Making Tracking Strategies

Abstract: When modelling non-GSO satellite systems, the geometry is always changing, and so it becomes necessary to consider the method by which the active satellite is selected. In Visualyse Professional, this is done via the Tracking Strategy object, which is used by a Dynamic Link to select an end station based upon rules such as highest elevation. The Tracking Strategy can be used to make sure the "right" non-GSO satellite is active at each time step taking into account factors such as minimum elevation angle and exclusion zones around the GSO arc. This updated Technical Note (TN) describes the Tracking Strategies in Visualyse Professional and describes some of the most common selection methods.

Introduction To Tracking Strategies

For non-GSO satellite constellations, there can be multiple satellites visible to an Earth Station (ES) that it could communicate with. The question is then, which one should the ES select at each moment in time, or in a Visualyse Professional simulation, for each time step? This is done by defining a "Tracking Strategy" which is a set of rules that can be used to identify which satellite to select from a constellation.

The basic Tracking Strategy has two stages:

- 1) Filtering: from those satellites that are visible to the Earth Station, use a filter to identify which are possible candidates to be used at this time step and which are not suitable. For example, those satellites which are below a minimum elevation angle or close to the GSO arc might not be suitable and should not be considered further.
- 2) Selection: from those satellites which are possible candidates, select the preferred one to use at this time step. For example, it could be the satellite which has the highest elevation angle at the ES or is the nearest.

The basic Tracking Strategy can be extended by an initial stage that considers whether the satellite selected at the previous time step is still suitable in order to support "continue to track" or "longest hold time" satellite selection methods.

Note that while these examples consider an ES selecting a satellite from a constellation, the Tracking Strategy is a generic Station selection tool, and so it could also be used:

- To connect to a single non-GSO satellite including rules such as minimum elevation angle, as in the first example below
- By a non-GSO satellite to select the nearest gateway to communicate with
- By a GSO satellite to select a non-GSO satellite to communicate with, such as for an inter-satellite link (ISL), as in the example below
- By a 5G network's user terminal (UT) to select a base station (BS).

There is also the option in Visualyse Professional to have a Link start at the end Station of another Link, allowing endto-end communication over multiple Links.

This TN is an updated document for March 2024 that includes two new sections, as identified below.

Example Tracking Strategies

This section describes how to configure the following satellite selection methods:

- 1. Set a minimum elevation angle
- 2. Set a minimum elevation angle and GSO arc avoidance angle
- 3. Use highest elevation vs. random selection methods
- 4. Include a constellation avoid selection method
- 5. Advanced constellation avoid methods to avoid active antennas or beams (new)
- 6. Select longest track option
- 7. Configuring a gateway with many antennas
- 8. Model inter-satellite links
- 9. Derive visibility statistics.



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In addition, tracking strategies and a traffic object parameter can be combined to provide diversity when the first choice of link is not available (new).

Set a Minimum Elevation Angle

While Tracking Strategies are often used with constellations containing many non-GSO satellites, they can also be used for satellite systems with the single satellite. One reason for using Tracking Strategies in these cases is if there are (say) minimum elevation angle constraints associated with the ES.

Consider a scenario with:

- Single non-GSO satellite in sun-synchronous orbit, providing remote sensing data
- Single ES, communicating with the satellite only when it is above 5° elevation angle.

This scenario can be modelled by putting the single non-GSO satellite in a station group, similar to this:

| Station Group | | × |
|---------------------------|--|--------|
| Falconeye satellite group | | Wizard |
| In the Simulation: | In the Group: | |
| Falconeye ES Falconeye | Falconeye Falc | |
| Filter: | | |
| OK Cancel | Apply | Help |

Then the minimum elevation angle of 5° constraint can be coded into the Tracking Strategy as follows:



The non-GSO satellite Station Group and Tracking Strategy can then be used in the end Station selection of a Dynamic Link as follows:

| Dynamic Link | × |
|-----------------------------------|-----------------------------|
| | |
| Falconeye 1 | Propagation: Space<>Earth ∨ |
| Start End Start->End End->Start | Traffic Advanced |
| Tracking strategy: | |
| Tacking suategy: | Add or Edit |
| 15 Falconeye | |
| Track a station from Falconeye sa | tellite group |
| | |
| | |
| | |
| | |
| different transmit antenna | |
| Transmit antenna: | Receive antenna: |
| Antenna1 V | Antenna1 V |
| | |
| | |
| | |
| | |
| | |
| | |
| | OK Cancel Apply |
| | |

This Link will then only be active when the satellite is at elevation angle of 5° or higher at the ES.

Set a Minimum Elevation Angle and GSO Arc Avoidance Angle

In bands where non-GSO systems share spectrum with GSO systems, one way to reduce interference levels (in either direction, but in particular into GSO systems) is for the non-GSO system to not transmit when the line from the ES to the satellite could go close to the GSO arc. An exclusion zone can be defined around the GSO arc using the α = alpha angle, which is the minimum angle from a line to a non-GSO satellite and any point on the visible GSO arc, as in the figure below.



This selection method is available in the Tracking Strategy object and can be combined with other methods, such as a minimum elevation angle. For example, consider a non-GSO constellation with the following constraints:

- Elevation of an active satellite must be at least 45°
- Angle to the GSO arc of an active satellite must be at least 8.4°.

