Technical support for licensing

Abstract: Spectrum managers are increasingly focused on the impact of new radio systems on spectrum sharing potential and sometimes require detailed technical inputs to be developed as part of their domestic licensing procedures. Technical support for these licence applications is available via our consultancy service and our Visualyse Professional software can be used to generate key inputs.

1. Introduction

Licensing procedures for radiocommunications systems sometimes require detailed technical inputs from the applicant involving aspects of spectrum engineering not always considered during system design. Spectrum sharing and compatibility are now an important feature of domestic spectrum management. This can include software modelling of the radio interference environment and this may involve some speculation about future radio systems.

In our Technical Note we set out some examples of the type of inputs that we have helped to develop for system operators involved in domestic licensing applications. We touch on the design of a practical interference protection criterion, the generation of a receiver contour via an area analysis simulation in Visulayse Professional and the impact of a candidate radio system on the human population.

2. Interference protection criteria

When spectrum managers run frequency assignment and frequency coordination procedures associated with a licensing regime, they often design the interference protection criteria used in the technical calculations. However, some licensing procedures can require the *applicant* to propose and justify an interference protection criterion for their candidate system. Such criteria could be obtained from the literature but a more practical approach can be taken using the candidate system's link budgets which often neglect consideration of interference; this is especially the case if the interference under consideration is sourced to potential future radio systems.

A good example is that of an NGSO satellite downlink with practical link budgets focused on the wanted link's received signal and the ratio between the energy-per-symbol and noise-density at the receiver.

In the first table below, we show an extract from an example 27 GHz NGSO satellite downlink budget with a target energy-per-symbol to noise-density ratio T_{E_s/N_0} of 7.1 dB. With no interference present, the calculated E_s/N_0 delivers a margin $M_{E_s/N_0}$of 0.22 dB.

IRL	Isotropic Receive Level	-169.25	dBW
G/T	Figure of Merit	29	dB/K
R	Symbol rate	80	Msps
M_d	Demodulation margin	2	dB
E_s	Energy per symbol	-221.28	dBW
k	Boltzmann's constant	-228.6	dBW/K-Hz
E_s/N_0	Energy per symbol to noise density ratio	7.32	dB
T_{E_s/N_0}	Target energy per symbol to noise density ratio	7.1	dB
M_{E_s/N_0}	Margin for energy per symbol to noise density ratio	0.22	dB

This example represents a worst-case downlink budget where the satellite is at maximum range and our link margin is already small when there is no interference present. Let us say that we are required to propose an interference protection criterion for the satellite's earth station receiver expressed as I/N. One approach would be to introduce interference such that the link margin remains positive in this worst-case budget. If we introduce a degradation of Noise via an interference margin M_I of 0.14 dB, say, leading to the adjusted link budget given below and assuming that the entire interference margin is utilised, our link margin is reduced to 0.08 dB.

IRL	Isotropic Receive Level	-169.25	dBW
G/T	Figure of Merit	29	dB/K
R	Symbol rate	80	Msps
M_d	Demodulation margin	2	dB
E_s	Energy per symbol	-221.28	dBW
k	Boltzmann's constant	-228.6	dBW/K-Hz
E_s/N_0	Energy per symbol to noise density ratio	7.32	dB
M_I	Interference margin	0.14	dB
$E_s/(N_0+I_0)$	Energy per symbol to noise + interference ratio	7.18	dB
$T_{E_s/(N_0+I_0)}$	Target energy per symbol to noise + interference ratio	7.1	dB
$M_{E_s/(N_0+I_0)}$	Margin for energy per symbol to noise + interference ratio	0.08	dB

We have specified an interference margin M_I = 0.14 dB on the downlink. Then the aggregate interference-to-noise ratio $\Sigma I/N$ at the earth station receiver is calculated using

$$\Sigma\, I/N = 10.\log_{10}\left(10^{M_I/10} - 1\right)$$

which delivers $\Sigma I/N$ = -15 dB.

We should note that the $\Sigma I/N$ derived here is associated with long-term interference and based on an evaluation of a worst-case link budget assuming that interference is present and that $\Sigma I/N$ is satisfied exactly. However, in versions of the link budget assuming a shorter range on the wanted path or with a lower $T_{E_s/(N_0+I_0)}$, the link margin is larger. Our $\Sigma I/N$ is obtained via practical calculations and is not definitive. $\Sigma I/N$ will likely be an important input to technical calculations such as that for a receive contour discussed in the next section.

