Application Note

CREATING SATELLITE FADING SCENARIOS WITH THE R&S SPACE NEXUS

Products:

► R&S®SMW200A

► R&S®SMW-K820

► R&S Space Nexus

Jean-Pierre Messmer | 1GP147 | Version 3a | 04.2026

https://rohde-schwarz.com/appnote/1gp147

ROHDE&SCHWARZ

Make ideas real

Contents

1 Overview

With the rise of Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) satellite constellations for broadband data connectivity over the last few years, the need to dynamically simulate the channel between the satellite and user equipment (UE) or the satellite and the ground station (GS) has grown at a staggering pace. The satellite channel is subject to various atmospheric effects and the relative motion between the satellite and UE, resulting in frequency and level variations that depend on the satellite's position in the sky. Consequently, it is essential for manufacturers of related receivers and other hardware components to consider these effects during the design and production phases to ensure optimal performance and reliability.

In this application note, the focus will be on giving an overview of the functionalities of the R&S Space Nexus and explaining how to use the software to create realistic fading files out of a given Two Line Elements (TLE) file that is describing the trajectory of a satellite. Afterwards the approach for using this file to simulate a realistic satellite fading scenario using the R&S®SMW200A equipped with a R&S®SMW-K820 (custom dynamic fading option), is explained.

2 Introduction

2.1 Motivation

In satellite testing, it is crucial to ensure that the communication system can withstand the harsh conditions of space. However, testing the system in a real-world satellite environment is not feasible due to the high costs and logistical challenges of launching a satellite into space. Moreover, the satellite channel introduces various impairments such as signal attenuation, delay, Doppler shift, and interference, which can significantly impact the system's performance.

The increasing use of LEO and MEO satellites further exacerbates these challenges, as their lower orbits result in high orbital velocities and therefore in significant and rapidly changing Doppler shifts, requiring even more sophisticated testing and validation to ensure reliable communication. To overcome these challenges, an emulation of the satellite channel is necessary to simulate the real-world conditions in a controlled laboratory environment. This allows engineers to test and validate the satellite communication system's performance, identify potential issues, and optimize its design before the actual launch, thereby reducing the risk of costly rework or even mission failure.

2.2 Test Setup

Rohde & Schwarz offers two ways to perform channel emulation with the R&S®SMW200A. The first one only includes the SMW200A: Here the wanted signal is generated internally in the SMW200A before the channel simulation is applied to the signal and the signal is transmitted to the UE. This is used for RF performance testing of a device under test (DUT).

Figure 1: RF Performance Testing

The second one includes a combination of R&S®SMW200A and R&S®FSW to create a RF fader for End-to-End system testing. This allows the testing of an entire system from transmitter to receiver with the channel emulation between. The FSW functions as a digitizer and the SMW then applies the channel parameters.

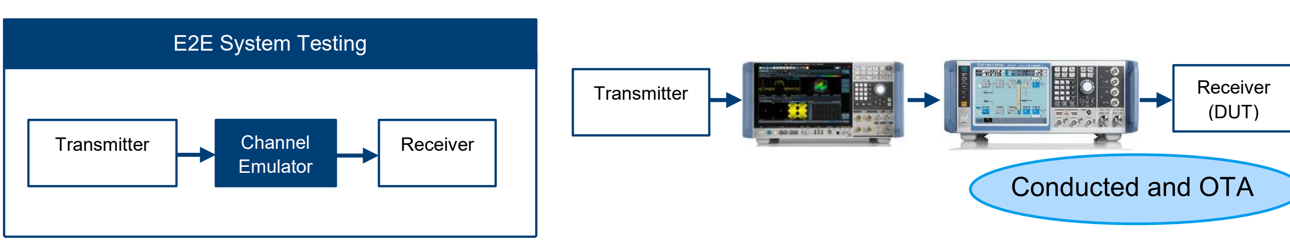


Figure 2: E2E System Testing

The benefits of those setup include:

– Reduced testing time and cost by simulating various scenarios in a controlled laboratory environment.

– Improved test accuracy, reliability and reproducibility.

- Possibility to generate worst case scenarios with high levels of Doppler shift or attenuation.
- Flexibility to simulate various scenarios and signals.
- Possibility to use the signal generator and signal analyzer, also for different test and measurement set ups.

3 Background

3.1 Satellite Orbits

An orbit is the trajectory of an object around a celestial body. In satellite communications (SatCom), there are 3 main orbits that are used:

- Geosynchronous Equatorial Orbit (GEO)
- Medium Earth Orbit (MEO)
- Low Earth Orbit (LEO)

Each of them has advantages and disadvantages when it comes to their properties concerning SatCom. In the following table we list the most relevant characteristics of each orbit:

	GEO	MEO	LEO
Hight	35 786 km	5000 – 12 000 km	200 – 2000 km
Propagation Delay (earth to space)	120 ms	40 ms	5ms
Visibility	always	2 – 4 h	< 15 min
Orbital period	24 h	5 – 12 h	1,5 – 5 h
Max. Doppler at 30 GHz	Negligible	592 kHz	802 kHz

Some other orbits also include Highly Elliptical Orbits (HEO), Geosynchronous Orbits (GSO) and Very Low Earth Orbits (VLEO).

3.2 Satellite Channel Propagation

The most basic way to describing the channel propagation between 2 objects is the Free Space Path Loss (FSPL), this also represents the biggest factor in satellite communication due to the large distances present between the transmitter and receiver. It is described by the following formular:

$$\mathrm{FSPL} = \left(\frac{4\pi d f}{c}\right)^2$$

Where d is slant range, the direct distance between the satellite and the UE, f the frequency of the transmitted signal and c the speed of light. Since d is permanently changing over the trajectory of the satellite, this needs to be calculated for each time step.

The other main influence factor that influences the propagation is the Doppler shift occurring due to the relative movement between the satellite and the user terminal. The doppler shift to be applied to the signal can be calculated the following way:

$$\Delta f = \frac{\Delta v}{c} f_0$$

Where Δf represents the difference between the emitted frequency f_0 and the observed frequency and c again the speed of light. Δv denotes the relative velocity between the satellite and the user terminal along the line connecting the two objects, specifically referred to as the radial velocity. It is positive if the transmitter and receiver are moving towards each other and is negative if they move away from each other, this also influences the sign of the Doppler shift. This formula is essential in satellite communications, as it allows for the adjustment of the received signal frequency to account for the effects of relative motion, ensuring accurate signal processing and communication.

Additionally environmental effects, such as rain, fog, and atmospheric gases, can further attenuate the signal. For instance, heavy rain can cause significant scattering and absorption of radio waves, especially at higher frequencies, leading to increased path loss. The Space Nexus can incorporate models that account for these environmental conditions, allowing for more accurate predictions of signal degradation. By understanding and quantifying these effects, satellite communication systems can be optimized to mitigate losses and maintain reliable connectivity, even in challenging weather conditions.

Signal latency is another critical consideration in satellite communications, as it impacts the overall performance of the communication link. Latency arises from the time it takes for a signal to travel from the UE to the satellite and back, as well as any additional processing delays at the satellite and ground stations. It is important analyze both the direct latency to a selected satellite and the total latency that includes the entire communication path to the Gateway, which may involve multiple satellite hops. This comprehensive analysis allows for a more realistic representation of the communication system's performance, as it takes into account the complexities of signal routing and the varying distances between satellites and the UE. By accurately modeling signal latency, the system can provide valuable insights into the expected performance of satellite communication links under different operational scenarios, facilitating better planning and optimization of network resources.

4 Overview of Features

The R&S Space Nexus software offers the following possibilities:

- **Satellite Selection and Visualization**: Users can select and view the satellites included in a specified TLE (Two-Line Element) file, facilitating easy access to relevant orbital data.
- **Visibility Analysis**: The software allows users to identify which satellites from the selected TLE file are visible from a given user equipment (UE) position or trajectory. It also provides an overview of the visibility duration for each satellite, enabling effective planning for communication links.
- **Modeling and Calculation of Channel Conditions**: The software models and calculates channel conditions that account for environmental effects, such as atmospheric attenuation and path loss due to obstacles. It also incorporates signal path latency, providing a comprehensive understanding of how these factors impact signal quality and communication performance.
- **Channel Parameter Specification and Plotting**: Users can specify and plot relevant channel parameters to verify the communication scenario before generating the fading file, ensuring that all conditions are accurately represented.
- **Fading File Creation**: The software enables the creation of fading files for use with the R&S®SMW200A, allowing for realistic simulations of signal propagation and performance under various conditions.

These fading files are loaded into the R&S®SMW-K820 that enables the R&S®SMW200A to do custom dynamic fading. Those functionalities include:

- Frequencies up to 67 GHz.
- A fading bandwidth of up to 200 MHz.
- A maximum Doppler shift applied to the signal of 1.953 MHz
- A maximum path delay of 1 s.

- A minimum time resolution between 2 fading samples of 50 µs.

5 Installation Guidelines

At the moment, the R&S Space Nexus Software is only available as an unofficial product of Rohde & Schwarz, meaning that no bug fixing or any additional support for the tool is provided. It is available for download as a ZIP file in the R&S SalesWeb under SMW -> Application and Solutions -> Application Notes.

[Vector signal generators]

If you are from outside R&S please contact your responsible sales representative to get access to the software.

When downloaded, unzip the ZIP file and navigate to down the file tree to the folder exe.win-amd64-3.8 and click on the .exe file in this folder to start the program, you will not need no further program or files to run the software. The software is only available for windows.