A Tracking Strategy comes with an elevation angle constraint, so this can be configured to handle the first constraint:

| | Tracking Constraint | × |
|---------------------------------|---|----------|
| | Elevation Angle Ensure that the elevation angle at the tracking station is at least 45.0 deg | |
| | OK Cancel | |
| The second constraint can be in | ncluded by clicking on Add and then selecting | j "Avoid |



This can then be configured in a similar way to the elevation angle constraint:

| Tracking Constraint | × |
|--|-------|
| Avoid G50 Arc | |
| Consider stations that avoid the GSO arc by at least 8.4 deg Calculate these angles at the earth station | |
| ОК Са | ancel |

The two constraints can then be seen in the list here:

| Tracking Strategy | \times |
|---|----------|
| Avoid GSO arc | |
| Stations must meet all of the following constraints: | |
| Elevation Angleat least 45.0 degAvoid GSO Arcangle at earth station at least 8.4 deg | |
| | |
| + Add 🌶 Edit 🖬 Duplicate 🗱 Delete | |
| When more than one station meets the constraints, the software needs to know which station to pick. | |
| Choose the Advanced <click edit=""> \checkmark Edit Handover Options</click> |] |
| OK Cancel | |

Use Highest Elevation vs. Random Satellite Selection

After filters have identified the possible candidate satellites, the Tracking Strategy's next task is to select the one to use for this time step. A number of methods could be used, such as highest elevation or random satellite selection, as in the examples below:

| Choose the | Highest Elevation \sim | Edit | Choose the | Random Station 🗸 🗸 | Edit |
|------------|--------------------------|------|------------|--------------------|------|
| | | - | | | - |

These can result in very different statistics. For example, in the figure below the highest elevation satellite above London is nearby and at this latitude there will be a large angle to the GSO arc:



However, if the random method is used, then the selected satellite could be a long way from the ES and potentially closer to being in-line with the GSO arc:



It can be useful to consider how sensitive the simulation results are to the satellite selection method. Factors to consider include:

• Operational behaviour: it might be that the operational system would be more likely to select the satellite directly overhead rather than one far away.

• Identification of worst case: by selecting "random" it is possible to search a wider range of geometries to identify one that could cause harmful interference.

Other more advanced methods can also be considered by selecting "Advanced <clicked Edit>" which allows additional controls to be used, as in the figure below:

| Custom Selection Method | \times |
|---|----------|
| Station Selection | |
| Pick the station with the 1 \checkmark st highest elevation angle | |
| | |
| Resource Restrictions | |
| Ignore stations that are already being tracked by another: | |
| \checkmark If the 1 st choice station has no resources available, don't try the next best station | |
| Use minimum track angle at antenna or beam | |
| Minimum track angle: Not avail: deg | |
| OK Cancel | |

Some of these options can be useful to extend the basic selection methods.

For example, consider the highest elevation satellite selection method when there are multiple ES each with their own Dynamic Link and the non-GSO satellites use steerable Antennas. It could be that at some time steps, multiple ES try to select the same satellite: what happens if more Links try to use a satellite than it has available steerable Antennas?

One of the constraints with Visualyse Professional is that each steerable Antenna can only point in one direction at each time step. Hence if there are (say) 3 Links each trying to use a satellite with (say) 2 Antennas, the last Link will not be able to get an Antenna to point in its direction.

Note that typically in this case the Antenna selection method is "Any tracking antenna".

A number of possible behaviors could be considered for the third and final Link:

- 1) The Link fails as it is unable to identify a suitable and available Antenna
- 2) The Link uses a different satellite, one that has an available Antenna
- 3) The Link uses another Antenna on the first satellite, even though it will result in degraded performance as there would be a significant reduction in antenna gain at the satellite towards the ES. One way this could be done is by using a named Antenna for multiple links.

The first two of these options can be selected by checking the "If the 1st choice station has no resources available, don't try the next best station" field.

However, the second of these options can be selected by clearing this field. This tells Visualyse Professional that if the preferred station doesn't have any available tracking Antennas or Beams, then it is ok to select another satellite. In this case, Visualyse Professional will return a list of possible candidate satellites, sorted by one of the metrics such as elevation angle, and work its way down the list:

| Custom Selection Method | \times |
|--|----------|
| Station Selection | |
| Pick the station with the highest elevation angle | |
| | |
| Resource Restrictions | |
| Ignore stations that are already being tracked by another: | |
| If the 1 st choice station has no resources available, don't try the next best station | |
| Use minimum track angle at antenna or beam | |
| Minimum track angle: Not avail; deg | |
| | |
| OK Cancel | |

Include a Constellation Avoid Selection Method

As well as avoiding the GSO arc, it is possible for a non-GSO constellation to avoid pointing towards satellites of another constellation. This can be a useful tool during the satellite coordination process.

This can be included by adding the following constraint to the satellite selection phase:

| Select Constraint | × |
|--|---|
| Elevation Angle Restrict the elevation angle at the tracking station. Azimuth Angle | Avoid/Maintain Alignment Pick stations based on their proximity to alignment with a particular station |
| Restrict the azimuth angle at the tracking station. Distance Select stations based on their distance from the tracking station. | Avoid GSO Arc Prevent the earth stations from tracking satellites that are in the direction of the GSO arc. Latitude Difference |
| Avoid Constellation Use this to avoid pointing earth stations towards satellites in other constellations Avoid G50 Systems | Place restrictions on the difference in latitude between the tracked and the tracking stations. C Longitude Difference Place restrictions on the difference in langitude between the tracked and |
| Prevent the earth stations from tracking satellites that a group of earth stations sees in the direction of the GSO arc | the tracking stations. |

The avoidance angle can be defined either at the ES or at the satellite:

| Tracking Constraint | \times |
|---|----------|
| Avoid Constellation | |
| Consider stations from: Sats B group Logic to use: | |
| Only line to station location $\qquad \qquad \lor$ | |
| Line to station calculation: Calculate these angles at the earth station This angle should be at least 10.0 deg | |
| Boresight line calculation: | |
| Boresight line angle to check: | |
| ~ | |
| This angle should be at least 10.0 deg | |
| OK Cancel | |

There are additional options that can be used, as discussed further in the next section.

