RF Channel Modeler:
High-Fidelity Wireless Channel Modeling in Dynamic Virtual Terrestrial Environments

Modeling wideband 5G and6G wireless channels in high fidelity dynamic virtual environments, simulated at real time.

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For more information about Ansys RF Channel Modeler, go to:
www.ansys.com/products/missions/ansys-rf-channel-modeler
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Executive Summary

Wireless network planning and optimization in dynamic, dense urban areas continues to be a growing challenge for 5G and future 6G telecommunications providers. Network engineers lack the tools they need to sufficiently predictsignal coverage, evaluate waveform performance in bespoke locations, combat interference, and achieve the right balance between coverage and capacity.

Ansys has created an effective simulation solution to meet our customers' challenges. The Ansys RF Channel Modeler enables engineers to model high-fidelity, wireless 5G and 6G communications networks in accurate virtual design spaces that replicate real-world conditions. RF Channel Modeler combines decades of subject matter expertise and proven technologies to provide a game-changing solution for the world's telecommunications providers as they strive to connect everyone, everywhere, at every moment.

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Urban Network Dilemma: Optimizing Coverage

Modern 5G and6G wireless networks share congested high-frequency bands, which makes it difficult to predict coverage and mitigate interference issues. In addition, network planners must consider the physical environment, mobile obstacles within the environment, dynamic user behavior, environmental conditions, regulatory constraints, budget limitations, and other factors when evaluating alternatives. Finally, they must achieve a design that satisfies the right balance between coverage and capacity. If there is too little coverage, critical services will be interrupted. If there is too much coverage, interference potential and hardware and energy costs increase. Planners need tools that can accurately account for all of these real-world factors. The only tools available until now have been low fidelity propagation models, empirical and statistical models, and expensive physical drive tests; all of which have produced subpar results at mid-band and above.

Digging Deeper: Understanding the Role of a Network Engineer

The role of a network engineer is to perform radio network planning and optimization. They are experts in 5G and6G technology, beamforming, signal processing and carrier aggregation. They understand how to troubleshoot issues related to mobility, coverage, and load balancing. They care about signal data quality and the tools and algorithms used to process it, as these elements form the backbone of the decision support system necessary to ensure subscribers have enough speed and a consistent, predictable, and sustained data rate.

The primary goals of planning a wireless network are to maximize data transmission speeds to all connected subscribers, eliminate signal loss due to multi-path, fading and blockage shadowing, and mitigate interference. To that end, engineers must determine the optimal locations to place base stations and their antenna systems. This is a much more difficult problem than it seems, due to the complexity of the underlying signal propagation physics and the many factors contributing to interference and signal loss — especially at new 5G and 6G frequencies above 2 GHz and extending to well above 350 GHz. To effectively mitigate these issues, the network engineer must have the ability to replicate the physical environment (terrain, buildings, static and mobile objects, etc.) in a virtual design space and simulate wireless channel behaviors. They can then use this data in an iterative design of experiments (DoE) workflow to optimize the system physical layer performance. Unfortunately, existing propagation models, drive tests, and other existing tools do not provide these capabilities with sufficient fidelity.

Many existing analysis tools are well-suited for modeling the radio transmitter and performing signal processing on the receiver. However, telecommunications providers have long searched for a comparable solution for modeling the channel in the middle (see Figure 1).

Telecommunication providers have expressed interest in using Ansys Systems Tool Kit (STK), but until recently, it was not able to support the multi-frequency, multi-phase channel requirements of 5G/6G. But with the introduction of the Ansys High Frequency Structure Simulation (HFSS) GPU-SBR engine, those limitations no longer exist.

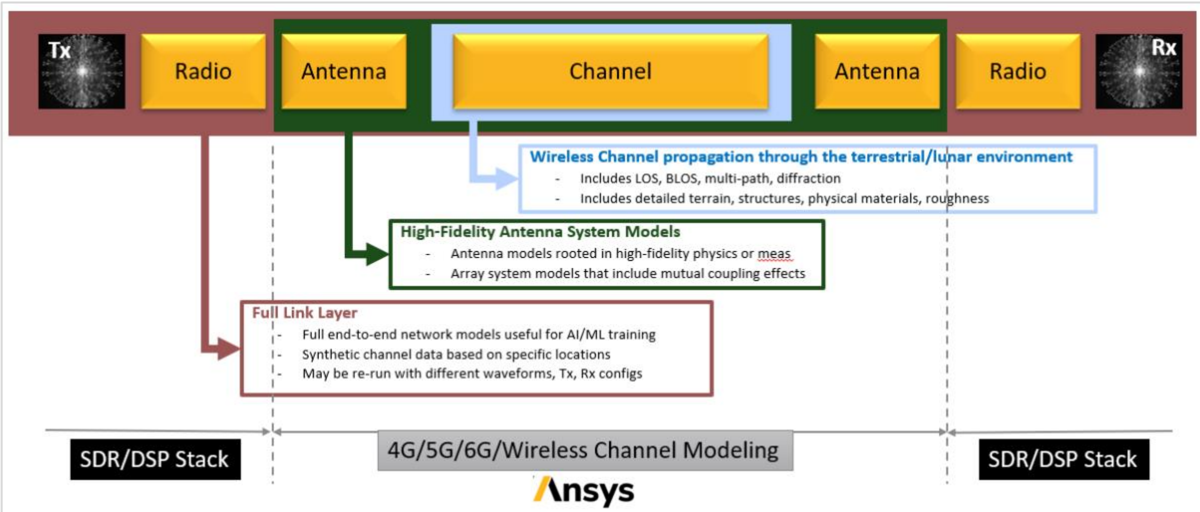


Figure 1. Virtualizing full end-to-end communication.

