Area Monte Carlo Analysis of Non-GSO ES into 5G BS Using Text Files Macros

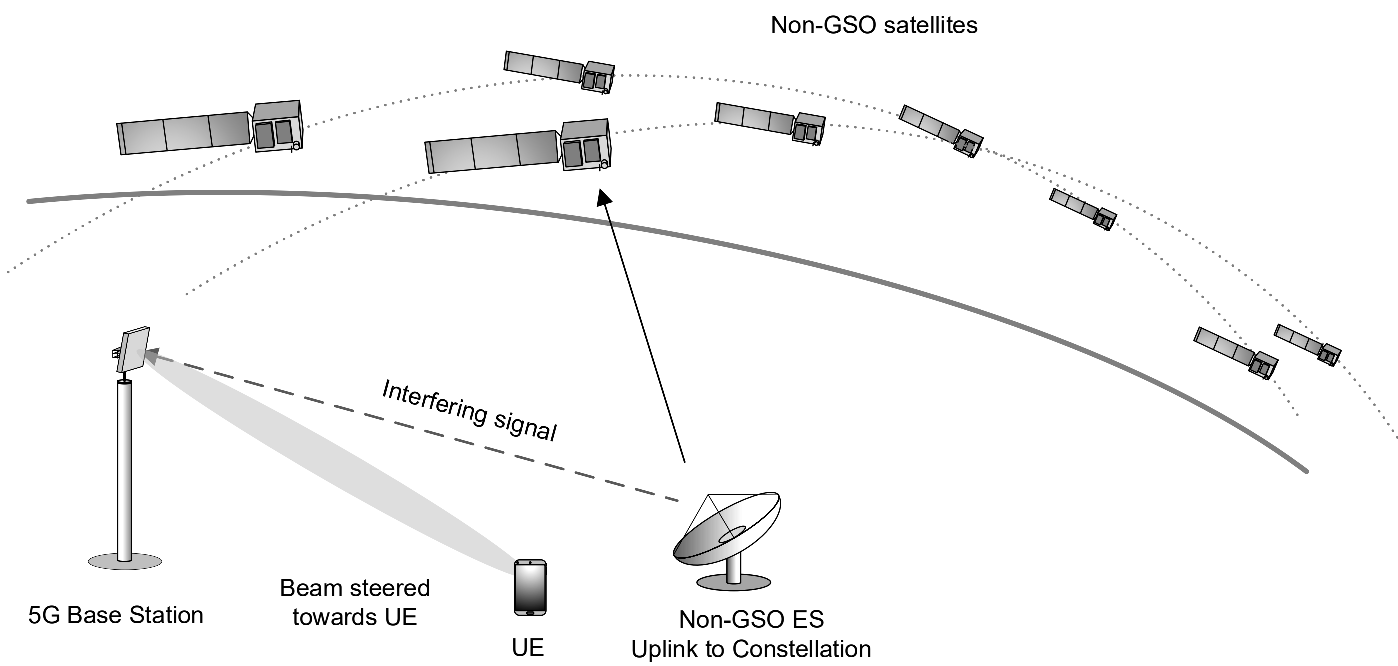
Abstract: The methodology used to undertake interference analysis can make a significant difference to the results. In order to ensure accurate results, it can be useful to avoid worst-case assumption, as is often the case with simple static analysis, and use more detailed modelling techniques. This paper considers the coordination of a non-geostationary orbit (non-GSO) Earth station (ES) with 5G base stations (BS) at 28 GHz considering static vs. area Monte Carlo methodology using the Visualyse Professional tool.

1. Scenario to Model

The scenario under consideration involves the following two systems:

- Non-GSO fixed satellite service (FSS) ES transmitting to a constellation of non-GSO satellites
- 5G base station communicating with a user equipment (UE) within the sector of the BS

Both are operating at 28 GHz and are shown in the figure below.



The parameters in the analysis are given in the sections below.

Note that all parameters have been selected to demonstrate the methodology and are not to be taken as representative of any specific system or sharing scenario.

1.1. Non-GSO ES Parameters

The non-GSO ES system parameters are given in the table below.

