) AND MOBILE RNSS RECEIVERS

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.

1.4.1 Simulation Parameters

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

- Average permanent station density = 1 stn / 3333 km^2
- Simulation area: According to the station density = 58 x 58 km
- Transmitter frequency: 1297 MHz
- Transmitter antenna gain: 13 dBi
- Transmitter eirp: 25 Watts
- Effective height of the amateur station antenna: 25 meters
- Receiver antenna height: 1.5 meter
- Receiver max interference threshold: -134.5 dBW
- Receiver antenna gain: -6 dBi, omnidirectional.
- P1546 'area' parameter: Rural, Urban and Dense Urban
- P1546 clutter height: 10m, 20m and 30m (according to the area parameter)
- 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%
- 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 "wraps around" back into the area. It means that the number of RNSS receivers inside the simulation remains constant.

1.4.2 Simulation Method

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

1.4.3 Simulation Results

Percentage of mobile RNSS receivers impacted by one fixed permanent amateur station:

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

Table [gg]: Amateur Permanent Station and Impacted Mobile RNSS receiver results

When a RNSS receiver is impacted, the percentage of the amateur emission time can be evaluated:

Area Setting Parameter	Average	Standard Deviation
Rural	24.54%	0.50%
Urban	15.96%	0.48%
Dense urban	13.49%	0.40%

Table [hh]: Impacted RNSS receiver time percentage

1.5 OBSERVATIONS

In the fixed RNSS receivers and static amateur home station scenario the percentage of impacted receivers in the simulation area population is always less than 1% with one exception. This is the case where the amateur station density is highest (i.e. simulation area smallest) and the propagation model environment is set to "rural" (i.e. lowest clutter height). This seems to make sense as more of the RNSS receivers are closer to the amateur radio transmitter. However even in this case it is still less than 2%. Generally the percentage of impacted receivers is higher for the highest amateur station density case.

This trend is true also for the mobile RNSS receiver scenario and the percentages are again higher for the maximum amateur station density case. In this case up to 4.3% of mobile receivers are impacted and the figures are highest as the density of mobile receivers is the same in all cases but relative to the overall RNSS receiver population, more are closer to the amateur transmitter in the smaller simulation area. In the other amateur station densities the percentage of impacted receivers is always far less than 1%. Interestingly the cumulative time percentage of the impacted RNSS receivers remains nearly the same for all propagation model settings and amateur station densities. This would seem to make sense as the amateur station parameters do not change.

For the permanent amateur station (repeater output channel) and mobile RNSS receiver scenario only a single average density figure is available. The results show smaller impacted receiver and time percentages compared to home station simulations due to the lower transmitter power in this case despite the higher installation height.

In all simulations the low standard deviation figures provide good confidence in the convergence of the results.

However, these simulations have not considered 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 for the mobile simulations is excessive for a home station although it could be reasonable for a permanent station.

The activity factors for the amateur stations need to be considered for a complete picture of the likelihood of interference.