What is GPU-SBR?

GPU-SBR is a proven technology that powers the Ansys AVxcelerate Real Time Radar solution for mm-wave automotive radar simulation. It is a computational electromagnetic (CEM) simulator that employs the shooting and bouncing ray (SBR) technique based on the physical optics framework for rapid computation of electromagnetic (EM) solutions. The simulatorleverages graphic processing unit (GPU) acceleration features to enable a significant reduction in analysis time. Output data is provided in terms of frame-by-frame range-Doppler data, or in terms of raw receiver I/Q channel data..

Introducing the Ansys RF Channel Modeler

Over the last year, Ansys has worked with its telecommunications customers and conducted a cross-product integration effort to bring the Ansys HFSS GPU-SBR engine into STK. The effort culminates with the release of the RF Channel Modeler — an innovative network planning and optimization solution. The powerful combination of Ansys technologies enables network engineers to realistically evaluate 5G/6G performance in urban environments ahead of expensive physical deployments and product development efforts (see Figure 2). Network engineers can:

- Model wideband 5G/6G channels in accurate, dynamic virtual environments
- Conduct wireless channel modeling with wave behavior
- Simulate wireless channels at symbol rates *with physics* in real time

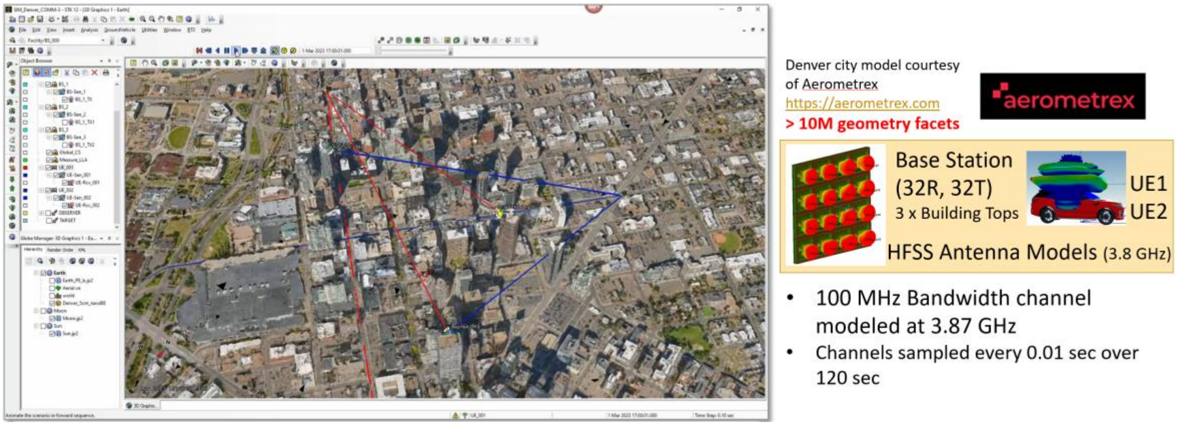


Figure 2. Wireless channel modeling in dynamic environments for multi-domain access points and subscribers.

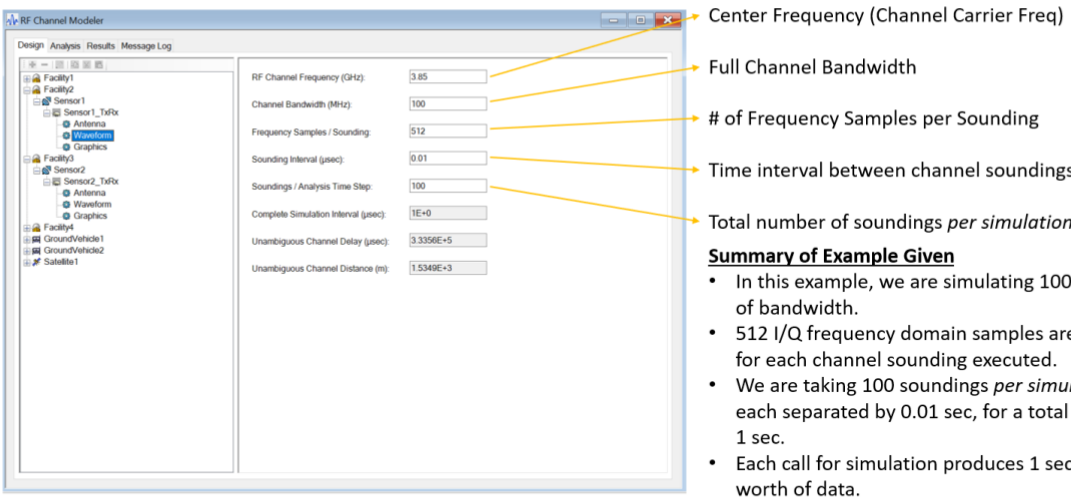
A Familiar Network Planning Workflow

The RF Channel Modeler satisfies a network planning and optimization engineer's primary use case: determining where to place base stations and antennas to maximize data transmission speeds and eliminate signal loss as subscribers move through the environment.