Note that you can have two "Avoid Constellation" constraints, one defined at the ES and the other at the satellite. It is also possible to have "Avoid Constellation" used by the Tracking Strategies of each system to protect the other.

Advanced Constellation Avoid Selection Methods (New)

The avoid constellation is a method to facilitate sharing spectrum between two or more non-GSO constellations. But it can lead to spectrum inefficiencies, as can be seen in the example below:



Here ES-A has a choice of three satellites: {A1, A2, A3}, where the first two are "better" choices in that they have a higher elevation angle than satellite A3. But these two satellites are close to satellites {B1, B2} of system B and so an "avoid constellation" tracking strategy rejects them.

But in this case, System B satellites {B1, B2} are serving ES at locations far away from the ES-A, so there would be a large angular separation at the satellite. Hence it could be feasible for ES A to communicate with either satellites A1 or A2 without causing harmful interference.

This can be modelled by an advanced "avoid constellation" method as shown in the figure below:

| Tracking Constraint | X Tracking Constraint X |
|--|---|
| Avoid Constellation | Avoid Constellation |
| Consider stations from: Sats B group | Consider stations from: Sats B group |
| Logic to use: | Logic to use: |
| Only line to station location $\qquad \qquad \lor$ | Line to station location OR boresight line \sim |
| Line to station calculation: | Line to station calculation: |
| Calculate these angles at the earth station | Calculate these angles at the earth station |
| This angle should be at least 10.0 deg | This angle should be at least 10.0 deg |
| Boresight line calculation: | Boresight line calculation: |
| Boresight line angle to check: | Boresight line angle to check: |
| ~ | Angle (tracking antenna boresight, line to ES) \sim |
| This angle should be at least 10.0 deg | This angle should be at least 10.0 deg |
| OK Cance | OK Cancel |

Original avoid constellation method

Enhanced avoid constellation method that also checks the satellite antenna boresight vectors

In the second case the avoid constellation checks each non-GSO satellite in constellation A to see if it is within 10 degrees of a satellite from constellation B. If it is, then it also checks whether at the same time the angle from the satellite in constellation B has a beam or antenna that is pointing towards Earth station A. If not, then this satellite could be used.

When this second option is selected, then either satellite A1 or A2 could be used, as seen in the following figure:



This method could be used to check just the beam boresights. For example, it could be possible for ES A to not communicate with those satellites from constellation A that are within 10 degrees of the boresight vector of one of the system B ES group.

Consider the example below:



Here satellite A2 is close to satellite B2 that is being used by ES B2. Satellite A1 is close to satellite B1 and a usual "avoid constellation" tracking method would not accept it as an acceptable candidate. But in this case, it is acceptable as there are no system B ES that are pointing towards that location in the sky.

This option can be selected by something like the following:

| Tracking Constraint | \times |
|--|----------|
| Avoid Constellation | |
| Consider stations from: ES B group | |
| Logic to use: | |
| Only boresight line \sim | |
| | |
| Line to station calculation: | |
| Calculate these angles at the earth station | |
| | |
| This angle should be at least 10.0 deg | |
| | |
| Boresight line calculation: | |
| Boresight line angle to check: | |
| Angle (tracking antenna boresight, line to satellite) $$ | |
| This angle should be at least 10.0 deg | |
| | |
| OK Cancel | |

Hence with the combination of avoiding stations near other stations or near the boresight of active stations, it is possible to create a range of tracking strategies that can assist during coordination. This check can be done at either the antenna level or beam and checked at either the satellite or ES.

Select Longest Track Option

Some constellations try to reduce the number of handovers between satellites by using a "continue to track" method which selects a satellite that is heading towards an ES and then tracks it for as long as possible.

This can be done in a Tracking Strategy by:

- 1) Entering the relevant filters, such as minimum elevation angle and GSO exclusion zone
- 2) Selecting the "Longest hold time" in the Selection phase:



3) Enabling the "Continue to track" option with the same constraints as the filtering stage.

The continue to track options are available from the "Handover Options" button:

| Handover Options | × |
|--|-----|
| | |
| Handover will normally occur as soon as a better station becomes available. | |
| However, you can force tracking to continue whilst certain conditions hold. | |
| As soon as any of these conditions fail to hold, a handover will be attempted. | |
| Continue tracking whilst all of the following constraints hold: | |
| Elevation Angle at least 20.0 deg | |
| Avoid GSO Arc angle at earth station at least 10.0 deg | |
| | |
| | |
| | |
| | |
| + Add 🖋 Edit 🔁 Duplicate 🗙 Delete | |
| | |
| Continue tracking for: | |
| Exactly 0 time steps | |
| A random number of time steps between zero and 0 | |
| | |
| | |
| OK Can | cel |
| | -5 |

This additional "Continue to track" step is necessary to avoid a repeat of the {Filtering, Selection} stages at each time step which would lead to multiple handovers.

The result is a satellite selection method that limits the number of handovers and continues to track for as long as possible.

Note that in the Advanced Selection Method, the "Continue to track" method is described as the "r dot v" method. For more information, see Recommendation ITU-R S.1325.