3. Receive contours

One feature of some contemporary licensing procedures is a requirement for the applicant to provide a receive contour. That is, a contour which captures areas where the candidate receiver's interference protection criterion is exceeded.

The contour allows the licensing authority to evaluate the impact of the candidate receiver in the radio interference environment including the potential for sharing with other services and the impact on the human population regarding access to these services. Hence, a practical approach is required if our aim is to make progress with sharing issues and to demonstrate that the candidate system is not overly burdensome.

A receive contour can be calculated using the area analysis feature in Visualyse Professional. Following on from section 2, we define an NGSO earth station and an interfering station for our area analysis. For our example analysis, the interferer is an IMT base station.

We have no knowledge of future IMT deployment plans but an area analysis allows us to test the presence of an active IMT base station located in each pixel on a regular grid in the neighbourhood of the candidate earth station.

The area analysis tests one pixel at a time which means that we have a single-entry interference model. A key input to the area analysis is the earth station receiver's $\Sigma I/N$ of -15 dB which we must adjust for the single-entry case. For this example we, somewhat arbitrarily, assume that n number of equal interferers dominate ΣI and we calculate a single-entry I/N for $n = 2.5$

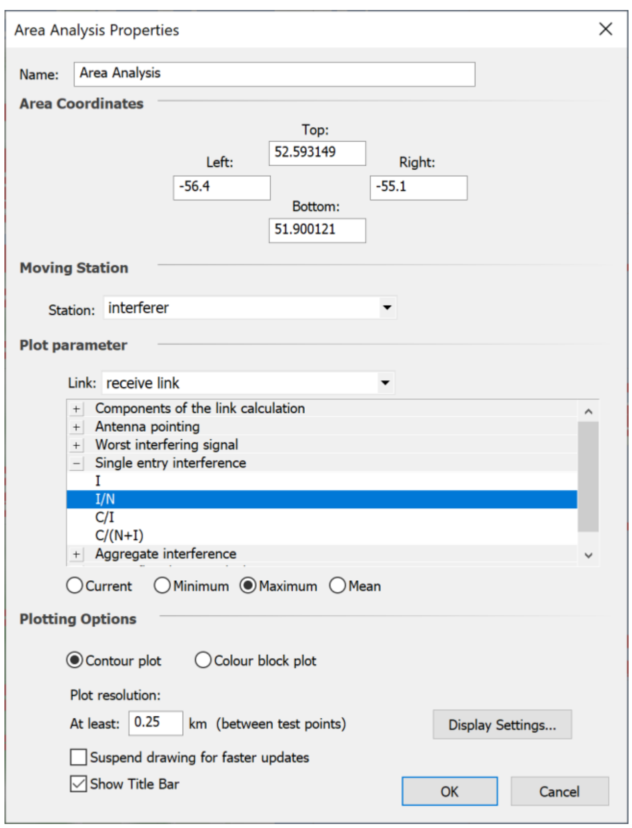
$$I/N = \Sigma I/N - 10.\log_{10}(n)$$

which delivers $I/N = -19$ dB.

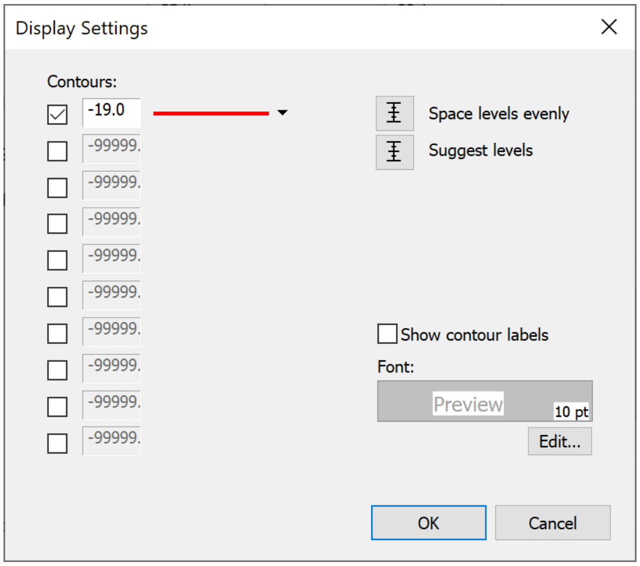
We set out a simplified example in this Technical Note. The table below summarises the key inputs used to characterise the earth station receiver, IMT interferer and radio interference path in Visualyse Professional:

Earth station antenna gain towards IMT interferers	15	dBi
Base Station EIRP towards the earth station	-35	dBW/Hz
Frequency	27	GHz
Interference path losses	ITU-R P.452 (20%)	dB
Surface data	SRTM V3.0 (90 m)	-

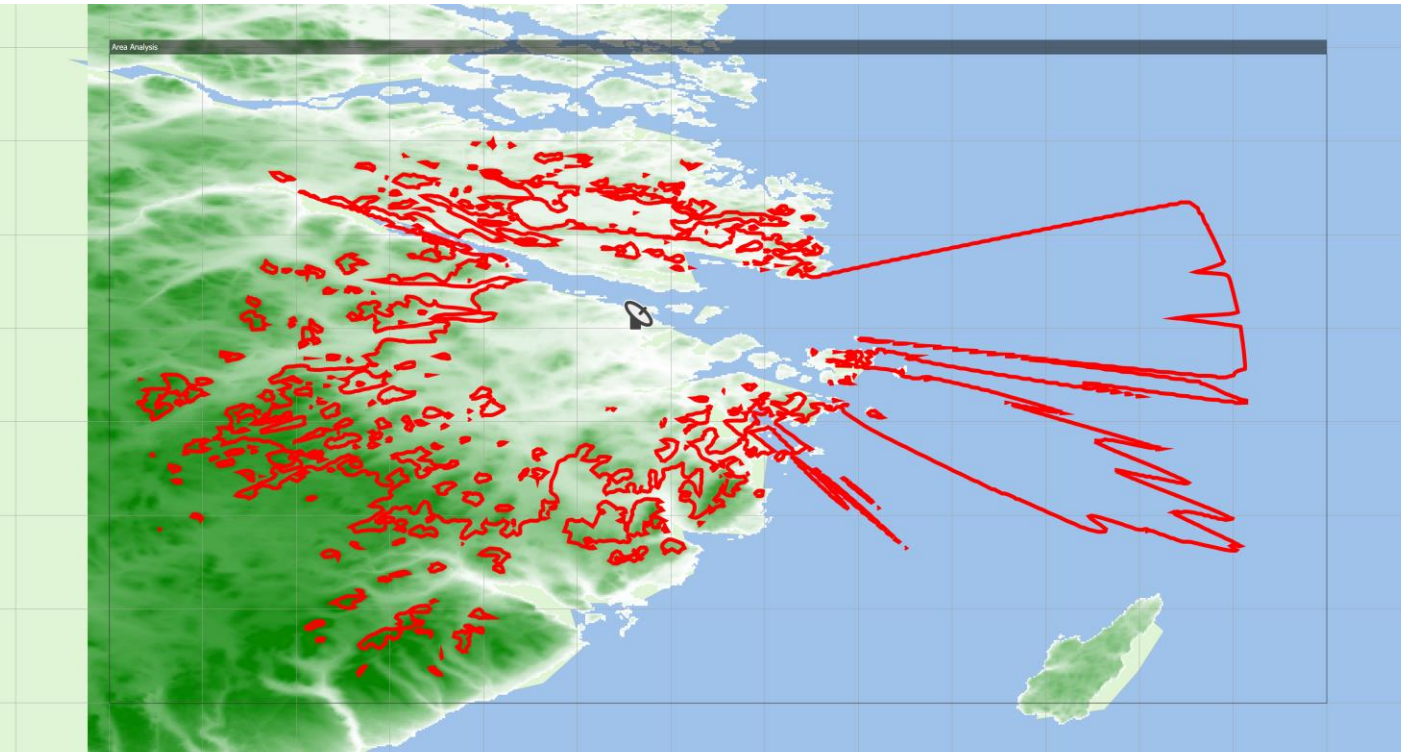
The Area Analysis Properties window shows how the simulation is configured. The area coordinates define the bounds of the area under analysis and the Moving Station is our interferer. At each step in the simulation, interference is sourced to a base station located in one pixel of the area under analysis. The Plot parameter in this case is I/N and we specify a contour plot with Plot resolution set at 0.25 km.



Selecting the Display Settings button in this window allows us to configure the contour. This is set to -19 dB and coloured red. That is, any pixels coloured red or enveloped by the red contour in the area analysis are locations where the presence of the IMT base station leads to excess interference at the receiver.