6 How to use the R&S Space Nexus

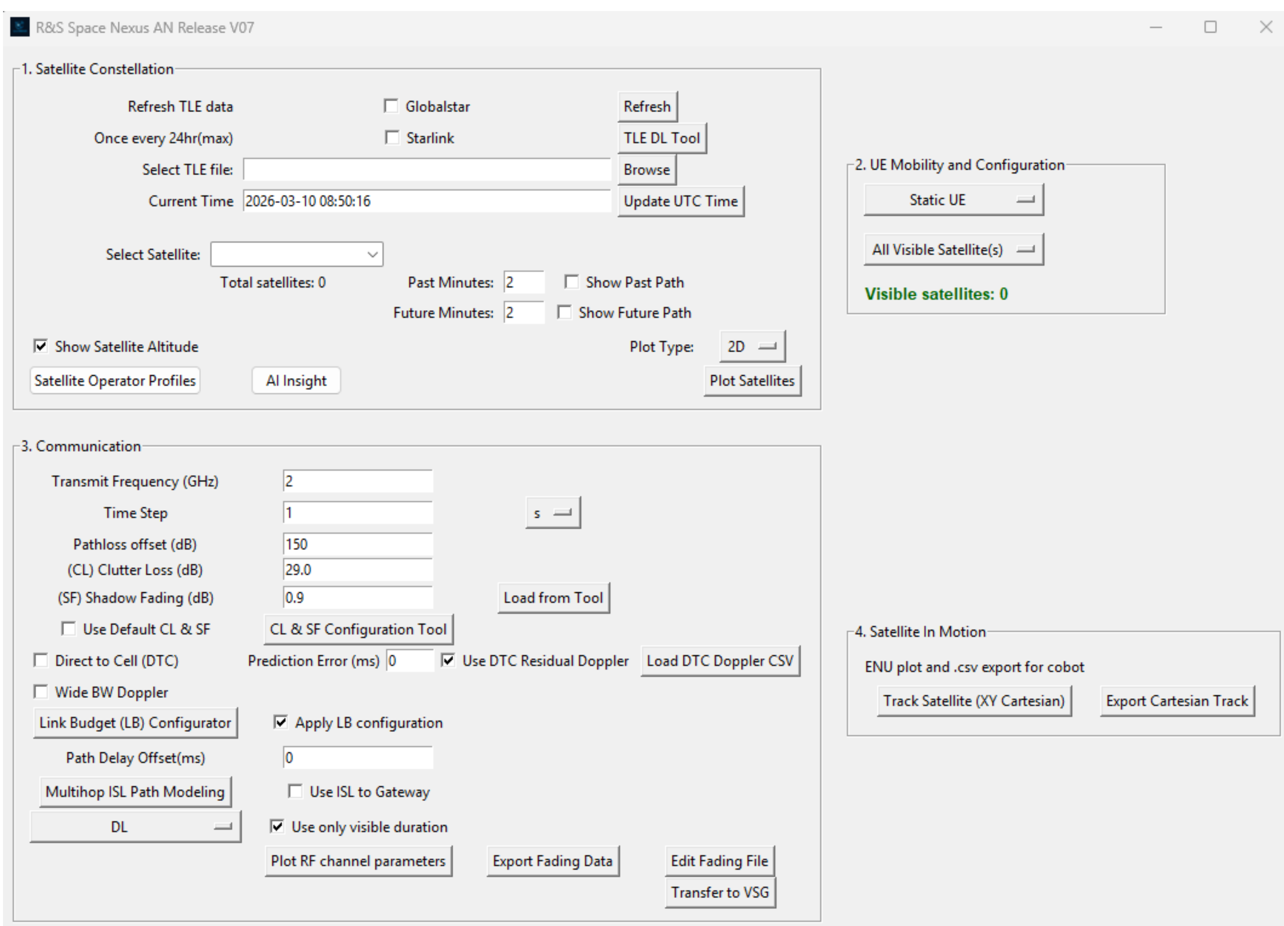


Figure 3: Overview of the R&S Space Nexus

The R&S Space Nexus is separate into 4 parts:

1. **Satellite Constellation**: This part allows the user download TLE files, selecting TLE files and displaying all the satellite orbits included in the TLE file.
2. **UE Properties and Motion**: This section gives the possibility to define the position and the movement of the UE either manually or by selecting a GPX file. It also gives the possibility of plotting all the visible satellite for the chosen UE parameters and getting information about the visibility of the different satellites.
3. **Communication**: By choosing the characteristics of the transmission, the resulting propagation parameters can be plotted and exported into fading files that can be used on the R&S®SMW200A.
4. **Satellite in Motion**: This part visualizes the motion of the satellite as seen from the UE, however this section is not part of this application note.

6.1 Satellite Constellation

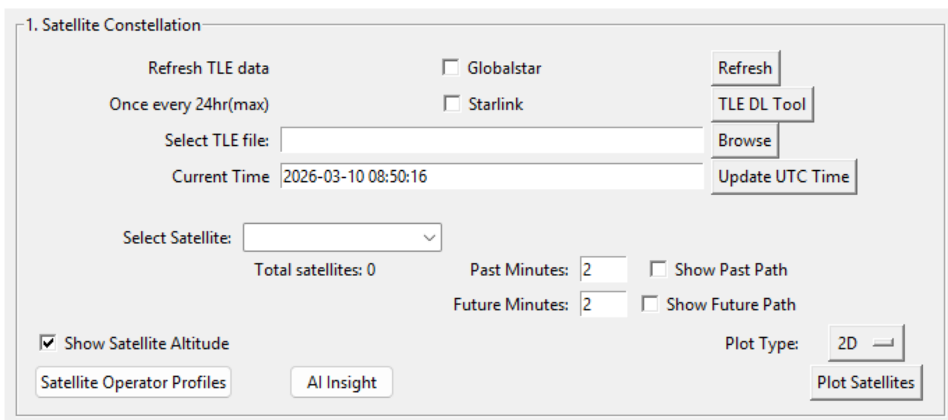


Figure 4: Satellite Constellation section of the R&S Space Nexus

TLE files especially for LEO satellites, lose their accuracy already after 24 hours, for MEO satellites this time can be longer. Therefore, the Satellite Constellation section offers the possibility to simply download the newest TLE files from the internet. This function includes:

- **Globalstar**: Check to select the newest Globalstar constellation TLE file to be downloaded.
- **Starlink**: Check to select the newest Starlink constellation TLE file to be downloaded.
- **Refresh**: Click to download the newest TLE files from the selected constellations.
- **TLE DL Tool**: Open the TLE Data Downloader, described in 6.1.1, that allows the download of other constellations TLE files.

Furthermore, the Satellite Constellation section allows the visualization of the content of TLE files using the SGP4 model [1]:

- **Select TLE file / Browse**: Choose the TLE file that should be used in the R&S Space Nexus.
- **Current Time**: Sets the time to with the constellation should be displayed.
- **Update UTC Time**: Set the time to the current time.
- **Select Satellite**: Select all or one specific satellite to be displayed.
- **Past Minutes / Show Past Path**: Select and specify how much of the past trajectory should be displayed.
- **Future Minutes / Show Future Path**: Select and specify how much of the future trajectory should be displayed.

- **Show Satellite Altitude**: Check to display the altitude of every satellite.
- **Plot Type**: Switch between 2D and 3D plot.
- **Plot Orbits**: Plot the orbits according to the previous done selection.

Depending on the size of the constellation and the selection chosen the computational time can vary. For larger constellations it is recommended to reduce the selection of additional features.

6.1.1 TLE Data Downloader

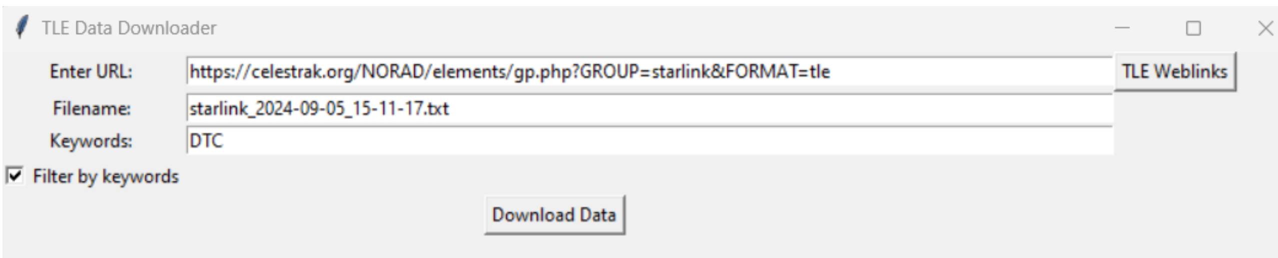


Figure 5: TLE Data Downloader

The TLE Data Downloader allows direct downloading of TLE files from specific websites that offer those downloads. The TLE file can also be filtered to download only satellites with a specific Keyword.

- **Enter URL**: Enter URL of TLE file to be downloaded.
- **TLE Weblinks**: List of TLE Weblinks for simple copy and pasting.
- **Filename**: Define the name for the file to be downloaded.
- **Keywords / Filter by keywords**: Turn on a filter and specify a keyword for which the TLE should be filtered for. Only satellites from the constellation including this keyword will be included in the downloaded file.
- **Download Data**: Download the TLE file according to the previous selection.

6.1.2 Satellite Operator Profiles AI Insight

The Satellite Operator Profiles button opens a table containing commonly used technical parameters for various satellite operators, presented in a structured format.

If country-specific information is required, the AI Insight feature can be used. Figure 3Figure 6 shows the AI Insight window and the required configuration. The figure also illustrates a portion of the source code demonstrating how the API call function is implemented. When configuring the API, ensure that the model deployment name is correctly specified for the response calls.

From the user perspective, once the endpoint, deployment name, API version, and subscription key are entered, the only inputs that typically need to be modified are the satellite operator and country fields. Clicking Run will retrieve the requested information from the configured AI model.

Since the information is generated by an AI model, it should be reviewed carefully, as AI systems may occasionally produce inaccurate or hallucinated outputs.

```
endpoint = "https://microsoft.openai.azure.com/"
model_name = "gpt-5.2"
deployment = "gpt-5.2"

subscription_key = "<your-api-key>"
api_version = "2024-12-01-preview"

client = AzureOpenAI(
    api_version=api_version,
    azure_endpoint=endpoint,
    api_key=subscription_key,
)

    resp = client.chat.completions.create(
        model=deployment,
        messages=[
            {"role": .....},
            {"role": "user", "content": prompt},
        ],
        temperature=0.2,
    )
```

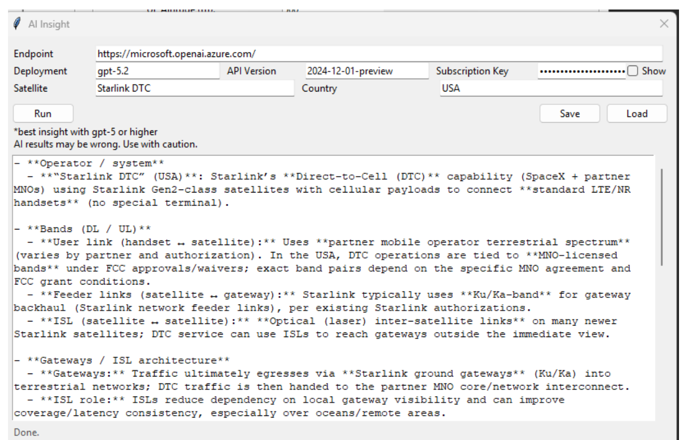


Figure 6: AI Insight Tab and API call implementation

6.2 UE Properties and Motion

The UE Properties and Motion section allows the choice between Manual Entry and Import GPX, additionally it offers a common visibility check to visualize which satellites are visible during the time of the specified scenario.

