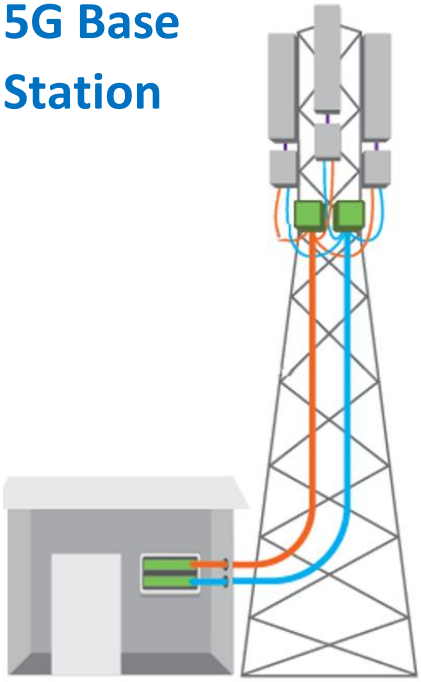
Base Stations and Mobile Stations

using the **Spirent Vertex RF Channel Emulator** with its **ACM software** option

5G Base Station



Mobile C2 on armored vehicles Integrated Tactical Network (ITN)

Executive Summary

Both the Base Station and Mobile Station act as the over-the-air (OTA) RF to Core Network interface, in which all voice, video and data must pass through. Nothing gets transmitted or received without the use of one of these stations. They are a fundamental component for all wireless communications and are the closest endpoint between the network and the user.

Being that both stations operate outdoors it's complicated to perform ongoing modeling and testing on them due to external factors like: availability of the Electromagnetic Spectrum (EMS), external RF interference, and environment conditions.

The solution is to bring this modeling and testing into the Lab, in a controlled environment, where measurements can be automated, and costs can be reduced.

This whitepaper discusses our proven solutions for modeling and testing both Base Stations and Mobile Stations with a singular hardware instrument, the Spirent Vertex RF Channel Emulator, and Spirent's Advanced Channel Modeling (ACM) software.

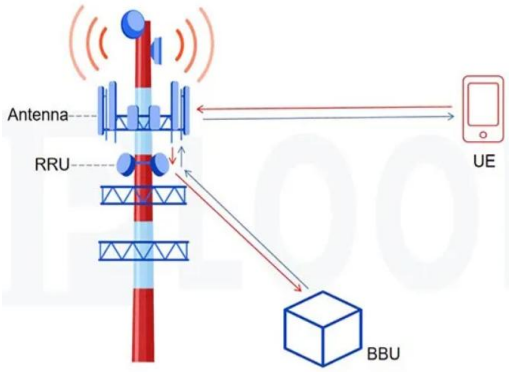
Base Station

Is a **fixed station** that uses radio waves (RF) to communicate with user devices (UEs). It serves as the link between the user's device and the Core Network.

Base stations range in size and area of coverage. Some may cover a radius of several kilometers while others cover only a few city blocks. Most stations transmit in all directions but there are also directional antennas aimed at a specific direction.

Traditional Base Stations consists of:

- Antenna – responsible for the transmission and reception of signals, connected to the RRU.
- Remote Radio Unit (RRU) – can be divided into several sectors for the transmission of 3G, 4G-LTE and 5G signals. Signal generation and extraction of radio signals are performed here.
- Baseband Unit (BBU) – placed in the equipment room and connected with RRU via optical fiber, is the core of the base station, and is the unit that processes the original signal.



RF Channel Emulator and ACM software option can model up to 16 Base Stations with their required parameters – from 30MHz to 6GHz and mmWaves up to 48GHz (3G/4G-LTE/5G)

In addition, we offer an Array Modeling Tool (AMT) software option for Beam forming, Beam steering, and Phase Shifting. [*see Dualos Phased Array Antenna whitepaper***]**

Mobile Station

Network mobility is vital for today's military. Which means every mobile equipment platform (vehicular, UAV, fixed wing, rotary wing, and satellite) should be able to act as a Network Router to keep our Warfighter seamlessly connected to Command and Control (C2).

The current Army initiative to make this happen is **Capability Set 23** (CS23), which will bring their Integrated Tactical Network (ITN) onboard the Stryker™ armored vehicle platform. The Stryker™ is a multi-functional platform available in 10-variants used for: troop transport, medical ground evacuation, EW&SIGINT preventing IED attacks, and ITN use cases.

