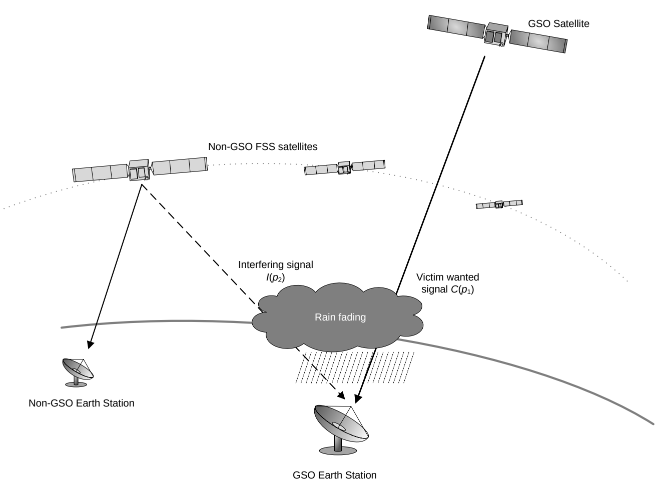
Technical Note: Application of Recommendation ITU-R S.1323 Thresholds in Visualyse Professional

Abstract: A key question when analysing radio spectrum compatibility is whether the interference levels are harmful or acceptable. This requires selection and application of a suitable threshold which can be agreed between parties, for example one based upon work done at the ITU-R. For time invariant interference into the fixed satellite service there are thresholds in Recommendation ITU-R S.1432 based upon the I/N at the receiver, but what approach should be used for time varying interference? One approach that can be used to model time varying interference between fixed satellite service networks is given in Recommendation ITU-R S.1323, and this document addresses how Visualyse Professional can be configured to use them.

Introduction

This Technical Note (TN) describes how to apply the thresholds in Recommendation ITU-R S.1323-2 to simulations using Visualyse Professional.

The scenario used to demonstrate this feature relates to WRC-19 Agenda Item 1.6, namely development of a regulatory framework for non-GSO fixed satellite service (FSS) systems in Q/V band, as shown in the figure below.



This TN builds on a previous TN on "Managing Correlation Between Propagation Path"[1] in which a non-GSO and GSO system are operating their downlinks co-frequency in a similar region.

The question is:

- How to determine whether the interference from the non-GSO system into the GSO system is harmful or acceptable?

The basis of the analysis in this TN will be to use the thresholds in Recommendation ITU-R S.1323-2.

Recommendation ITU-R S.1323

This Recommendation has the title:

> *Maximum permissible levels of interference in a satellite network (GSO/FSS; non-GSO/FSS; non-GSO/MSS feeder links) in the fixed-satellite service caused by other codirectional FSS networks below 30 GHz*

It contains a number of thresholds to take account of various aspects of a system performance that must be protected, including short term, long term and also decrease in capacity.

In particular it contains the following Recommends:

Short Term Threshold:

> *5 that for a non-GSO (non-GSO/FSS; non-GSO/MSS feeder links) network in frequency bands subject to RR No. 9.11A (which is not subject to the limits in RR Nos. 22.5C, 22.5D and 22.5F), the internetwork interference caused by the aggregate emissions from the earth and space stations of all GSO FSS networks operating in the same frequency band should:*
>
> *5.1 be responsible for at most 10% of the time allowance for the BER (or C/N value) specified in the short-term performance objectives of the desired network and corresponding to the shortest percentage of time (lowest C/N value);*

Long Term Threshold:

> *9 that this allowance corresponding to long-term interference, when used in addition to recommends 3, 4, 5 and 6, should be expressed by requiring that the aggregate interference*

[1] https://tslstorage.blob.core.windows.net/papers/Propagation_Correlation.pdf

should not exceed 6% of the total system noise power for more than 10% of the time;

In addition there is a provisional threshold in terms of reduction in capacity for those systems using adaptive coding and modulation of 10%.

Baseline Simulation

This section describes the simulation used in this TN. More information on how these parameters mapped onto Visualyse Professional objects is given in the TN on “Managing Correlation Between Propagation Path”.

GSO System

The GSO system was assumed to have the following characteristics:

Direction	Downlink
Frequency	40 GHz
Satellite peak gain	40 dBi
Satellite beam beamwidth	1°
Satellite beam gain pattern	Rec.S.672 Ls = -25 dB
Earth station dish size	1.2m
Earth station efficiency	0.6
Earth station gain pattern	Rec. S.580

The GSO satellite was located over the Americas and ES in Florida with following parameters:

GSO satellite longitude	-90°E
GSO ES latitude	26°N
GSO ES longitude	-81°E

Non-GSO System

The non-GSO system was assumed to have the following parameters:

Orbit height	1,400 km
Number of planes of satellites	7
Number of satellites/plane	11
Orbit inclination	88°
Spot beams	Tracking
Beam peak gain	30 dBi
Beamwidth	5°
Gain pattern	Rec.S.672 Ls = -25 dB

The position of each satellite was randomised using Monte Carlo techniques that kept the internal phasing of the constellation consistent.