6.2.1 Static UE

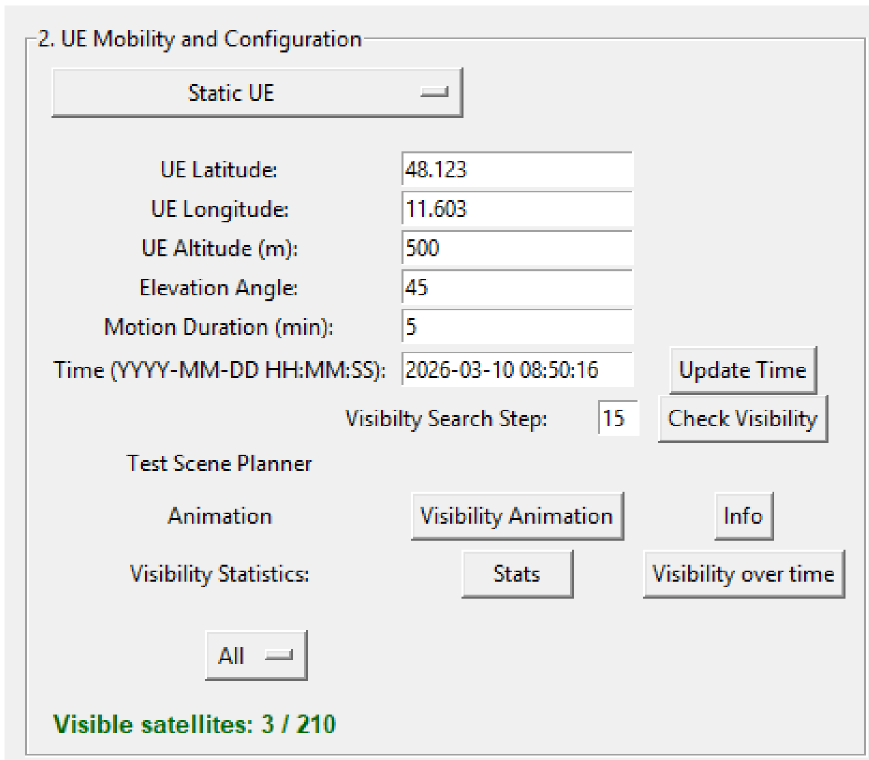


Figure 7: Static UE configuration box

In the Static UE dialog, the location, the movement and the cornerstones of the scenarios are defined.

- **UE Latitude**: Specify the latitude of the UE in degree.
- **UE Longitude**: Specify the longitude of the UE in degree.
- **UE Altitude**: Specify the altitude of the UE in meters.
- **Elevation Angle:** Specify the angle at which a satellite is visible in degree. This angle is defined as the angle between a horizontal plane and the line crossing the satellite and the UE. Must be between 1° and 85°.
- **Motion Duration:** Sets the simulation time of the scenario.
- **Time:** Sets the starting time of the scenario. This entry needs to be in (YYYY-MM-DD HH:MM:SS) format.
- **Update Time Button:** Set the time to the current time.

6.2.2 Mobile UE

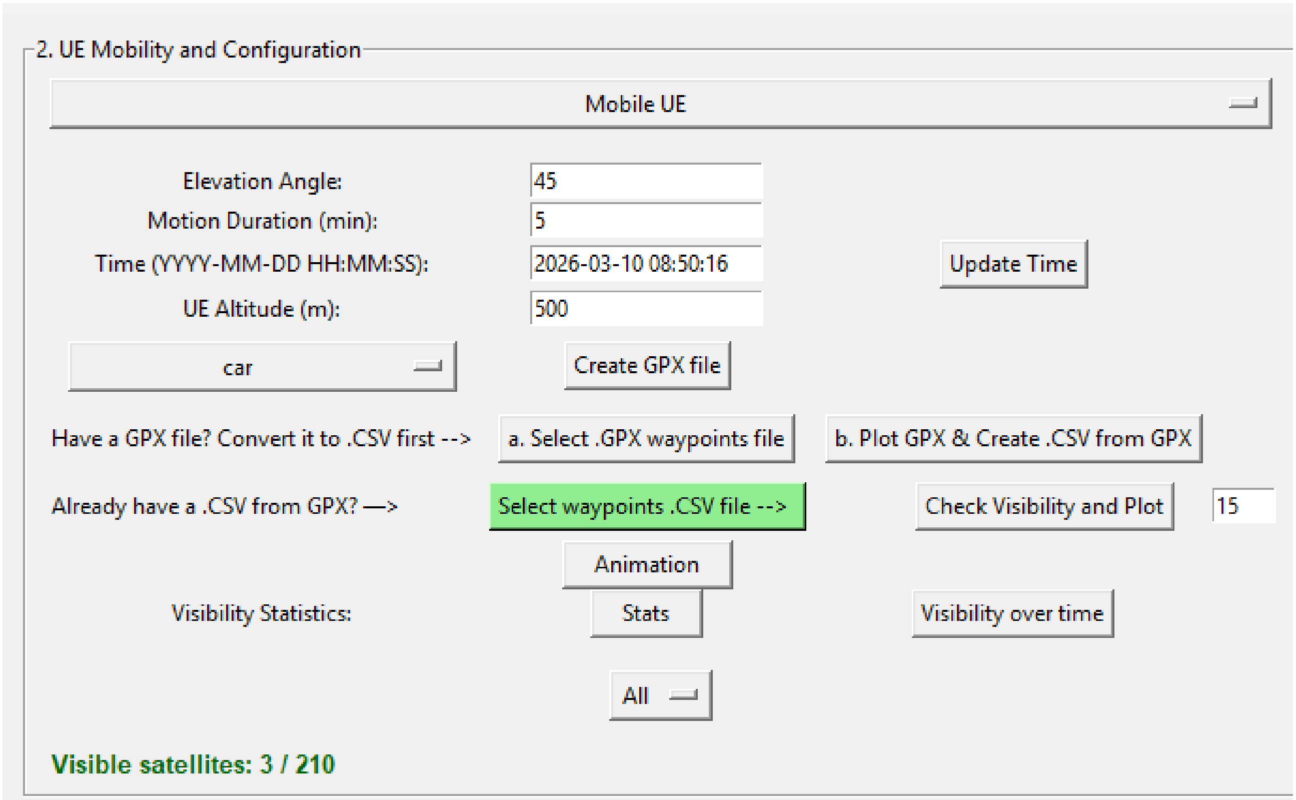
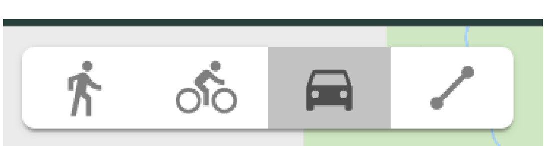


Figure 8: Mobile UE Dialog

GPS Exchange Format (GPX) file are files used to describe a track and is made out of multiple waypoints. The R&S Space Nexus allows the import of such files to describe the trajectory of the UE via the Mobile UE dialog box for cars. The dialog allows the following settings:

- **Elevation Angle**: Specify the angle at which a satellite is visible in degree. This angle is defined as the angle between a horizontal plane and the line crossing the satellite and the UE. It must be between 1° and 85°.
- **Motion Duration:** Sets the simulation time of the scenario.
- **Time:** Sets the starting time of the scenario.
- **Update Time:** Set the time to the current time.
- **Car (drop down menu):** Select between car and custom waypoint. If custom waypoint is selected the button **Generate Waypoints** is available opening the flight path generator menu described in 6.2.3.
- **Create GPX file**: Opens OnTheGoMap in the browser to create GPX files with the car symbol.



- **a. Select GPX Waypoints**: Select the GPX file to be used.

  b. Plot GPX & Create . CSV File: When this button is clicked, the software queries the OpenStreetMap public API to retrieve the road names and maximum legal speed limits for the locations defined in the GPX file. Based on this information, a realistic vehicle driving profile is generated and exported as a CSV file, which is required for the subsequent satellite visibility check step. The generated CSV file can be reused for any satellite constellation scenario, allowing the same UE route and driving profile to be loaded directly without repeatedly querying the OpenStreetMap API. This avoids unnecessary API calls and significantly speeds up scenario setup.

6.2.3 Custom Waypoint Feature of UE Mobility & Configuration

This feature is used for generating the waypoint for Mobile UEs such as drones, jets, planes or other aerial flight objects. The window of the Flight path generator is shown in Figure 9.

Generate Waypoint: this button opens a new window to design the waypoint of arial mobile UEs

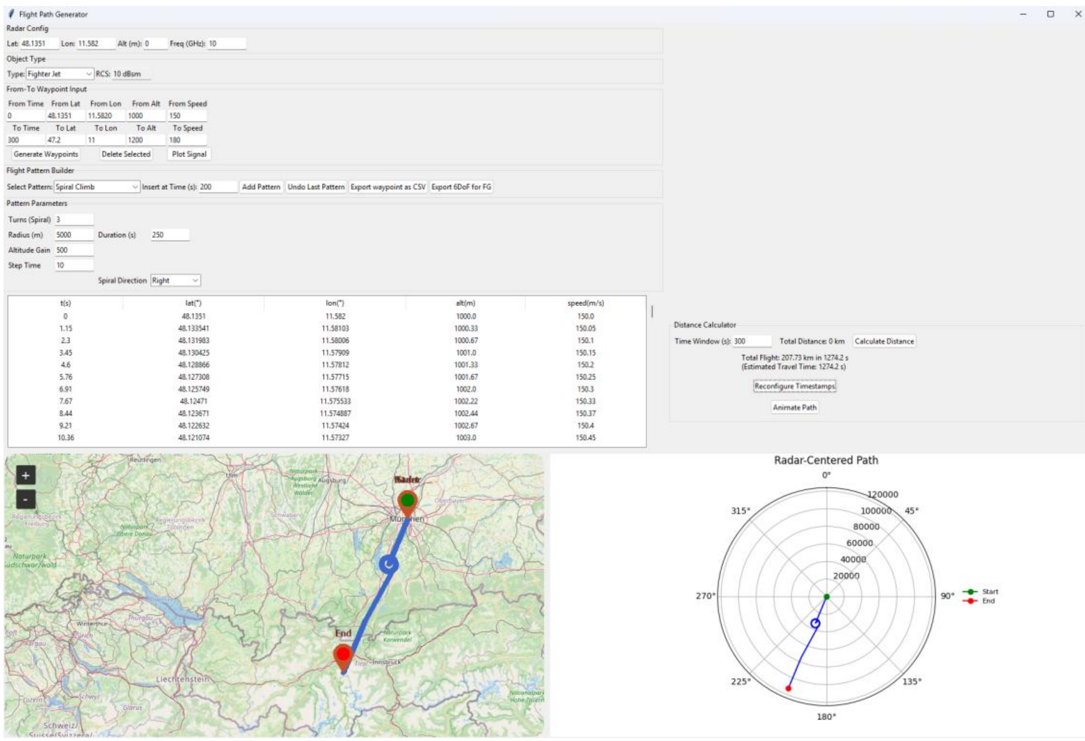


Figure 9: Flight Path generator

► From – To Waypoint Input:
Define the start and end positions by entering the latitude, longitude, altitude, and speed (m/s), then click Generate Waypoint. The software will automatically generate intermediate latitude, longitude, and altitude points along the path.