ITN is the Army's primary tactical communications network providing voice, video, and data to commanders across the full spectrum of battlefield operations. ITN operates across a wide spectrum of Radio bands: HF-, VHF-, UHF-, L-, S-, C-, X-, Ku-, K-, and Ka- bands in both terrestrial and non-terrestrial domains. (These bands operate from 3MHz to 40GHz)

CS23 is part of the Army's Capability Sets initiative to achieve all-domain Electromagnetic Spectrum (EMS) dominance, keep pace with industry advancements, and deliver a modernized tactical network. The Army is fielding Capability Sets (CS) in two-year increments which began in FY2021. Each CS builds off the previous and is infused with commercial solutions informed by DoD-led experimentation. The CS construct leverages Army and DoD science and technology, coupled with industry and academia's research and development advancements and commercial off-the-shelf solutions. Building to standard with advanced waveforms, mission command applications, cyber security, data management, satellite communications and artificial intelligence are core to the success of this phased approach.

Each mobile equipment platform has different top end speeds and delays that need to be accounted for when emulating and modelling their Mobility Stations.

ACM Mobile Station software models each of the platforms

RF Channel Emulator and ACM software option can model up to 16 Mobile Stations with their required parameters – from 3MHz to 6GHz and mmWaves up to 40GHz (HF/VHF/UHF/SHF)

RF Channel Emulator has three options for Doppler Shift:
± 4kHz for Warfighter Use Cases (terrestrial MANET radios)
± 12kHz for Armored Vehicle, Rotary Wing, UAV, or Fixed Wing (terrestrial MANET radios)
± 2MHz for SATCOM (non-terrestrial) [*see Dualos SATCOM whitepaper*]
- Doppler Resolution: 0.01Hz

RF Channel Emulator has two options for Delay:
up to **± 4msec** for all terrestrial MANET radios
up to **± 2sec** for SATCOM (non-terrestrial) Use Cases [*see Dualos SATCOM whitepaper*]
- Delay Resolution: 0.1nsec

Vertex RF Channel Emulator

Spirent Vertex RF Channel Emulator along with the Advanced Channel Modeling (ACM) software enables you to model both Base Stations and Mobile Stations technology in the lab providing a controlled environment, repeatable measurements, and reducing costs.

Vertex is a fully modular and scalable platform

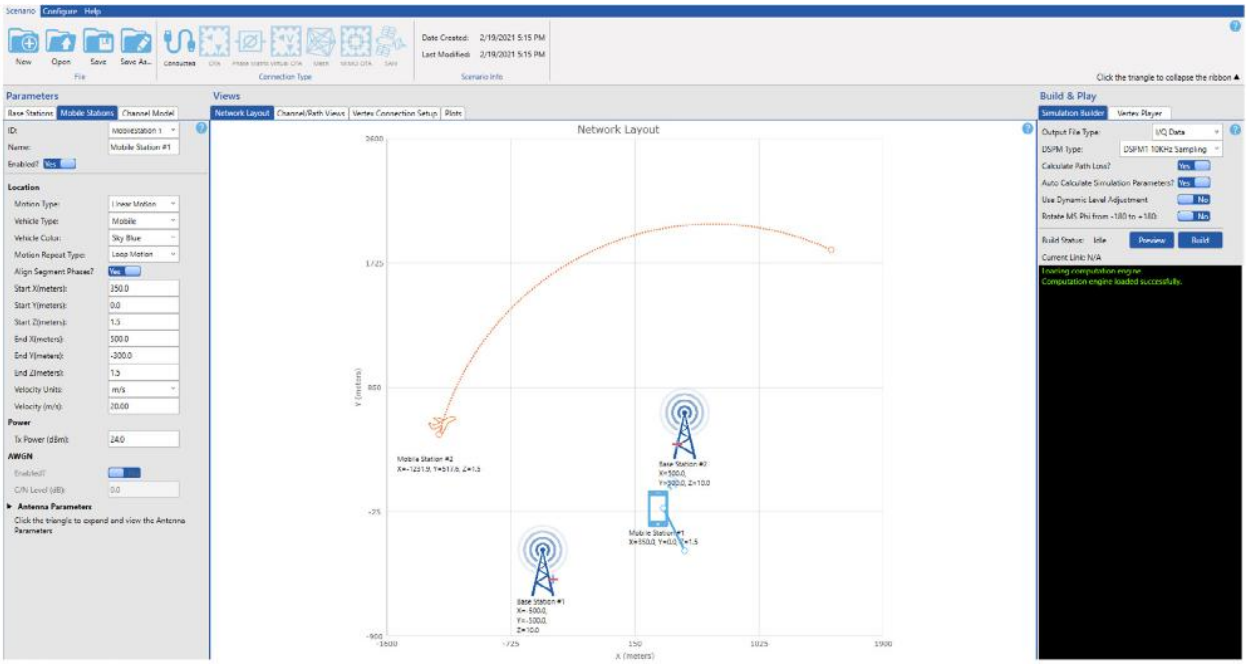
- Operating Freq: 30MHz to 6.0GHz
- Channel BW: 40MHz up to 1.20GHz
- Number of RF Ports: 2x2 up to 16x16

Extend Operating Freq by adding:

- HF-band Upconverter for 3MHz to 30MHz
- mmWave High Freq Converter (HFC) for 28GHz and 40GHz

Advanced Channel Modeling (ACM) software

Spirent ACM enables you to quickly and easily create highly complicated scenarios without needing to fully understand all the involved channel propagation characteristics using its simple graphical user interface.