Configuring a gateway with many antennas

A gateway can have multiple antennas, and the objective is for each antenna to track a different satellite to provide the best service. This could be done by having as many Tracking Strategies as Antennas, with the selection method:

- Antenna 1: Use a Tracking Strategy that selects the 1st highest elevation satellite
- Antenna 2: Use a Tracking Strategy that selects the 2nd highest elevation satellite
- Etc.

While this method would work, another, simpler, method is to ask that the Tracking Strategy excludes those satellites that are already being tracked by another Antenna at the ES. This can be done using the configuration below.

1. The gateway Station is configured with multiple Antennas, each with pointing defined as "Allow the link to set the pointing". This is needed so that the Tracking Strategy can work out which satellite is being tracked by each Antenna.



2. Each Link then uses a different Antenna i.e. Link-N uses Antenna-N:

| Dynamic Link | × |
|--|-----------------------------|
| Link 1 | Propagation: Space<>Earth ~ |
| Start End Start->End End->Start 1 | Traffic Advanced |
| OUse a named station: | |
| Gateway | • |
| OUse the end station of the link selecte | d below: |
| <click a="" link="" select="" to=""></click> | Ŧ |
| | ☐ different receive antenna |
| Transmit antenna: | Receive antenna: |
| A1 ~ | A1 ~ |
| | |
| | |
| | |
| | |
| · | |
| | OK Cancel Apply |

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3. All Links use the same Tracking Strategy:

| Dynamic Link | × |
|--|------------|
| Link 1 Propagation: Space Start End Start->End End->Start Traffic Advanced | e<>Earth ∨ |
| Tracking strategy: Avoid GSO arc gateway Track a station from NonGSO | |
| Transmit antenna: Antenna 1 Antenna 1 | ~ |
| OK Car | ncel Apply |

4. The Tracking Strategy uses the "Ignore stations that are already being tracked by another" option and then selecting the Antenna option (an alternative would be to track at the Beam level):

| Custom Selection Method | \times |
|--|----------|
| Station Selection | |
| Pick the station with the highest elevation angle | |
| | |
| Resource Restrictions | |
| \checkmark Ignore stations that are already being tracked by another: Antenna \checkmark | |
| If the 1 st choice station has no resources available, don't try the next best station | |
| Use minimum track angle at antenna or beam | |
| Minimum track angle: Not availe deg | |
| | |
| OK Cancel | |

This method can be extended to include a minimum angle at the ES between active Links. This can be useful to avoid intra-system interference:

| Custom Selection Method | \times |
|---|----------|
| Station Selection Pick the station with the highest elevation angle | |
| Resource Restrictions Ignore stations that are already being tracked by another: If the 1 st choice station has no resources available, don't try the next best station | |
| ✓ Use minimum track angle at antenna or beam Minimum track angle: ^{5.0} deg | |
| OK Cancel | |

Model Inter-satellite Links

In the examples above, a Dynamic Link was used to connect an Earth Station (as the start of the Link) to a constellation of one or more non-GSO satellites (the end Station of the Link). However, a Tracking Strategy can be used in any situation, whether the start or end Station is a satellite or not. So, it could also be used by a satellite to select another satellite as part of an intersatellite link (ISL).

An example of this is shown below, taken from the Modelling AI 1.17 Newsletter



Here a Tracking Strategy is used by a GSO satellite to select the Earth Exploration Satellite Service (EESS) satellite to communicate with. This is done using the following configuration:

| Trac | king Strategy | | | | × |
|------|---|---|----------------------|--------------|---------|
| EES | SS TrackStrat | | | | |
| | Stations must meet all | of the following co | nstraints: | | |
| | Distance Alignment | at most 38609.8 angle to (az,el) = | ۳ (-7.4,0.0) at n | nost 7.0 deg | |
| | | | | | |
| | + Add 🌶 Edit | Duplicate | 🗶 Delete | | |
| | When more than one st to know which station to | ation meets the cons | straints, the so | ftware needs | |
| | Choose the Advanced | <dick edit=""> ~</dick> | Edit | Handover | Options |
| | | | | OK | Cancel |

The distance factor is used to make sure the satellite is within the cone of coverage. For GSO systems, this geometry can be converted into a distance to the EESS satellite, D_1 , using the triangle below:



The second constraint is the alignment option. This is to select the satellite based upon the angle at the GSO satellite between:

- The line from the GSO satellite to the non-GSO satellite
- The line from the GSO satellite to a vector in direction (azimuth, elevation) = (-7.4°, 0.0°), which in this case is towards the UK.

The alignment constraint is then used in the selection phase, using the following:

| Custom Selection Method | × |
|---|---|
| Station Selection Pick the station with the Image: Station with the | |
| Resource Restrictions | |
| \checkmark Ignore stations that are already being tracked by another: Antenna \checkmark | |
| \checkmark If the 1 st choice station has no resources available, don't try the next best station | |
| Use minimum track angle at antenna or beam | |
| Minimum track angle: Not avail deg | |
| | |
| OK Cancel | |

This selects the EESS satellite closest to the vector direction (azimuth, elevation) = $(-7.4^{\circ}, 0.0^{\circ})$ which is within the cone of coverage, i.e. the EESS satellite nearest the victim non-GSO system's ES in the UK.

Derive Visibility Statistics

As well as being used for satellite selection in a Dynamic Link, the Tracking Strategy object can also be used to generate visibility statistics. The "If the 1st choice station has no resources available, don't try the next best station" option can be used to return a list of candidate stations (as described above) and the number of stations on that list can be shown and used to generate statistics.