After generating the waypoints, click Reconfigure Timestamps to adjust the total scenario duration based on the instantaneous speed.

Once the waypoint path is finalized, select Export Waypoint as CSV. The generated CSV file can be imported into the Nexus tool to represent the UE position over time.

► Flight Pattern Builder:
The Flight Pattern Builder includes several preprogrammed common aerial maneuvers. To insert one of these maneuvers into your route, simply click Add Pattern, and the selected maneuver will be appended to the current flight path.

6.2.4 Visibility Check & Test Scene Planner

The bottom part of the Static UE Entry and Mobile UE dialog are identical, its function is to check for the visible satellites for the given UE position and trajectory. It also gives some statistic about which satellite is visible for which amount of time.

- **Check Visibility and Plot**: This button determines which satellites are visible from the UE during the defined scenario duration and plots both the UE trajectory and the visible satellites on a world map.
- The tool evaluates satellite visibility over the specified observation period (e.g., 5 minutes in Figure 7 and Figure 8). By default, the visibility calculation is performed with a 1-second time resolution. For large constellations such as Starlink (9000+ satellites), the visibility search step can be increased (e.g., 15 s or 30 s) to reduce computation time. In this case, visibility is evaluated only at the selected interval rather than every second. While this significantly speeds up processing, satellites that are visible for shorter durations than the selected step interval may not be detected. The default step size is 15 seconds, but any integer value can be configured depending on the desired balance between accuracy and computation time.
- If the UE is mobile, the CSV file contains the instantaneous UE speed and position over time. During each visibility iteration, the UE position is updated based on the travelled distance derived from the instantaneous speed. As a result, the visibility calculation always uses the current UE position, providing a precise and realistic evaluation. For example, if the GPX route is 15 km long, but a satellite is visible for 100 seconds, the software only considers the actual distance travelled during those 100 seconds (e.g., about 1.2 km) rather than the entire route length.

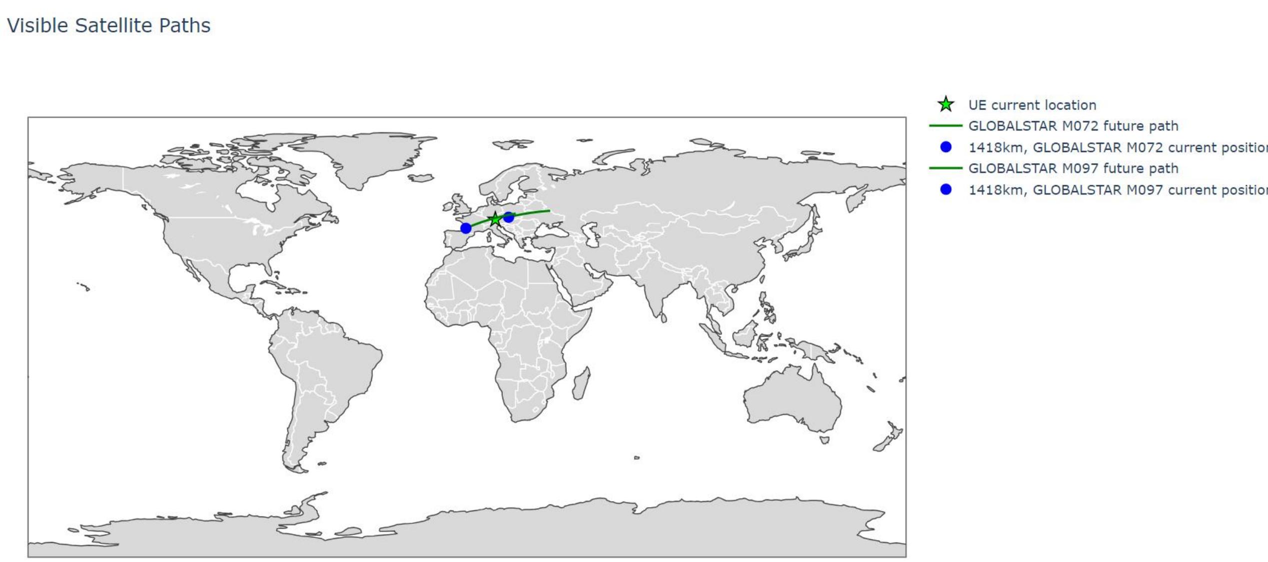


Figure 10: Visibility Check Plot Example

- **Visibility Animation**: Creates an animation of all visible satellites, the time of the animation is fixed at 10 min. It is recommended to not use the feature for constellations with a large amount of satellites(based on the cache settings of the default browser, this may lead to runtime errors). The movement of the UE is not considered for the animation.

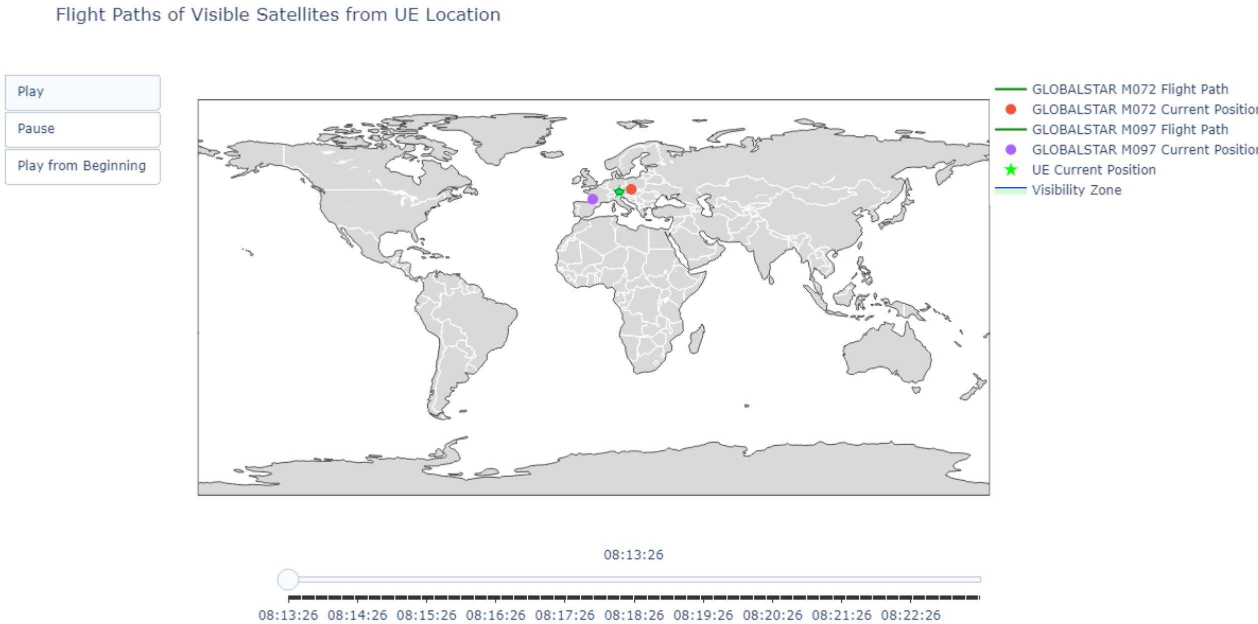


Figure 11: Visibility Animation Example

- **Info**: Gives information over some features of the UE Properties and Motion section.
- **Stats**: Displays detailed information about satellite visibility, including the start and end times of visibility for each satellite as well as the total visibility duration at the UE location. For the statistics calculation, a 1-second step size is used by default for the visibility search iteration interval. For a static UE, the computation is very fast. For a mobile UE, the calculation may take slightly longer since the UE position must be updated continuously during the visibility evaluation.

```
UE points loaded: 171 (using every 1th)
UE GPX visibility stats
Start (UTC): 2026-03-10 08:50:16
Duration window: 5 min
Elevation >= 45.0°
Total satellites in TLE: 210
Satellites ever visible: 3
Runtime: 14.55 s

Satellite                                                   Visible(s)  Visible(min)     First seen (UTC)       Last seen (UTC)
------------------------------------------------------------------------------------------------------------------------------
KUIPER-00279                                                        28          0.47  2026-03-10 08:53:55  2026-03-10 08:54:23
KUIPER-00044                                                        22          0.37  2026-03-10 08:54:53  2026-03-10 08:55:15
KUIPER-00178                                                        12          0.20  2026-03-10 08:50:46  2026-03-10 08:50:58
```

Figure 12: Statistics result window view

- **Visibility over time**: Plots the number of satellites that are visible at each time step throughout the defined duration.
- **Visible Satellite dropdown button:** Selection of the satellite for which the channel conditions should be simulated. This button is important for the next steps in calculating the fading channel parameters or the robot trajectory for beam steering testing.