ACM software enables you to emulate and model for Base Stations and Mobile Stations.

Base Station – tab

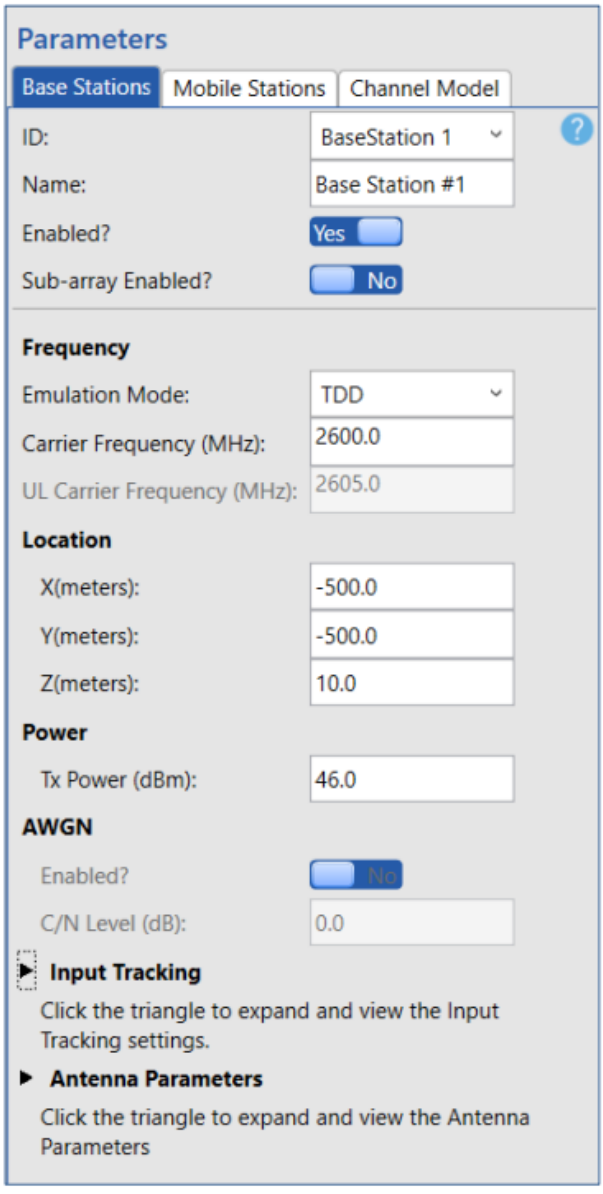
Enables you to configure the settings for up to 16 base stations.

For each base station, you can configure sub-array usage, frequency emulation mode, carrier frequency, location X/Y/Z coordinates, height of the antenna, transmit power, AWGN and C/N ratio level, and antenna parameters such as theta tilt, theta down tilt, phi rotation, antenna pattern, and the configuration of the antenna array.

- ID:
- Name:
- Enabled?
- Sub-array Enabled?
- Frequency
  - Emulation Mode:
  - Carrier Frequency (MHz):
  - UL Carrier Frequency (MHz):
- Location
  - X(meters):
  - Y(meters):
  - Z(meters):
- Power
  - Tx Power (dBm):
- AWGN
  - Enabled?
  - C/N Level (dB):

▶ Input Tracking
Click the triangle to expand and view Input Tracking settings

▶ Antenna Parameters
Click the triangle to expand and view Antenna Parameters

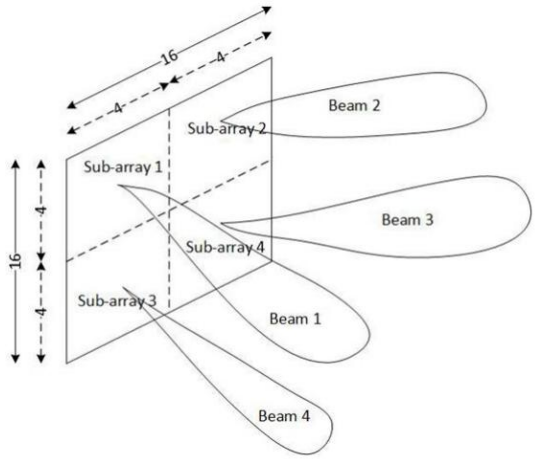


Base Station – Parameters and Settings

- ID:
  Select the base station you want to configure.
- Name:
  You can customize this label consisting of 25 characters.
- Enabled?
  Allows you to enable or disable the selected base station.
- Sub-array Enabled?
  Allows you to enable or disable the Sub-array function for the selected base station.

