The O3B Network and EPFD

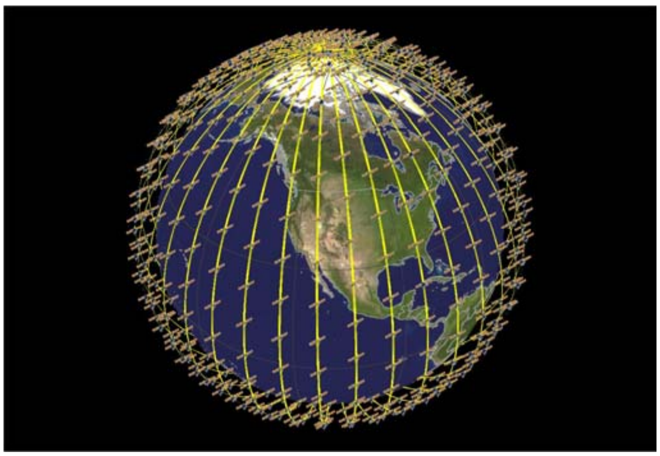
Abstract: In the 1990s there was a number of high profile non-geostationary fixed satellite service networks such as Teledesic and SkyBridge that dominated WRCs but ultimately didn't lead to an operational service. Now one is looking like it will be launched, namely O3B. O3B stands for the "Other 3 Billion" and it aims to provide tier 1 internet access to developing countries using satellites in non-geostationary orbits. But what is the regulatory framework? What issues might come up during coordination? And what is EPFD and why is it so important? These questions are addressed in this White Paper from Transfinite Systems Ltd.

History of Non-GSO FSS

In the 1990s debates about non-geostationary (GSO) fixed satellite service (FSS) networks dominated World Radiocommunications Conferences (WRCs). Just 0.1 dB difference between parties was enough to keep arguments going until 4 am.

The problem was that introducing non-GSO FSS networks would cause interference into GSO networks, but it wasn't clear whether it would be harmful in either regulatory or engineering terms. Different non-GSO networks proposed different regulatory and engineering solutions.

Firstly there was the USA network Teledesic, an 840 satellite constellation that dominated WRC 95:



It proposed to use Ka band where there weren't (at the time) many GSO satellites. By coordinating with these few that were before them in the ITU filing queue Teledesic believed they could provide a service.

However any GSO network that filed after them would find it near impossible to operate and so there were many that feared this would lock out Ka band for use by GSO networks.

WRC 97 was dominated by Europe's reply, the 80 satellite SkyBridge constellation. This proposed to use Ku band and claimed it could share with GSO networks by switching off those beams that could cause in-line events, reducing interference to below harmful levels.

These acceptable levels of interference were defined by a new metric, Equivalent Power Flux Density or EPFD and tables of EPFD entered the Radio Regulations in Article 22.

The regulatory framework for non-GSOs in Ku and Ka band was secured by WRC 2000 just as the realities of developing such complex systems were becoming apparent. The costs were too high and capital markets too risk adverse, particularly after seeing the non-GSO mobile satellite service (MSS) networks of Iridium and Globalstar struggle and then enter Chapter 11.

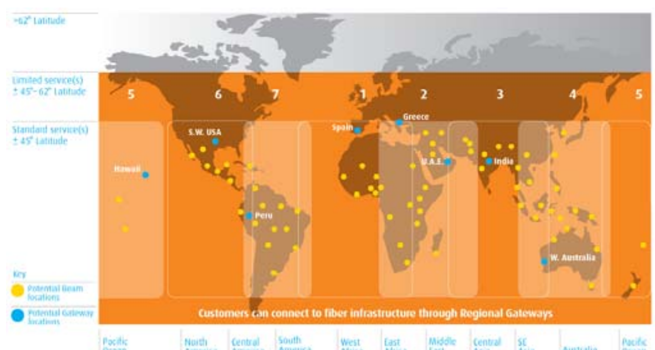
It seemed that all the hard work by hundreds of engineers around the world would come to nothing - until O3B.

What is O3B?

O3B was founded in 2007 and stand for the "other 3 billion". Its aim is to provide tier 1 internet connections to developing countries, as often they are constricted by their international connection.

Backed by a consortium that includes Google and SES World Skies it has recently raised $ 1.2 billion and on 18th July 2011 announced it had completed the critical design review (CDR). This suggests their satellite manufacturer Thales Alenia Space is on-track to enable O3B to launch their first satellite in Q1 2013.