The Tracking Information object is contained with the Dynamic Link and can be shown on the Watch Windows like this:

| Example non-GSO Constellation statistics.SIM:2 | | | | × |
|---|-------------|-------|-----|------|
| Modify Watches | | | D | Сору |
| Variable | Value | Units | | |
| Dynamic link.Station Tracking Information | | | | |
| Number of stations that meet the tracking crite | . 4 | | | |
| Steps spent tracking the current station | 1 | | | |
| Tracking Info | | | | |
| Allocation factor | Distance | | | |
| Traffic Load | 0.0 | | | |
| Track Values | | | | |
| Elevation | 71.208163 | deg | 9 | |
| Azimuth | 0.0 | deg |) | |
| Distance | 1256.137448 | km | 1 | |
| GSO Angle | 72.018679 | deg | 9 | |
| Angle Azelr | 0.0 | deg | 9 | |
| Delta Lat | 0.0 | deg | 9 | |
| Delta Long | 0.0 | deg | 9 | |
| R dot V | 0.0 | km^2 | 2/s | |
| Group Track Test Angle | 0.0 | deg |) | |
| Group Test Track Angle | 0.0 | deg | 9 | |
| Group Angle GSO | 0.0 | deg |) | |
| GSO Projection Distance | 0.0 | km | 1 | |
| GSO X Angle | 0.0 | deg | 9 | |
| Group X Angle GSO | 0.0 | deg |) | |
| | | | | |

The "Number of stations that meeting the tracking criteria" can then be the variable used by a User Defined Statistics object, such as this:

| Collect statistics for: Dynamic link.Station Tracking Information.Number o | × |
|---|---|
| Simulation variable | |
| Other constellation Dynamic link Dynamic link Override Default Propagation Models Override Default Statistics Options Override Default Statistics Options Station Tracking Information Override of stations that meet the tracking criteria Steps spent tracking the current station Tracking Info Override of station Override of station Override of stations Override of stations that meet the tracking criteria Override of stations that meet the tracking criteria Override of stations that meet the tracking criteria Override of stations Override of stat | |
| Statistics Options | |
| Register an event when the value below 2 | |
| Create distributions Resolution: 1.0 | |
| OK Cancel | |

Then statistics can be generated for the number of satellites that meet the specified filtering constraints, in this case minimum elevation angle and GSO arc avoidance angle, as shown in the figure below:



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Constellation Avoid with Diversity (New)

In some cases, if there is use of avoid pointing tracking strategies to protect another non-GSO constellation, it could be that no satellites are available at a specific time step. In this case, one way to maintain connectivity with a non-GSO constellation is to provide access via a second, backup, earth station that would have a different geometry.

Consider the case where a satellite from system A can be used if one of the following is true:

- 1. The satellite from system A is at least 10° away from any satellite of system B as seen by the system A ES
- 2. The beams from the satellites of system B in item 1. above point at least 10 degrees away from the ES as seen by the satellite of system B.

This can be configured as follows:

| Tracking Constraint | \times |
|--|----------|
| Avoid Constellation | |
| Consider stations from: Sats B group Logic to use: Line to station location OR boresight line v | |
| Line to station calculation: Calculate these angles at the earth station This angle should be at least 10.0 deg | |
| Boresight line calculation: Boresight line angle to check: Angle (tracking antenna boresight, line to ES) This angle should be at least 10.0 deg | |
| OK Cancel | |

Examples of these two cases are shown below:







Here the satellites are close together, but the ES are separated

In many cases, this would allow communication to continue. But if both the satellite and ES are co-located or nearly colocated at the same time, the link would fail. In this case a new option would allow a backup link to operate, as in the following figure:



In Visualyse Professional, this is achieved by having two links, one for ES-A1 and another for ES-A2. Normally, having two links would mean that at most time steps there'd be two links active, and only one for the time step where both the satellite and ES are co-located or nearly co-located.

However, a new traffic object parameter allows it to be specified how many links can be active at each time step using that traffic object. Hence if both the ES-A1 and ES-A2 links use this traffic object with a maximum links = 1, as in the figure below, then only one will be active.

| anic settings | | | | | | | | |
|---------------|-----------------|---------------|--------|------------------|------------|---------------|--------|--|
| Traffic | | | | Set n | nax links: | Max: | 1 | |
| Level Excl | ude | | | | | | | |
| Description | Traffic | | | Method selection | on On | | \sim | |
| State Trans | ition Method | I ——— | | TDD Metho | d —— | | | |
| Sta | rt probability | Not available | % | TDD li | nk active | Not available | % | |
| Switch o | on probability | Not available | % | TDD forwa | rd active | Not available | % | |
| Switch o | off probability | Not available | % | TDD Synch | ronised | | | |
| Trigger Leve | el Method - | | | | | | | |
| Туре | | | \sim | Trigger level | Not avai | lable | % | |
| Distribution | | | \sim | X1 | Not avai | lable | | |
| | Edit distribut | ion table | | X2 | Not avai | lable | | |
| | | | | | | | | |
| Interpolation | | | \sim | Repeat c | vcle | | | |
| | Edit time of | day table | | Use local | time | | | |
| | | | | | | | | |
| | | OK | | Cancel | Ann | dv. | | |

Note that the ES-A1 link should be higher up on the list of Links so that is checked first before the ES-A2 link.

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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 Interplanetary
- Visualyse GSO
- Visualyse EPFD

These are described further below.