  This feature allows the simulation of antenna sub arrays by allowing the array at the base station to be sub-divided into a number of smaller arrays.

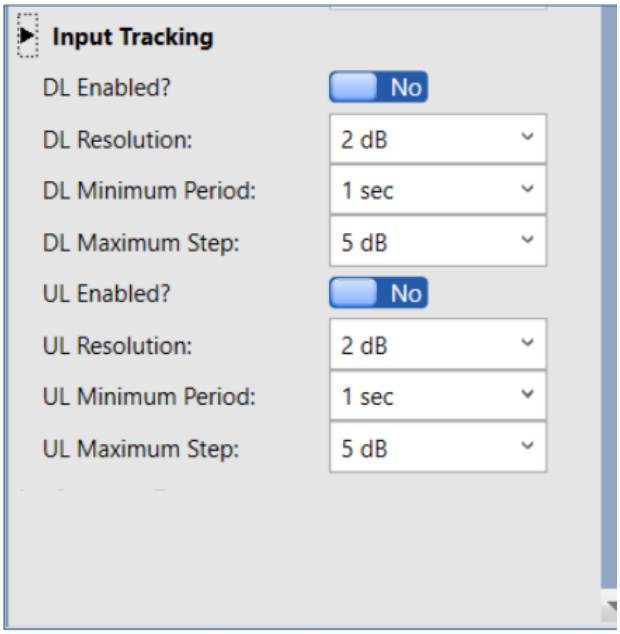
  EX: a 16x16 array may be sub-divided into four 4x4 arrays as shown. A channel model can then be assigned to each sub-array as well as weighting vectors for each element to allow the simulation of multiple beams.



- Frequency
  - Emulation Mode?
    Select the frequency mode you want to use. Choices are FDD and TDD.
  - Carrier Frequency (MHz):
    Specify the carrier frequency. Range is 30.0 to 5925.0MHz.
  - UL Carrier Frequency (MHz):
    Specify the uplink carrier frequency. Range is 30.0 to 5925.0MHz.
- Location
  - X(meters):
    Specify the distance from origin in the X direction. Range is -500,000.0 to 500,000.0
  - Y(meters):
    Specify the distance from origin in the Y direction. Range is -500,000.0 to 500,000.0
  - Z(meters):
    Specify the height of the antenna array. Range is -500,000.0 to 500,000.0
- Power
  - Tx Power (dBm):
    Specify the transmit power. This setting affects the expected output level and therefore the estimated RSSI (Received Signal Strength Indicator). This setting does not affect path loss. Range is -110.0 to 100.0 dBm.

- AWGN
  - Enabled?
    Allows you to enable or disable AWGN for the selected base station. When AWGN is enabled, this parameter sets the carrier to noise ratio as seen at the base station or mobile station.
  - C/N Level (dB):
    Specify the C/N (carrier-to-noise ratio) level. Range is -40.0dB to 40.0 dB

► **Input Tracking** – *clicked*
- DL Enabled?
- DL Resolution:
- DL Minimum Period:
- DL Maximum Step:
- UL Enabled?
- UL Resolution:
- UL Minimum Period:
- UL Maximum Step:



Input Tracking measures the input power and updates the expected input power accordingly.

Input Tracking – Parameters and Settings

- DL Enabled?
  Enable or disable Downlink (DL) of Input Tracking Parameters for selected base station.
- DL Resolution:
  Allows you to select a resolution value for the DL of 0.1, 0.5, 1.0, 2.0, & 5.0 dB for the selected base station. Resolution is the range over which the level will not be adjusted.
- DL Minimum Period:
  Allows you to select a DL minimum time value of 1, 10, 100, 500 ms, or 1, 2, 5 sec for the selected base station. This is the minimum time period between power measurements.
- DL Maximum Step:
  Allows you to select a DL maximum step value of 1, 2, 5, 10, 30 dB for the selected base station. This parameter sets the biggest step by which the input power can be changed to match the measured value.

- UL Enabled?
  Enable or disable Uplink (UL) of Input Tracking Parameters for selected base station.
- UL Resolution:
  Allows you to select a resolution value for the UL of 0.1, 0.5, 1.0, 2.0, & 5.0 dB for the selected base station. Resolution is the range over which the level will not be adjusted.
- UL Minimum Period:
  Allows you to select a UL minimum time value of 1, 10, 100, 500 ms, or 1, 2, 5 sec for the selected base station. This is the minimum time period between power measurements.
- UL Maximum Step:
  Allows you to select a UL maximum step value of 1, 2, 5, 10, 30 dB for the selected base station. This parameter sets the biggest step by which the input power can be changed to match the measured value.

Vertex offers two variations of Input Tracking:

- Automatic Input Tracking – in this mode, Vertex instrument measures the input power and updates the Expected Input Power accordingly.