The space segment architecture is based upon 8 satellites in equatorial circular orbit at an altitude of 8,063 km. Each satellite will have steerable spot beams operating in Ka band that point at user nodes or gateways located across equatorial regions as shown in the figure below:



Information about O3B is publically available from their filing in IFIC 2661 and their web site at:

http://www.o3bnetworks.com/homepage.aspx

Sharing Issues

The O3B network proposes to use parts of Ka band that are also used by GSO networks. Looking at the filing on the ITU's SNS it can be seen the frequencies used are in the following bands:

Uplink: 27.5 – 30.0 GHz

Downlink: 17.8 – 20.2 GHz

In the ITU-R Radio Regulations these bands include a number of allocations and footnotes. For example footnote 5.523A, which relate to the bands 17.8 – 19.3 / 28.6 – 29.1 GHz, specifies that coordination is subject to RR 9.11A (i.e. coordination with priority by filing date). In other bands there are EPFD limits that must be met specified in RR Article 22.

A number of interference paths can exist between O3B and GSO networks including:

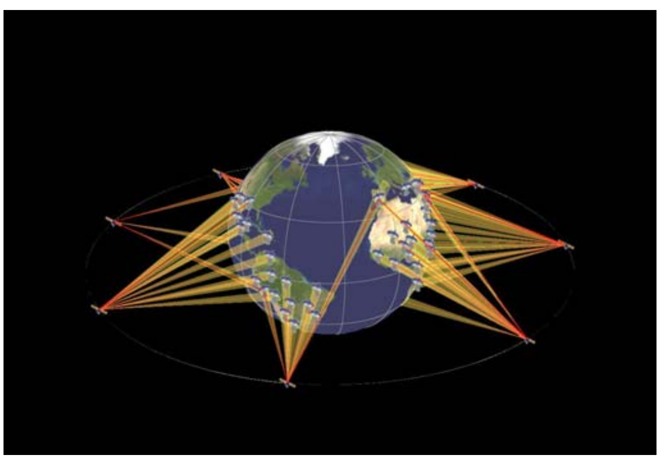
- From O3B uplink into GSO uplink
- From O3B downlink into GSO downlink
- From O3B downlink into GSO uplink
- From GSO uplink into O3B uplink
- From GSO downlink into O3B downlink
- From GSO uplink into O3B downlink

This raises a number of questions, such as:

- Does the O3B network meet the EPFD(down), EPFD(up) and EPFD(IS) limits in RR Article 22?
- Can the O3B network be coordinated with GSO networks in bands where EPFD does not apply?

Modelling O3B

To be able to answer these questions it is necessary to be able to model the O3B network within simulation tools. The screenshot below shows the O3B network modelled by the Visualyse Professional tool:



This model included:

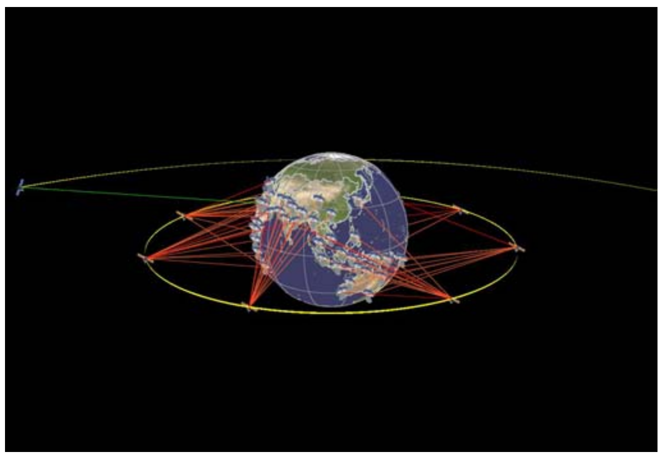
- Orbital dynamics for the satellites in the O3B constellation
- Distribution of gateways and user station based upon O3B graphic
- Emissions for uplink and downlink based upon parameters in the ITU IFIC 2661
- Gateways with multiple antennas to track multiple O3B satellites
- O3B satellites with multiple steerable user and gateway beams
- Satellite selection using tracking strategies using rules like "Select 2nd highest elevation satellite at least 5 degrees from the GSO arc"
- Run time step and duration selected based upon beam sizes and constellation repeat geometry

Modelling GSO Networks

The next step is to include the GSO network: this can use data in the ITU's SRS to extract:

- GSO shaped beams
- Location and characteristics of earth stations
- Emission levels and receiver noise characteristics

These can be included in the O3B simulation file to model interference from the O3B network into one or more GSO networks, as in the figure below:



The figure also shows one of the key issues – the geometry involved. The O3B network satellites orbit at an altitude much less than that of the GSO.

Hence for GSO networks serving earth stations at high latitudes there is never one of those in-line events that can cause harmful interference.

However for GSO networks serving earth stations near the equator it can be seen there could be a potential problem as there will be times when the O3B satellite will be directly inline between the GSO satellite and an earth station on the equator.

