Resolution 770 After WRC-23

Abstract: The World Radiocommunication Conference (WRC) in 2019 approved Resolution 770 which can be used to determine whether non-GSO FSS systems operating in parts of Q/V band meet the requirements of Article 22 to protect GSO networks. The Resolution included parameters of generic links and an algorithm to calculate the increase in unavailability and loss of throughput due to interference, which could then be compared against the 3% limits in Article 22.5L. During the cycle from WRC-19 to WRC-23, this algorithm was examined further and, while found to be basically sound, minor adjustments were made. This Technical Note (TN) describes these changes and the new regulatory framework.

Background

In response to WRC-19 Agenda Item 1.6, that conference approved Resolution 770:

> *Application of Article 22 of the Radio Regulations to the protection of geostationary fixed-satellite service and broadcasting-satellite service networks from non-geostationary fixed-satellite service systems in the frequency bands 37.5-39.5 GHz, 39.5-42.5 GHz, 47.2-50.2 GHz and 50.4-51.4 GHz.*

This defined an algorithm to calculate how interference from a non-GSO system could result in higher levels of unavailability and lower levels of throughput in a GSO network. This could then be compared against the thresholds in Article 22.5L:

> *22.5L A non-geostationary-satellite system in the fixed-satellite service in the frequency bands 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space) shall not exceed:*
>
> *– a single-entry increase of 3% of the time allowance for the C/N value associated with the shortest percentage of time specified in the short-term performance objective of the generic geostationary-satellite orbit reference links; and*
>
> *– a single-entry permissible allowance of at most 3% reduction in time-weighted average spectral efficiency calculated on an annual basis for the generic geostationary-satellite orbit reference links using adaptive coding and modulation. (WRC-19)*

During the cycle from WRC-19 to WRC-23, this algorithm was examined, and while found to basically sound, minor adjustments were made. In addition, the revised algorithm was documented in a new Recommendation, namely:

> *Recommendation ITU-R S.2157-0: Procedures for the evaluation of interference from any non-geostationary-satellite system into a global set of the generic geostationary-satellite reference links in the frequency bands 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space)*

At WRC-23, this Recommendation was then incorporated by reference into a revision to Resolution 770 (WRC-23) and the algorithm removed. This allowed the Recommendation to be updated at the ITU-R Study Group (SG) level rather than requiring a full WRC cycle to update.

This Technical Note describes in overview the algorithm in Resolution 770 and the changes made in the Recommendation ITU-R S.2157.

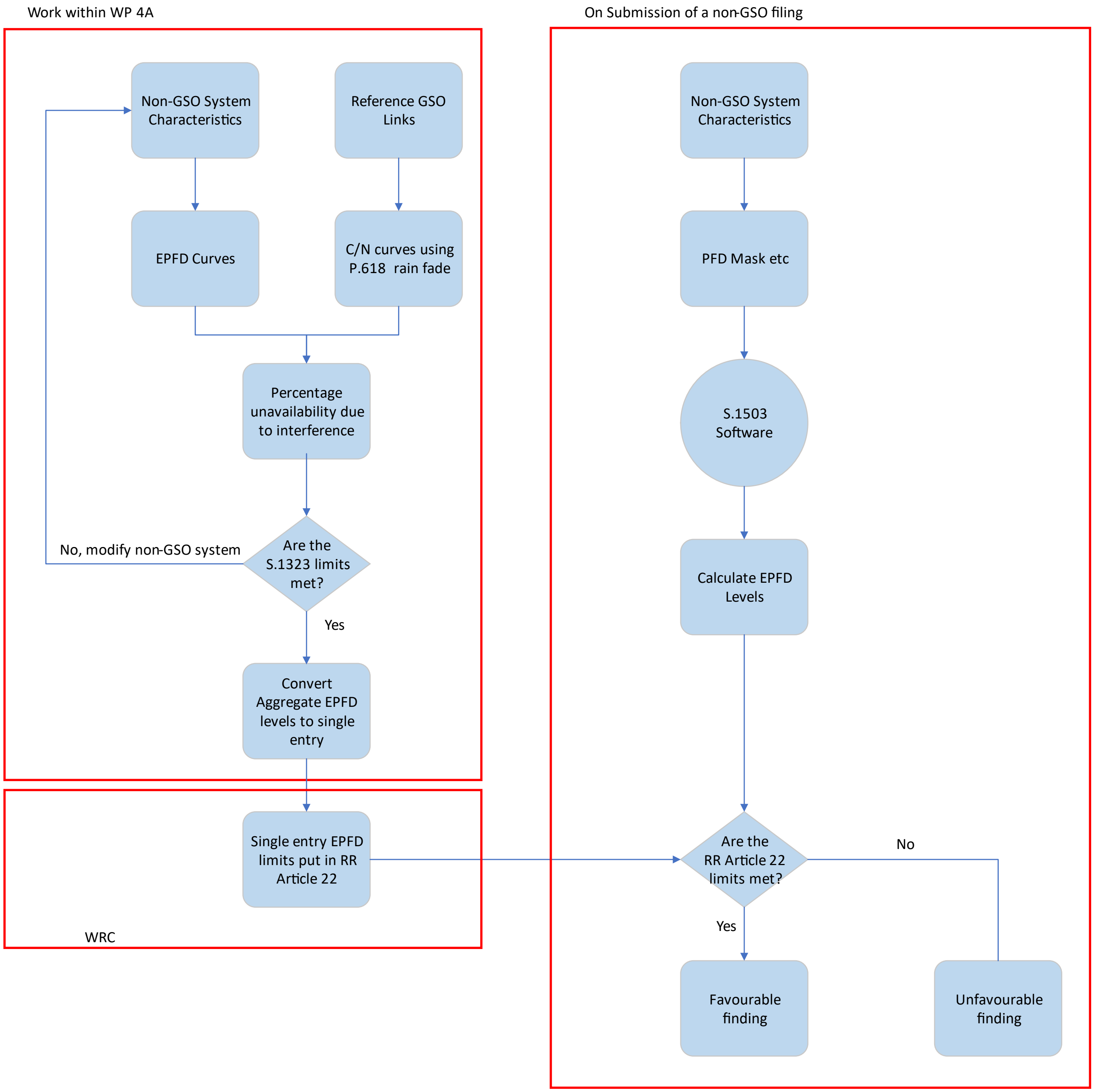
These revisions have recently been used to update the Visualyse EPFD software tool, described further later in this TN.