  Three settings allow you to customize Automatic Input Tracking: Resolution, Minimum Period, and Maximum Step Size.

  1. Resolution (dB): The range over which the input level will not be adjusted. For example, a resolution of 2 dB means that the input power will not be adjusted unless it is measured to be +/- 2 dB from the current setting.

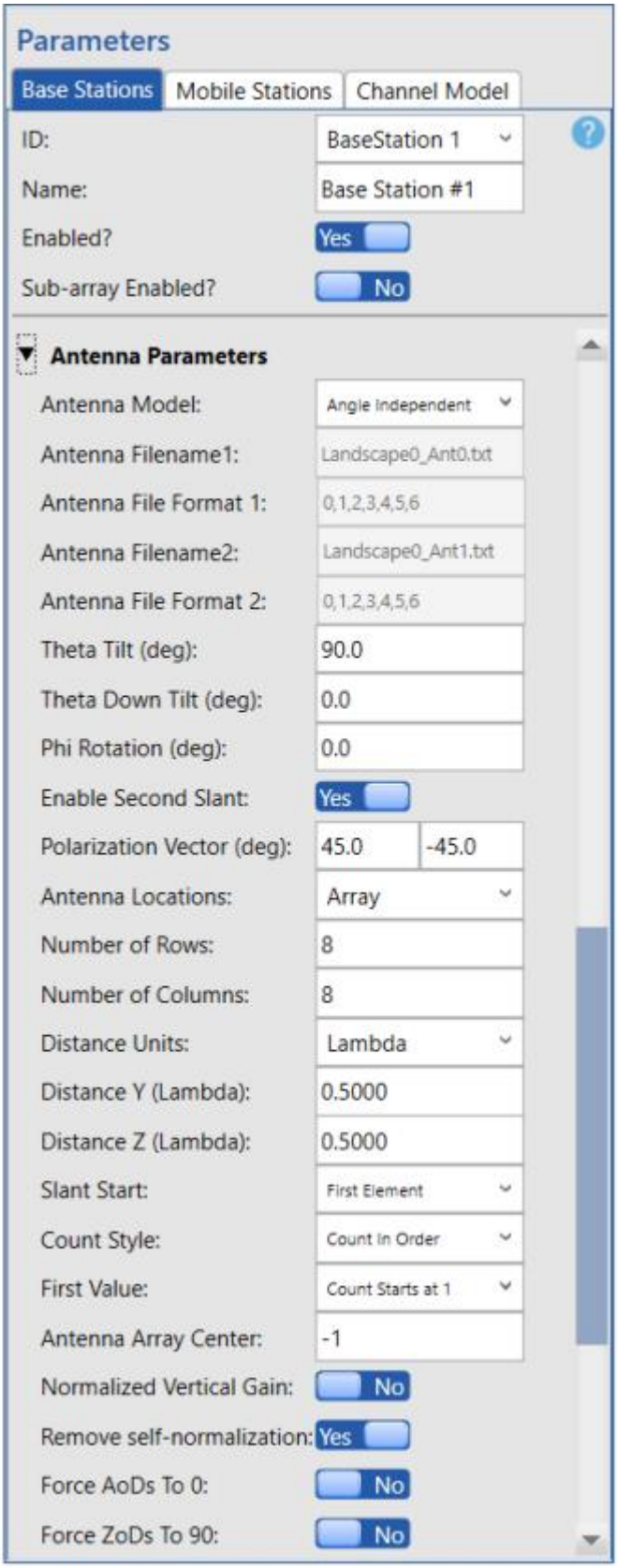
  2. Minimum Period (ms): The minimum time between power measurements.

  3. Maximum Step Size (dB): The biggest step by which the input power can be changed to match the measured value.

- Predicted Input Tracking – in this mode, a port uses the received loss to determine the necessary transmit input power.
  NOTE: Predicted Input Tracking is only available for Bidirectional configurations and when the Output Mode is set to Loss.

► **Antenna Parameters** – *clicked*

- Antenna Model:
- Antenna Filename1:
- Antenna File Format 1:
- Antenna Filename2:
- Theta Tilt (° degrees):
- Theta Down Tilt (° degrees):
- Phi Rotation (° degrees):
- Enable Second Slant?
- Polarization Vector (° degrees):
- Antenna Locations:
- Number of Rows:
- Number of Columns:
- Distance Units:
- Distance Y (Lambda):
- Distance Z (Lambda):
- Slant Start:
- Count Style:
- First Value:
- Antenna Array Center:
- Normalized Vertical Gain?
- Remove Self-normalization?
- Force AoDs to 0°?
- Force ZoDs to 90°?
- Force Uncorrelated?
- Normalize Output Power?
- Normalize Power per Tap?