The output of the area analysis is the contour shown below.



Our example illustrates an initial, worst-case, assessment and there is scope to refine this model. Additional inputs and further study effort would likely include consideration of:

- Clutter losses at the earth station receiver and/or at transmitter locations

- A detailed model of earth station antenna gain towards the horizon at each azimuth. For an NGSO link this model can be built by logging antenna gains at each azimuth as the earth station antenna tracks its target satellites.
- Antenna discrimination at the Base Station antenna. This can be calculated via Monte Carlo simulations where a population of base stations equipped with electronically steerable antennas point towards a randomly positioned user within their cell sector and the gains towards the earth station are logged.
- Simulations to determine the ratio of worst-interferer-to-aggregate interference sourced to the population of base stations. This ratio can be used to calculate the single-entry I/N more precisely.

The contour could be used by the spectrum manager to protect the receiver from excess interference. However, they may specify constraints such as the dimensions of the contour in order to encourage a more practical approach towards spectrum sharing. Hence, the emphasis may be on satisfying these constraints whilst ensuring that the receiver has adequate protection rather than on generating a large receive contour that would protect the receiver with a sizeable margin but that could impact unnecessarily on the deployment of other services.

4. Impact on the human population

Spectrum managers sometimes consider the impact of radio systems on the human population. For a receive contour, such as that shown in section 3, this means counting the human population captured by the contour. The data may then be used to assess the impact of the receive contour on the population's access to other radio services, for example.

Visulayse Professional is able to capture the human population covered by a contour and this can then be exported via a CSV file.

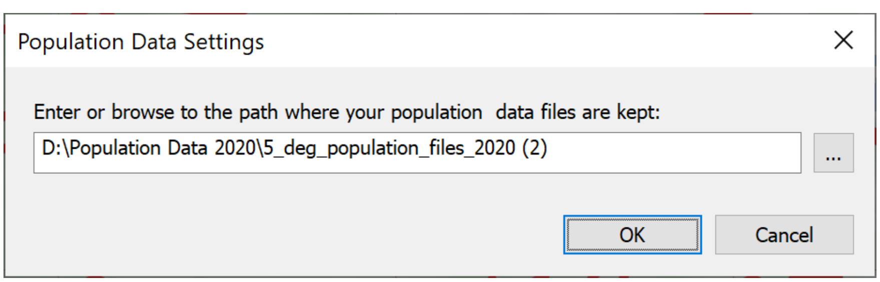
The population data made available by Transfinite Systems is the NASA gridded population of the World (GPW). This gives the population in each 30 arc-second pixel over the Earth's surface from 60°S to 85°N. Other data sources may be used from time-to-time in our consultancy work.

Two versions of the NASA data are made available by Transfinite Systems: data for 2015 and data extrapolated to 2020. These can be downloaded from our web site:

https://www.transfinite.com/population/5_deg_population_files_2015.zip

https://www.transfinite.com/population/5_deg_population_files_2020.zip

Having downloaded the relevant zip, the files should be extracted into a directory on your PC. This directory can then be selected in Visualyse Professional, use the menu option "File | Population Data Settings" as shown:



We can then export the population data by right clicking in the Visualyse Professional simulation file and selecting "Export Population Data". A CSV file with the data can then be saved to a suitable location by the user.

In our example, the human population captured by the contour is 623.9 . As discussed in Section 3, the spectrum manager may impose constraints on the receive contour and this could include a constraint on the human population impacted by the contour.

More information about the use of population data can be found in our Technical Note: *Using Population Data in Visualyse Professional*.

Email us at info@transfinite.com for further information or to give your views on this Technical Note

5. About Transfinite

We are one of the leading consultancy and simulation software companies in the field of radiocommunications. We develop and market the leading Visualyse products:

- Visualyse Professional
- Visualyse Interplanetary
- Visualyse GSO
- Visualyse EPFD and associated PFD Mask Generator Tool