Example Analysis

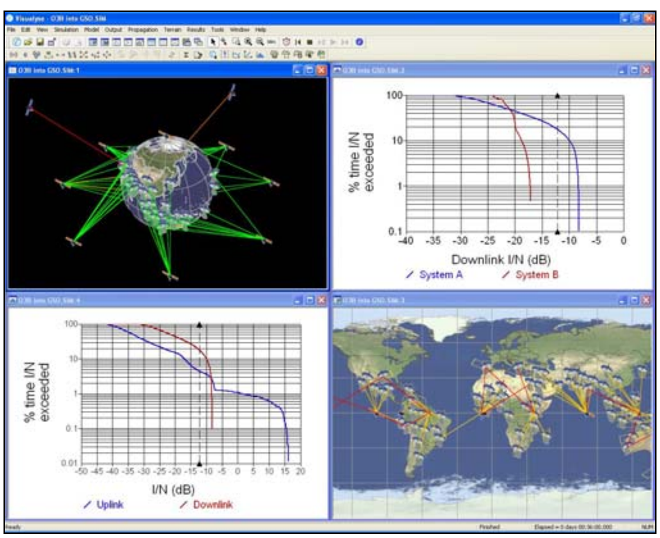
This model can be the basis of an analysis of the potential to share and get answers to the two questions raised above. The analysis can raise further more detailed questions, such as:

- Which GSO networks are most susceptible to interference?
- Is the GSO uplink or downlink more susceptible to interference?
- How can the O3B network provide a service in equatorial regions?
- How bad could interference be on equatorial locations?
- What is the right metric to use for harmful interference?

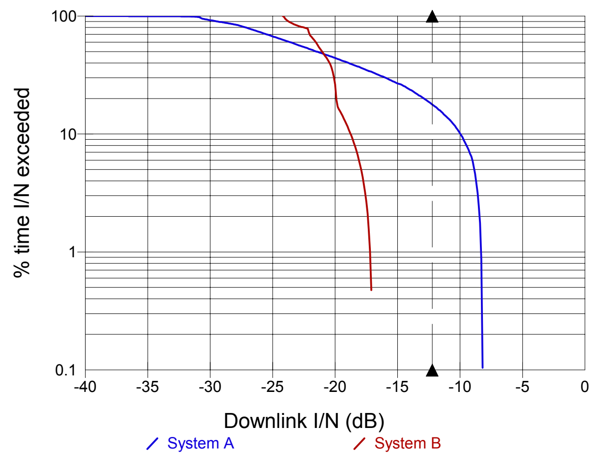
Regarding the last question, a number of metrics could be used, including:

- I/N
- C/I
- C/(N+I)
- EPFD

All of these can be modelled within Visualyse Professional. In addition as the scenario is time dynamic, statistics can be generated and compared against availability targets, as in the screen shot below:

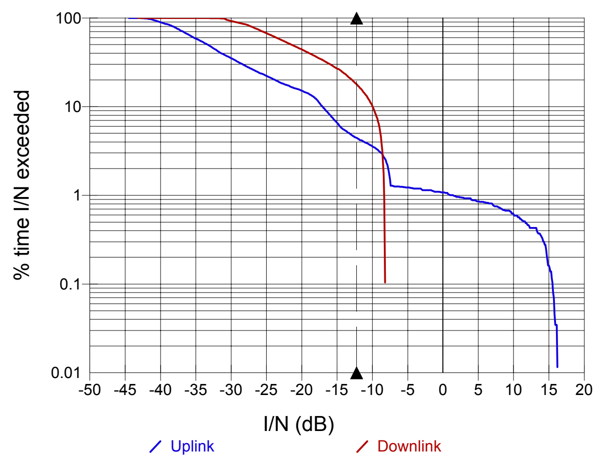


In the simulation file shown it was found that as expected the interference level varied depending upon GSO network earth station latitude, as shown in the figure below:



Here System A, which was nearer the equator than System B, experiences a worst case downlink I/N greater than the threshold of -12.2 dB (i.e. a DT/T = 6%).

However the System A uplink I/N value were even higher, as can be seen by the figure below.



It can be seen from this analysis that there is the potential for there to be an interference issue if mitigation is not employed.

Tools such as Visualyse Professional can be used to analyse this scenario as part of coordination between O3B and GSO networks.

Alternatively Transfinite consultants can undertake studies or provide support at coordination meetings.

EPFD Analysis

To determine whether the O3B network meets the EPFD limits in Article 22 of the Radio Regulations it is necessary to run specialised software.