Context and EPFD

In parts of C, Ku and Ka band there are Equivalent Power Flux Density (EPFD) limits to protect GSO networks from harmful interference from non-GSO systems. The EPFD is statistical in nature and calculated using the algorithm in Recommendation ITU-R S.1503.

During the cycle leading up to WRC-19, ITU-R Working Party (WP) studied how such protection of GSO from non-GSO could be implemented at the higher Q/V band frequencies, such as 37 – 51.4 GHz. One approach would have been to introduce new EPFD limits for these frequency bands, but that was rejected as the EPFD curves can be system specific and accepting one could introduce technological bias. In addition, there are some differences in modelling at these higher frequencies, in particular that the rain fades are greater. Finally, since the original EPFD limits had been implemented, there was now greater knowledge and understanding of the sharing scenario.

The original EPFD limits, developed during the WRC-97 to WRC-2000 cycle had been developed based upon the following framework:



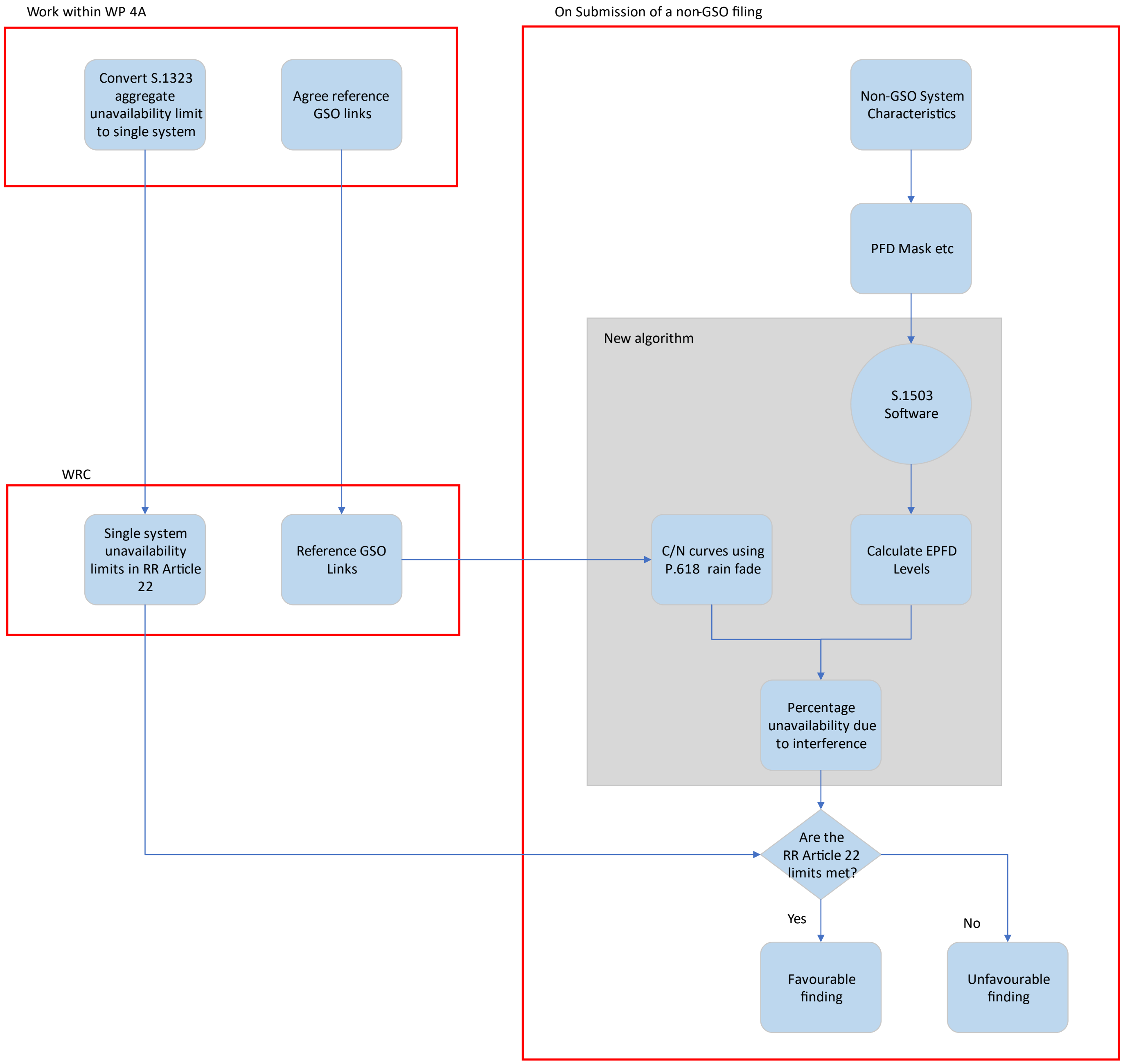
The main steps were:

1. A set of reference GSO links were developed by WP 4A from which C/N cumulative distribution functions (CDFs) were calculated using the rain model in Recommendation P.618
2. The non-GSO operators proposed candidate aggregate EPFD limits, again as CDFs.
3. The C/N CDF and EPFD CDF were convolved together to derive the C/(N+I) CDF
4. From this the percentage of unavailability due to interference could be calculated and compared against the 3% limit in Recommendation S.1323.

5. The candidate aggregate EPFD limits which met this limit for all reference GSO link and was acceptable to all was converted then into single entry EPFD limits and agreed at WRC-2000 to be included in Article 22[1]
6. When a non-GSO system filing is submitted, the BR then calculates the EPFD it would generate using software that implements the algorithm in Recommendation ITU-R S.1503
7. If the EPFD is less than that in Article 22, the filing would receive a favourable finding, otherwise unfavourable.

This process has been used successfully by the BR to check filings in parts of C, Ku and Ka band since WRC-2000.

The Resolution 770 Algorithm



The process used in the algorithm in Resolution 770 is fundamentally very similar but with the components re-arranged.

[1] Note that the aggregate EPFD limits were included in Resolution 76 which included the N_{sys} = 3.5 factor used to convert between aggregate and single system EPFD limits.

Whereas the C, Ku and Ka band EPFD limits were derived from a database of GSO reference links, this wasn't feasible in Q/V band as there was much less experience in operating in these bands. Hence the approach taken was to develop generic links which iterated over a range of link attributes such as:

- Latitude
- Elevation angle
- Height of ES
- Rain height
- Rain rate
- Receiver noise
- Etc.

As some combinations might not be feasible, there was an initial step that verified that a specifc generic link was valid, in particular:

- That the resulting probability of rain was within the limit $0.001\% \leq p_{rain} \leq 10\%$
- That the rain fade margin was at least 3 dB.

If the generic link was valid, then the C/N CDF was derived using the rain model in Recommendation P.618.

During the examination of non-GSO system, the EPFD calculated using the algorithm in Recommendation ITU-R S.1503 could then be convolved with this C/N distribution to calculate:

- The increase in unavailability
- The decrease in average spectrum efficiency.

These could then be compared with the thresholds in Article 22.5L.

Hence, the algorithm was similar to that used to derive the EPFD thresholds but more of the steps were done at the later stage during the examination of a non-GSO system. While the structure of the EPFD calculation (e.g. Appendix 4 parameter and algorithm in Recommendation ITU-R S.1503) continued to be used, there were no constraints on the shape of the EPFD curve that could bias the algorithm towards specific non-GSO systems. What was retained was the requirements to protect GSO networks, with the unavailability metric complemented by the decrease in spectrum efficiency.

There were some differences in the underlying algorithm. In particular for the downlink direction, it was assumed that there was full correlation between rain fades for the wanted and interfering links, as suggested by SG 3.

Algorithm Changes in Recommendation ITU-R S.2157

The algorithm in Resolution 770 was reviewed between WRC-19 and WRC-23 and found to be fundamentally sound. A few minor changes were suggested during work within WP 4A. Some were trivial, such as the need to specify a value for the speed of light.

