Technical Note: Verifying Visualyse Professional Simulations

Abstract: One of the key parts of building a simulation using Visualyse Professional when undertaking study work is the process to check it is operating as expected. There are a number of techniques that can be used to verify the simulation as discussed in this Technical Note.

Overview

An important part of building a simulation using Visualyse Professional is the ability to check it has been configured correctly and the various components have the right input parameters and are working as expected.

This can also help in explaining the simulation to others, whether within your organisation or at meetings.

A number of techniques can be used, including:

- Checking the wanted link budget
- Checking the worst interfering link budget
- Checking the PFD calculate against a PFD mask
- Checking the propagation loss and plot the path loss against distance
- Checking gain patterns
- Checking antenna and beam pointing
- Calculating the (azimuth, elevation) angles
- For terrestrial scenarios, looking at the path profile
- For non-co-frequency scenarios, looking at the frequency view
- Comparing results from those generated by other implementations
- Walk through the parameters.

These are discussed further below.

Some of the simulation files used as examples for this verification process are those that were generated in the following two previous Technical Notes (TNs):

- TN (a): Building a 5G Network in Visualyse Professional
- TN (b): Building a 5G Reference System in Visualyse Professional
- TN (c): 5G Features in Visualyse Professional

Some of the other screen shots come from the example files.

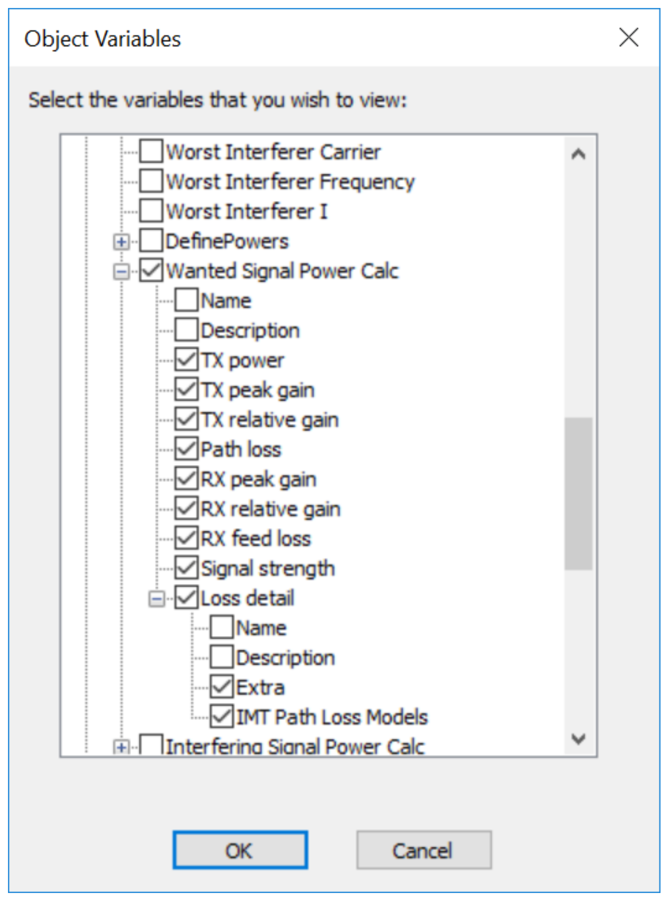
Link Budgets

The first step in the verification process is almost always to look at the link budgets to make sure that all the parameters are as expected. If there are just one or two links then the best way to do this is via the Watch Window. If there are more links than that then it is better to use a Table View.

Wanted Link Budget

The reference 5G network simulation as described in TN (a) was used as an example of looking at the wanted link budget. As this file included three base station (BS) to user equipment (UE) links, a Table View was used.

The Link Group with the three 3 UE links was selected and then the following variables:



Other parameters can be selected, such as link length, frequency, bandwidth and the link budget for the return direction.