Latitude (deg N)	51.5
Longitude (deg E)	0
Height above terrain (m)	5
Dish size (m)	1.8
Efficiency	0.6
Gain pattern	Static analysis: Rec. ITU-R S.580 Monte Carlo analysis: Bessel
Transmit power (dBW/MHz)	-10

The non-GSO ES is communicating with a constellation of non-GSO satellites with the following parameters:

Number of planes	15
Satellites per plane	30
Orbit height	700
Inclination angle (deg)	60
Inter-plane phasing (deg)	6
Minimum elevation angle (deg)	15
Satellite selection	Random

1.2. 5G System Parameters

The 5G system parameters are given in the table below:

BS height (m)	20
UE height (m)	1.5
Sector shape	Hexagon
Sector radius (km)	0.5
Sector azimuth	Towards the non-GSO ES
Receive noise figure (dB)	10
BS gain pattern	Rec. ITU-R M.2101
BS peak gain	23.1 dB

The interference threshold was taken as:

Tr(I/N) = -6 dB for no more than 20% of the time

The interference path considered was from the non-GSO ES into the BS with the interfering signal calculated using the propagation model in Recommendation ITU-R P.2001.

2. Static Analysis

In static analysis, parameters are kept constant, typically at conservative values. For example, static analysis could assume:

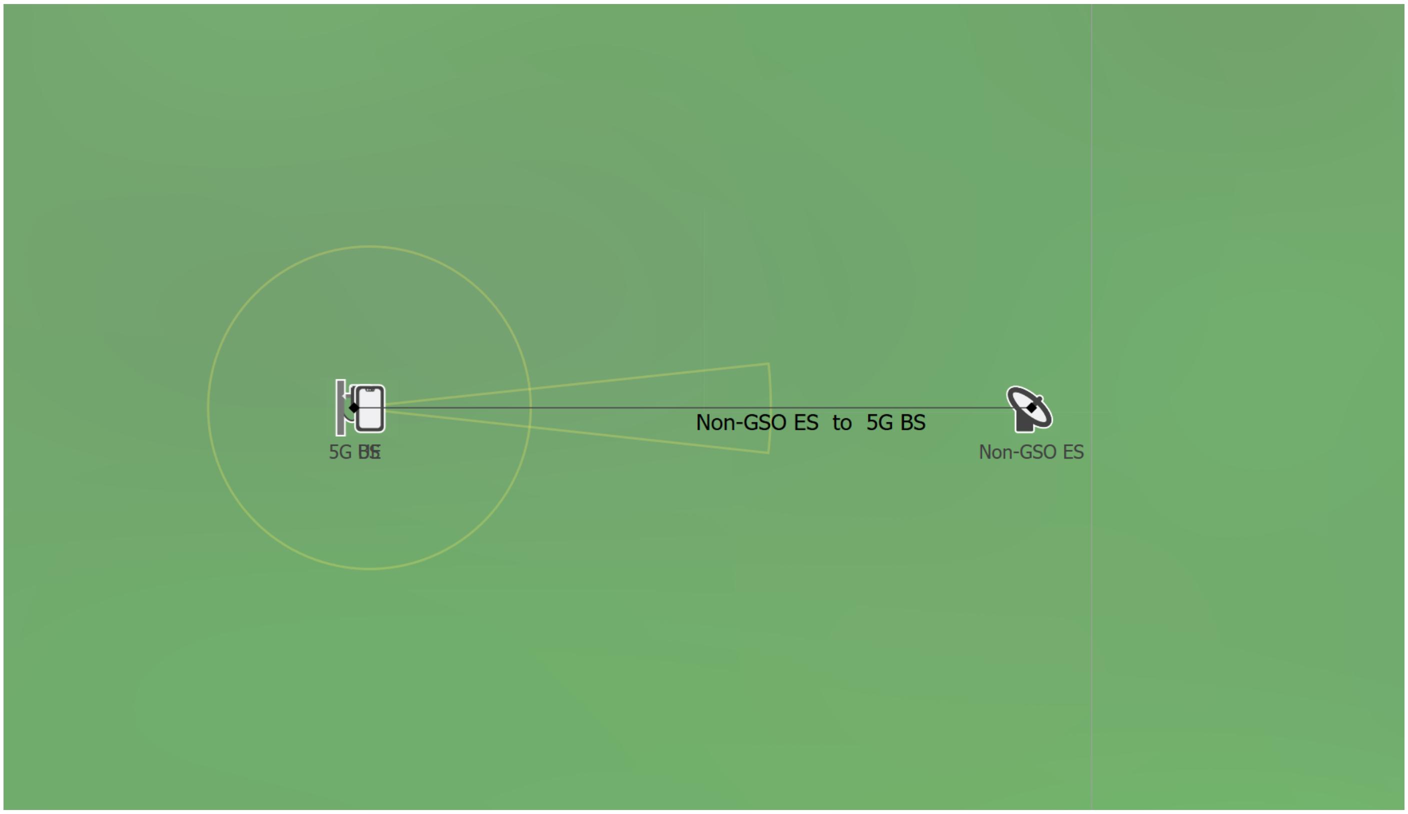
- The non-GSO ES is pointing at its minimum elevation angle in the direction of the BS
- The BS is pointing at the UE location that is most directly aligned with the non-GSO ES.

