Managing Change at the ITU-R

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Abstract: Change is one of constants of life and the ITU is no exception, with pressures for changes come from economic forces, technological development, market changes and new knowledge. The processes of the ITU are designed to handle these changes through managed updates of the key documents, such as the Radio Regulation and Recommendations. But how are these changes undertaken and what tools are required to undertake the necessary studies? This paper discusses these topics with case studies from recent World Radiocommunication Conferences.

Why are there so many ITU-R meetings?

On the International Telecommunication Union (ITU) web site there is the meetings schedule for the next year: there are about 40 meetings listed within the Radio Sector alone, of groups with acronyms like WP 3M, WP 4A and SG 5. Some meetings are huge undertakings. World Radiocommunications Conferences (WRCs) last 4 weeks and are attended by almost 4,000 delegates at a likely total cost of tens of millions of dollars. Thousands of experts and officials spend large parts of their life flying round the world and then being buried in buildings for up to 18 hours a day. But why?

The reasons for all the meetings include:

- The need to manage the change occurring in the world outside the ITU-R
- To adapt spectrum to new circumstances
- To modify the instruments of the ITU-R that assist in the management of the spectrum.

This paper looks at how change is managed within the ITU-R, giving Case Studies as appropriate, and showing how this process can be assisted using software tools that predict the potential for interference between services and systems.

Forces of Change: External Pressures

It is well known that the telecommunications industry is in a period of unprecedented rapid development and that it is continually finding new and innovative ways of using radio ways. Change can result from many external pressures including:

- **Economic**: for example as mass production reduces the price of equipment it becomes possible to introduce new services or, as countries develop and their GDP increases, they can afford new advanced systems
- **Technological**: for example the development of the use of higher frequencies, use of constellations of non-geostationary (GSO) satellites, and the expectation of ubiquitous access to broadband internet
- **Market**: as users request new services such as higher data rate services, increased mobility, or need new types of scientific measurements
- **Knowledge**: as the behaviour of radio waves and equipment are better understood, how they are characterised in propagation models can be improved.

While these are the “big picture” pressures driving the industry there can be more personal motivations. Iridium was allegedly in part inspired due to a question asked by the wife of Motorola executive Bary Bertiger. While on holiday in the Bahamas Karen Bertiger asked whether he could devise a way for her to phone home wherever she was – even on holiday on a remote island[1]. It was a good time to ask such a

[1] Eccentric Orbits: The Iridium Story, by John Bloom

question as there were rapid technological changes that would soon allow systems to be designed to provide such a service.

While usually there are one or more organisations that instigate change, there may be many more who are affected by the changes proposed or have alternative, conflicting suggestions.

Changes can be minor – for example a parameter of a propagation model is updated to reflect new measurements. Or a change can dominate the ITU-R for years, such as the development of International Mobile Telecommunications (IMT) standards or the proposals for non-GSO Fixed Satellite Service (FSS) such as SpaceX's Starlink.

What has to be changed?

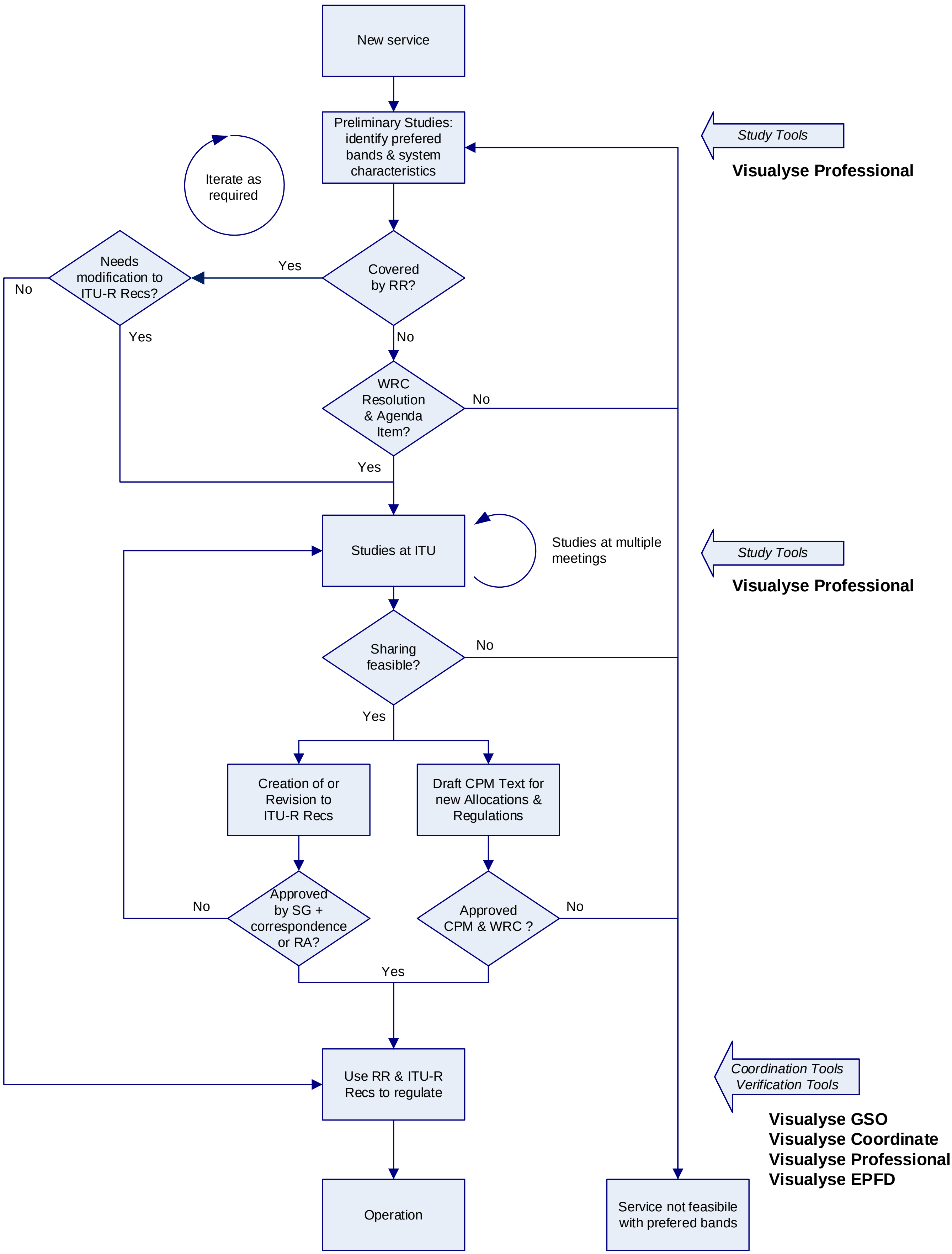
The two principal tools employed at the international level to manage use of the radio spectrum are the Radio Regulations (RR) and the ITU-R Recommendations (Recs). Major changes, such as the introduction of new types of system, are unlikely to be accommodated by the existing RR and Recommendations. Therefore the protagonists are likely to need to change the RR and modify existing or create new Recs. This is particularly true if the service requires a new allocation.

This process can require the following stages:

1. Identification where the RR and ITU-R Recommendation require changes
2. If necessary, creation of WRC Agenda items
3. If necessary, creation of ITU-R Questions
4. Analysis at ITU-R Study Groups (SGs) and Working Parties (WPs)
5. If necessary, creation of (or revision to) ITU-R Recs.
6. If necessary, update of RR at WRC
7. If successful, operational use of measures in RR and Recs.

These steps in the process are shown in the diagram below which is simplified, as the actual process:

- Could require multiple cycles to make all the required updates and/or revisions to the initial regulations
- Updates to the regulations for one service can result in updates to other services in reaction
- There can be several interdependent changes being processed simultaneously
- The figure excludes update of Questions (in practice work at the ITU is driven by the level of activity of participants: Questions have been updated retrospectively to reflect work already underway)
- There can be several routes to achieve the same goals (for example approval of Recommendations by Approval or via the Radio Assembly)
- Failure can lead to several alternative courses of action (minor errors might be fixed editorially, more significant ones could result in documents being returned to Study Groups for further work, while situations like study showing sharing is not feasible can result in completely new strategies or recognition that the goal is not achievable).