The resulting Table View shows these link budget parameters for the three links:

5G sim stage 1 with 3 UEs.SIM:2

Group to use: UEs links | Edit Variables... | Variables in rows

Group Item	Link to UE-1	Link to UE-2	Link to UE-3
Length	0.0465334	0.0307555	0.0459997
ForwardPath.Frequency	26.0	25.94	26.06
ForwardPath.Receive temperature	2900.0	2900.0	2900.0
ForwardPath.Wanted bandwidth	60.0	60.0	60.0
ForwardPath.Wanted Signal Power Calc.TX power	-9.7	-9.7	-9.7
ForwardPath.Wanted Signal Power Calc.TX peak gain	15.8873146	23.0172577	17.0385563
ForwardPath.Wanted Signal Power Calc.TX relative gain	0.0	0.0	0.0
ForwardPath.Wanted Signal Power Calc.Path loss	114.5940415	103.2247069	115.7667372
ForwardPath.Wanted Signal Power Calc.RX peak gain	15.3379679	8.7776491	7.8725099
ForwardPath.Wanted Signal Power Calc.RX relative gain	0.0	0.0	0.0
ForwardPath.Wanted Signal Power Calc.RX feed loss	0.0	0.0	0.0
ForwardPath.Wanted Signal Power Calc.Signal strength	-93.0687591	-81.1298001	-100.55567...
ForwardPath.Wanted Signal Power Calc.Loss detail.Extra	4.0	4.0	4.0
ForwardPath.Wanted Signal Power Calc.Loss detail.IMT Path Loss Models	110.5940415	99.2247069	111.7667372
ReturnPath.Frequency	26.0	25.94	26.06
ReturnPath.Receive temperature	2900.0	2900.0	2900.0
ReturnPath.Wanted bandwidth	60.0	60.0	60.0
ReturnPath.Wanted Signal Power Calc.TX power	-24.2488131	-34.9015605	-8.0
ReturnPath.Wanted Signal Power Calc.TX peak gain	15.3379679	8.7776491	7.8725099
ReturnPath.Wanted Signal Power Calc.TX relative gain	0.0	0.0	0.0
ReturnPath.Wanted Signal Power Calc.Path loss	101.9764694	91.8933462	115.8915025
ReturnPath.Wanted Signal Power Calc.RX peak gain	15.8873146	23.0172577	17.0385563
ReturnPath.Wanted Signal Power Calc.RX relative gain	0.0	0.0	0.0
ReturnPath.Wanted Signal Power Calc.RX feed loss	0.0	0.0	0.0
ReturnPath.Wanted Signal Power Calc.Signal strength	-95.0	-95.0	-98.9804363
ReturnPath.Wanted Signal Power Calc.Loss detail.Extra	4.0	4.0	4.0
ReturnPath.Wanted Signal Power Calc.Loss detail.IMT Path Loss Models	97.9764694	87.8933462	111.8915025

It is worth checking that *all* the link budget numbers are as expected.

For example, in this 5G simulation, it would make sense to check that:

- The relative gain at the BS is zero i.e. that the beam is pointing directly at a UE. For other simulations, the gain should be consistent with the gain pattern and pointing angles (as discussed further below)
- The path loss values look reasonable (see further analysis below)
- The resulting C/Ns are in the expected range

In addition, if the simulation is stepped forward, the link budgets values can be seen to update and hence it is possible to check that they continue to be reasonable.

Interfering Link Budget

A similar process could be done with the interfering link budgets, in particular the worst interferer.

For the aggregate interference, it can also be useful to check that the total number of interferers is as expected. This could be the number of interfering links but also might be modified by:

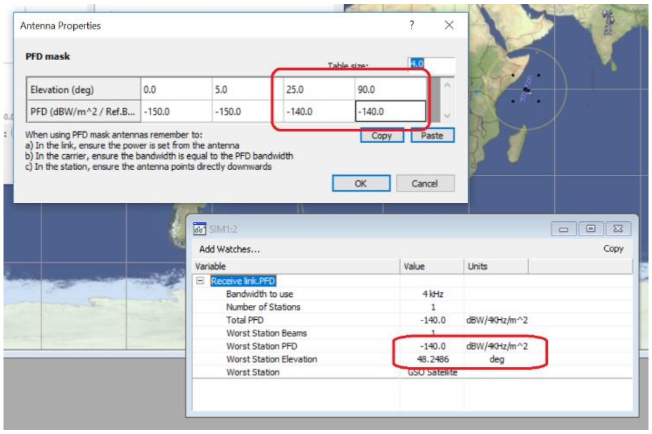
- For space to Earth scenarios: the number of stations visible. This can be checked by ensuring there is an isotropic antenna at each satellite so their footprints can be shown on a Map View. Then the number of satellites with footprints that cover the victim can be counted.
- For scenarios involving traffic, the likelihood that the link is active. This could vary due random elements in the traffic modelling but if (say) there were 100 interfering links with a traffic model for which the likelihood of being on was p = 0.5, then you'd expect around 50 interferers at each time step.