In addition, there can be assumptions like:

- Use of an antenna gain mask at the ES, in this case the gain pattern in Recommendation ITU-R S.580
- Smooth Earth model without terrain or clutter.

With all other parameters fixed, it is possible to determine the I/N for 20% of time by putting that percentage of time in the propagation model which in this analysis was assumed to be Recommendation ITU-R P.2001.

The BS was then located at the position that resulted in the threshold just being met, as in the figure below.



Here the necessary separation distance was around 18 km, making a total exclusion zone of 1,018 km^2.

This is a large area, but could it be reduced by using more accurate modelling techniques?

3. Detailed Modelling

3.1. Area Monte Carlo Analysis

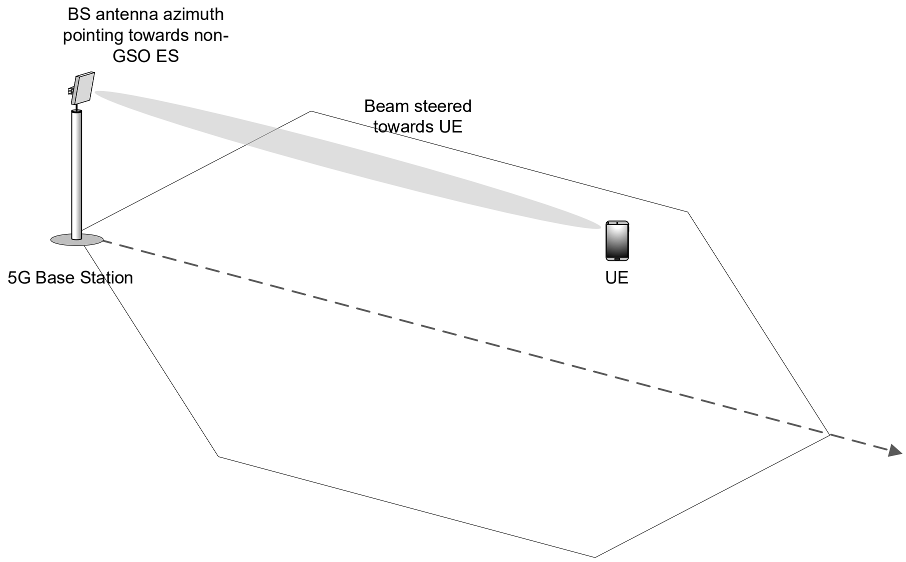
The first step in more detailed modelling, is to use Monte Carlo techniques rather than static analysis. For example, the following factors can be randomised at each time sample:

- The non-GSO constellation is configured at random
- Non-GSO ES randomly select a satellite to point towards of those above the minimum elevation angle
- The UE is located at random within the sector
- The propagation model percentage of time is taken at random.

In addition, more detailed modelling can take account of:

- The actual gain pattern at the non-GSO ES. Without a specific measured data for this study, the Bessel function was used
- The terrain and obstructions (e.g. using a surface database or land use database) in the area around the ES. In this study the SRTM surface database was used.