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A number of Case Studies will be used in this paper when describing the process:

- *Creation of WRC Agenda Items*: these will consider analysis of potential sharing scenarios involved in Direct to Device (D2D) and non-terrestrial networks (NTN) in parts of the UHF band.
- *Study within the ITU-R and Update of Recommendations and Radio Regulations*: this will consider sharing between IMT and other services and providing additional spectrum to operate intersatellite links (ISLs).
- *Operational use of measures in RR and Recs*: this will consider the coordination of satellite Earth Stations (ES), coordination of non-GSO systems and validation that non-GSO FSS satellite systems meet the requirements of Article 22.

Creation of WRC Agenda Item

Each WRC decides the Agenda for the next meeting. There are two general approaches to consider new allocations:

- Request that the ITU-R search for new allocation(s) of spectrum within a certain range. An example of this would be WRC-27 Agenda Item (AI) 1.13:

  1.13 to consider studies on possible new allocations to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage, in accordance with Resolution 253 (WRC-23)

  where Resolution 253 requested that WRC-27:

  study possible allocations to the MSS in the frequency range between 694/698 MHz and 2.7 GHz taking into account IMT frequency arrangements addressed in the most recent version of Recommendation ITU-R M.1036

- Request that the ITU-R study new allocation(s) of spectrum for specific band(s). An example of this would be WRC-27 AI 1.12:

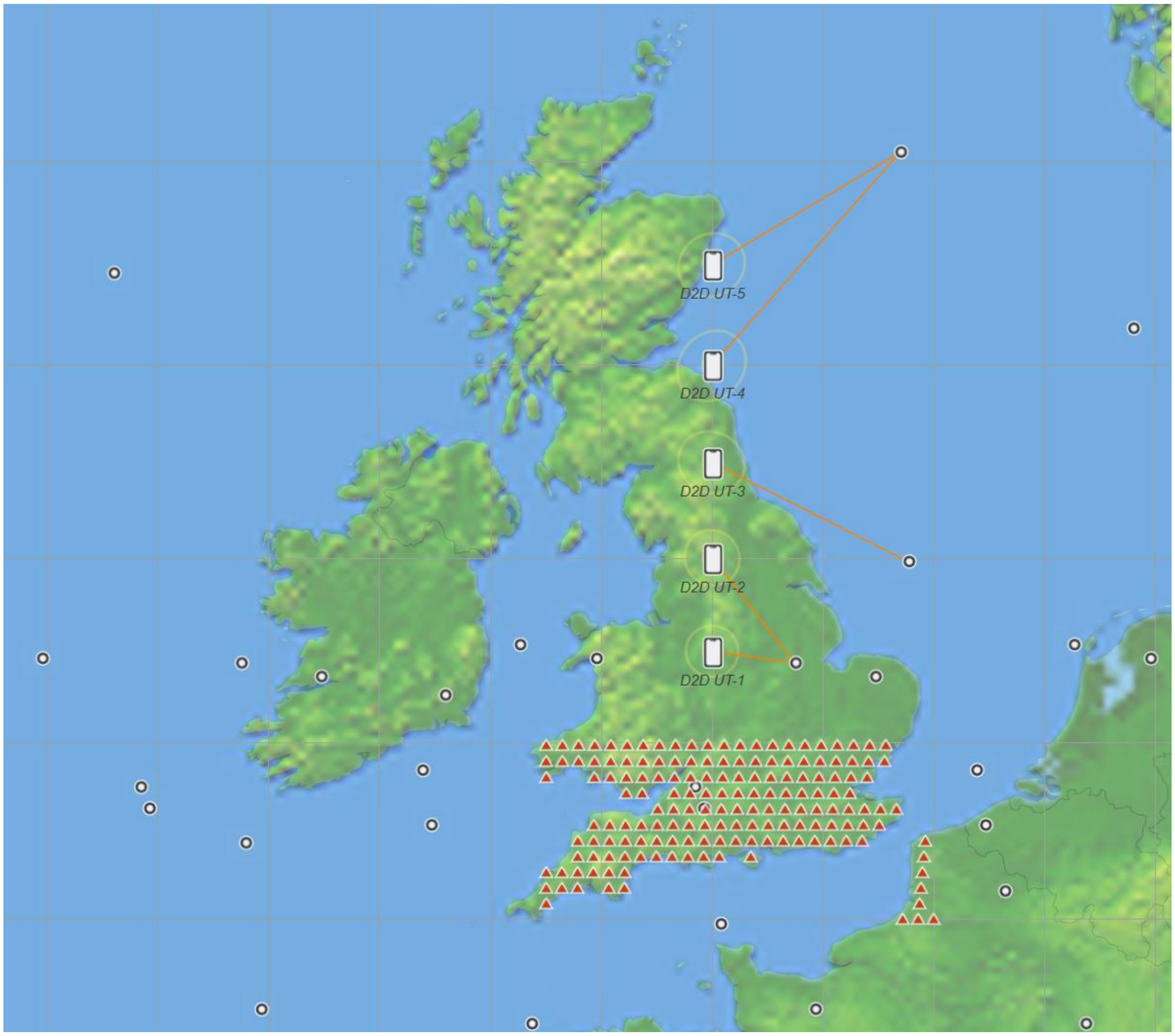
  1.12 to consider, based on the results of studies, possible new allocations to the mobile-satellite service and possible regulatory actions in the frequency bands 1 427-1 432 MHz (space-to-Earth), 1 645.5-1 646.5 MHz (space-to-Earth) (Earth-to-space), 1 880-1 920 MHz (space-to-Earth) (Earth-to-space) and 2 010-2 025 MHz (space-to-Earth) (Earth-to-space) required for the future development of low-data-rate non-geostationary mobile-satellite systems, in accordance with Resolution 252 (WRC-23);

WRC Agendas are usually very crowded and are compromises based upon input contributions from many Administrations. The sponsoring Administration or the organisation within its territory proposing change must undertake initial analysis of the feasibility of using the preferred band, plus, potentially, alternative bands. Feasibility of sharing can be determined using simulation. Computer software such as Visualyse Professional can be used to predict interference that would be generated by the new service.

Case Study 1: Modelling D2D Using Visualyse Professional

External pressure for change: operators (satellite / terrestrial) wanting to provide internet access to unmodified or standard mobile phones using satellite networks

The figure below shows Visualyse Professional configured to analyse sharing between a non-GSO constellation providing services direct to handsets and a widescale deployment of terrestrial mobiles.



Simulation software for interference analysis such as Visualyse Professional is based upon:

1. Defining an algorithm to use in simulation, that can be static, dynamic, or use Monte-Carlo techniques
2. Determining dynamic characteristics of transmitters and receivers, such as locations, heights, and speeds, orbit models
3. Defining antenna characteristics such as gain patterns, pointing angles
4. Including RF characteristics such as powers, bandwidths, polarisations and carrier shapes
5. Including propagation effects such as dry air, water vapour, rain, and terrain
6. Calculating receive signal strength using a link budget similar to:

Received Signal	=	*Transmit Power*
	+	*Transmit Peak Gain*
	+	*Transmit Relative Gain*
	-	*Propagation Losses*
	+	*Receive Peak Gain*
	+	*Receive Relative Gain*
	-	*Feed Losses*

7. Calculating interference based upon criteria such as *I, I/N, C/N, C/(N+I), PFD, EPFD* and derived metrics such as unavailability and average throughput
8. Comparing interference against a threshold that defines degradation of service

The simulation above could have interference in four directions:

a) From the satellite DL into the mobile network's DL
b) From the satellite UL into the mobile network's UL
c) From the mobile network's DL into the satellite DL
d) From the mobile network's UL into the satellite UL.

Of these paths, the final case, into the satellite UL, was found to be the most susceptible to interference. This, and related topics, will be studied further within the ITU before options for regulations can be proposed for WRC-27.

More information is available in the full description of this analysis that can be found here:

- Modelling D2D Systems in Visualyse

Analysis at ITU-R and Update of Recommendations and the RR

Typically, just one side often does this initial analysis involved in developing a new WRC AI, which in this case would be an operator that would like to offer D2D satellite services. During the study phase in the ITU-R, work can be done by both representatives of the incumbent services as well as the newcomer, allowing the rights of existing and new services are balanced.

The Working Parties (and sometimes additional Task Groups, Joint Groups etc.) which do the actual study work, with usually several meetings per group within a WRC cycle. This results in development of or revisions to Recommendations (via the Study Groups) and text for the CPM Report for the next Conference to update the RR. There is often overlap between the two - for example a Recommendation to define PFD limits that also is included in the RR.