PFD Calculation

If you are using a PFD mask as source of interference then it can be useful to check that the PFD measured at the victim is as expected.

For example, in the screen shot below it can be seen that:

- In the Watch Window, the highest PFD was -140 dBW/m^2/4 kHz with elevation angle 48.2°
- This PFD is the expected value given the PFD mask entered into the Antenna Type:



If the PFD is different from the expected value then it's worth checking:

1) That the antenna that is using the PFD mask is pointing directly below the station (see the section below on pointing)
2) That the bandwidth used for the PFD mask is the same as that in the carrier (and possibly also for the PFD metric under statistics)
3) That the link is selecting the power from the antenna i.e. not using fixed transmit power or power control.

Note that PFD is calculated:

- Only for interfering paths, not wanted paths
- Assuming the PFD equation from Article 21 of the Radio Regulations:

$$pfd = \frac{eirp}{4\pi d^2}$$

This is effectively the PFD assuming just spreading loss i.e. free space.

If you want to calculate PFD taking into account other propagation models (in particular for terrestrial paths) then the best approach is to calculate the wanted or interfering signal at an isotropic receiver and then adjust for the effective area using:

$$PFD = I - A_e$$

Where:

$$A_e = 10log_{10}\left(\frac{\lambda^2}{4\pi}\right)$$

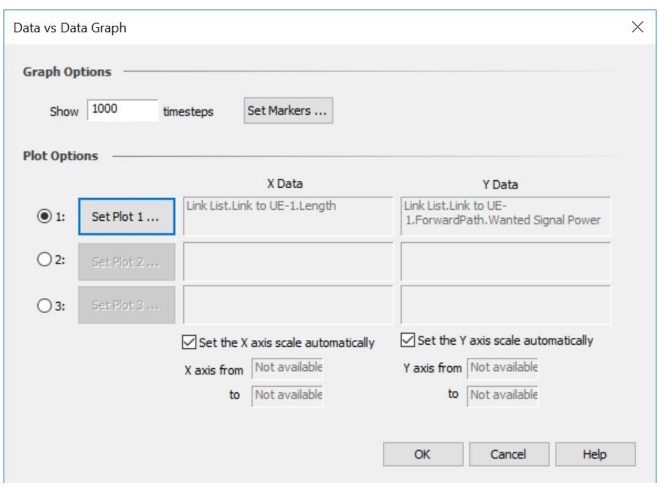
Propagation Loss

The propagation model will have a significant impact on the results and so it is useful to get a feel for the sort of values it is generating.

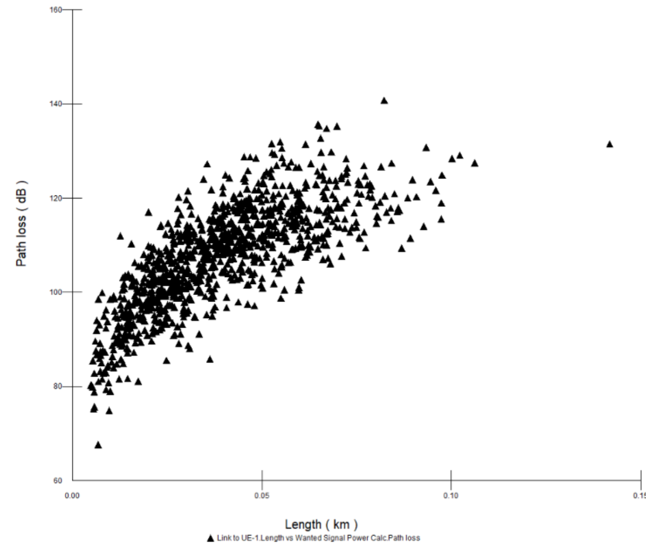
The Watch and Table Views, as described above, are a good starting point as they show not just the total path loss but also the various contributions.