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 nonco-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.

| File Edit View Tools Help | | | | | | | | | | P 308 | an (canveg) | |
|---------------------------------------|---|---------------------------------------|--|----------|--|-----------------------|----------------|--------------------------|--|-------------------------|---------------------------------------|------------|
| | | | | | | | | | | | | |
| | | | PM | | | | | | | | | |
| fic2983.mdb | Fou | and 16 Cases / 56 | Overlaps with INMARSAT-8-73E | | | | 78 DT/T C | ises 688 Beam Overlaps | Beam Overlaps | | | |
| | Qao | <u> </u> | V USGOVSAT-10 | 336.21 % | Separation = 13.0 deg | | | | USD3 of INMARSAT-6-73E -> TK | R of USGOVSAT-10 | | |
| careno care | | D (11111 | V AS VECTIM | 336.21 % | | | | | | | | (|
| | | | I Downink (20.200000 - 21.200000) | 336.21 % | Outside Coordination Arc by 5.0 deg | | 32 beam pairs | Detailed Courdinatio | | | | 7 |
| | | | > Uplink (30.000000 - 31.000000) | 24.73 % | Outside Coordination Arc by 5.0 deg | | 32 beam pairs | Detailed Coordinatio | | | | - |
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| | Cramina D | | V USGOVSATA | 11.99.56 | Securities = #5.0 dea | | | | | ALC: NO | 127 | |
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| | | | h I Samalak (20.100000, 31.100000) | 11.00.00 | Particle Combination Are by TTD day | | 22 hours only | Particular Consultants | | | | |
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| | | | - Anna (Anna - Anna | | County Containant Inc. by 77.0 Mg | | Ja beam para | Control Contraine | | | | |
| | | | AS INTERPORT | 5.08 % | | | | | | | | |
| | | | ▷ ✓ Downlink (20.200000 - 21.200000) | 5.08 % | Dublide Coordination Arc by 77.0 deg | | 32 beam pairs | Detailed Coordinatio | | | | |
| | | | > VUBRAK (30.000000 - 31.000000) | 0.57 % | Outside Coordination Arc by 77.0 deg | | 32 beam pairs | Detailed Coordinate | | | | |
| | | | V USGOVBAT-12 | 11 % | Separation = 102.0 deg | | | | 1.1.1 | | | |
| | | | V AS VECTIM | 11% | | | | | 1.1.1 | | | |
| | | | ▷ Downlink (20.200000 - 21.200000) | 11 % | Outside Coordination Ar: by 94.0 deg | | 32 beam pairs | Detailed Coordinatio | Within band on beam one | fan. | | |
| | | | ▷ ✓ Uplink (30.000000 - 31.000000) | 1.61.% | Outside Coordination Arc by 94.0 deg | | 32 beam pairs | Detailed Coordinatio | | | | |
| | | | ∀ ✓ AS INTERFERER | 4.65.% | | | | | Coordination Trigger | | | |
| | | | ▷ ✓ Downink (20.200000 - 21.200000) | 4.65 % | Dutade Coordination Arc by 94.0 deg | | 32 beam pairs | Detailed Coordinate | ▼ Networks | | | |
| | | | ▷ ✓ Uplink (30.000000 - 31.000000) | 0.53 % | Outside Coordination Arc by 94.0 dep | | 32 beam pairs | Detailed Coordinatio | Interfering Network | INMARSAT-6-73E | | |
| Interference direction(s) Hy Networks | <-> Coordinating - Sort by F | Ranking v | V USGOVSAT4R | 9.97.% | Separation = 125.5 deg | | | | Administration | 6 | | |
| ! when Inside Arc (++) Or -> [| ✓ DT/T > 6.00 % | | V AS VECTEM | 9.97.% | | | | | Notification Type | C | | |