The work undertaken by WPs is very varied and depends upon the external pressure. Recommendations could contain an update of or definition of:

- Databases with new system characteristics
- Propagation models or gain patterns to reflect new systems or new information
- Algorithms that can be used in sharing studies or coordination exercises
- Results of sharing studies between proposed studies
- System performance thresholds, including interference thresholds
- Technical characteristics such as EIRP, power, PFD or EPFD limits that would assist sharing.

For CPM text it can include:

- Summary of studies including any conclusions about potential for systems to share
- Information on demand for new systems and implications regarding need for allocations
- Options for WRC to consider as to how to address the agenda item
- Information about algorithms defined in Recommendations that can be used in sharing studies or coordination exercises which could be included in the RR
- Technical characteristics such as EIRP, power, PFD or EPFD limits that would assist sharing.

To support this work, delegates use a wide range of tools, from pencil and scraps of paper to software packages such as Visualyse Professional, designed with flexibility in mind to be a "Study Tool". As new types of systems are always being proposed with all sorts of applications in almost any band, it is necessary to have tools that can analyse the widest possible range of sharing scenarios, in detail sufficient to be able to update Recommendations and the RR with confidence.

There are two main results from work at ITU-R SGs (including their WPs, TGs, and JTGs):

- Creation of or revision to Recommendations
- Production of text to be included in the CPM report to advise WRC on changes to the RR including allocations

So after many years of debate, analysis, arguments, negotiations, and political compromise text can be prepared for approval. For Recommendations this can either be at the Radio Assembly, or in many cases now, using Approval via Correspondence.

For CPM text it is agreed at WPs, possibly provisionally with square brackets, and then at the final CPM text is collated into a single Report for the following WRC. At the WRC, Administrations propose changes to the RR via their input contributions, with the CPM Report a guide to assist the work of the Conference.

Changes to RR and new Allocations are the result of many years work - not just the study work at ITU-R groups, but prior to the previous WRC, where much preparation was needed to get the issue on the Agenda.

Two case studies below show examples that needed simulation tools to help address the relevant agenda item.

Case Study 2: WRC-19 AI 1.13: Sharing between IMT and other services

Pressure for change: Demand for more spectrum for mobile broadband services

One of the major recent projects within the ITU has been the development of the regulatory framework to facilitate the introduction of the next generation of terrestrial mobile applications. An example would be WRC-19 AI 1.13:

> *1.13 to consider identification of frequency bands for the future development of International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution 238 (WRC-15);*

Resolution 238 (WRC-15) called for:

> *Studies on frequency-related matters for International Mobile Telecommunications identification including possible additional allocations to the mobile services on a primary basis in portion(s) of the frequency range between 24.25 and 86 GHz for the future development of International Mobile Telecommunications for 2020 and beyond*

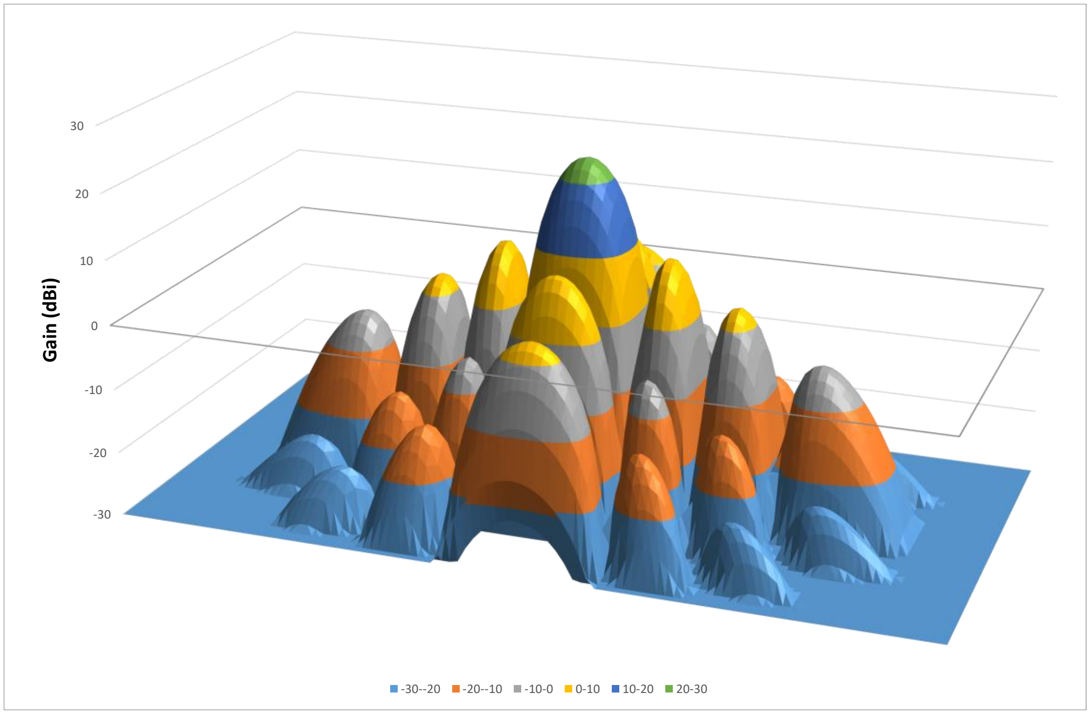
The work under this AI is included in the Conference Preparatory Meeting (CPM) Report to WRC-19 in Chapter 2/1.13/. This chapter considered the following:

- *a description of the estimated spectrum needs for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz;*
- *the sharing and compatibility studies carried out by ITU-R for each frequency band under study;*
- *the methods to satisfy agenda item 1.13;*
- *regulatory and procedural considerations for each frequency band under study.*

One of the most important bands under study was the 24.25 – 27.5 GHz band where services to be protected including the Earth Exploration Satellite Service (EESS) and FSS, amongst others. These considered both co-frequency and non-co-frequency scenarios, such as:

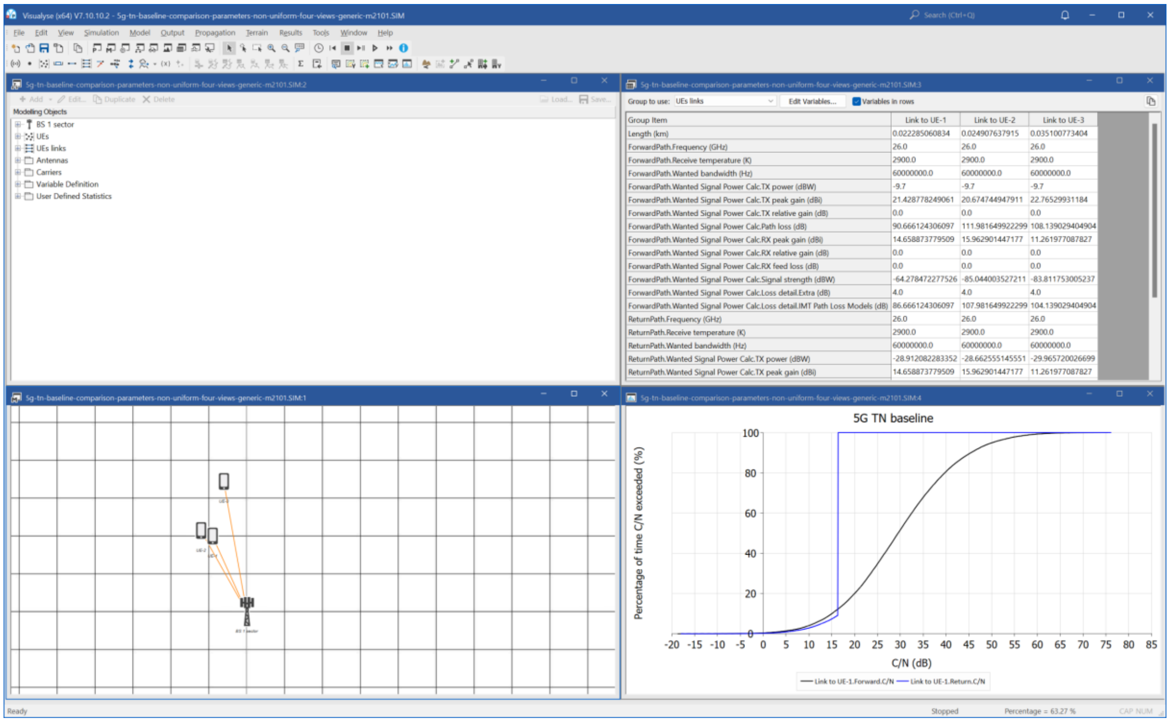
- Co-frequency: sharing between IMT and Earth Stations (ES) of the EESS/SRS (space-to-Earth) or from IMT into FSS Earth-to-space into space station receivers.
- Non-co-frequency: sharing between the IMT and EESS(passive) in the band 23.6 – 24.0 GHz band.