More information can be useful: for example, for terrestrial paths, it can be helpful to plot the wanted link's path loss vs. path length using the XY graph in Visualyse Professional.

This can be done by configuring the data selection dialog to show the path loss vs. the link length for the last 1,000 steps as follows:



The resulting plot for the 5G reference system as in TN a) was as follows:



Note this chart has been changed to a scatter plot from the default of a line drawing.

It can be seen that there are multiple values of the path loss for any given distance: this is as expected given the random variation σ factor.

This could be extended by using an Area Analysis to show how the propagation loss varies in two dimensions, possibly taking terrain into account. The Path Profile View can also provide helpful information, as described below.

Some things to look out for when assessing whether the path loss value is as expected include:

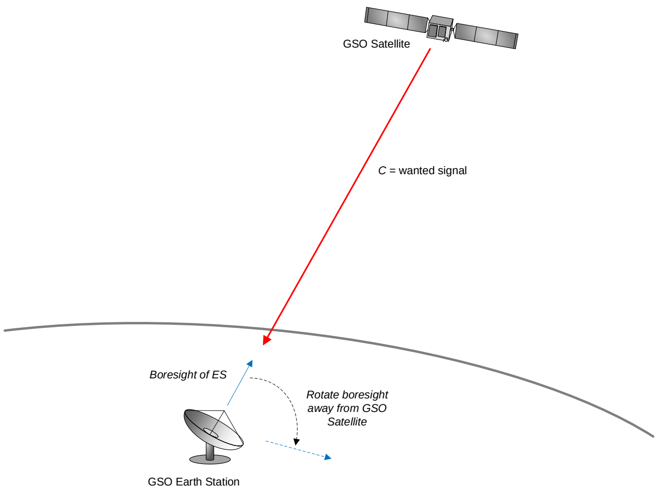
- Path loss is zero: this is a sign that the propagation model was unable to calculate the pathloss - unless the model has been set up with zero path loss, e.g. when calculating aggregate EIRP as in TN (b). If the path loss is zero and this is not expected then check the validity of the propagation model (i.e. height, frequency etc.) and also station type. For example, the IMT path loss models require one station to be Fixed and the other to be Mobile.
- Path loss is much higher than expected. For example, if the P.676 gaseous attenuation is very large (e.g. over 100 dB) then it could be that the terrestrial model has been applied for a space to Earth link and the model needs to be informed to use the space to Earth version.

Checking Gain Patterns

The gain pattern can make just a significant impact on the results as the propagation model and so it is important to ensure the pattern is as expected.

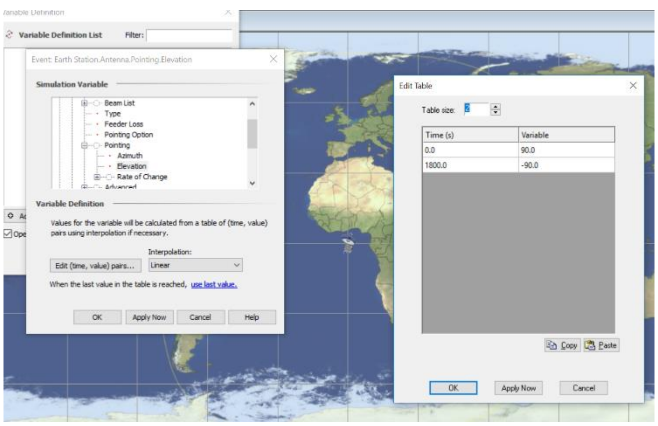
A number of techniques can be used to plot the gain pattern which can help understand and explain a simulation.