The reason is that analysis must be done according to a very specific algorithm given in Recommendation ITU-R S.1503:

"*Functional description to be used in developing software tools for determining conformity of non-geostationary-satellite orbit fixed-satellite system networks with limits contained in Article 22 of the Radio Regulations*"

Note that EPFD is defined using the following equation:

$$epfd = 10\log_{10}\left[\sum_{i=1}^{N_a} 10^{\frac{P_i}{10}} \cdot \frac{G_t(\theta_i)}{4\,\pi\, d_i^2} \cdot \frac{G_r(\varphi_i)}{G_{r,max}}\right]$$

Transfinite has developed the Visualyse EPFD software tool to determine whether a non-GSO network meets the Article 22 limits. This uses as its inputs not the beams and emissions taken from the IFIC but, for the EPFD(down) case, a satellite PFD mask that gives an envelope of what power levels the system could generate.

Any particular combination of beam pointing, emission level and traffic patterns would be permitted as long as the aggregate emissions are less than the filed satellite PFD mask.

For the EPFD(up) and EPFD(IS) scenarios the inputs are also masks, but in this case EIRP masks for the earth stations and satellites respectively.

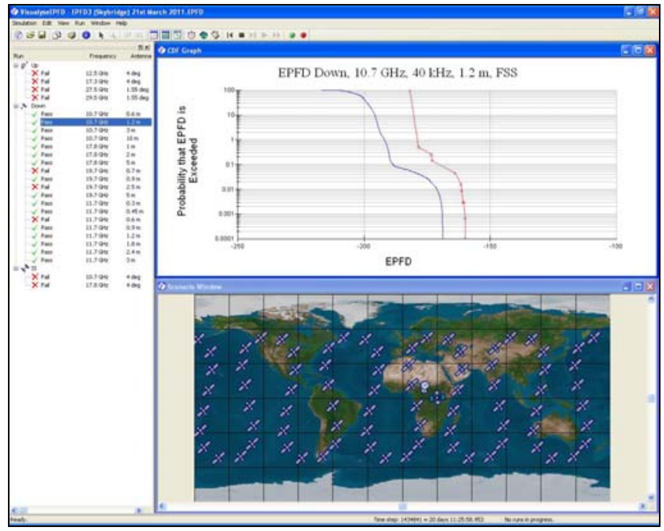
Given these inputs the software tool works out the EPFD using algorithm in Recommendation ITU-R S.1503 automatically with no user input required. The results are then be compared against the EPFD limits in Article 22 (as in the example table below) to give a "pass" or "fail" decision.

TABLE **22-1A** (WRC-03)

Limits to the epfd↓ radiated by non-geostationary-satellite systems in the fixed-satellite service systems in certain frequency bands[3, 4, 5, 6]

Frequency band (GHz)	epfd↓ (dB(W/m²))	Percentage of time during which epfd↓ may not be exceeded	Reference bandwidth (kHz)	Reference antenna diameter and reference radiation pattern[7]
10.7-11.7 in all Regions; 11.7-12.2 in Region 2; 12.2-12.5 in Region 3 and 12.5-12.75 in Regions 1 and 3	−175.4 −174 −170.8 −165.3 −160.4 −160 −160	0 90 99 99.73 99.991 99.997 100	40	60 cm Recommendation ITU-R S.1428-1
	−181.9 −178.4 −173.4 −173 −164 −161.6 −161.4 −160.8 −160.5 −160 −160	0 99.5 99.74 99.857 99.954 99.984 99.991 99.997 99.997 99.9993 100	40	1.2 m Recommendation ITU-R S.1428-1
	−190.45 −189.45 −187.45 −182.4 −182 −168 −164 −162 −160 −160	0 90 99.5 99.7 99.855 99.971 99.988 99.995 99.999 100	40	3 m Recommendation ITU-R S.1428-1
	−195.45 −195.45 −190 −190 −172.5 −160 −160	0 99 99.65 99.71 99.99 99.998 100	40	10 m Recommendation ITU-R S.1428-1

The figure below shows the Visualyse EPFD software running with a SkyBridge style system.



Transfinite is working with the ITU BR to integrate Visualyse EPFD into the ITU's workflow.

About Transfinite

We are one of the leading consultancy and simulation software companies in the field of radio communications. Our business activities can be broadly categorized into the following areas:

a) Visualyse software products

b) Consultancy services

c) Technical training

We also develop and market the market leading Visualyse products:

- Visualyse Professional
- Visualyse GSO
- Visualyse Coordinate
- Visualyse EPFD
- Visualyse Spectrum Manager

We also can provide consultancy services including:

- Sharing studies
- Interference analysis
- Coordination studies
- Coordination support
- Meeting representation

More information about these products and services is available by contacting us at:

Web: http://www.transfinite.com

Email: info@transfinite.com

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