These studies needed to develop models for the technology described as IMT-2020 which included new technologies such as beamforming antennas. One of the key developments was Recommendation ITU-R M.2101: *Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies*. This included definition of how to model the beamforming antenna's gain pattern generated by an array of elements, which can contain multiple peaks and nulls as in the figure below:



This Recommendation, and other documents generated during the cycle, defined additional characteristics such as IMT deployment models, traffic models, carrier shaping, antenna heights, propagation models, power levels and thresholds. Modelling methods included static, time dynamic and Monte Carlo.

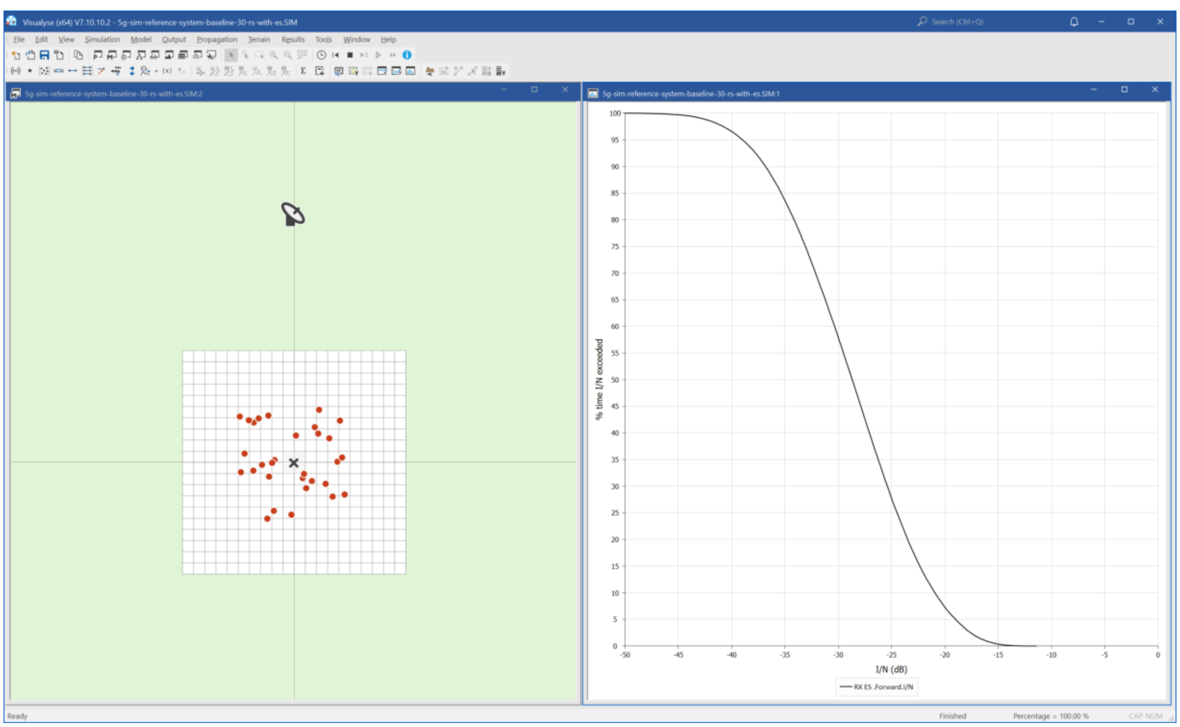
Visualyse Professional was used during this cycle to help identify power levels, both in-band and adjacent-band, that would facilitate sharing between the services involved. The first step was to create an accurate model of an IMT cell, as shown in the figure below:



From this, a deployment model could be used to determine the aggregate interference into other services from widescale deployment of IMT systems. One approach used was the Reference System concept that:

- Stage 1: Created a simulation file to determine the aggregate EIRP from a cluster of IMT systems
- Stage 2: Used the aggregate EIRP distribution to create a widescale deployment involving large numbers of IMT systems.

An example of this is shown in the screenshot below:



With analysis such as this, WRC-19 was in a position to make a decision on the various options proposed. For example, the draft Final Acts stated had the following addition:

ADD

5.A113 The frequency band 24.25-27.5 GHz is identified for use by administrations wishing to implement the terrestrial component of International Mobile Telecommunications (IMT). This identification does not preclude the use of this frequency band by any application of the services to which it is allocated and does not establish priority in the Radio Regulations. Resolution COM4/8 (WRC-19) applies.

Resolution COM4/8 (WRC-19) references Resolution 750 (WRC-19) which was updated to contain unwanted emission limits, as in this extract:

EESS (passive) band	Active service band	Active service	Limits of unwanted emission power from active service stations in a specified bandwidth within the EESS (passive) band
23.6-24.0 GHz	24.25-27.5 GHz	Mobile	−33 dBW[a] in any 200 MHz of the EESS (passive) band for IMT base stations −29 dBW[b] in any 200 MHz of the EESS (passive) band for IMT mobile stations

The two notes are:

a) A limit of −39 dB(W/200 MHz) will apply to IMT base stations brought into use after 1 September 2027. This limit will not apply to IMT base stations which have been brought into use prior to this date. For those IMT base stations, the limit of −33 dB(W/200 MHz) will continue to apply after this date.

b) A limit of −35 dB(W/200 MHz) will apply to IMT mobile stations brought into use after 1 September 2027. This limit will not apply to IMT mobile stations which have been brought into use prior to this date. For those IMT mobile stations, the limit of −29 dB(W/200 MHz) will continue to apply after this date.

Simulation tools such as Visualyse Professional were an important part of the process, developing sharing models that could analyse the impact of unwanted emission power limits such as these and supporting those at WRC-19 in making an informed decision.

More information about how Visualyse Professional can model these scenarios can be found in these two Technical Notes:

- Building a 5G Network in Visualyse Professional
- Building a 5G Simulation using Reference Systems

Case Study 3: WRC-23 AI 1.17: Additional spectrum to provide ISLs

Pressure for change: Requirement to allocate more spectrum for inter-satellite links

Recently there has been a large increase in satellites operating in low Earth orbit (LEO) providing a wide range of services including communications and remote sensing. These require connectivity, for example, for a remote sensing satellite to transmit the observations, which might be time sensitive, to ground stations. There was perceived to be insufficient capacity in the existing inter-satellite allocations and so WRC-23 AI 1.17 called for the ITU-R to:

1.17 to determine and carry out, on the basis of ITU-R studies in accordance with Resolution 773 (WRC-19), the appropriate regulatory actions for the provision of inter-satellite links in specific frequency bands, or portions thereof, by adding an inter-satellite service allocation where appropriate;

Resolution 773 (WRC-19) covered the:

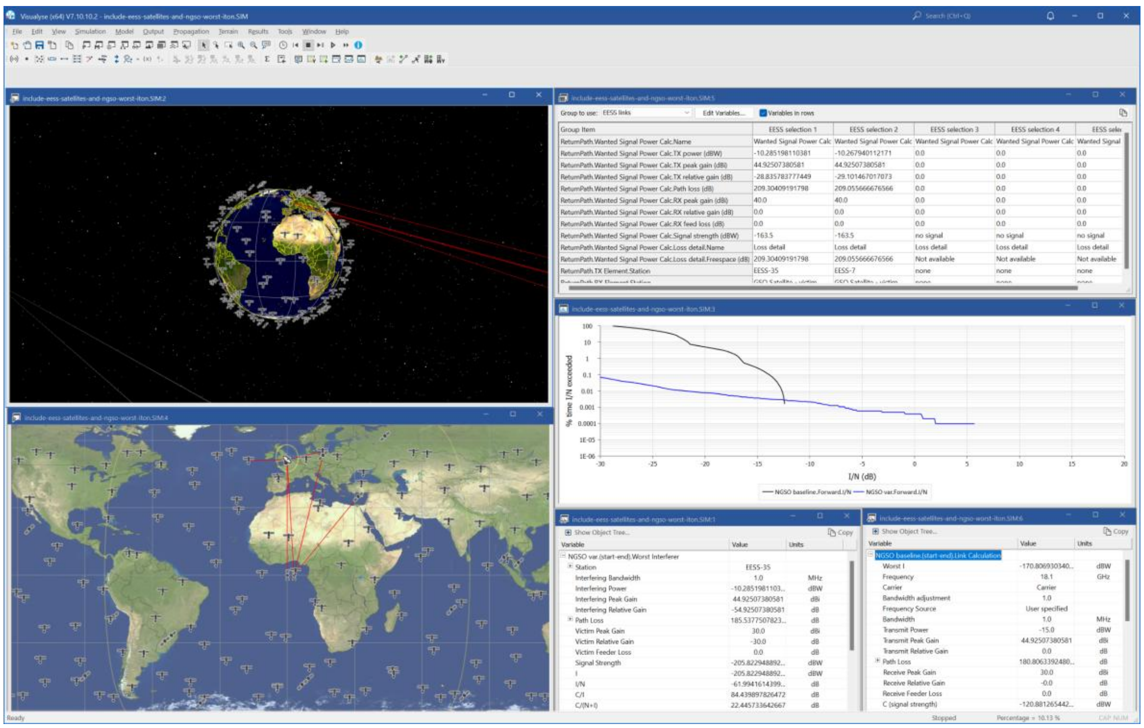
Study of technical and operational issues, and regulatory provisions for satellite-to-satellite links in the frequency bands 11.7-12.7 GHz, 18.1-18.6 GHz, 18.8-20.2 GHz and 27.5-30 GHz.

This top was studied in the cycle between WRC-19 and WRC-23. Issues considered included spectrum requirements, geometric constraints, EIRP values (peak and offaxis) and out-of-band emission limits.

The CPM Report to WRC-23 suggested either no change (NOC) or an approach that could include satellite operations:

- *allocated through a fixed-satellite service (FSS) allocation in RR Article 5;*
- *allocated through an inter-satellite service (ISS) allocation in RR Article 5;*
- *allowable only within the cone of coverage of the non-GSO and GSO FSS space station;*
- *allowable outside the cone of coverage of the GSO FSS space station.*

Studies with the ITU-R considered a wide range of scenarios, including sharing with fixed, mobile, HAPS and satellite services (GSO and non-GSO) FSS. Visualyse Professional was used to undertake some of these studies, and an example screenshot is shown below:



Visualyse Professional could model all the services involved including non-GSO satellites in both LEO and also medium Earth orbit (MEO) and concepts such as in-the-cone using tracking strategy objects.

Outputs from the studies were limits, such as the on-axis EIRP spectrum power density required to protect victim receivers.

WRC-23 discussed this concept in detailed and the following footnote added:

> *5.521A For use of the frequency bands 18.1-18.6 GHz, 18.8-20.2 GHz and 27.5-30 GHz, or parts thereof, by space stations in the inter-satellite service, Resolution 679 (WRC-23) shall apply. Such use is limited to space research, space operation and/or Earth exploration-satellite applications, and also transmissions of data originating from industrial and medical activities in space. When using these frequencies, administrations shall ensure that this inter-satellite service is used only for the aforementioned purposes and is not subject to coordination under No. 9.11A. For use of the frequency bands 18.1-18.6 GHz, 18.8-20.2 GHz, 27.5-29.1 GHz and 29.5-30 GHz by space stations, the allocation is limited to inter-satellite links between non-geostationary satellites or*

between non-geostationary satellites and geostationary satellites. For use of the frequency band 29.1-29.5 GHz by space stations, the allocation is limited to inter-satellite links between non-geostationary satellites and geostationary satellites. No. 4.10 does not apply. (WRC-23)

Details of the constraints were given in Resolution 679 (WRC-23) which included an Annex contain maximum EIRP constraints that varied by non-GSO space station altitude and year in which it was brought into use as in the table below:

Transmitting non-GSO space station operational altitude (km)	Maximum total e.i.r.p. (dBW) (brought into use on or before 31 December 2036)	Maximum total e.i.r.p. (dBW) (brought into use after 31 December 2036)
altitude < 450	63	66
450 ≤ altitude < 600	61	64
600 ≤ altitude < 750	58	58
750 ≤ altitude < 900	55	55
900 ≤ altitude < 1 350	25	44
altitude ≥ 1 350	Not applicable	Not applicable

Visualyse Professional allows analysis to be undertaken as to the implications of values such as these, allowing participants at WRC-23 to make informed decisions.

More information about the types of studies that can be undertaken with Visualyse Professional to support scenarios such as those under WRC-23 AI 1.17 can be found here:

- Modelling AI 1.17 using Visualyse Professional

Operational use of measures in RR and Recs.

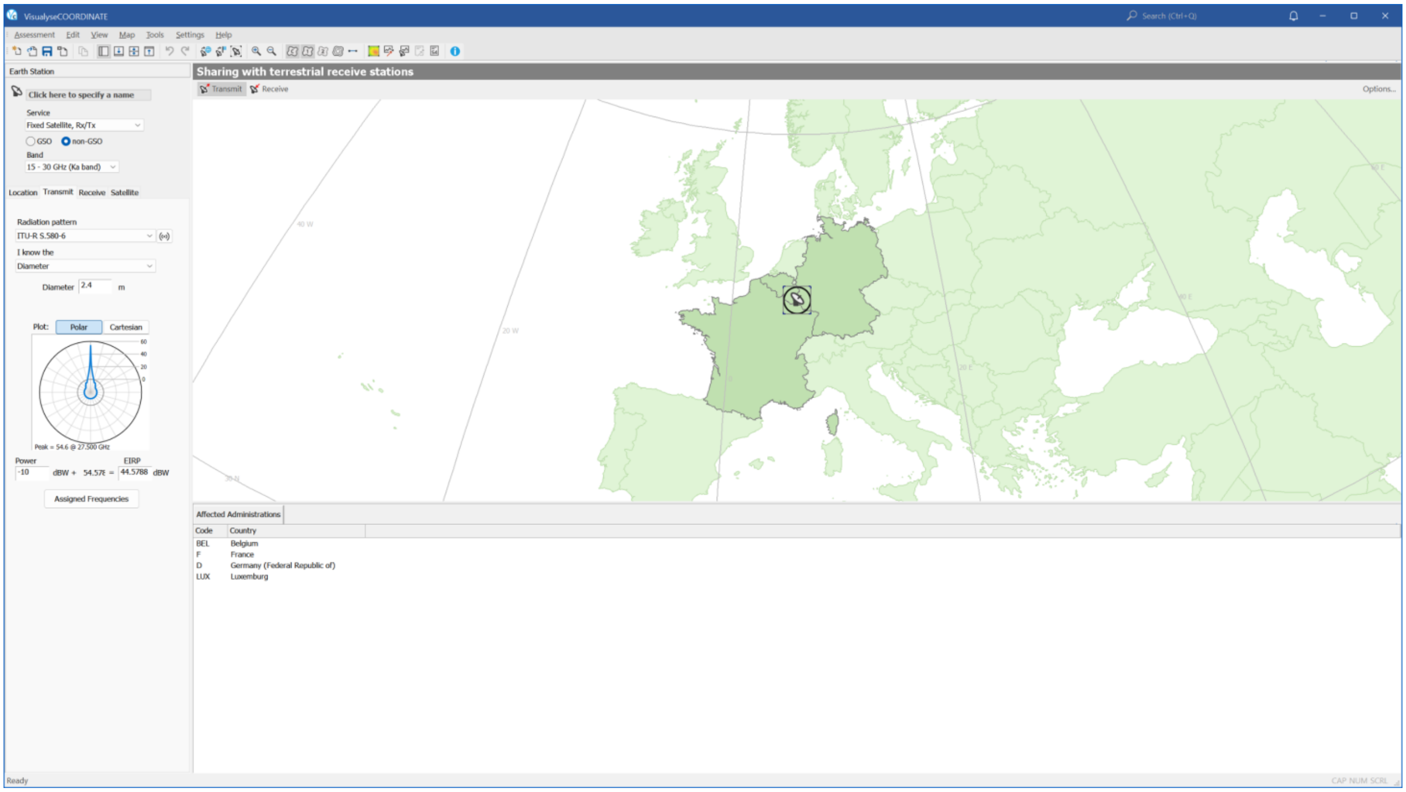
When RR and Recommendations are approved, then they form the basis for regulating the radio spectrum by Administrations world-wide. In the majority of cases this is done by national Administrations who are responsible for management of the radio spectrum in their territory. The ITU-R BR assists, mostly in cases involving satellites that are by their nature international.