One approach is to create a plot of gain vs. offaxis angle using a simulation as shown in the figure below:



Here a GSO satellite with longitude = 0 is transmitting to a GSO Earth station at (latitude, longitude) = (0, 0). The ES antenna starts with pointing angle (azimuth, elevation) = (0, 90) and then the elevation angle is changed so that the antenna gradually points away from the GSO satellite.

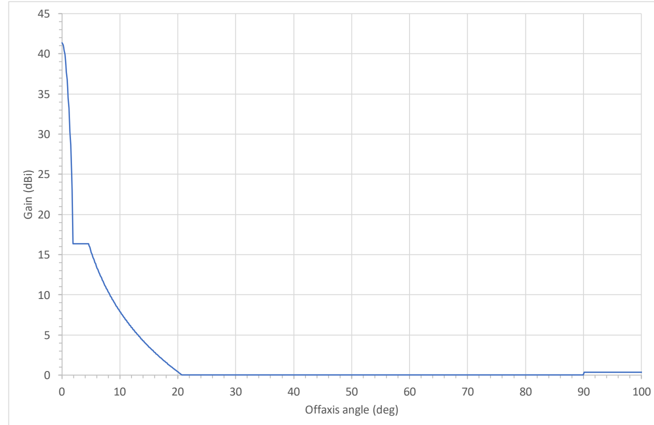
The easiest way of creating this pointing method is via a Table Define Variable:



The receive gain at the ES can then be outputted (e.g. to a log file) and for each value the offaxis angle will be known as it is:

OffaxisAngle = 90 – ElevationAngle

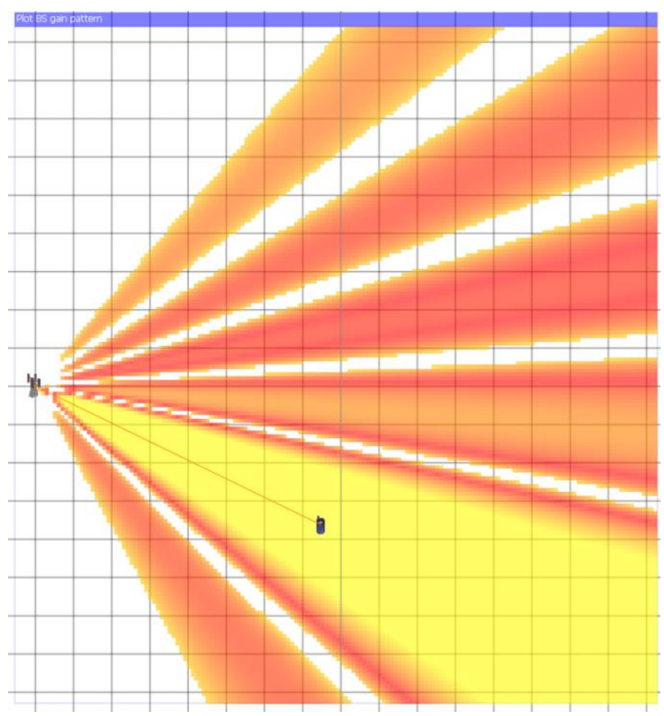
Hence a plot can be generated in tools such as Microsoft Excel like this:



Note this example uses a GSO satellite and ES but the gain pattern could be that of any service as long as it has a static gain pattern i.e. not those using beamforming that change depending upon pointing direction.

For those antenna types that use beamforming another approach could be used, based upon creating an Area Analysis (AA) of the gain at specific locations.

This approach was used in TN (c) to show the gain of a 5G beamforming antenna:



This was achieved by noting that the interfering calculation link budget is:

$$I = P_{tx} + G_{tx} - L_{path} + G_{rx} - L_{feed}$$

If the transmit power, pathloss, feedloss and receive gain are also zero then:

$$I = G_{tx}$$

Hence by creating a special link with:

Transmit power = 0 dBW

Path loss = Extra Models, Fixed Loss = 0 dB for the interfering path

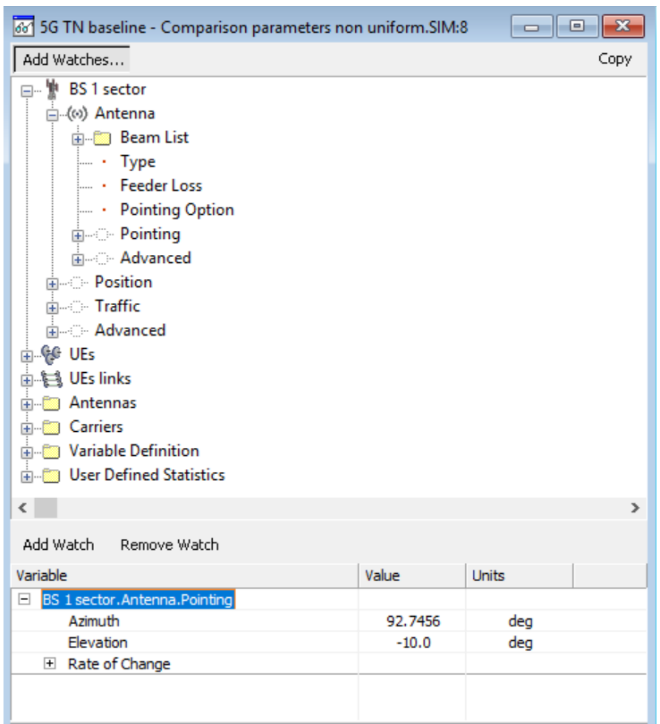
Receive gain = isotropic 0 dBi antenna type

Receive feed loss = 0 dB

Then a plot of the BS antenna gain can be shown by creating an AA of the interfering signal at a test point with this isotropic antenna from a link from the BS to the UE.

Antenna and Beam Pointing

If the gain pattern is right, the next question is where are the antennas pointing and are they in the expected directions. This can be checked by opening a Watch Window (or Table View if there are many stations to check) and looking at the antenna pointing angles, as in this example from TN (a):



Calculating the Azimuth and Elevation

A related question to checking where the antenna is pointing is to determine what the (azimuth, elevation) of one station is as seen by another.

One top tip to find out what the angles are is to create an antenna just to identify these angles. The antenna can be called something like "Point" and then pointed at the required target station. A Watch Window can then be opened as in the example above.

Note that if transmit links are being used that care is required to ensure this additional antenna does not cause extra interference. One way to do this is to create an isotropic antenna with gain = -999 dBi so that its EIRP will always be very low.

Look at the Path Profile

For terrestrial scenarios that involves terrain it can be very useful to look at the path profile.

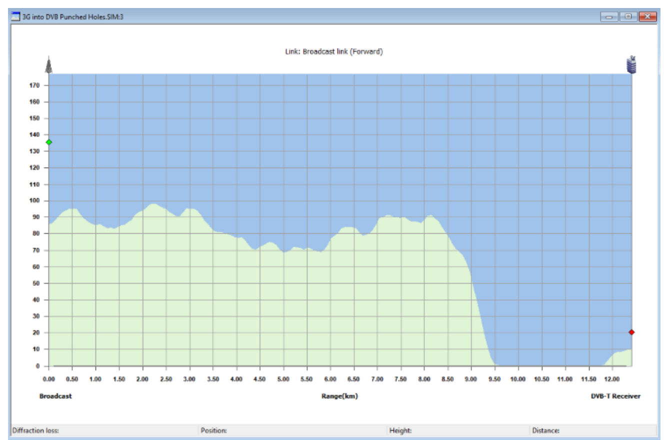
The Path Profile shows a slice through the terrain between two stations. These could be between:

- The transmit and receive stations of a wanted link
- The interfering transmit station into the victim receive station

This can be useful to identify (say) if there is line of sight and, if not, the propagation loss could be higher due to diffraction effects.

Note that if the Path Profile has been selected via a link (either wanted or worst interferer) then the view will show at the bottom left the diffraction loss if there is any.

The Path Profile also shows the distance between the two stations.