Others related to the use of the propagation model in Recommendation ITU-R P.618, such as:

- The calculation of P_0, the probability that there will be rain, is determined via the P_0 parameter. This requires both latitude and longitude be available, but for the generic links only latitude is specified
- For very small percentages of time, the rain loss CDF can be non-monotonic
- In practice, it is very hard to get unavailabilities of p = 0.001% for Q/V band GSO links.

Another issue was that the calculation of throughput based upon the equations in Recommendation ITU-R S.2131-0 which did not have a maximum spectrum efficiency, which is unrealistic.

These issues were considered and addressed in Recommendation ITU-R S.2157. For example:

- $c = 2.99792458 \times 10^5$ km/s.
- The resulting probability of rain is checked to be within the changed range of $0.01\% \leq p_{rain} \leq 10\%$

- A table of p_{min} and p_1 are defined for each of the generic links in Resolution 770 based upon the specific frequencies of 37.5 GHz (downlink) and 47.2 GHz (uplink).
- A method is defined to calculate rain loss taper up to the 10% point:

$A_{rain}(p_{min})$	$0\% \leq p \leq p_{min}$
$A_{rain}(p)$	$p_{min} < p \leq p_1$
$A_{rain}(p_1)\ (\log_{10}(p)-1)/(\log_{10}(p_1)-1))$	$p_1 < p \leq p_{max}$
0 dB	$p_{max} < p \leq 100\ \%$

- The calculation of throughput was updated to the equations in Recommendation ITU-R S.2131-1 which does include a maximum spectrum efficiency.

The result is an algorithm that is clear, unambiguous and implementable.

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 EPFD
- Visualyse Professional
- Visualyse Interplanetary
- Visualyse GSO.

These are described further below.

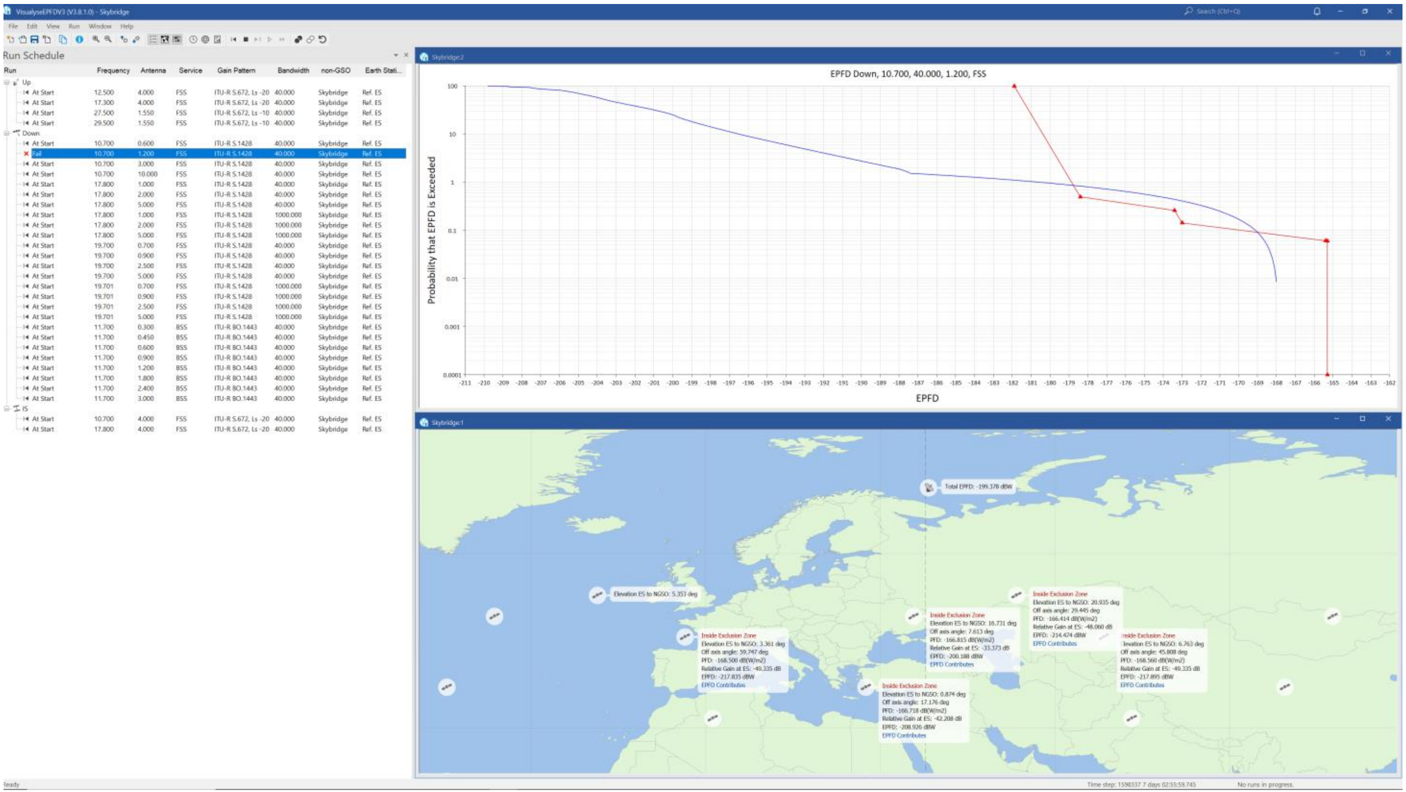
Visualyse EPFD

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:

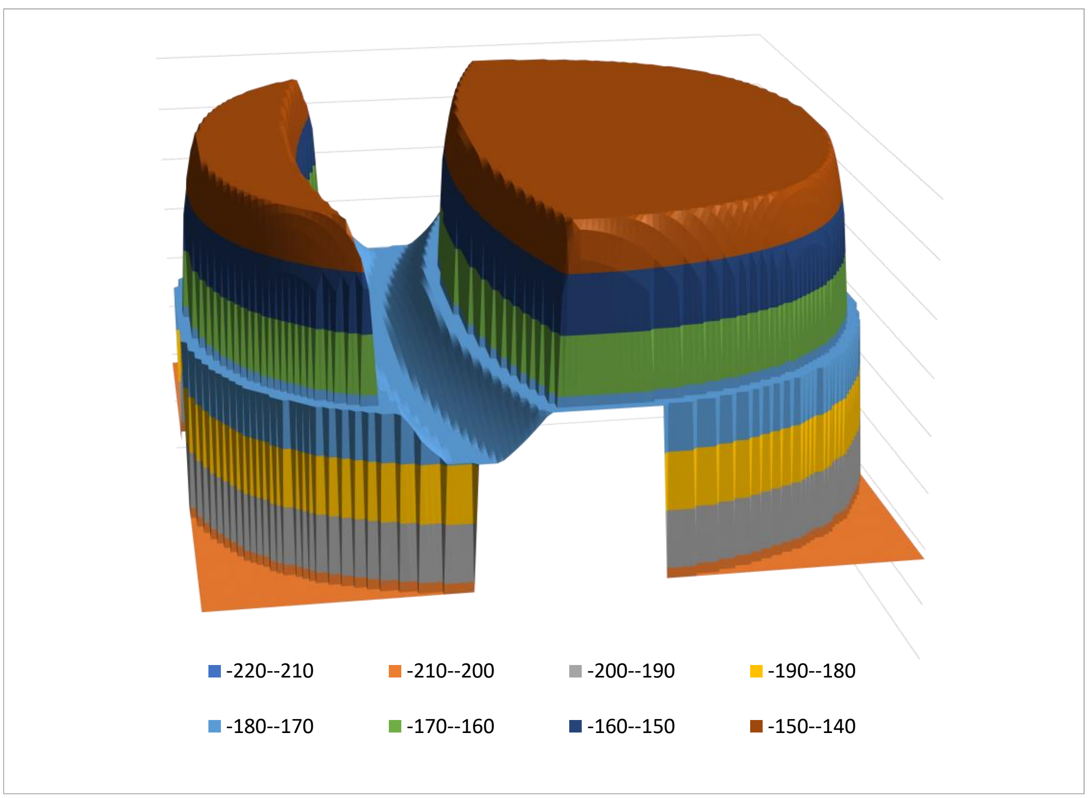
- EPFD (Up)
- EPFD (Down)
- EPFD (IS)

It can also analyse both the Article 22 and Articles 9.7A / 9.7B cases and also undertake Resolution 770 analysis using the algorithm in Recommendation ITU-R S.2157.

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.



An additional tool is available to assist in the generation of PFD masks:

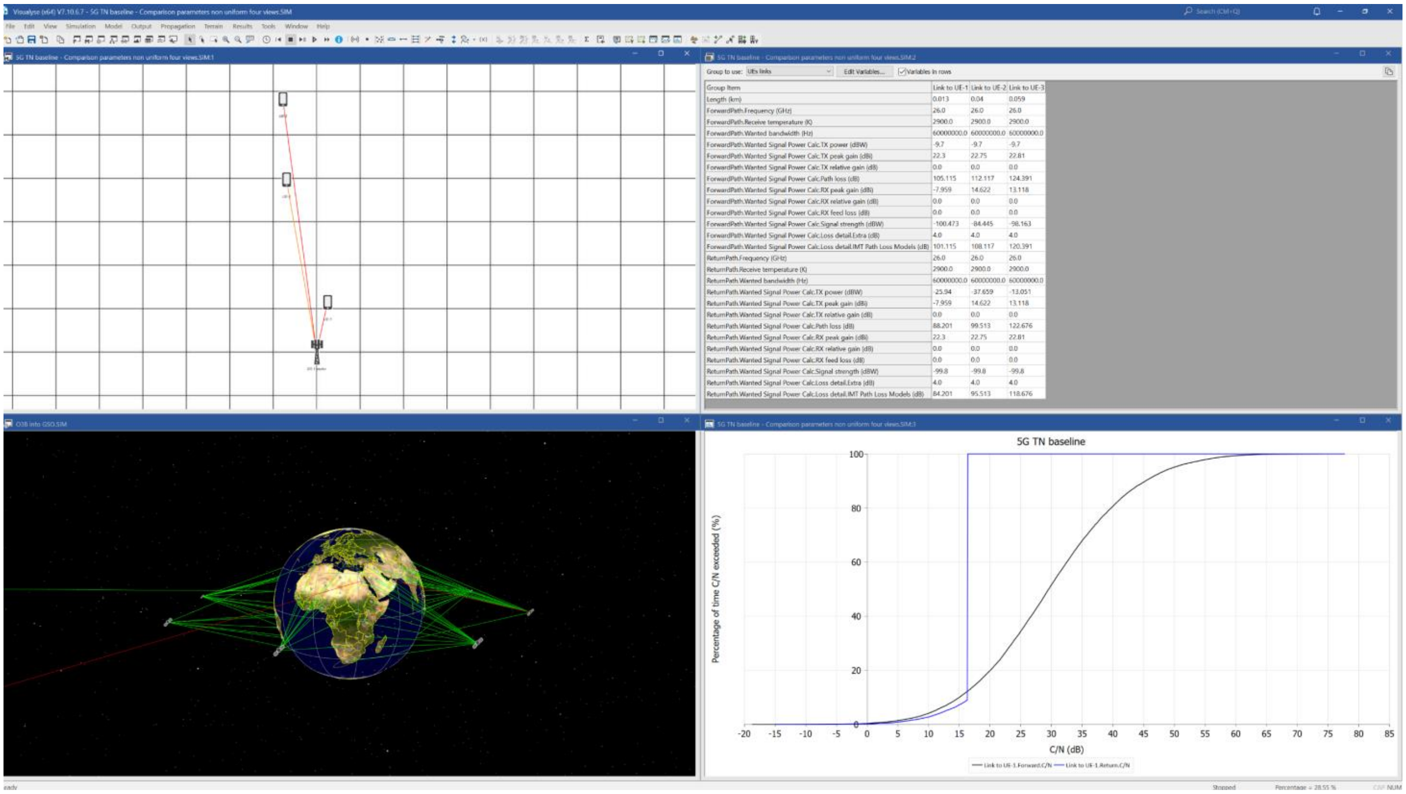


Visualyse Professional

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:

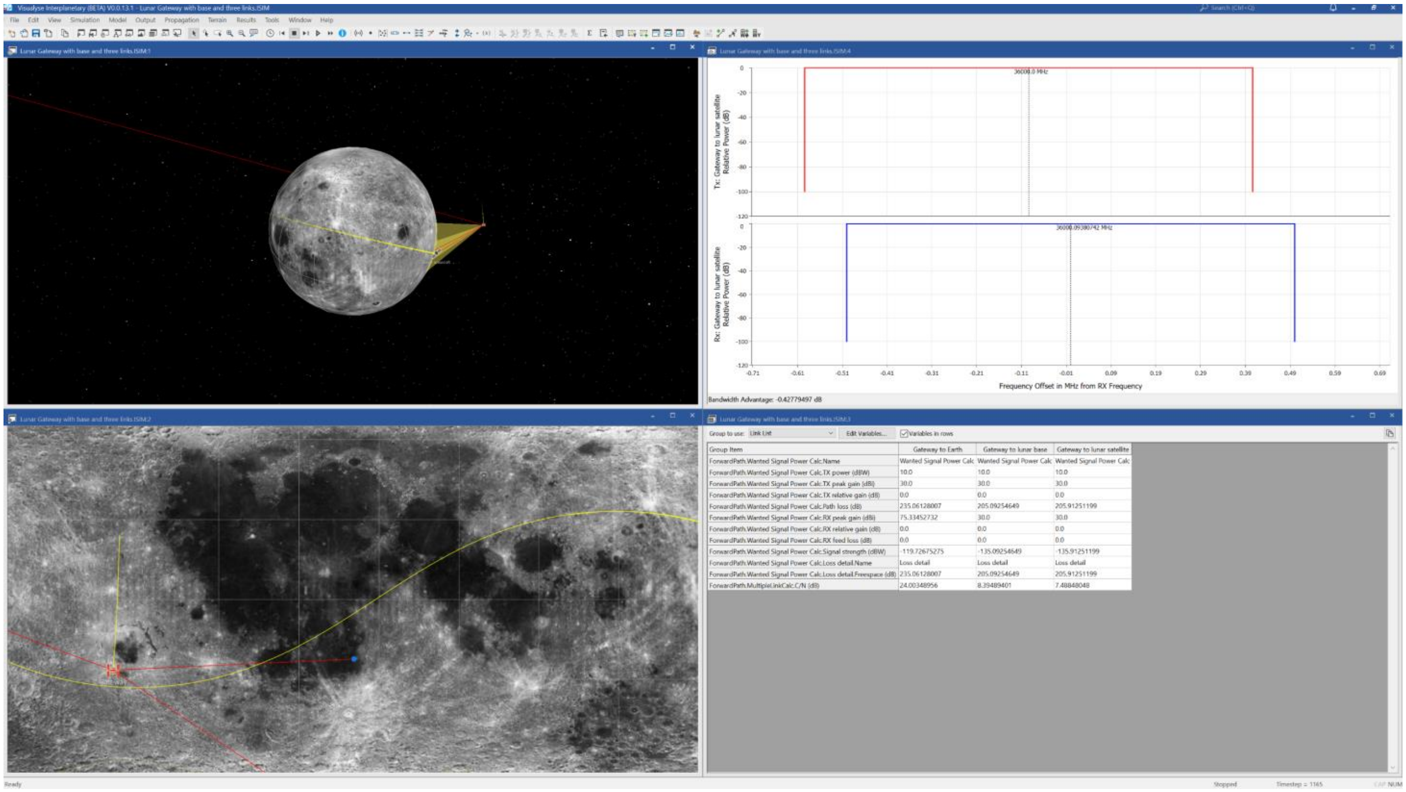


Visualyse Interplanetary

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

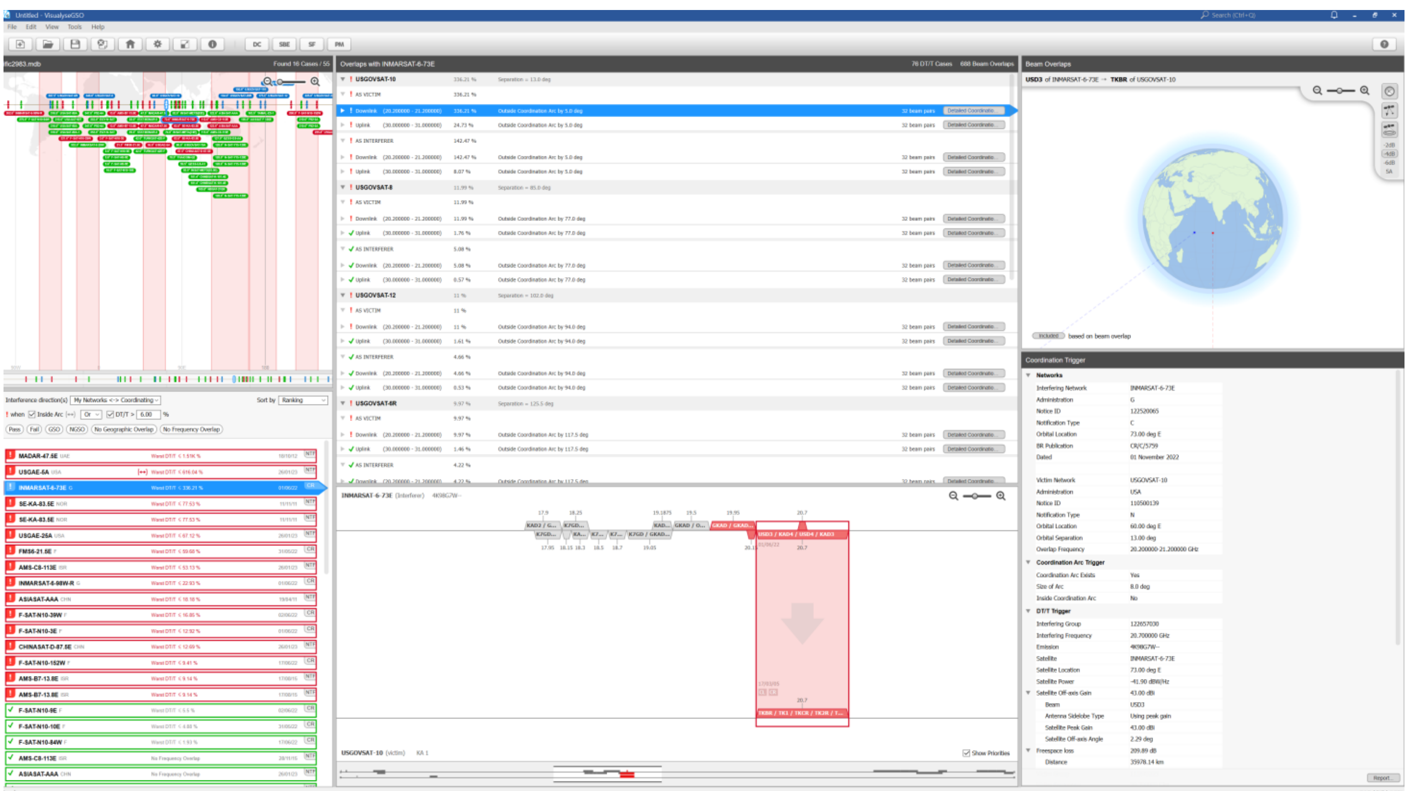
1. Modelling of stations around other celestial bodies including the Moon and Mars
2. Enhance the geometric framework with a more detailed description of the Earth's shape and rotation characteristics.