Antenna – Parameters and Settings

- Antenna Model:
  Specify the type of antenna model. Choices are ForeShortening, Angle Independent, and Read From File.
- Antenna Filename1:
  Select the text file that contains the antenna pattern of the vertical slants. Parameter is available when Antenna Model is set to Read From File. Default is **Landscape_Ant0.txt**.
- Antenna File Format 1:
  Enables you to arrange the columns of data in the selected file to match the expected order for ACM.
- Antenna Filename2:
  Select the text file that contains the antenna pattern of the horizontal slants. Parameter is available when Antenna Model is set to Read From File. Default is **Landscape_Ant1.txt.**
- Antenna File Format 2:
  Enables you to arrange the columns of data in the selected file to match the expected order for ACM.
- Theta Tilt (º degrees):
  Specify the electrical tilt of the antenna pattern. Range is 0.0º to 180.0º degrees.
- Theta Down Tilt (º degrees):
  Specify the mechanical tilt of the antenna pattern. Range is -90.0º to 90.0º degrees. 0.0º indicates the antenna pattern points to the horizon, 90.0º the antenna pattern points to the South Pole. -90.0º the antenna pattern points to the North Pole.
- Phi Rotation (º degrees):
  Specify the mechanical rotation of the antenna array. Range is -180.0º to 180.0º degrees.
- Enable Second Slant?
  Specify whether each antenna array location contains 2 slants. Choices are Yes and No.
- Polarization Vector (º degrees):
  Specify the polarization vector for the antenna array slant. The left box sets the polarization vector for the first antenna array slant. The right box sets the polarization vector for the second antenna array slant. Range is -180.0º to 180.0º degrees.
- Antenna Locations:
  Select the antenna locations. Choices are Array and Arbitrary.
- Number of Rows:
  Specify the number of rows in the antenna array. Range is 1 to 64.
- Number of Columns:
  Specify the number of columns in the antenna array. Range is 1 to 64.
- Distance Units:
  Specify the distance unit you want to use for the Distance Y and Distance Z settings. Choices are Lambda and Meters.

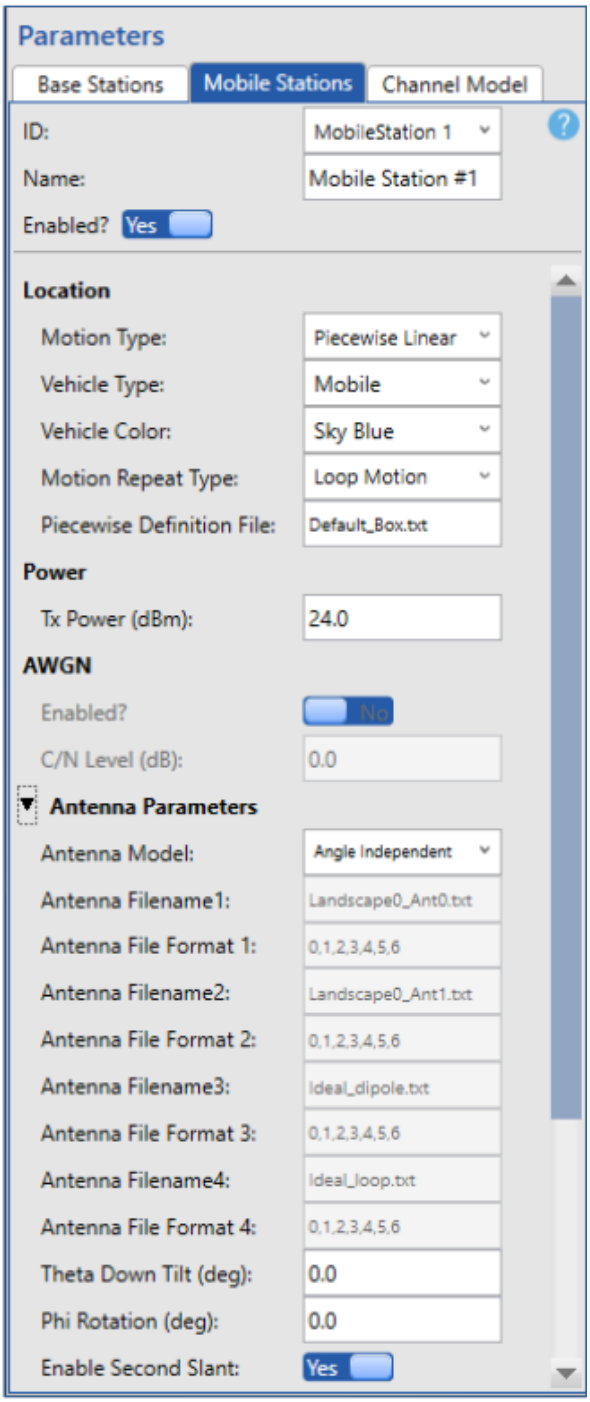
- Distance Y (Lambda):
  Specify the horizontal distance between adjacent antenna array elements that are in the same row of the antenna array. Range is > or = to 0.
- Distance Z (Lambda):
  Specify the vertical distance between adjacent antenna array elements that are in the same column of the antenna array. Range is > or = to 0.
- Slant Start:
  Specify which of the 2 Polarization Vector parameters is indexed first. Choices are First Element and Second Element. First Element is the polarization vector for the first antenna array slant. Second Element is for the second antenna array slant.
- Count Style:
  Specify how the two antenna array slants are indexed. Choices are Count in Order and Count Same Slant First. Count in Order indicates the two slants in the same location are indexed sequentially. Count Same Slant First indicates similarly slanted elements are indexed sequentially.
- First Value
  Specify whether the antenna elements indexing starts with 0 or 1. Choices are 0 and 1
- Antenna Array Center
  Specify the phase reference, which can be located at any slant location. If set to -1, it will reference the Antenna Array Center, which is not a slant location when the antenna array includes an even number of slants.
- Normalized Vertical Gain?
  Specify whether you want to use normalized vertical gain. Choices are Yes and No
- Remove self-normalization
  Specify whether you want to remove self-normalization. Choices are Yes and No.
- Force AoDs to 0°?
  Specify whether you want to ignore the path's azimuth angles of departure and replace them with 0° degrees. Choices are Yes and No.
- Force ZoDs to 90°?
  Specify whether you want to ignore the path's zenith angles of departure and replace them with 90° degrees. Choices are Yes and No.
- Force UnCorrelated
  Specify whether there is correlation between neighboring slants. Choices are Yes and No.
- Normalize Output Power
  Specify whether you want to normalize output power. Choices are Yes and No.
- Normalize Power Per Tap
  When Enabled, the total power is set to 1, and the power tap is set to exactly match what was described by the Relative Path Loss on the Channel Model tab for each cluster.