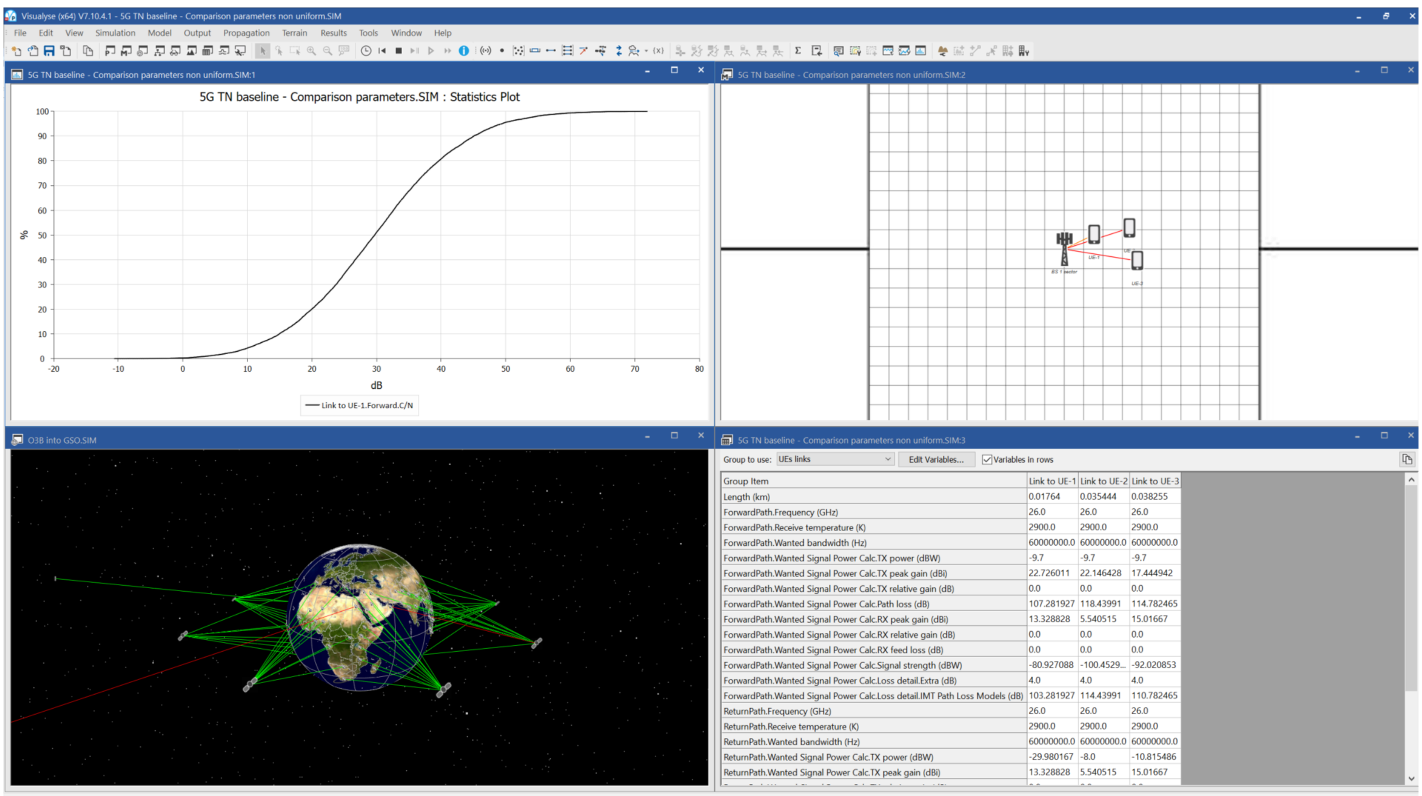
These are described further below.

5.1. Visualyse Professional

Visualyse Professional is a flexible study tool able to model a very wide range of radiocommunications systems that can be used to analyse system performance including the impact of interference. Visualyse Professional can model transmit and receive stations located at fixed positions, mobile stations, aircraft, ships and also satellite systems including Earth stations, geostationary orbit, GSO satellites, non-GSO satellites and highly eccentric orbit (HEO) satellites.

It can be configured to analyse spectrum sharing scenarios using a wide range of methodologies, including static, input parameter variation, area, dynamic, Monte Caro and combinations such as area Monte Carlo.

Visualyse Professional includes a wide range of advanced features to enable it to analyse both co-frequency and non-co-frequency scenarios, the impact of terrain or clutter, the impact of traffic and complex handover strategies between satellites. These features allow it to model anything from a 5G network to a non-GSO mega-constellations such as SpaceX's Starlink or OneWeb. An example screenshot of Visualyse Professional is shown below:



5.2. Visualyse Interplanetary

The objective of Visualyse Interplanetary is to extend the simulation ability of Visualyse Professional to allow:

1. Modelling of stations around other celestial bodies including the Moon and Mars
2. Enhance the geometric framework with a more detailed description of the Earth's shape and rotation characteristics.