6.3 Communication

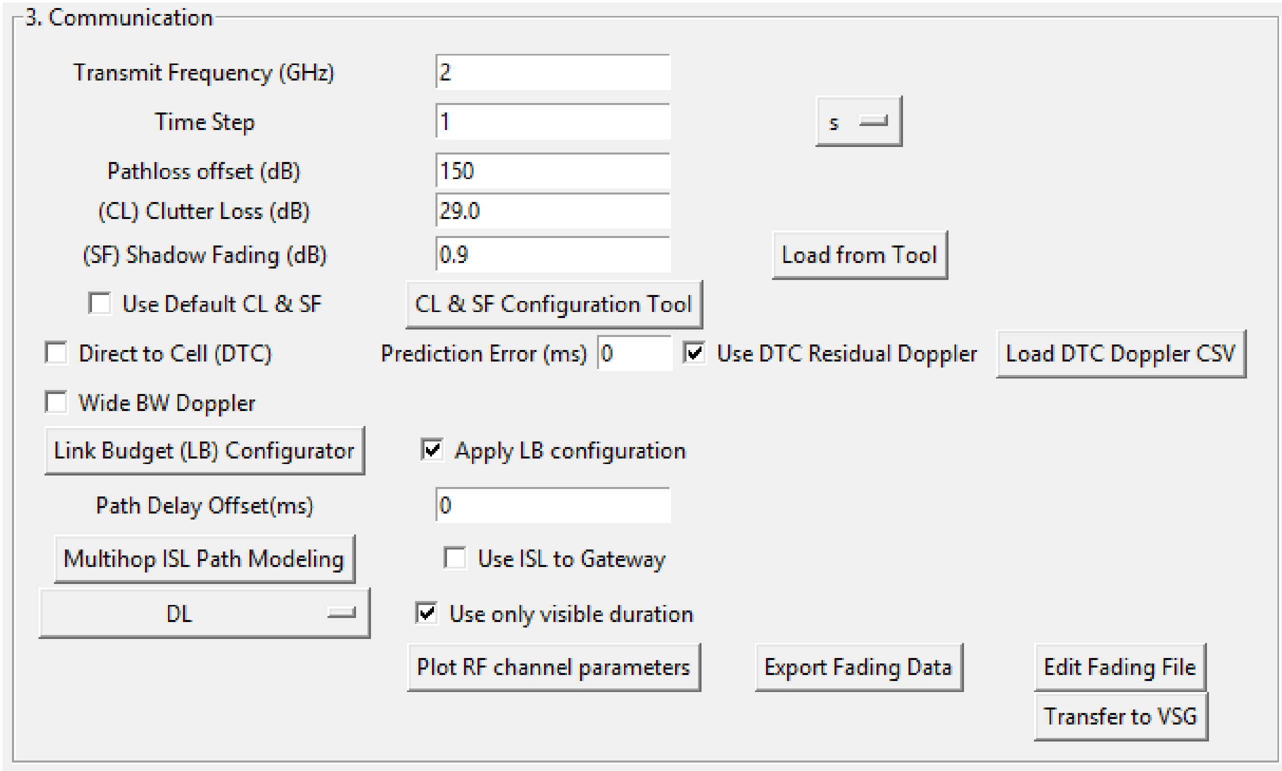


Figure 13: Communication section of the R&S Space Nexus

The Communication section allows the user to specify the transmission and channel parameters of the scenario, plot the result and export the .fad_udyn fading file that is needed for the R&S®SMW-K820. It has the following functionalities:

- **Transmit Frequency**: Set the transmission frequency of the signal to be transmitted in GHz.
- **Time Step**: Set the time step between two consecutive fading values. Can be switched between second, millisecond and microsecond. The minimum value possible with the R&S®SMW-K820 is 50 µs.
- **Pathloss offset**: Sets a value in dB that is subtracted from the attenuation that is applied to the signal. The reason for this parameter is that the maximum attenuation settable in the R&S®SMW-K820 is 50 dB and therefore an offset must be applied to the path loss since satellite transmission from LEO can reach well over 200 dB in attenuation depending on frequency.
- **(CL) Clutter Loss**: Specify a value in dB for clutter loss that occurs for Non-Line of Sight (NLOS) scenarios.
- **(SF) Shadow Fading**: Specify a value in dB for shadow fading.
- **Load from Tool**: Loads the CL and SF values from the CL & SF Scenario Selection tool described in 6.3.1.
- **Use Default CL & SF**: Use default values for CL and SF, those are CL = 29 and SF as a random normal distribution with a mean of 0 and a variance of 1.
- **CL & SF Configuration Tool**: Opens the CL & SF Scenario Selection described in 6.3.1.
- **Direct to Cell (DTC)**: Removes the doppler effect from the simulation. This considers that the doppler pre-compensation is done on the satellite side. And only the signal latency and pathloss needs to be tested.

- **Prediction Error(ms)**: Slight inaccuracies in UE location and satellite position cause residual doppler issues. This changes the fading channel calculation. By default, 0ms is used but this can be set as required. Typical value would be for example 50ms.
- **Wide BW Doppler**: Needs to be checked to enable the generation of Doppler shifts of up to 1,953 MHz. If this field is unchecked the maximum Doppler shift is limited to 190 kHz.
- **Link Budget (LB) Configurator**: Opens the Link Budget Configurator described in section 6.3.2.
- **Apply LB configuration**: Use the values specified in the Link Budget Configurator to perform the channel simulation. The resulting channel parameters are calculated dynamically for each sampling step.
- **Path Delay Offset**: Sets an offset for the path delay in ms to add extra fixed delay to the propagation delay.
- **Multihop ISL Path Modeling**: Opens the Satellite Path Delay Simulator described in 6.3.3.
- **Use Shortes Path to Gateway for Latency**: Check to use the values calculated in the Satellite Path Delay Simulator for the delay element of the channel simulation.
- **DL/UL**: Switch between Down Link and Up Link for the naming of the file as well as signal latency consideration if the short path to gateway is selected.
- **Use only visible duration:** this will plot only during the visible conditions not the entire duration set in previous tab.
- **Plot RF channel parameters**: Plots the different propagation parameters including Doppler shift, satellite altitude, elevation angle, propagation delay, doppler rate and path loss. This can take a longer time for smaller time steps.

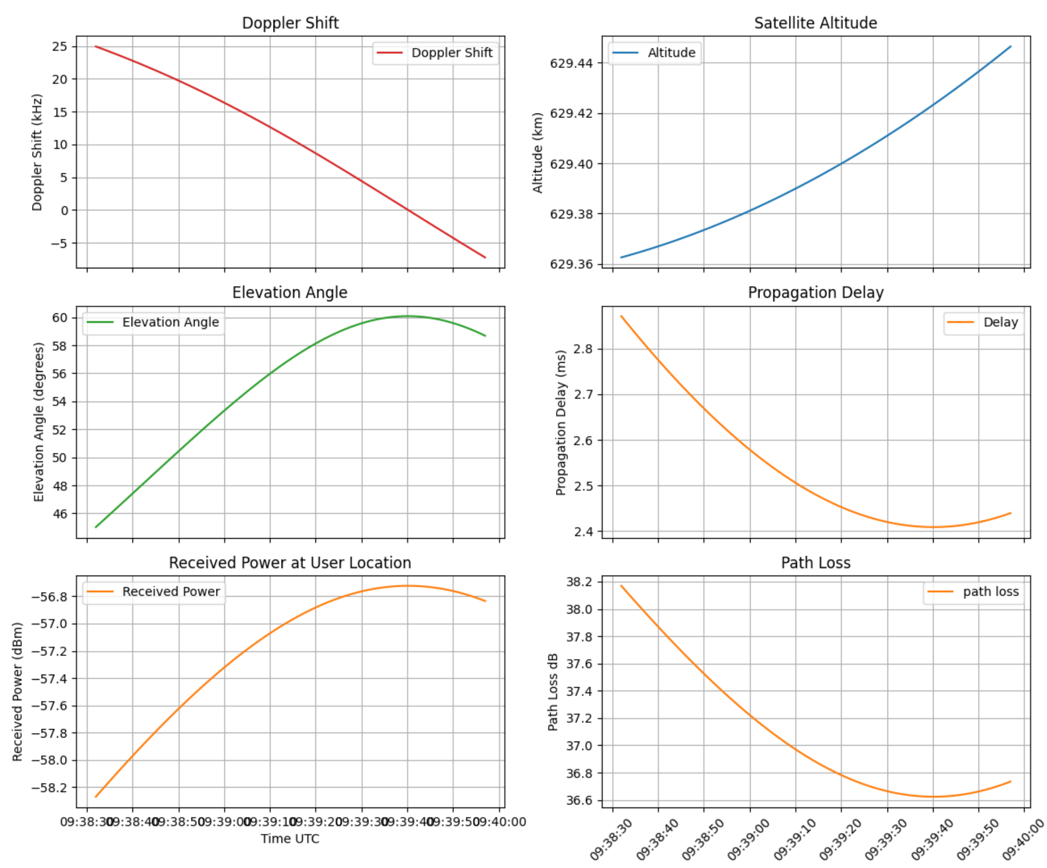


Figure 14: Propagation parameter plot example

- **Export Fading Data**: Generates a .fad_udyn file and opens a file explorer window to select a folder to save the file. This can take a longer time for small time steps. If the file is renamed later, be aware that the filename must be in the format “*_customer_*.fad_udyn” .
- **Transfer to VSG**: Opens a menu to transfer the .fad_udyn file to the R&S®SMW200A. For detailed explanation see 7.3.

6.3.1 CL & SF Scenario Selection

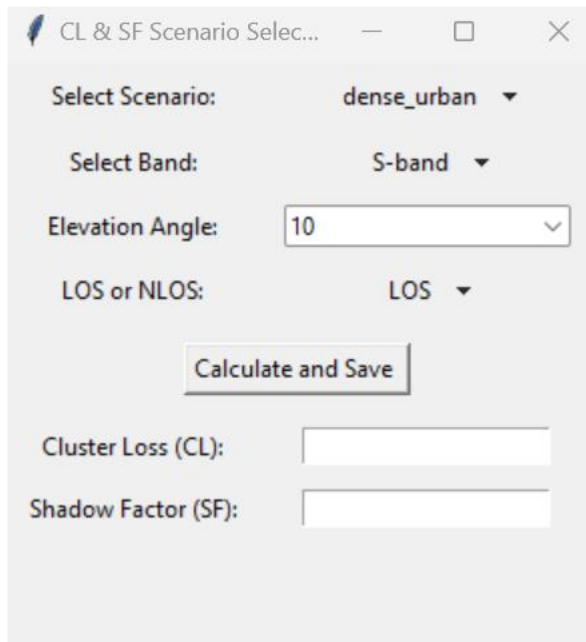


Figure 15: CL & SF Scenario Selection

The CL & SF Scenario Selection allows the easy selection of the CL & SF parameters for a given scenario according to 5G NTN standard 3GPP TR 38.811 V15.4.0.