Mobile Station – tab

Enables you to configure the settings for up to 16 mobile stations.

For each mobile station, you can configure motion type, vehicle type, motion repeat type, velocity, distance to be traveled, begin and end coordinates, transmit power, AWGN and C/N ratio level, and antenna parameters such as theta down tilt, phi rotation, antenna pattern, and the configuration of the antenna array.

- ID:
- Name:
- Enabled?
- Location
  - Motion Type:
  - Vehicle Type:
  - Vehicle Color:
  - Motion Repeat Type:
  - Piecewise Definition File:
- Power
  - Tx Power (dBm):
- AWGN
  - Enabled?
  - C/N Level (dB):
- Antenna Parameters
  - Antenna Model:
  - Antenna Filename1:
  - Antenna File Format 1:
  - Antenna Filename2:
  - Antenna File Format 2:
  - Antenna Filename3:
  - Antenna File Format 3:
  - Antenna Filename4:
  - Antenna File Format 4:
  - Theta Down Tilt (° degrees):
  - Phi Rotation (° degrees):
  - Enable Second Slant?



Mobile Station – Parameters and Settings

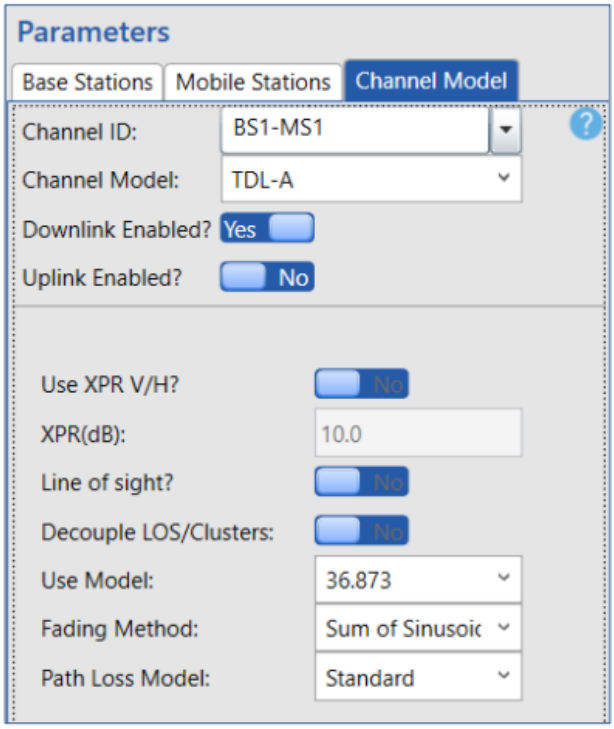
- ID:
  Select the mobile station you want to configure.
- Name:
  You can customize this label consisting of 25 characters.
- Enabled?
  Allows you to enable or disable the selected mobile station. Choices are Yes and No.
- Location
  - Motion Type:
    Specify the motion type for the mobile station. Choices are Static, Linear Motion, Circular Motion, and Piecewise Linear Motion.
  - Vehicle Type:
    Specify the vehicle type for the mobile station. Choices are Mobile, Car, Train, Airplane, Helicopter, and Drone.
  - Vehicle Color:
    Specify the vehicle color for the mobile station. This color will be displayed for the selected mobile station on the Network Layout tab. Choices are Lime, Tangerine, Smoke, Sky Blue, and Dark Blue.
  - Motion Repeat Type:
    This parameter is used when Motion Type is set to Linear Motion, Circular Motion, or Piecewise Linear Motion. Specify how the mobile station moves when it reaches its destination.
  - Piecewise Definition File:
    Specify the text file that contains the Cartesian coordinates and velocity for each segment of the custom path you want to use.
- Power
  - Tx Power (dBm)
    Specify the transmit power. This setting affects the expected output level and therefore the estimated RSSI (Received Signal Strength Indicator). This setting does not affect path loss. Range is -110 to 100 dBm.
- AWGN
  - Enabled?
    Enable or disable AWGN for the selected mobile station. Choices are Yes and No.
  - C/N Level (dB)
    Specify the C/N (carrier-to-noise ratio) level. Range is -40 dB to 40 dB