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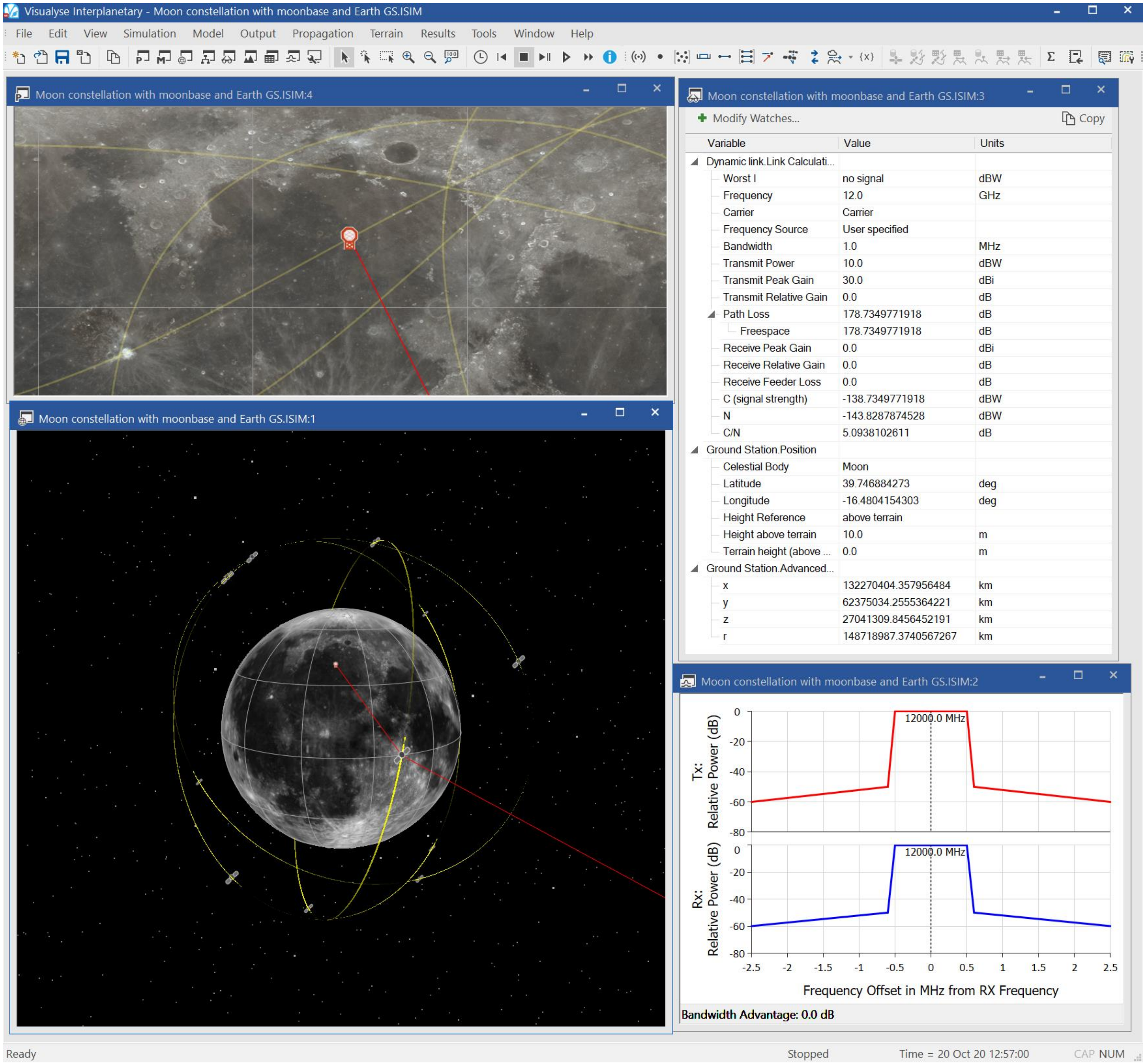