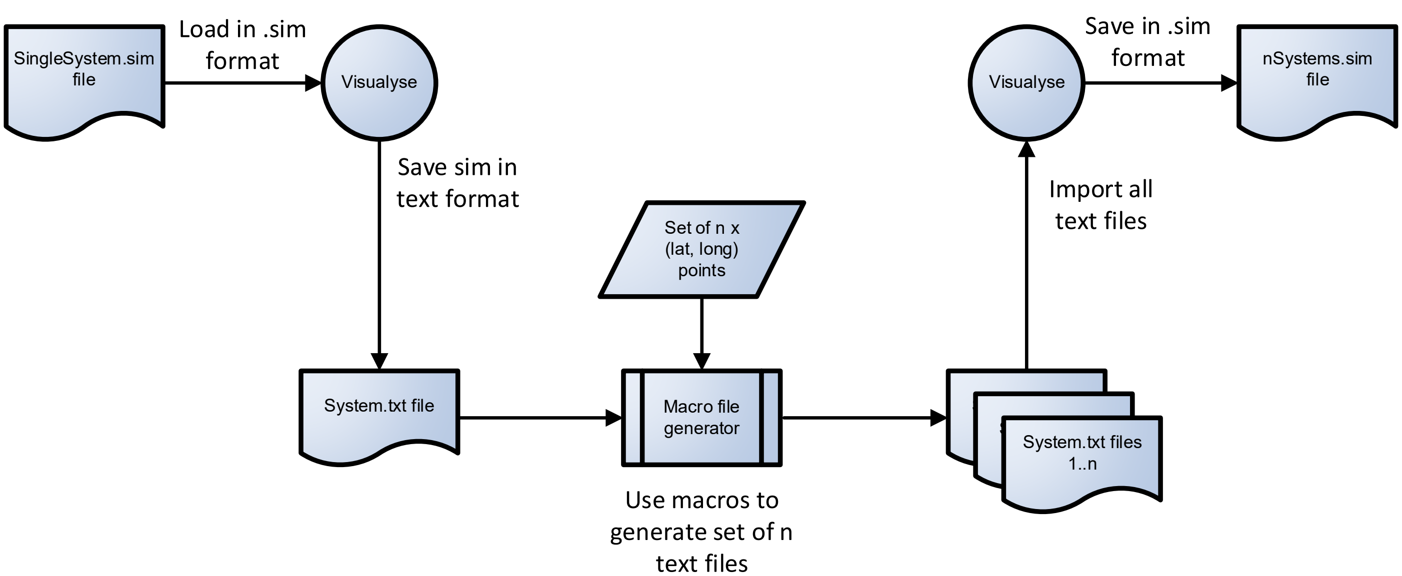
This analysis can be undertaken at a single point but in this scenario, it is more useful to consider how the interference varies across a geographic area, using area Monte Carlo methodology. This involves undertaking a Monte Carlo at a set of points over an area to identify how the likelihood of interference varies. This requires a detailed model at each location, for example, a grid of identical systems, in this case 5G cells as in the figure below:



But how to create a grid of identical systems in Visualyse Professional?

3.2. Creating Arrays of Systems using Text File Macros

It is possible to create a complex scenario involve large numbers of identical systems using the Visualyse Professional text file, using the process shown in the figure below:



The process is as follows:

1) Create a simulation file that defines a single system, in this case a 5G cell as in the figure above
2) Load the simulation file into Visualyse Professional
3) Save this simulation file in .txt format

4) Create a file that defines how the system file should be varied across the area of interest. This could involve a set of (lat, long) points plus also in this case the BS antenna and sector azimuth which should point towards the ES
5) Use a macro to process the single system .txt file to adjust the (lat, long) and other parameters to create a set of n .txt files, one per location
6) These new .txt files can then be individually imported into Visualyse Professional
7) Once all n .txt files are import the file can be saved into a new .SIM Visualyse simulation file.

A text file has sections and fields as in the following extract:

[Header]

Program=Visualyse

Version=710.109

[Simul]

Name=c:\papers\AreaMonteCarloAnalysis\5g_cell.sim

Description=Radio Interference Simulation

Comments=

Run state=Start

Number timesteps=10000.0

Elapsed time=0.0

Random number seed=12345678

This text file can be read into a post-processing set of macros and re-written as required. For example, the latitude and longitude in these fields could be replaced:

[Simul.Station List.5G BS.Start LatLongHeight]