Channel Models – tab

Enables you to configure the channel model settings for each channel. A channel ID consists of the base station number and the mobile station number. For each channel ID, you can set downlink status, uplink status, and select either a predefined channel model such as SCME UMi, SCME UMa, High Speed Train, CDL-A, CDL-B, CDL-C, CDL-D, CDL-E, TDL-A, TDL-B, NTN-CDL-A, NTN-CDL-B, NTN-CDL-C, NTN-CDL-D, NTN-TDL-A, NTN-TDL-B, NTN-TDL-C and NTN-TDL-D or create and save a custom configuration.

NOTE: Custom configuration, configure parameters such as power angle spectrum, street width, average building height, paths / mid-paths settings, cluster settings, and scaling factors.

- Channel ID:
- Channel Model:
- Downlink Enabled?
- Uplink Enabled?
- Use XPR V/H?
- XPR (dB):
- Line of Sight?
- Decouple LOS/Clusters?
- Use Model:
- Fading Method:
- Path Loss Model:



Vertex operates in several different Fading modes. The Fading mode determines the nature of the parameters entered in the channel model.

Classical Channel Models: These channel models are suitable for narrowband technologies. The input parameters consist of propagation conditions and the correlation.

Geometric Channel Models: These channel models are suitable for wideband technologies, and multiple antenna technologies.

Channel Models – Parameters and Settings

- Channel ID:
  Select the channel you want to configure. Channels are labeled by their connection, making it easier for you to identify channels.
- Channel Model:
  Specify the model for the selected channel. Choices are SCME UMi, SCME UMa, CDL-A, CDL-B, CDL-C, CDL-D, CDL-E, TDL-A, TDL-B, TDL-C, NTN-CDL-A, NTN-CDL-B, NTNCDL-C, NTN-CDL-D, NTN-TDL-A, NTN-TDL-B, NTN-TDL-C, NTN-TDL-D, and High Speed Train.
- Downlink Enabled?
  Enable or disable the Downlink for the selected channel. Choices are Yes and No.
- Uplink Enabled?
  Enable or disable the Uplink for the selected channel. Choices are Yes and No.
- Use XPR V/H?
  XPR is the cross-polarization ratio. Vertical(V) and Horizontal(H) components. Choices are Yes and No.
- XPR (dB):
  Specify the cross-polarization ratio, which measures the correlation between the vertical and horizontal elements. Range is 0 to 200 dB
- Line of Sight?
  Specify whether there is line of sight beam between the base station and the mobile station. Choices are Yes and No.
- Decouple LOS/Clusters?
  Specify whether you want to decouple LOS/clusters. Choices are Yes and No.
- Use Model:
  Specify whether the geometric model is based on 3GPP recommendation. Choices are 36.873 and 38.901
- Fading Method:
  Specify the fading method to use. Choices are Sum of Sinusoids and Filtered Noise.
- Path Loss Model:
  Specify the path loss model to use. Choices are Standard and Custom.

Vertex other Use Cases

Outlined in this white paper is how Vertex and our ACM software can emulate and model the complexities of Base Stations and Mobile Stations. Vertex along with other software packages has been used to emulate and model other complex RF environments:

* 5G FR1 & FR2, 4G-LTE, 3G
* Dynamic Spectrum Sharing (DSS)
* SATCOM
* Electronic Warfare (EW) & Signal Intelligence (SIGINT)
* MANET and other MESH topologies
* Maritime Ship to Shore (LOS/NLOS)

Want to learn more and schedule a Demo…

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