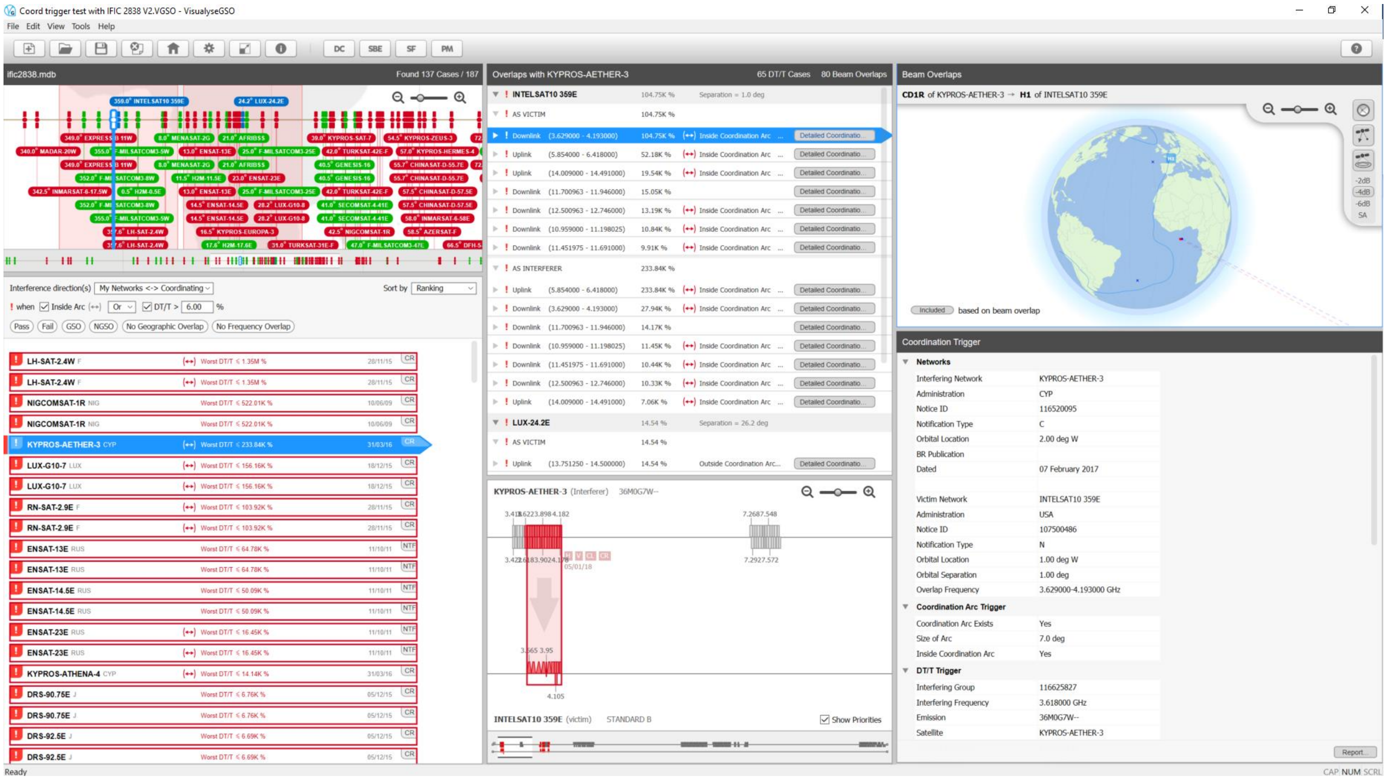
An example screenshot of Visualyse Interplanetary is shown below:



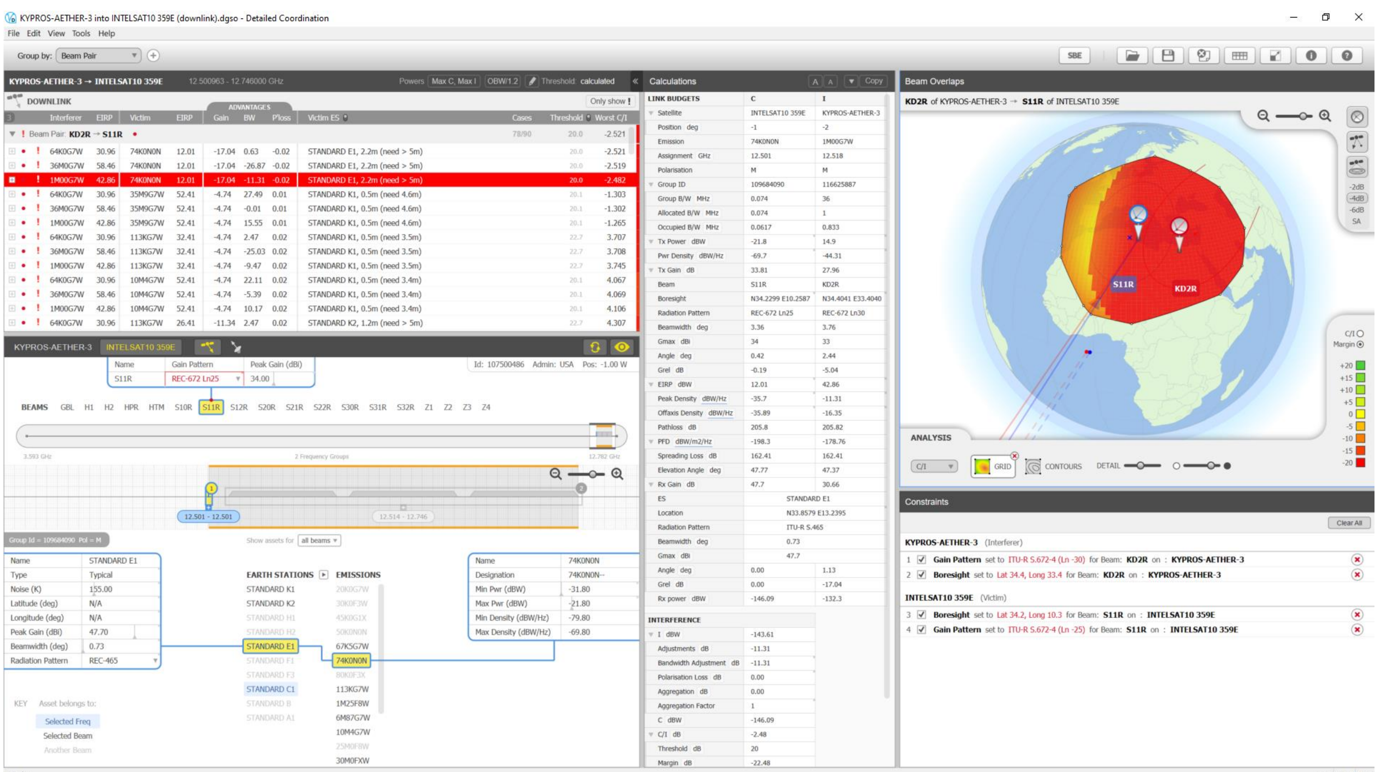
5.3. Visualyse GSO

We have developed Visualyse GSO to support satellite coordination tasks, in particular for GSO satellites. It includes IFIC checking functionality, detailed C/I calculation tool and integrates with ITU databases such as the SRS/IFIC and GIMS.

The IFIC checking is designed to identify the coordination requirements of both GSO and non-GSO satellites.



The figure above shows the IFIC checking coordination trigger tool while the figure below shows the Visualyse GSO detailed coordination tool.



5.4. Visualyse EPFD

Our Visualyse EPFD software is the leading implementation of the algorithm in Rec. ITU-R S.1503. It has been verified during testing with the ITU BR and can calculate:

- EPFD (Up)
- EPFD (Down)
- EPFD (IS)

It can also analyse both the Article 22 and Articles 9.7A and 9.7B cases.

It is available in two versions, one the ITU's "black-box" for pass/fail decisions and the other a product with graphical user interface that provides feedback on the calculation process and allows additional options to be modified.

The Visualyse EPFD software is also capable of undertaking analysis using the methodology in Resolution 770 and includes methods being proposed for inclusion in a revision to Recommendation ITU-R S.1503, such as the Alpha Table Methodology. A screenshot is provided in Section 6.

An additional tool, the PFD Mask Generator Tool is available to assist in the generation of PFD masks, as described in Section 6.

5.5. Training Courses

We also provide training courses in the use of our products including advanced training that can cover modelling of specific systems and scenarios, as non-GSO satellite coordination.

5.6. Consultancy Services

We can provide a wide range of consultancy services using our world-leading experts and software tools to rapidly generate solutions, including:

- Interference analysis and spectrum sharing studies
- Coordination support and meeting representation
- ITU-R and CEPT meeting representation and support
- Strategic consultancy to achieve regulatory goals.

5.7. Contact Us

More information about these products and services is available at our web site:

https://www.transfinite.com

If you have any questions or comments about this Newsletter or would like more information, please do not hesitate to contact us at:

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