| (Pers) (Fell (650) (N050) (No G | eographic Overlap) (No Frequency Overlap) | | ⊨ Downlink (20.200000 - 21.200000) | 9.97 % | Dutade Coordination Arc by 117.5 deg | | 32 beam pairs | Detailed Courdinatio | Orbital Location | 73.00 deg E | | |
| | | INTE | ⊢ 🗸 Uplink (30.000000 - 31.000000) | 1.45.% | Outside Coordination Arc by 117.5 deg | | 32 beam pairs | Detailed Coordinatio | BR Publication | CR/C/5759 | | |
| MADAR-47.5E DV2 | WellOfit C139K % 18 | Jarre | ∀ ✓ AS INTERFERER | 4.22 % | | | | | Dated | 01 November 2022 | | |
| USGAE-6A USA | (++) WestDT/T C616.04 % 28 | 90123 | - J Downley, 120 200000 - 21 200000 | 4.22.% | Outside Coordination Arc Inc 112 Scient | | 12 hears sairs | Detailed Coordinate | Victim Network | USGONSAT-10 | | |
| INMARSAT-6-73E G | West DT/T < 335.21 % 05 | 10622 | INMARSAT-6-73E (Interferer) 4938G | 7W- | | | | Q Q | Administration | USA | | |
| SE-KA-83.5E NOR | West 07/T 472 53 % 11 | 51511 822 | | | 17.9 18.25 19.1875 19.5 19.95 | 20.7 | | | Notice ID Notification Tomo | 110500139 | | |
| SE-KA-83.5E NOR | West DT/T C 77 53 % | STATE MER | | | KAD2 / G \K7GD_ KAD \GKAD / G. \GKAD / GKAD / GKAD | | | | Orbital Location | 60.00 deg E | | |
| USGAE-25A USA | WassEDT/T K 67.12 % 26 | 01/23 NTF | | | K7GD / /KA / K7 / K7GD / GKAD / | KAD4 / USD4 / KADO | | | Orbital Separation | 13.00 deg | | |
| FMS6-21.5E / | Want DT/T < 59.65 N 31 | 105/22 CR | | | 17.95 10.15 10.3 10.5 10.7 19.05 20.1 | 20.7 | | | Overlap Frequency | 20.200000-21.200000 GHz | | |
| AMS-CB-113E IOR | WassE0T/T < 53.13 % 26 | 901/23 NTF | | | | | | | Coordination Arc Trigger | | | |
| INMARSAT4-98W-R | West07/7 < 22:83 % 05 | 10622 | | | | | | | Coordination Arc Exists Size of Arc | Yes 8.0 deg | | |
| ASIASAT-AAA CHN | Watel DT/T < 18.18 % 19 | 1411 NTF | | | | | | | Inside Coordination Arc | No | | |
| F-SAT-N10-J9W | Want DT/T 5 16.05 % 02 | 10622 08 | | | | | | | V DT/T Trigger | | | |
| F-SAT-N10-JE | West DT/T < 12.52 % 05 | 10672 CR | | | | | | | Interfering Group | 122657030 | | |
| | North Control of State | NTE | | | | | | | Interfering Frequency | 20.700000 GHz | | |
| | North Table 1 | 0.00 | | | | | | | Setelite | INMARSAT-6-73E | | |
| P-3A1-010-162W | Well DTT CS415 | INTE | | | | | | | Satelite Location | 73.00 deg E | | |
| ANS-87-13.8E IRR | Wavet DT/T < 9.14 % 12 | Land | | | 12/03/0 | 5 | | | Satelite Power | -41.90 dBW/Hz | | |
| AMS-87-13.8E == | WassEDT/T 5 9,54 % 12 | 10015 20 | | | 11 C | 20.7 | | | Satenite Um-axis Gain Ream | 43.00 08 | | |
| ✓ F-SAT-N10-9E F | West DT/T < 5.5 % 02 | 10622 | | | TKDR. | TKL / TROR / TK28 / T | | | Antenna Sidelobe Type | Using peak gain | | |
| ✓ F-SAT-N10-10E F | Want DT/T < 4.88 % 35 | 105/22 (08) | | | | | | | Satellite Peak Gain | 43.00 dBi | | |
| F-SAT-N10-84W F | Warst 07/T < 1.93 % 12 | 10622 | | | | | | | Satellite Off-axis Angle | 2.29 deg | | |
| ✓ AMS-C8-113E === | No Finquescy Overlap 20 | ATE ATE | USGOVSAT-10 (victim) KA 1 | | | | | Show Priorities | Distance | 35978.14 km | | |
| ASIASAT-AAA CHN | No Fraquency Overlap 26 | 01123 NTP | ····· | | | | | | | | | Report |
| i . | | Terret | | | | | | | | | | Control |