An example screenshot of Visualyse Interplanetary is shown below:



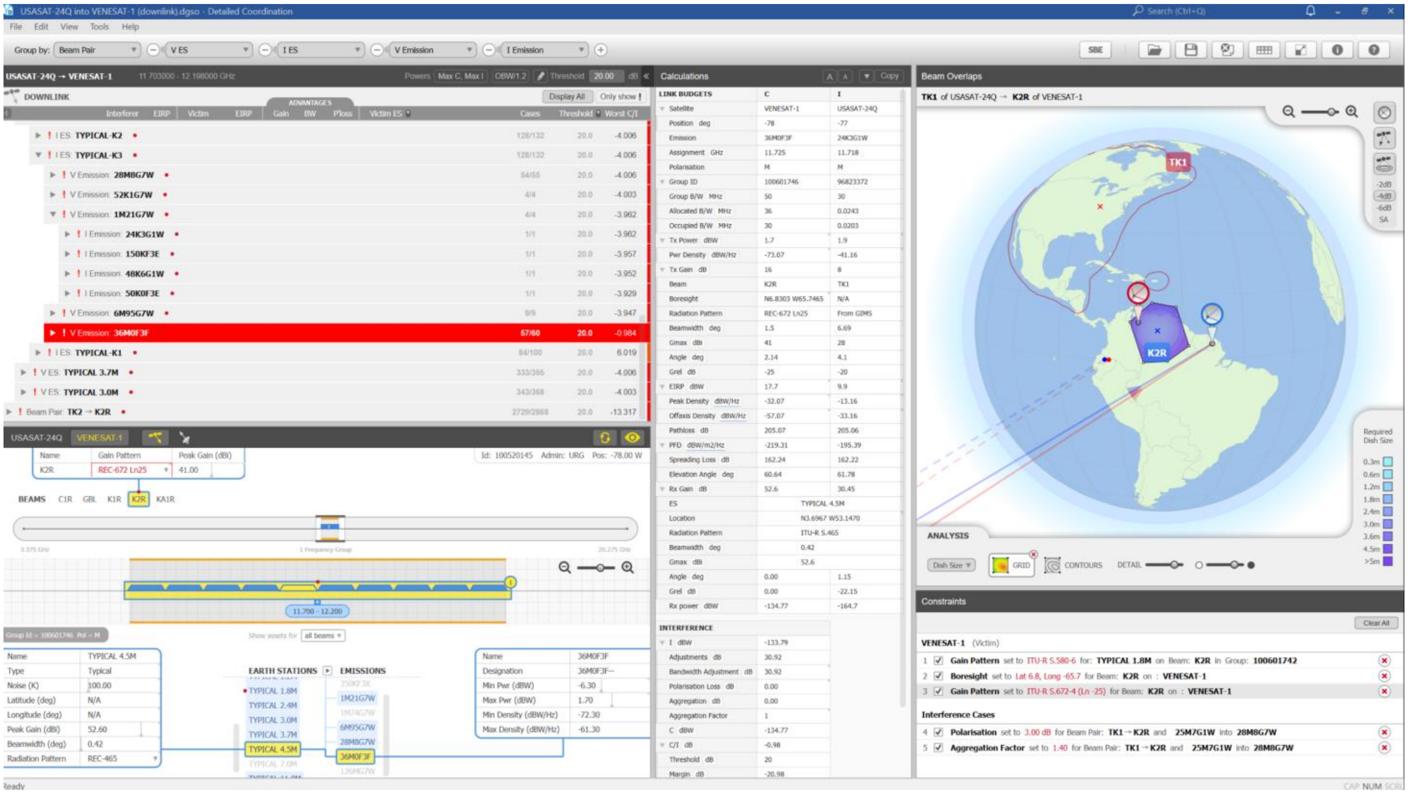
Visualyse GSO

We have developed Visualyse GSO to support satellite coordination tasks, in particular for GSO satellites. It includes IFIC checking, detailed C/I calculations and integrates with ITU databases such as the SRS/IFIC and GIMS. It can be also used to identify coordination requirements of non-GSO satellites.



The figure above shows the coordination trigger tool while the figure below shows the detailed coordination tool.

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



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.

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.

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:

info@transfinite.com