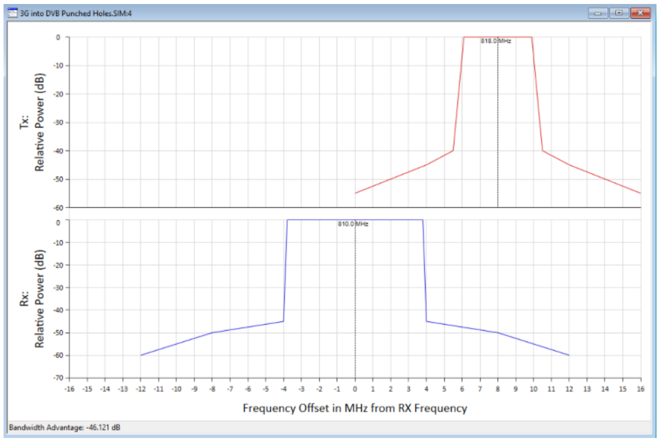
It can be useful to compare this view against the link budget's path loss components.

Note that terrain is used by the propagation models in Recommendations P.452, P.526, P.530, P.1546, P.1812 and P.2001, plus also in Longley-Rice.

Look at the Frequency View

For non-co-frequency scenarios which use the mask integration adjustment A_{MI} (i.e the net filter discrimination or NFD) it can be useful to check the frequency view to make sure the transmit and receive spectrum masks and frequency separation are all as expected.

An example of the Frequency View can be seen below, from one of the demonstration files:



Note that the A_{MI} (i.e. the NFD) is shown in the bottom left of the view in the form that it is shown in the Watch Window, namely as the bandwidth advantage.

Comparing Results

Comparing results can mean one of two things:

1) Comparing the results generated using Visualyse Professional in two different ways
2) Comparing the results generated using Visualyse Professional with those generated by another tool

An example of the first of these was given in TN (b) in which the same scenario was modelled:

- In detail, taking into account all transmitters within a given area
- Using the aggregate eirp (AIERP) calculated using the detailed simulation

These should give very similar outputs and can be a way of checking that the reference system approach will give results consistent with detailed simulations.

To compare the results generated by Visualyse Professional against another tool a number of approaches could be used. The simplest is to repeat some of the calculations in Microsoft Excel, though this tends to only be feasible for very simple scenarios.

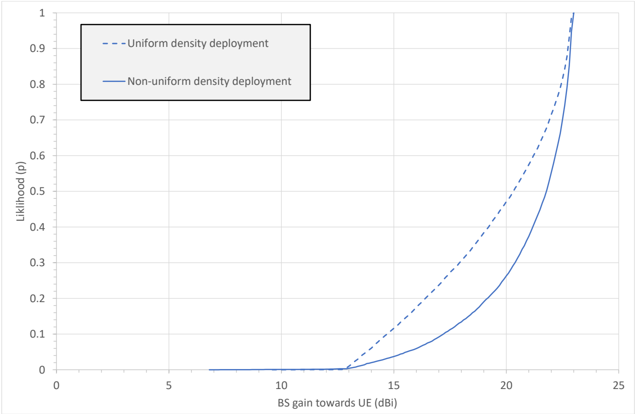
If results are available from other simulation tools then they could be used as a reference. For example, TN (a) described results for an example implementation of the 5G reference system which included CDFs of:

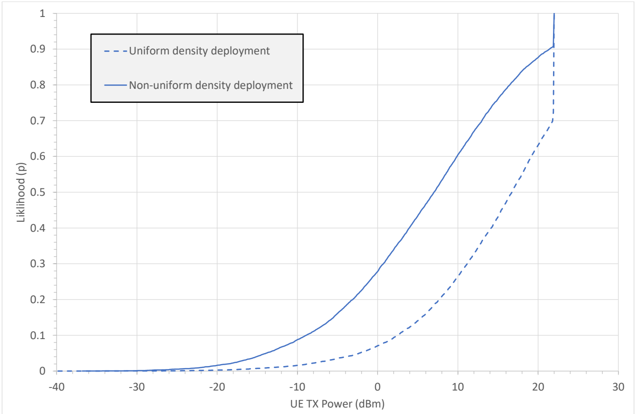
1) Gain at the BS towards the UE
2) Transmit power at the UE (single UE and 3 UE per sector cases)
3) C/N of the downlink