Case Study 4: Coordination of Satellite ES

Pressure for change: increased number non-GSO constellations requiring gateways

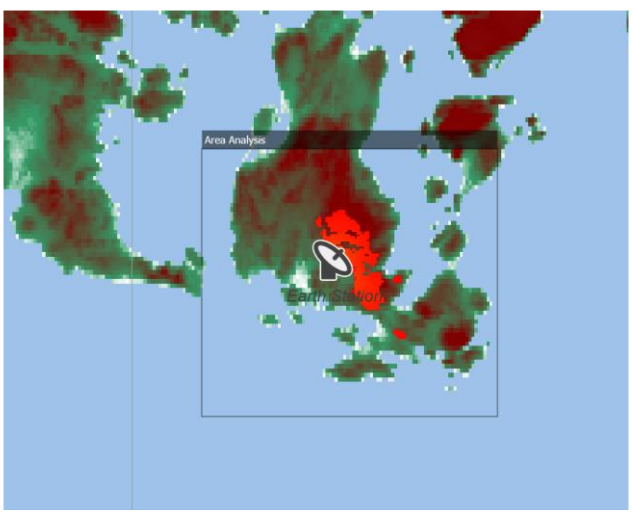
Satellite ES often operate in bands used for other services, including fixed and mobile services. Authorisation of a satellite ES can require both national and international regulations. For example, introduction of a new ES can require international coordination using the algorithm in Appendix 7. This involves the generation of a coordination contour and identification of which other countries could be affected by the new ES.

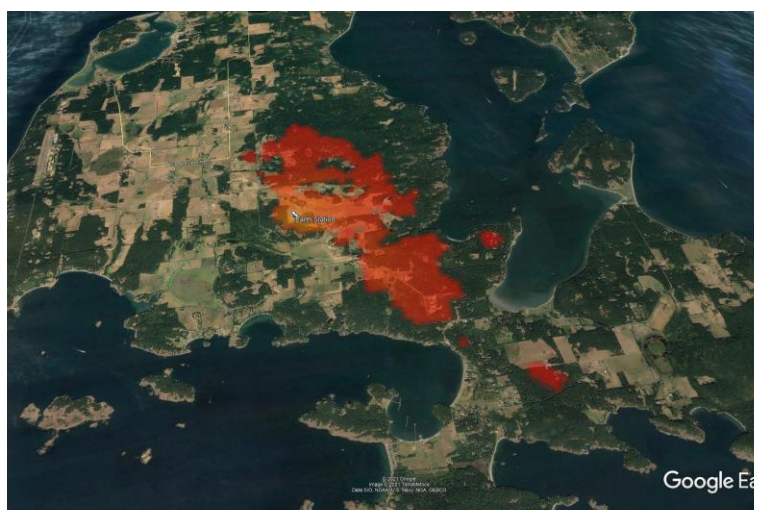
An example is shown in the figure below, generated using the Visualyse Coordinate tool:



In addition, each country is likely to have its own regulations. For example, within the United States, the FCC Rules for the 27.5 – 28.35 GHz band include procedures to share with stations of the Upper Microwave Flexible Use Service (UMFUS). The requirement in the FCC's Section 25.136 is to identify the area where the ES generates a PFD at 10 m above ground level of greater than or equal to -77.6 dBm/m2/MHz.

This type of analysis can be undertaken using the Visualyse Professional tool which can generate contours, export to Google Earth and calculate the population within the contour, as in the figures below.





More information on Visualyse Coordinate and using Visualyse Professional to generate PFD contours can be found at these links:

- Visualyse Coordinate
- Generating ES PFD Contours using Visualyse Professional

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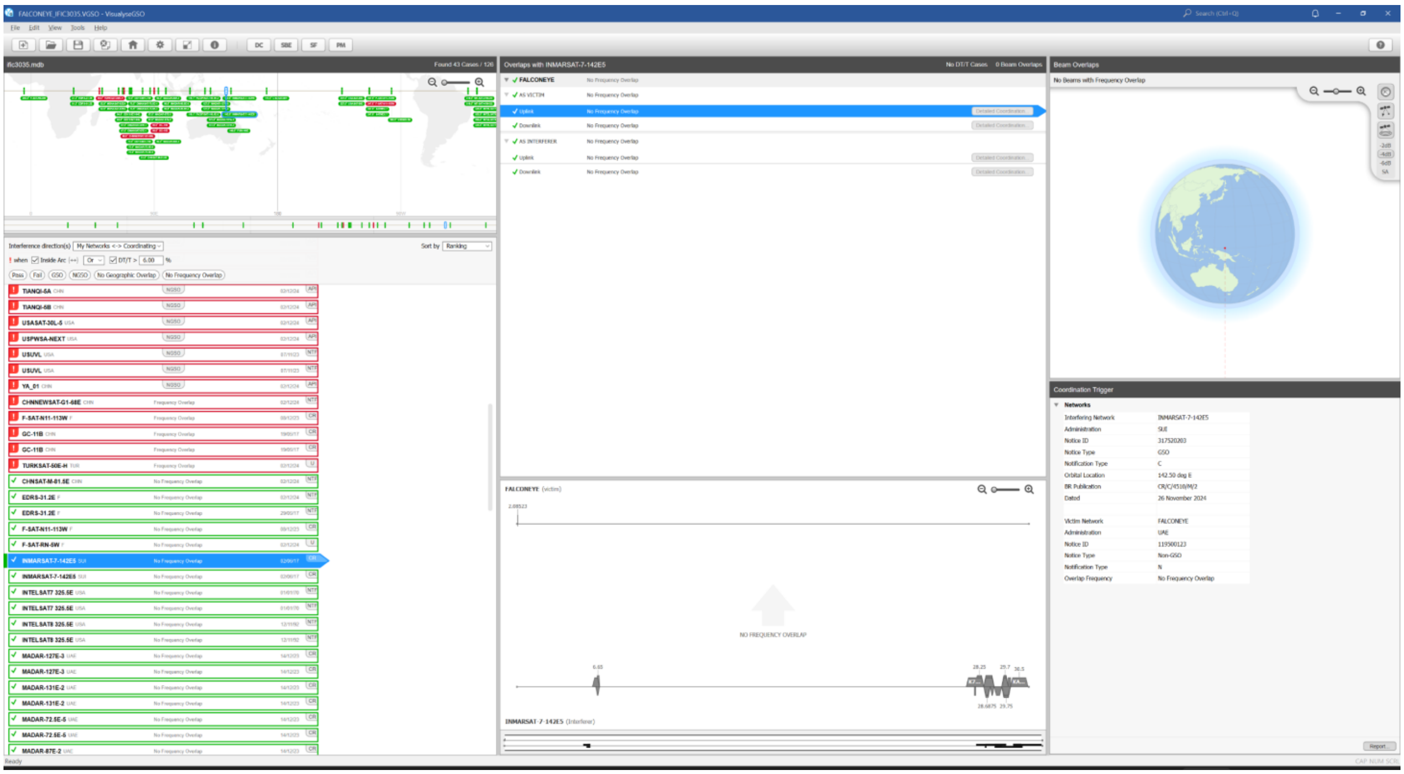
Case Study 5: Coordination of Non-GSO Satellite Systems

Pressure for change: increased number non-GSO constellations

There has been an increase in the number of non-GSO systems that are filed and this leads to the requirement for coordination under Article 9. This process involves a number of stages:

1) Identification of coordination cases
2) Coordination with potentially affected systems including undertaking any necessary sharing studies
3) Registration of the results of coordination with the ITU using the procedures in Article 11.