- **Select Scenario**: Select the base scenario.
- **Select Band**: Select the transmission band.
- **Elevation Angle**: Specify an elevation angle for the CL & SF factor.
- **LOS or NLOS**: Choose between Line of Sight (LOS) and Non-Line of Sight (NLOS)
- **Calculate and Save**: Calculates the CL & SF value for the chosen configuration and displays them in the fields below.

6.3.2 Link Budget Configurator

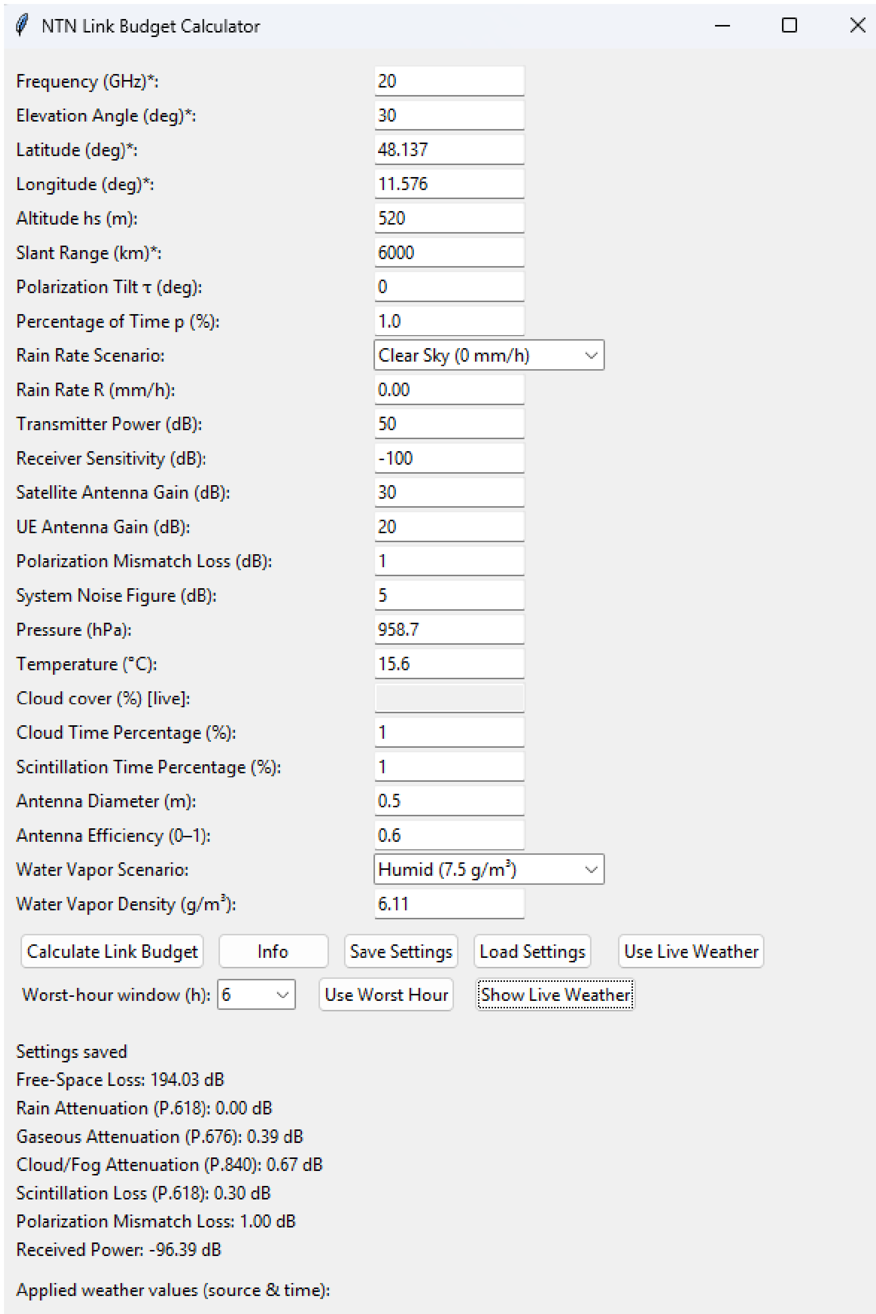


Figure 16: Link Budget Configurator

The Link Budget Configurator offers the possibility to define a large range of satellite channel specific transmission parameters and include:

- **Frequency:** Set the frequency of the transmission in GHz.
- **Elevation Angle:** Set the elevation angle for the rain fading calculation, this taken dynamically during a satellite scenario.
- **Latitude:** Set the latitude of the UE in degree for the rain fading calculation, this value is taken from section 2. UE Properties and Motion.
- **Longitude:** Set the longitude of the UE in degree for the rain fading calculation, this value is taken from section 2. UE Properties and Motion.

- **Altitude:** Set the altitude of the UE in meters for the rain fading calculation, this value is taken from section 2. UE Properties and Motion.
- **Slant Range:** Set the slant range from the satellite to the UE in kilometers for the rain fading calculation this taken dynamically during a satellite scenario.
- **Polarization Tilt Angle:** Set the polarization tilt angle for the rain fading calculation.
- **Percentage of time:** Set the percentage of time in which rain fading occurs.
- **Rain Rate Scenario:** Select between Heavy Rain, Light Rain and Clear Sky.
- **Rain Rate:** Specify a rain rate in mm/h.
- **Transmitter Power:** Set the transmitter power in dB for the link budget calculation.
- **Receiver Sensitivity:** Set the receiver sensitivity in dB for the link budget calculation.
- **Satellite Antenna Gain:** Set the satellite antenna gain in dB for the link budget calculation.
- **UE Antenna Gain:** Set the UE antenna gain in dB for the link budget calculation.
- **Polarization Mismatch Loss:** Set the polarization mismatch loss in dB for the link budget calculation.
- **System Noise Figure:** Set the system noise figure in dB for the link budget calculation.
- **Pressure:** Set the pressure in hPa for the calculation of the cloud attenuation.
- **Temperature:** Set the temperature in °C for the calculation of the cloud attenuation.
- **Cloud Time Percentage:** Set the percentage of time clouds are present for the calculation of the cloud attenuation.
- **Scintillation Time Percentage:** Set the percentage of time that signal undergoes scintillation for the calculation of the scintillation loss.
- **Antenna Diameter:** Set the antenna diameter in meter for the calculation of the received power.
- **Antenna Efficiency:** Set the antenna efficiency for the calculation of the received power.
- **Water Vapor Scenario:** Select between Dry, Humid and Wet scenario.
- **Water Vapor Density:** Set the water vapor density in g/m^3 for the gaseous attenuation calculation
- **Calculate Link Budget:** Click to calculate all values using the values provided above.
- **Use Live Weather:** Automatically configures relevant simulation parameters using real-time weather data from the UE location, retrieved via a public weather API. This helps populate the required values based on the actual environmental conditions at the UE location, simplifying scenario setup and improving realism.
- **Use Worst weather:** Automatically configures and populates the relevant simulation parameters using weather data from the UE location, retrieved via a public weather API over a selectable observation window of up to 48 hours. For satellite RF links, the worst-case weather condition typically corresponds to periods with heavy precipitation, as rain can introduce significant rain attenuation and signal degradation at higher frequencies (e.g., Ku/Ka bands). The tool therefore identifies the time interval with the highest expected atmospheric attenuation within the selected window and automatically applies these conditions to the simulation parameters.
- **Show Live Weather:** This shows a window with the weather at the UE location over the next 6 hours.

6.3.3 Satellite Path Delay Simulator

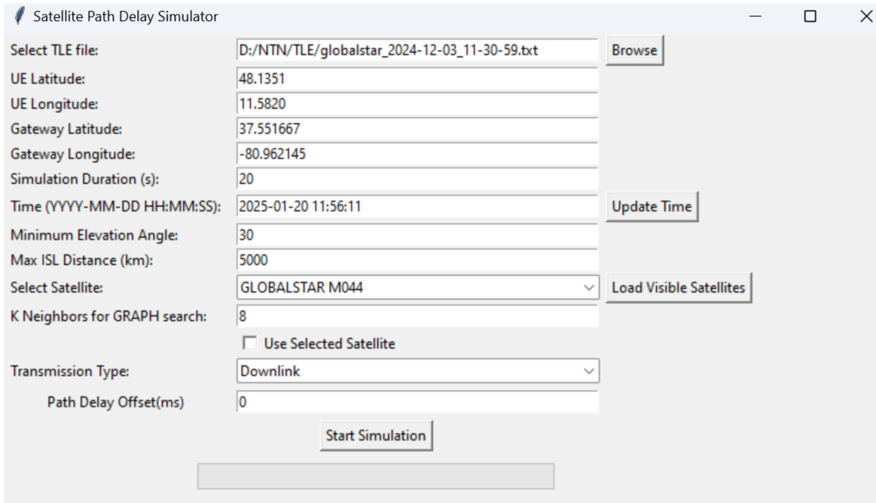


Figure 17: Satellite Path Delay Simulator

The Satellite Path Delay Simulator allows to simulate the entire link delay between a UE and a gateway using Inter Satellite Link (ISL) in a satellite constellation. Here each satellite in the constellation is considered as node and the shortest path to GW is calculated. All inter satellite distance and corresponding signal delay are calculated and is used as the weight of the path. After that the relevant path from UE to GW are selected and the one with the shortest latency is plotted and used for the fading profile.

- **Select TLE file:** Select the TLE file that should be used for the path delay simulation.
- **UE Latitude:** Specify the UE latitude in degree.
- **UE Longitude:** Specify the UE longitude in degree.
- **Gateway Latitude:** Specify the gateway latitude in degree.
- **Gateway Longitude:** Specify the gateway longitude in degree.
- **Simulation duration:** Sets the time for the delay simulation in seconds.
- **Time:** Sets the starting time for the simulation in the format YYYY-MM-DD HH:MM-SS. Use the button **Update Time** to set the time to the momentary time.
- **Minimum Elevation Angle:** Specify the angle at which a satellite is visible in degree.
- **Max ISL Distance:** Specify the maximum inter satellite link (ISL) distance between 2 satellites in kilometers.
- **Select Satellite:** Select one visible satellite that should be used for the start of the ISL. Use the button Load Visible Satellite to simulate which satellite are visible for the specified UE position.
- **K Neighbors for GRAPH search:** Specifies the number of neighbors that should be used for the path finding algorithm to find the shortest path between the UE and the gateway.
- **Use Selected Satellite:** Check this box to force the algorithm to use the previously selected visible satellite for the ISL.
- **Transmission Type:** Select between an up- or downlink transmission.
- **Path Delay Offset:** Add additional path delay to the simulation in milliseconds.
- **Start Simulation:** Start the satellite path simulation and displays, when finished, the propagation delay over time as well as a map showing the ISL path the signal took at every timestep.