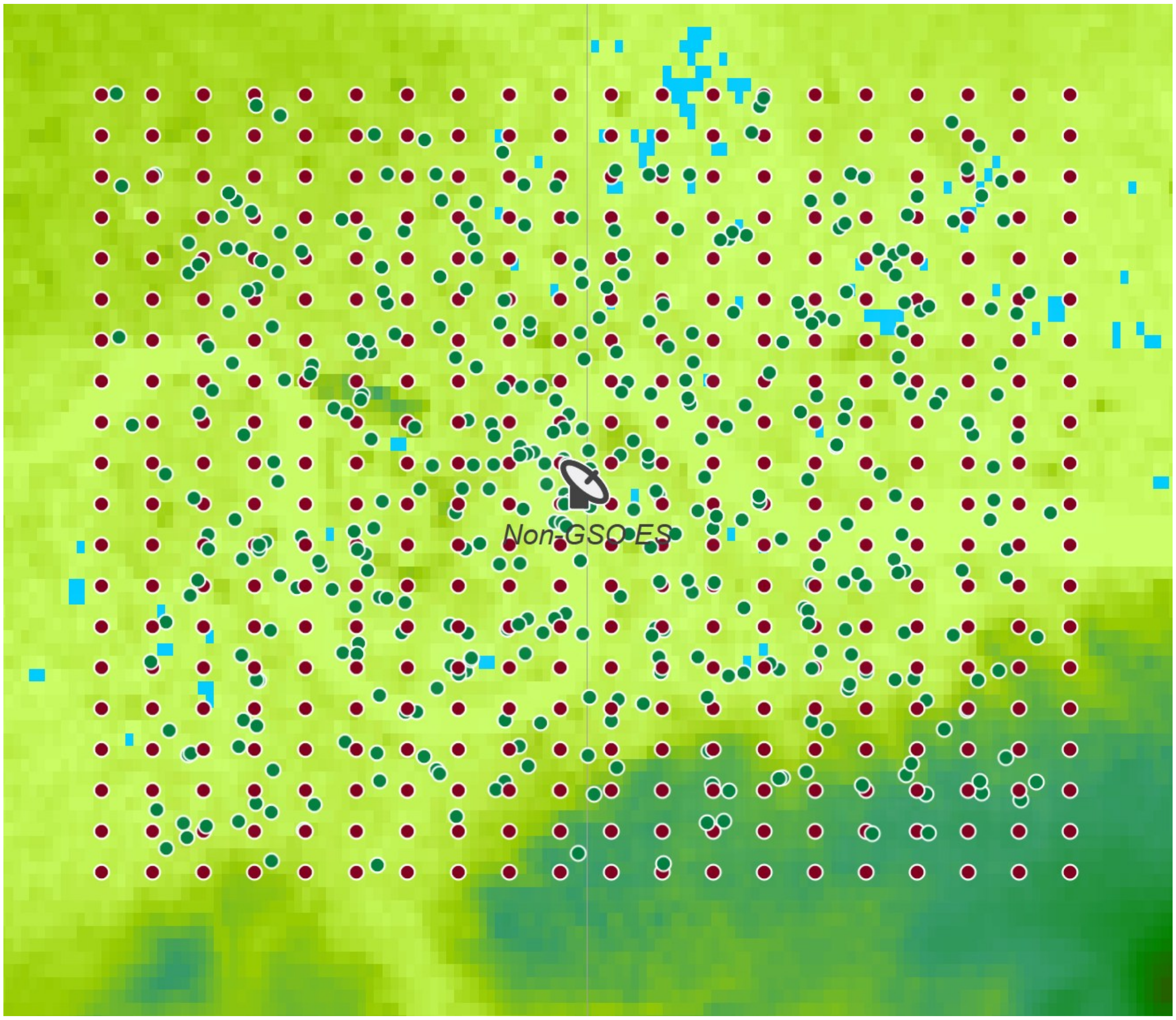
Name=Start LatLongHeight

Description=Start Earth latitude, longitude, height

Latitude=51.3

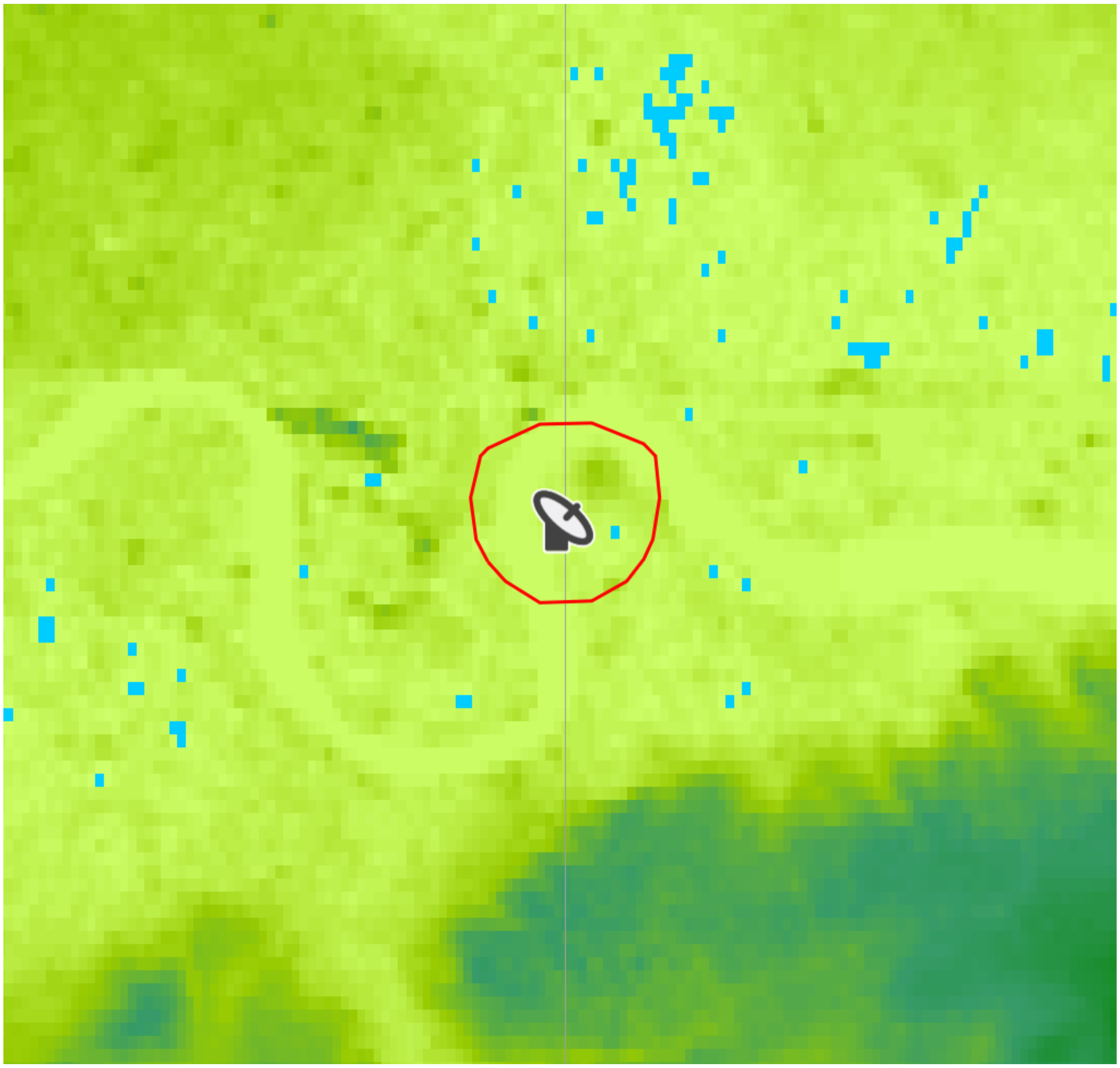
Longitude=-0.482

In this case, the result was a grid as shown in the figure below:



3.3. Output of Area Monte Carlo Analysis

The figure below shows the contour where the Tr(I/N) for 20% of time is met:



The area excluded here is around 1.35 km^2, significantly less than the area excluded using static analysis. If population data had been included, this would have resulted in significantly less population affected by the introduction of the non-GSO ES.

4. Conclusion

This paper has shown how more detailed modelling can facilitate sharing. In this case, the area that could suffer harmful interference around a non-GSO ES reduced from over a thousand square kilometres to just over one.

This paper has also shown how text files and macros can be used in Visualyse Professional to duplicate a system to create arrays and grids which could be used in area Monte Carlo analysis.