The first stage, identification of the coordination cases required, involves processing ITU databases, such as the SRS and IFICs. The criteria for coordination of non-GSO systems is given in Appendix 5 as frequency overlap, and the Visualyse GSO IFIC checker can be used to identify cases, as in the figure below:

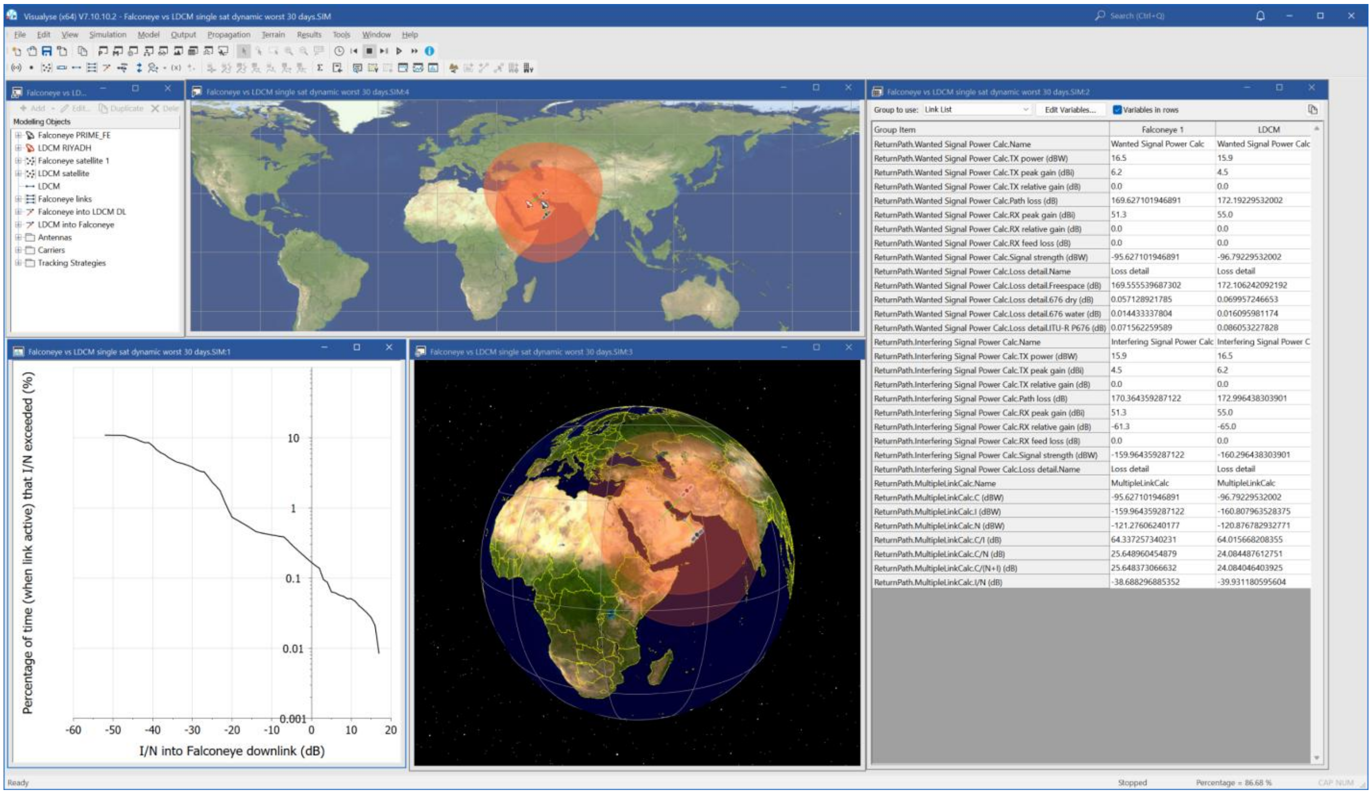


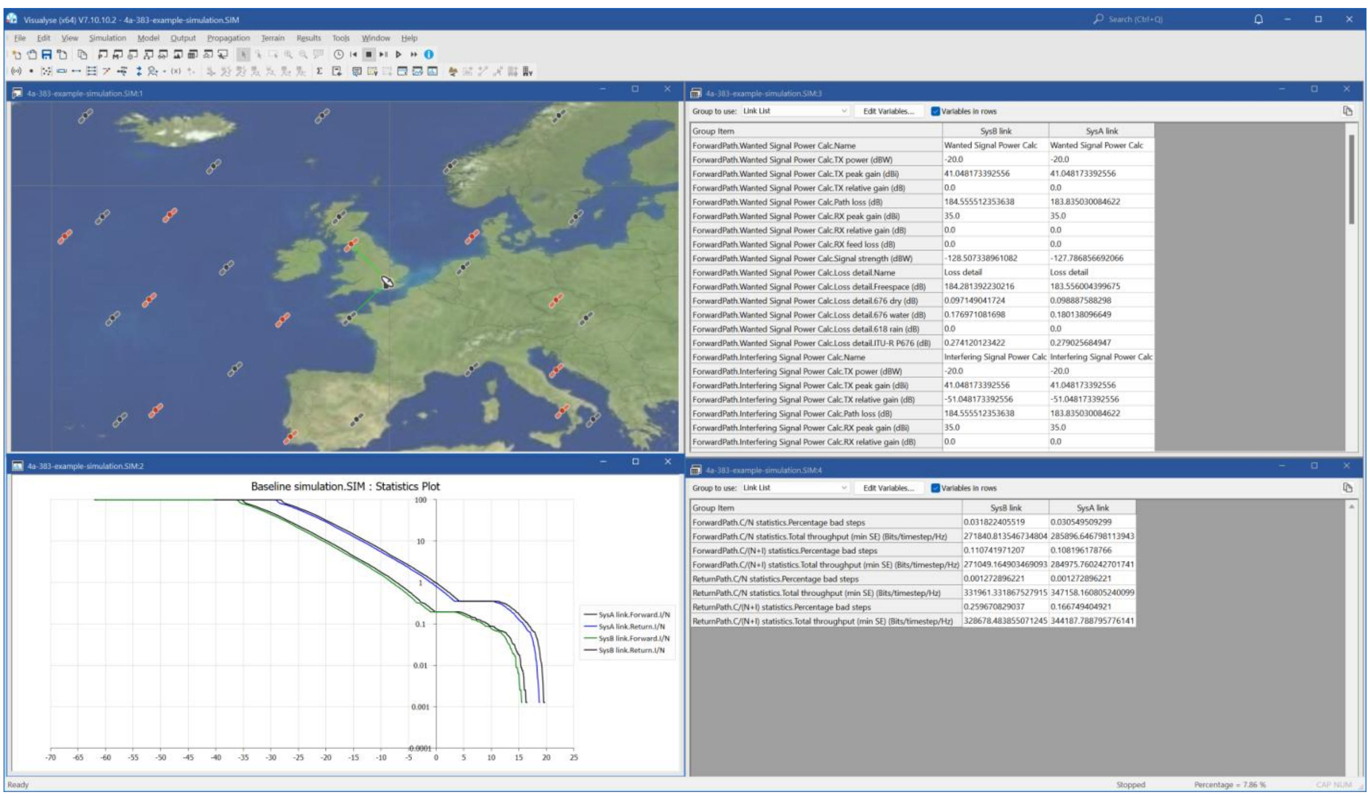
Having identified if coordination is required, then there is the need to undertake sharing studies of the potential for interference between the various systems involved. This type of study includes:

- Import of the orbit data of the satellite systems from the SRS / IFIC using the method in Recommendation ITU-R S.1503
- Definition of the antenna gain patterns at the satellites and ES using Recommendations such as S.465, S.580, S.672 and S.1528.
- Creating of the dynamic links between ES and satellites with suitable propagation models including those in Recommendations ITU-R P.525, P.618 and P.676.
- Specification of tracking strategies to identify the rules by which satellites are selected and include mitigation methods such as avoid pointing using components from Recommendation ITU-R S.1325.
- Calculation of metrics such as I/N, C/N, C/(N+I) and associated metrics such as unavailability and throughput and how they are impacted by interference.

- Time dynamic or Monte Carlo methods to generate statistics to compare against thresholds like those within Recommendations ITU-R SA. 1026, SA. 1027, S.1323 and 22.5L

The analysis method can be for small-scale systems with a small number of satellites or for large constellations potentially including multiple shells of satellites, as in the two figures below:





Such techniques can be used to identify how much interference there is, and, if necessary, determine the impact of mitigation methods. This can be used to develop a coordination agreement between the two satellite operators.