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

| USASAT-24Q into VENE Edit View Tools | IESAT-1 (downlink).dgso - Detailed C s Help | oordination | | | | | | | | Search (Ctrl+Q) | | φ - |
|---|--|-----------------------------|-----------------------------|--------------------|-------------------------|------------------|-----------------|----------------------------------|--|----------------------|------------------|----------|
| un hus (Room Dale | *) () (VE | | | 20 | | | | | ear | | 01 mm G | 2 0 |
| oop by. Usean year | | | | | | _ | | | | | | 111 |
| ISAT-24Q → VENESAT-1 | 1 11.703000 - 12.198000 GHz | F | Powers Max C, Max I OBW/1:2 | eshold 20.00 | 8 « Calculations | | A A V Copy | Beam Overlaps | | | | |
| DOWNLINK | | ADVANTAGES | Disp | olary All Only sho | W I LINK BUDGETS | с | 1 | TK1 of USASAT-24Q -+ K2R of VE | NESAT-1 | | | |
| 1 | Interferer EIRP Victim EIR | 9 Gain BW Ploss Victim ES | Cases T | hreshold 🔒 Worst (| // Satelite | VENESAT-1 | USASAT-24Q | | | | Q. | <u> </u> |
| > TIES TYPICAL | -10 • | | 128/132 | 20.0 -4.0 | Freesann | -78 36M0F3E | // - 246361W | | | | | |
| | ¥2 . | | 100/002 | 20.0 4.00 | Assignment GHz | 11.725 | 11.718 | | | | | |
| TTES IMPICAL | ···· · | | LED 132 | 22.0 .40.00 | Polarisation | м | м | | 1 | TK1 | | |
| VEmission | 1 28M8G7W • | | 54/55 | 20.0 -4.0 | 6 V Group ID | 100601746 | 96823372 | | 3 | 6.5 | | |
| VEmission | 52K1G7W • | | 4/4 | 20.0 -4.0 | Group B/W MHz | 50 | 30 | | 12 | 1 | | |
| V Emission | 1M21G7W • | | 4/4 | 20.0 -3.98 | Allocated B/W MHz | 36 | 0.0243 | | × | | | 4 |
| ► 1 I Emisr | sion 24K3G1W | | 1/1 | 20.0 -3.9 | Occupied B/W MHz | 30 | 0.0203 | Ar | | | | |
| | AFONTON . | | | | * Tx Power dBW | 1.7 | 1.9 | 6 | | | | |
| P. 1 Cmiss | SION. ISUKESE . | | | 20.0 -3.95 | Pwr Density dbW/H2 | -73.07 | -41.16 | | - the | | | |
| ► ! I Emiss | sion. 48K6G1W • | | 1/1 | 20.0 -3.95 | 2 Peam | +0 K2R | TKI | | (| | | |
| ► 🚦 I Emisa | sion: 50K0F3E | | 121 | 20.0 -3.93 | 9 Boresight | N6.8303 W65.2465 | N/A | 6 | | | | |
| ► I V Emission | 6M95G7W • | | 9.9 | 20.0 -3.9 | 7 Radiation Pattern | REC-672 Ln25 | From GIMS | | | | | |
| N. I. V. Emission | - 36MOETE | | 5788 | 20.0 0.00 | Beamwidth deg | 1.5 | 6.69 | | and the second s | × | | |
| V Emission | i somorsi | | 61760 Street | 20.0 -0.9 | Gmax dBi | 41 | 28 | | | 6 | | |
| ▶ TES TYPICAL | -K1 • | | 84/100 | 20.0 6.0 | ¹⁹ Angle deg | 2.14 | 4.1 | | | K2R | 5- | |
| I VES TYPICAL 3.7 | 7м • | | 333/365 | 20.0 -4.0 | Grel d8 | -25 | -20 | | 12 | | | |
| VES TYPICAL 3.4 | 0M • | | 343/368 | 20.0 -4.0 | 3 TEIRP dBW | 17.7 | 9.9 | | 11 | | | |
| Boom Pair TK2 -+ K2E | | | 2729/2868 | 20.0 .13.3 | Peak Density dBW/Hz | -32.07 | -13.16 | | | | 1 | |
| | | | | | Dataks Density Gew/Hz | -57.07 | -33.16 | | | | | |
| | AT-11 📉 🍾 | | | 8 < | v PED dBW/m2/Hz | 219.31 | :195.39 | 1.1.1 | | | 1 | |
| Name Gai | iin Pattern Peak Gain (dBl) | | Id: 100520145 Admin | : URG Pos: -78.0 | W Spreading Loss dB | 162.24 | 162.22 | | | 3 23 1 | | |
| K2R REC | C-672 Ln25 + 41.00 | | | | Elevation Angle deg | 60.64 | 61.78 | 11 11 | | 1 6 | | |
| | - | | | | * Rx Gain dB | 52.6 | 30.45 | | | | | |
| EAMS CIR GBL H | KIR K2R KAIR | | | | 15 | TYPICA | 4.4.5M | | | | | |
| | | | | | Location | N3.696 | 7 W53.1470 | | | | | |
| | | | | | Radiation Pattern | ITU-R : | 5.465 | ANALYSIS | | | _ | - |
| 1.375 (24) | | 1 Programmy Group | | 26.275 (24) | Beamwidth deg | 0.42 | | | - | | | |
| | | | 6 | ର —୦- ଡ | Contax dea | 52.6 | 1.00 | Dish Size * | CONTOURS DETA | ar — • • - | -0-0 | |
| | | · · · · · | · · · · · | | Coal da | 0.00 | .22.15 | | | | | |
| | | | | | Rx power dBW | -134.77 | -164.7 | Constraints | | | | |
| | | 11.700-12.200 | | | | | | | | | | |
| p Id = 100601746 Peri = M | | Show assets for all beams * | | | INTERFERENCE | 172 20 | | UPAIRENT A. ARADAN | | | | |
| TYPIC | AL 4.5M | | Name | 36M0F3F | Advestments dB | 30.92 | | VERCONT-1 (VICTIM) | | | | |
| e Typice | N | EARTH STATIONS F EMISSIONS | Designation | 36M0F3F | Bandwidth Adjustment d | 30.92 | | 1 ✓ Gain Pattern set to ITU-RS | ASSO-6 for: TYPICAL 1 | LISM on Beam: K2R in | Group: 100601742 | |
| e (K) 100.07 | 0 | 25082.35 | Min Pwr (dBW) | -6.30 | Polarisation Loss dB | 0.00 | | Z V Boresight set to Lat 6.8, Lo | ng -to:7 for Beam: K2 | a on : VENESAT-1 | | |
| tude (deg) N/A | | TVRCAL 2 4M | Max Pwr (dBW) | 1.70 | Aggregation dB | 0.00 | | 3 [V] Gam Pattern set to 110-R 5 | .0/2-4 (Ln-25) for Bea | The RZR on : VENESAL | -1 | |
| gitude (deg) N/A | | TYPICAL 3.0M | Min Density (dBW/Hz) | -72.30 | Aggregation Factor | 1 | | Interference Cases | | | | |
| ik Gain (dBi) 52.60 | | TYPICAL 3.7M 6M95G7W | Max Density (dBW/Hz) | -61.30 | C dBW | -134.77 | | 4 🕢 Polarisation set to 3.00 dB | for Beam Pair: TK1 -> 1 | K2R and 25M7G1W | nto 28M8G7W | |
| mwidth (deg) 0.42 | | TYPICAL 4.5M | | | ∀ C/I d8 | -0.98 | | 5 🗹 Aggregation Factor set to | 1.40 for Beam Pair: TK | 1→K2R and 25M7G | W into 28M8G7W | |
| diation Pattern REC-46 | K65 Y | TYPICAL 7.6M | | | Threshold dB | 20 | | | | | | |
| | | SUMMERAL AR PAR | | | Margin dB | -20.98 | | | | | | |

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

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 and 9.7B cases.

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.



The Visualyse EPFD software is also capable of undertaking analysis using the methodology in Resolution 770 and includes methods being proposed for inclusion in a revision to Recommendation ITU-R S.1503, such as the Alpha Table Methodology.

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



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:

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