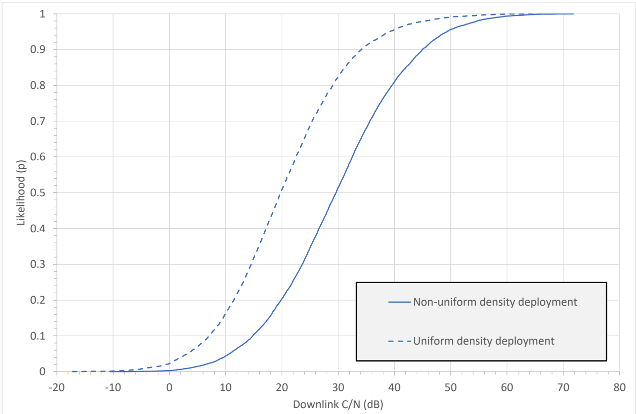
The equivalent outputs from Visualyse Professional could then be compared against these results.

This was a useful exercise when creating TN (a) as some differences were noted and in the resulting investigation it was observed that the example implementation assumed a uniform deployment density of UEs, when the latest ITU parameter set assumes non-uniform.

Hence plots were generated of the three parameters above for both the uniform and non-uniform deployments, as shown in the figures below.







It can be seen that there is good agreement of the uniform deployment results with those shown in the document: “Example implementation of the methodology in Recommendation ITU-R M.2101”.

However, it was also noted that the example implementation included a number of different results from different tools and there wasn’t exact agreement between them.

It can be very difficult to get exact agreement and it is necessary to check assumptions and implementations in great detail to identify the sources of any deltas.

Checking Parameters

The results from a Visualyse Professional simulation are dependent upon the input values used, and so it is helpful to be have a structured way to check the right parameters have been entered.

One way to check the parameters is to start with the interference path:

1) Look at the Interference Path and note the:
   - Wanted / victim and interfering Link(s)
   - Parameters used by the Interference Path, such as check overlap, polarisation adjustment and bandwidth adjustment
2) Then for each of the Links, whether wanted/victim or interfering:
   - Check the start and end Stations: for Dynamic Links check to see if a Tracking Strategy is being used
   - Check the Propagation Environment
   - Check the start→end path parameters (carrier, frequency, power, noise etc.). In particular, check whether the power and frequency for this Link is being defined on the Link or from the Antenna Type
   - If necessary, check the end→start parameters
   - Check if a Traffic Model is being used
   - Check if the global Propagation Environment or statistics are being over-riden on the advanced tab
3) If a Tracking Strategy is being used, then check its parameters
4) If a Traffic Model is being used, then check its parameters
5) Check the Propagation Environments used, including:
   - The wanted and interfering propagation models
   - For each model, the options / configuration used, in particular whether random or fixed percentage of time
6) Check the wanted/victim and interfering Carriers, in particular the bandwidths and (if NFD is being calculated) the transmit/receive spectrum masks
7) Check the Stations and Station Groups:
   - That the dynamics are as expected
   - That the Antenna Types selected are as expected
   - That the antenan pointing is as expected
8) Then for each Antenna Type check the gain pattern and associated parameters, plus whether the beam is electronically steered or not. If the power is being defined by the antenna type, then check the min/max EIRP
9) Check the Define Variables that have been created for this simulation
10) Check the number and size of time steps
11) Check statistics options and thresholds
12) Check other configuration options, such as terrain, clutter and logging, as required.

Having a structured approach to checking parameters can help ensure that nothing important is missed.

It is often useful to start with a simple simulation and only adding complexity when you are confident it is working correctly. Also, it can be helpful to keep the simulation file “clean” by:

- Deleting unused objects
- Using global Propagation Environment and statistics settings rather than on a link by link basis unless that is needed for other reasons (e.g. to manage propagation correlation)
- Setting transmit power in the Link rather than the Antenna Type (unless required for other reasons).

About Transfinite

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

- Visualyse Professional
- Visualyse GSO
- Visualyse Coordinate
- Visualyse EPFD

We also provide training courses in use of our products including advanced training that can cover modelling of specific systems and scenarios. More information about these products and services is available at our web site:

http://www.transfinite.com

Alternatively email us at:

info@transfinite.com

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