More information is available in this Technical Note:

- Non-GSO Satellite Coordination

Case Study 6: Verification of non-GSO Satellite System against Article 22 Limits

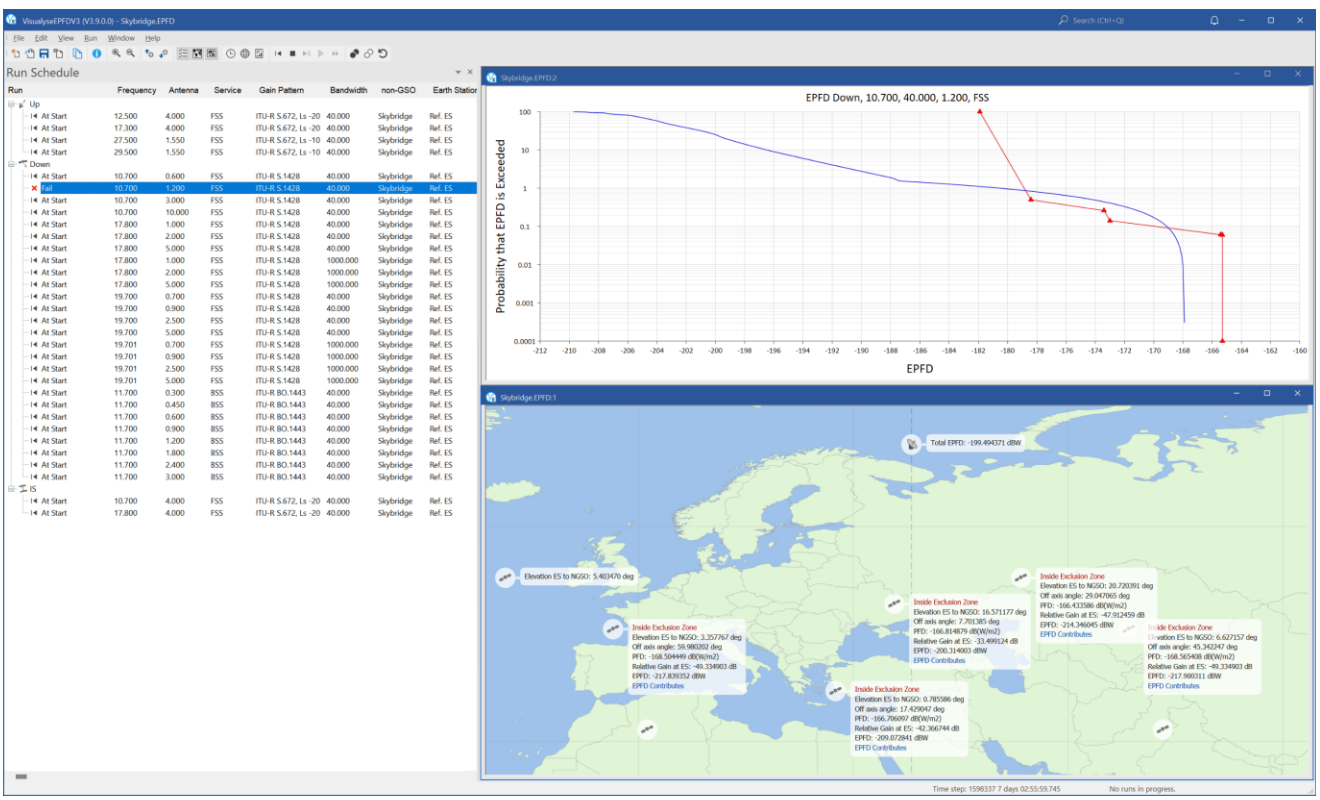
Pressure for change: increased number non-GSO constellations and need to protect GSO networks and proposals to operate in higher frequency bands

There have been a significant increase in the number of non-GSO constellations operating in bands where there are Article 22 limits including:

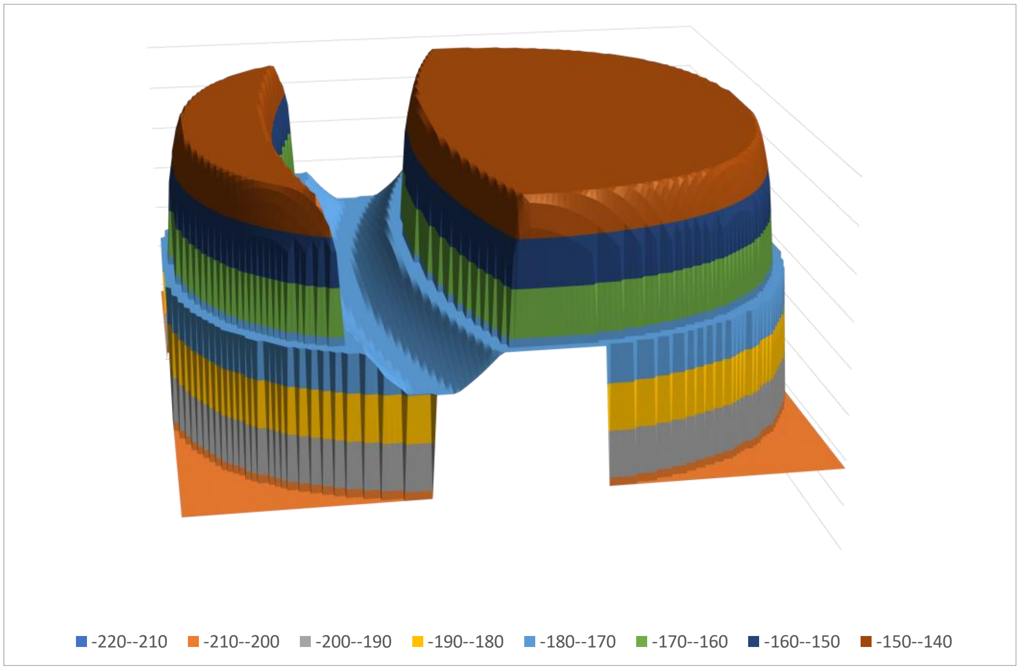
- In parts of C, Ku and Ka band, there are equivalent power flux density (EPFD) limits in 22.5C, agreed at WRC-2000 and WRC-03
- In parts of Q/V band, there are limits in 22.5L in terms of increase in unavailability and reduction in average throughput, agreed at WRC-19.

The process to evaluate whether the non-GSO system meets these limits involves the generation of EPFD statistics using the algorithm 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 service systems or networks with limits contained in Article 22 of the Radio Regulations*. This Recommendation has been developed within WP 4A, first approved just prior to WRC-2000 as part of a package of measures to facilitate non-GSO FSS while protecting GSO networks.

An example screenshot of the Visualyse EPFD is shown below:



For a non-GSO operator, significant work is required prior to submission of data to the ITU to ensure that the resulting analysis will generate a favourable finding. The non-GSO system's parameters can be used to generate the inputs required by the algorithm in Recommendation ITU-R S.1503, in particular the PFD mask, which has a structure similar to that shown below, created using the Visualyse PFD Mask Generator Tool (PMGT):



Iteration of the non-GSO system's parameters including PFD mask can be required to optimize the filing submitted to the ITU to ensure that the system can provide maximum service while meeting the EPFD limits.

For bands subject to 22.5L, there are additional procedures in Resolution 770, including using the EPFD statistics generated using Recommendation ITU-R S.1503 together with a set of generic reference links to determine and the algorithm in Recommendation ITU-R S.2157 to determine if these two thresholds are met:

> *– 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)*

These methodologies were developed within WP 4A during the cycle from WRC-15 to WRC-19 where they were approved within Resolution 770. In the cycle from WRC-19 to WRC-23, parts of the algorithm were moved from Resolution 770 into Recommendation ITU-R S.2157.

More information about EPFD, Visualyse EPFD, Visualyse PMGT and Resolution 770 can be found here:

- EPFD and Recommendation ITU-R S.1503
- Resolution 770 After WRC-23
- Visualyse PMGT

Some historical background to the process that led to the EPFD limits and Recommendation ITU-R S.1503 can be found here:

- History of JTG 4-9-11, Recommendation ITU-R S.1503 and the EPFD limits

Conclusions

This paper has considered how the ITU-R adapts to change. Case Studies have been presented that show how change can lead to extensive work updating the RR and ITU-R Recommendations, and it is for this reason that there are large numbers of ITU-R meetings.

Work within the Study Groups requires flexible tools to analyse the wide variety of sharing scenarios that might have to be considered. When the regulatory framework is stable the ITU BR and Administrations need Verification and Coordination tools to manage the spectrum.

Transfinite Systems can assist in providing analysis tools, including Visualyse Professional for study work, Visualyse EPFD for EPFD verification, Visualyse GSO to support the coordination of GSO and non-GSO satellites, Visualyse Coordinate for Appendix 7 coordination of satellite ES and FS.

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 GSO
- Visualyse EPFD with the Visualyse PMGT
- Visualyse Coordinate.

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

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