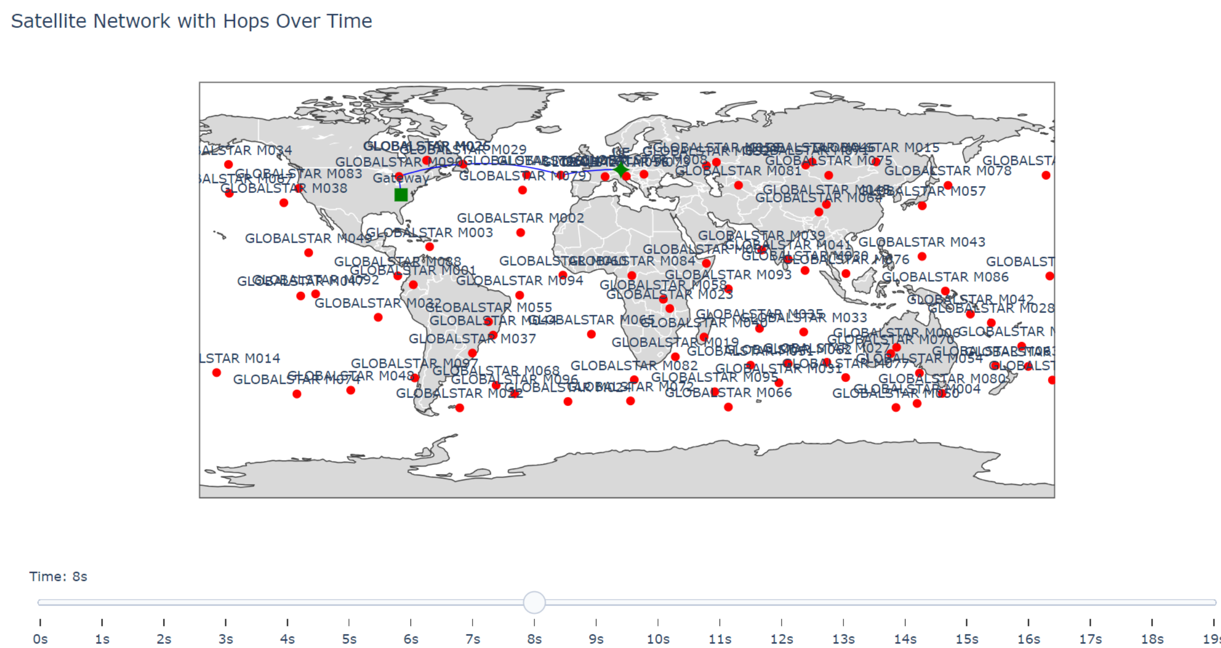


Figure 18: ISL path taken from the UE to the gateway

6.3.4 Edit Fading file

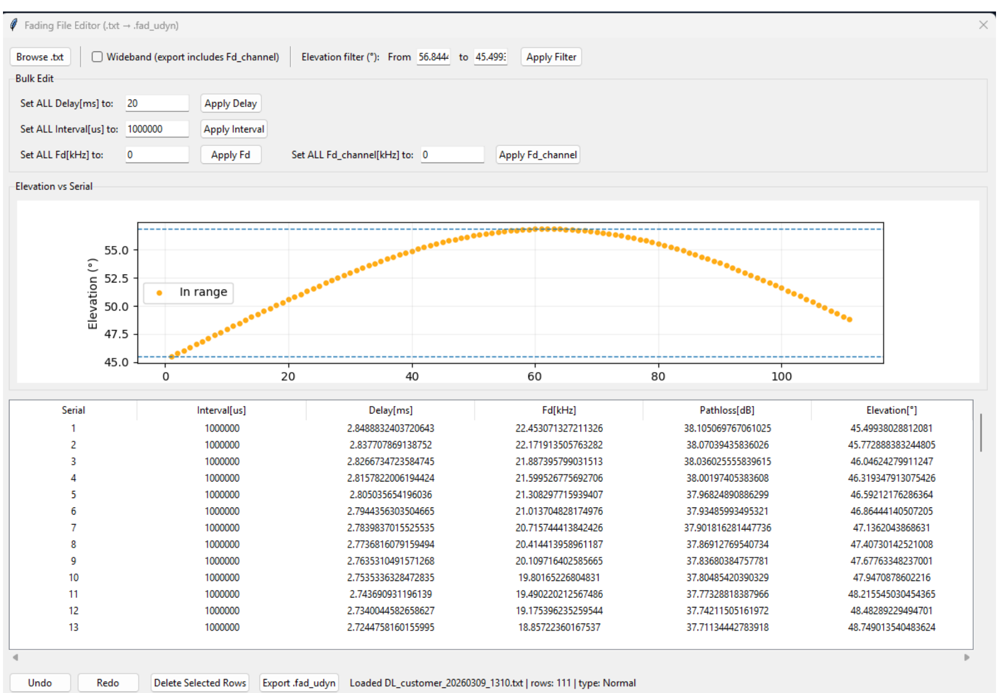


Figure 19: Fading File Editor

Clicking the **Edit Fading File** button opens a dedicated **Fading File Editor window**.

When fading files are exported using **Plot RF Channel Parameters**, two files are generated: the **.fad_udyn file** and an additional **.txt file**. The **.txt file** can be imported into the Fading File Editor for further modification, as shown in Figure 19**.**

► **Browse .txt:** Import a fading **(.txt)** file. If the file contains **wideband fading parameters**, it will be automatically recognized.

► **Elevation Filter:** Allows filtering of specific elevation angle ranges. For the filtered entries, the corresponding **delay, Doppler, and path loss values** are automatically set to **0.0**.

► **Apply Delay, Interval, Fd, and Fd_channel (wideband Doppler):** Applies the specified values to all corresponding fields in the dataset.

► **Manual Editing:** Individual entries in the workspace can be edited by **double-clicking the cell**, entering the desired value, and pressing **Enter**.

► **Delete Selected Rows:** Multiple rows can be selected by holding the **Shift key** and clicking the desired entries. The selected rows can then be removed in a single step using this button.

► **Export .fad_udyn:** Exports the edited fading data as a **.fad_udyn file** to the selected file location. To ensure compatibility with the **R&S SMW200A**, the filename must include the word **"customer"** (e.g., my_filename_customer.fad_udyn).

6.4 Satellite in Motion

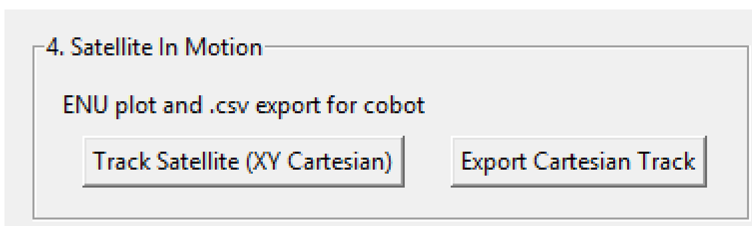


Figure 20: Satellite in Motion section

The Satellite in Motion section is used to export trajectory of the satellite as seen from the UE. This feature is used for another application where the ENU data of the satellite from the UE is exported as a .csv file. But this block isn't relevant here, therefore no further explanation for this feature is provided in this application note.

7 Using the R&S®SMW200A to generate Satellite Fading Scenarios

7.1 Minimum Device Configuration

The channel simulation can be used on the standard and wideband R&S®SMW200A, but we recommend the use of the wideband option. The following configuration is the minimum configuration for a standard R&S®SMW200A:

– R&S®SMW-B13/B13T
– R&S®SMW-B10
– R&S®SMW-B14
– R&S®SMW-K71
– R&S®SMW-K820

With this configuration a maximum of 160 MHz of modulation bandwidth, am maximum of 671 ms of path delay and a maximum of 190 kHz of doppler.

For a wideband R&S®SMW200A the following configuration is needed as a minimum:

– R&S®SMW-B13XT
– R&S®SMW-B9
– R&S®SMW-B15
– R&S®SMW-K71
– R&S®SMW-K820

With this configuration a maximum of 200 MHz of modulation bandwidth, am maximum of 1073 ms of path delay and a maximum of 1.953 MHz of doppler.

7.2 Manually Loading Fading Files

To access the Custom Dynamic Fading (CDF) mode, the SMW must be switched to "Advanced Mode" in the "System Configuration". Then access the fading block and select the configuration "Customized Dynamic"

Then in the "Path Table" tab the wanted fading file in the fad_udyn format can be selected. We recommend using the path 2 for line of sight and path 7 and 8 for any multipath scenarios.

7.3 Direct Fading File Import

The R&S Space Nexus allows also the direct import of fading files. By clicking on the "Transfer to VSG" a new window is opened that allows the entering of the SMW IP Address, the destination document path in the SMW and location of the fading file on your PC.