The model was simplified by only including two non-GSO ES which were co-located with the GSO ES and had similar characteristics. This is likely to result in an underestimation of the aggregate interference and a full simulation would include many more non-GSO ES. However the aim of this TN is to highlight how to model propagation correlation rather than aggregate interference.

It was assumed that the ES of the non-GSO system were selecting the two highest elevation satellites which meet the following criteria:

Elevation angle $\varepsilon_0 \geq 10^o$

Angle to GSO arc $\alpha_0 \geq 2^o$

The non-GSO satellite selected would then direct a steerable spot beam in the direction of the non-GSO ES.

Link Characteristics

Both the GSO and non-GSO were assumed to use downlink power control to compensate for rain fades with the following parameters:

Reference bandwidth	1 MHz
Target receive level	-127 dBW
Minimum transmit power	0 dBW
Maximum transmit power	10 dBW
Receive noise temperature	150 K
Resulting target *C/N*	19.8 dB
Threshold *C/N* or *C*/(*N*+*I*)	15 dB

The link budget can be seen to include some margin for interference and rain fade.

In addition to using adaptive power control, the link is assumed to use adaptive modulation. Hence the link is likely still to be active even if the C/N or C/(N+I) drops below these thresholds, except with lower through-put.

Propagation Models

For both the wanted and interfering paths the propagation models were selected to be:

- Recommendation ITU-R P.525: free space path loss
- Recommendation ITU-R P.618: rain loss
- Recommendation ITU-R P.676: gaseous attenuation.

The propagation paths were assumed to be fully correlated as described in the previous TN on "Managing Correlation Between Propagation Path".

Time step and run duration

The simulation was run for 1e6 time steps: this number of samples were required to get stability of statistics at low percentages of time. When using Monte Carlo methods the time step size does not have an impact on the results, but in this case it was set to 1 second.

Configuring the Thresholds

The results required statistics to be gathered on I/N, C/N and C/(N+I). The thresholds were:

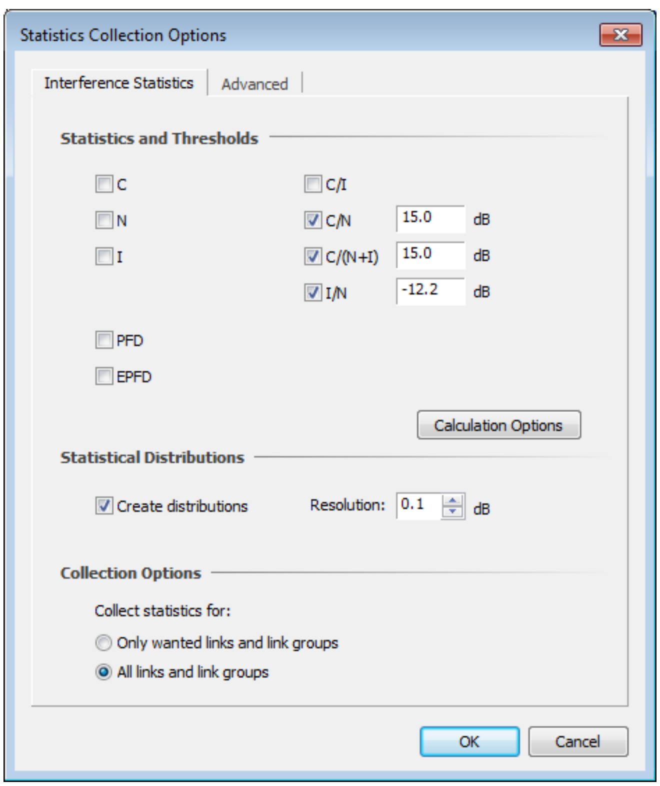
T(C/N) = 15 dB

T(C/(N+I)) = 15 dB

T(I/N) = -12.2 dB (i.e. DT/T = 6%)

To calculate the impact of interference on capacity it was also necessary to derive the histograms of the C/N and C/(N+I) so they could be post processed in Excel.

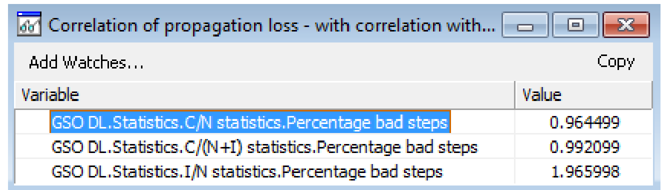
These thresholds and histogram bin size were entered into Visualyse Professional using the statistics dialog shown below:



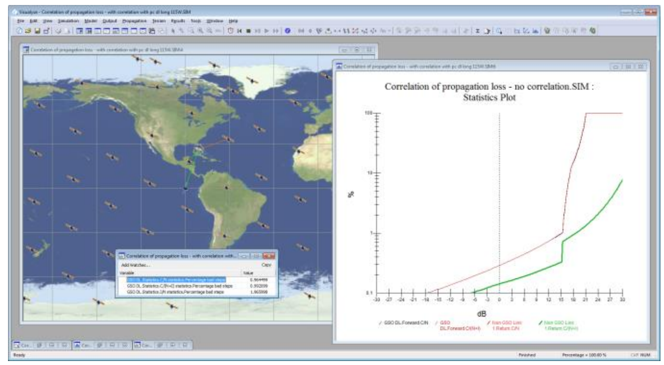
Simulation Results

The results were analysed taking into account the long term I/N threshold, the short term increase in unavailability threshold and the impact on capacity as described below.