This requires the RsVisa SW to be installed on your PC. This tool can be downloaded from the R&S webpage under the following link: R&S®VISA | Rohde & Schwarz

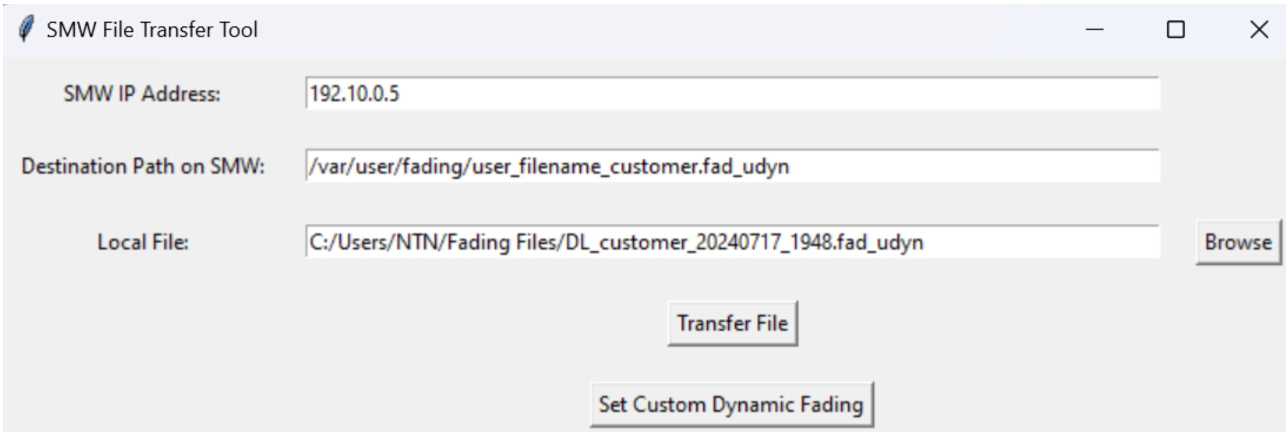


Figure 21: SMW File Transfer Tool

By clicking “Transfer File” the file can then be transferred to the Vector Signal Generator (VSG) and the button “Set Custom Dynamic Fading” automatically sets all parameters of the SMW according to the explanation given in 7.2

7.4 Simulation Example

For an example we simulate the Starlink constellation and select a static UE position in Munich.

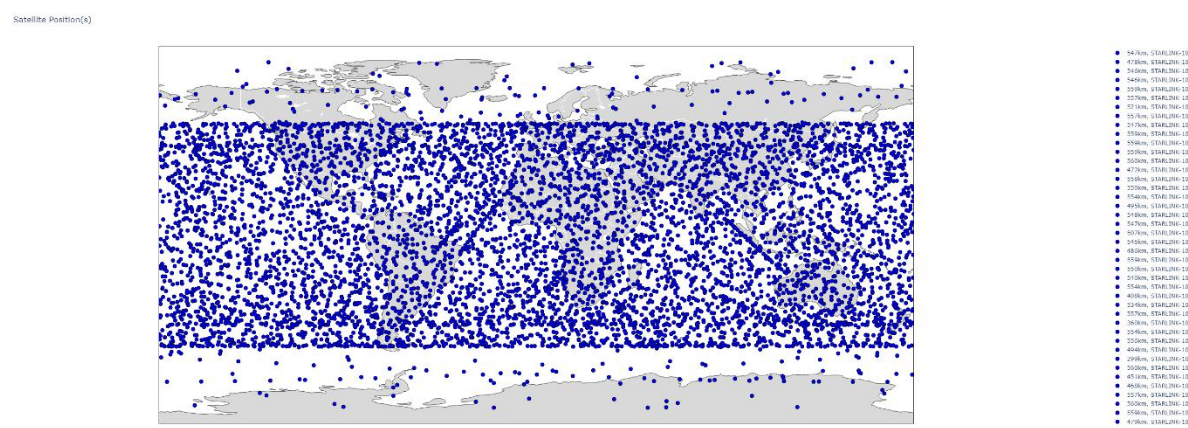


Figure 22: Plot of the Starlink Constellation

We select a satellite that is nicely viable from the UE location.

Figure 23: Selection of a satellite over Munich

For the communication part a simple setup with a transmission at 35 GHz is chosen and resulting in the following plot.

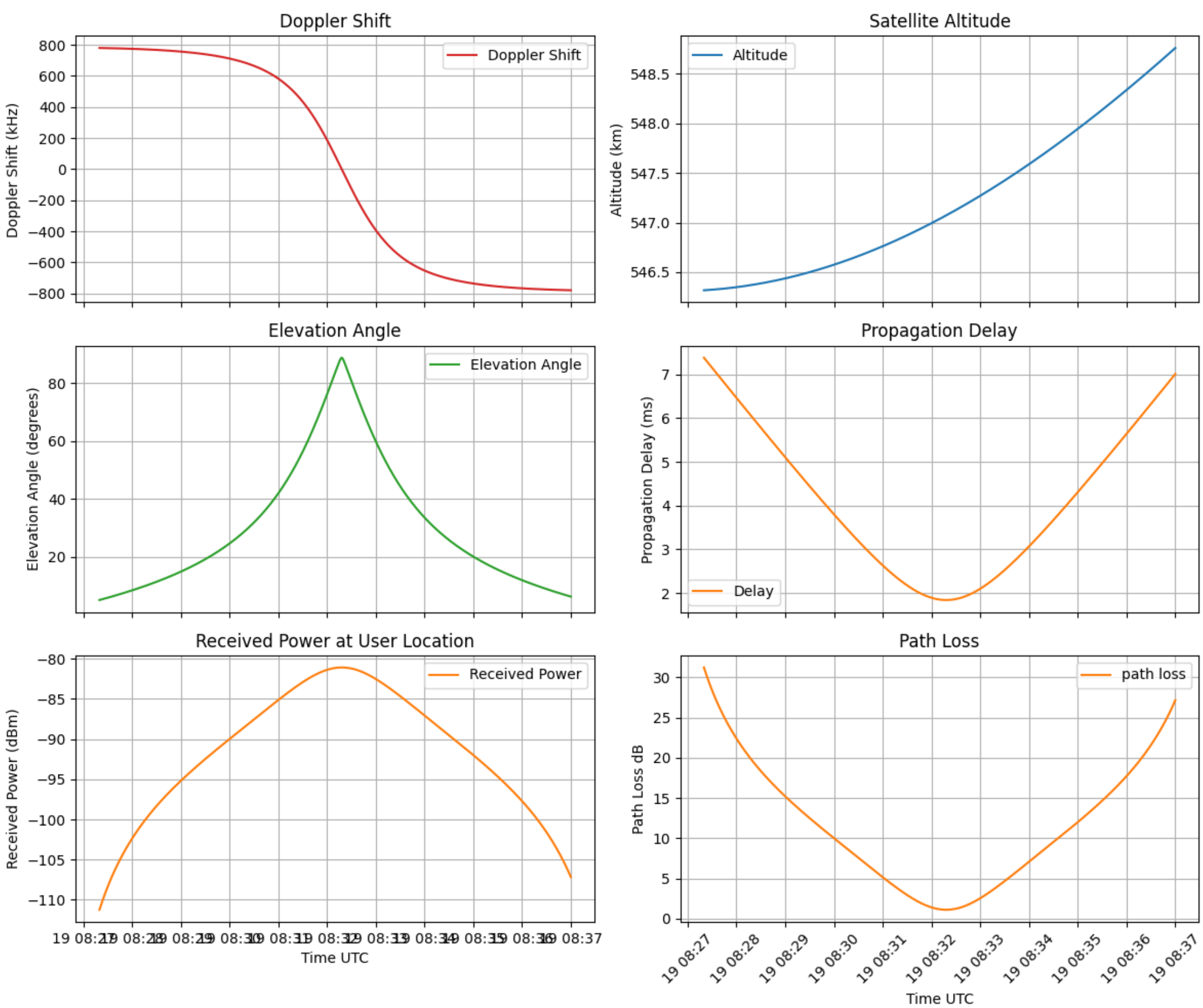


Figure 24: Example Plot at 35 GHz

The corresponding file is then load into the CDF function in the SMW200A where a DVB-S2X signal with a 16 APSK is generated and the outputted signal is analyzed on an FSW.

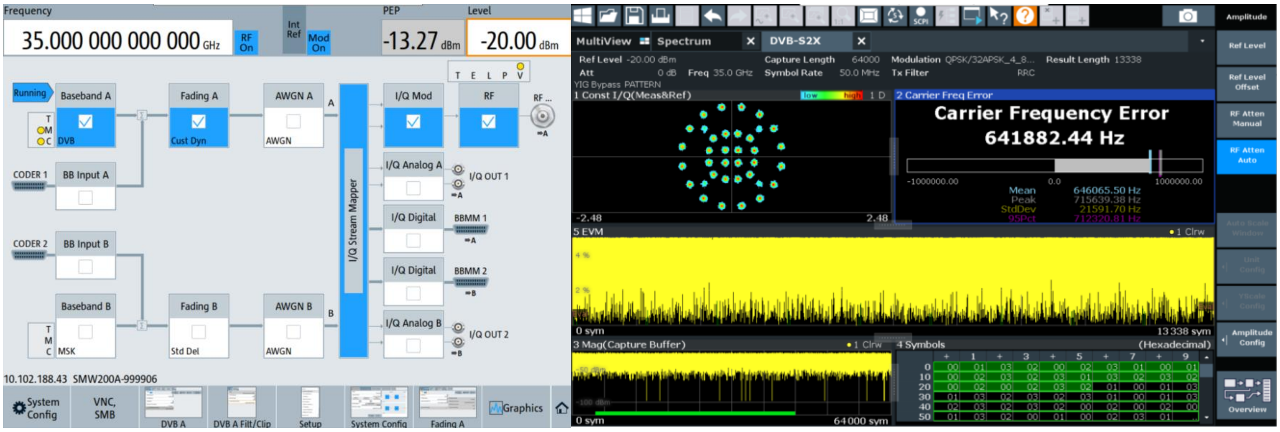


Figure 25: Simulation Example on SMW200A and FSW

There we can observe the resulting doppler shift in the Carrier Frequency error.

8 Appendix

A Literature

[1] D. A. Vallado and P. Crawford, "SGP4 Orbit Determination," 2008.

B Abbreviations

CDF	Custom Dynamic Fading
CL	Clutter Loss
DL	Down Link
DUT	Device Under Test
FSPL	Free Space Path Loss
GEO	Geosynchronous Earth Orbit
GPS	Global Positioning System
GPX	GPS Exchange Format
GS	Ground Station
HEO	Highly Elliptical Orbit

ISL	Inter Satellite Link
LEO	Low Earth Orbit
LOS	Line if Sight
NLOS	Non-Line of Sight
MEO	Medium Earth Orbit
SatCom	Satellite Communication
TLE	Two Line Elements
UE	User Equipment
UL	Up Link
VLEO	Very Low Earth Orbit
VSG	Vector Signal Generator

Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

www.rohde-schwarz.com

Certified Quality Management
ISO 9001

Rohde & Schwarz training

www.rohde-schwarz.com/training

Rohde & Schwarz customer support

www.rohde-schwarz.com/support

PAD-T-M: 3572.7186.00/02.00/EN

1GP147 | Version 3a | 04.2026
Application Note | Creating Satellite Fading scenarios with the R&S Space Nexus
Data without tolerance limits is not binding | Subject to change

www.rohde-schwarz.com