The key outputs were shown in a watch window as shown below:



This watch window can be seen in the screenshot of the final simulation below:



Long Term Threshold

The long term threshold was:

T(I/N) = -12.2 dB for no more than 10% of time

In this case it can be seen from the watch window above, the I/N threshold was exceeded for 1.96% of the time which was below the threshold of 10%.

Short Term Threshold

To determine the impact on unavailability, the C/N and C/(N+I) percentage bad steps (shown in the watch window above) were exported into Excel and then the following were calculated:

- Percentage increase in unavailability
- Percentage of total unavailability due to interference.

The calculations for these were as follows:

The unavailability of link when subject to rain fading alone, p_1, was derived from the C/N:

$$p_1 = p\left[\frac{C}{N} < T\left(\frac{C}{N}\right)\right]$$

The unavailability when subject to rain fading and interference, p_2, was derived from the C/(N+I):

$$p_2 = p\left[\frac{C}{(N+I)} < T\left(\frac{C}{N}\right)\right]$$

Hence the increase in unavailability as a percentage is:

$$U_i = 100 * \left(\frac{p_2 - p_1}{p_1}\right)$$

The percentage of the total unavailability due to interference is then:

$$U_p = 100 * \left(\frac{p_2 - p_1}{p_2}\right)$$

These are shown in the table below:

Unavailability without interference (p_1)	0.96 %
Unavailability with interference (p_2)	0.99 %
Increase in unavailability (p_2- p_1)	0.03 %
Percentage increase in unavailability (U_i)	2.9 %
Percentage of unavailability due to interference (U_p)	2.8 %

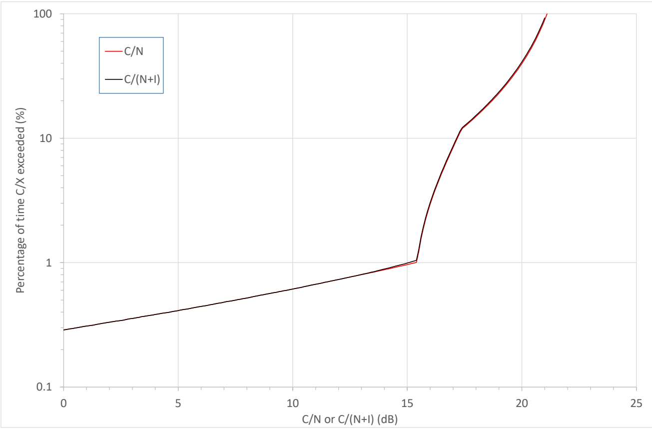
Note that the 10% of the unavailability is an aggregate and hence has to be apportioned. One approach taken within ITU-R WP 4A has to be identify that the aggregate 10% is apportioned into individual thresholds of 3%

It can seen that the percentage of unavailability due to interference is less than this threshold.

Impact on Capacity

For systems using adaptive modulation and coding, the impact of interference is to reduce capacity, as the C/(N+I) will be slightly lower than the C/N.

The histogram and CDF of the C/N and C/(N+I) can be extracted from the simulation and when the CDF is plotted it can be seen that there is a slight degradation due to interference, as shown in the following figure:



But is that sufficient to reduce the capacity below the provisional threshold of 10%?

A methodology to assess the relative reduction in capacity is currently being discussed in WP 4B, in particular in document:

> *Document 4B/116-E: Annex 3 to Working Party 4B Chairman's Report: PRELIMINARY DRAFT NEW RECOMMENDATION ITU-R S.[ACM-PERF] Performance objectives for satellite hypothetical reference digital paths using adaptive coding and modulation*

This gives two equations (nos. 2 and 3) to calculate the relative spectral efficiency, η, from the C/N $=\gamma$ such as the following for the minimum spectrum efficiency case:

$$\eta(\gamma) = 0.54465 + 0.14239\gamma + 0.00296\gamma^2$$

This equation can be applied to the C/N and C/(N+I) histograms to identify the relative reduction in capacity.

In this case the relative reduction in capacity was determined to be 1.58%.

Again, there might have to be a degree of apportionment from an aggregate threshold to single system, but it is likely that in this case the threshold would also be met.

Conclusion

This TN has shown how use Visualyse Professional to assess whether an interfering system will meet or exceed the FSS thresholds for time varying interference using the methodology in Recommendation ITU-R S.1323.

The assessment included multiple type of thresholds:

1. Short term based upon increase in unavailability
2. Long term based upon I/N
3. Impact on capacity assuming use of adaptive modulation and coding.

For this scenario and parameters, all three types of thresholds were met.

About Transfinite

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