A typical workflow begins with launching STK, creating a scenario, and importing the 3D tiles representative of the physical environment. Next, create objects to be used in the analysis (base stations, cars, airplanes, etc.) and optionally import additional 3D models for the objects participating as geometry facets in the GPU-SBR analysis run.

Once the scenario is created, launch the RF Channel Modeler plugin and import HFSS antenna patterns (FFD and EEP files) and configure their channel spectrum analysis settings and graphics properties (see Figure 3). This single-click load for complete HFSS phased array base stations simplifies the user experience, while enabling high-fidelity antenna designs to be easily integrated into the simulated environment.

After the antennas have been configured, complete the analysis configuration for submission to the GPU-SBR engine. An analysis configuration is the collection of metadata that informs the GPU-SBR engine what it should expect from STK when the analysis is executed. This includes the antenna patterns and properties, notations indicating which antennas have been designated as transmitters, receivers, or both, objects in the scenario participating in the analysis, the geometric area of the 3D tileset constrained to the analysis, the analysis timeframe, the location of the data output file, and other settings.



Summary of Example Given

- In this example, we are simulating 100 MH of bandwidth.
- 512 I/Q frequency domain samples are taken for each channel sounding executed.
- We are taking 100 soundings *per simulation*, each separated by 0.01 sec, for a total time of 1 sec.
- Each call for simulation produces 1 second's worth of data.

Figure 3. RF Channel Modeler waveform setup.

Figure 4 illustrates the simulation process that is executed when the user starts an analysis run. All of the terrain, buildings, objects, and materials contained in the 3D tiles are passed into the GPU-SBR engine as mesh triangle geometry facets and material properties. The GPU-SBR engine also ingests the antenna patterns, locations, velocities, and the parameters of the analysis configuration.

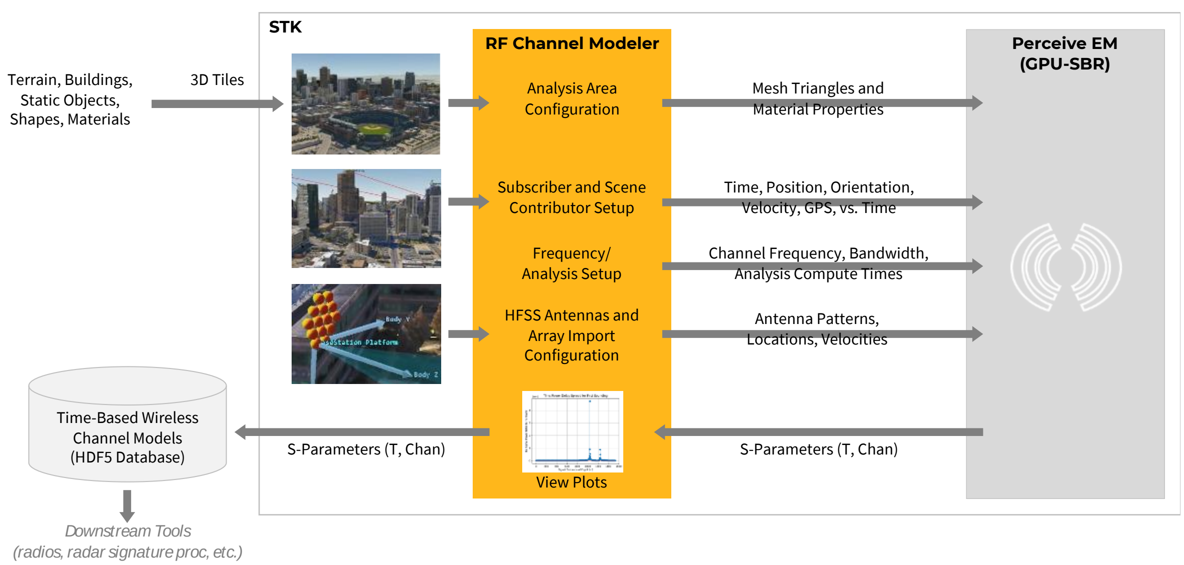


Figure 4. High-level simulation process.

The result of a successful analysis run takes the form of an HDF5 file, which contains high-fidelity scattering parameter (s-parameter) antenna-to-antenna coupling data between all antennas in the scenario over the specified analysis period. You can choose to view the s-parameter data in a variety of pre-formatted interactive plots on the results tab of the RF Channel Modeler (see Figure 5) or use other post-processing tools or scripts to parse the data in whichever manner best satisfies your needs.

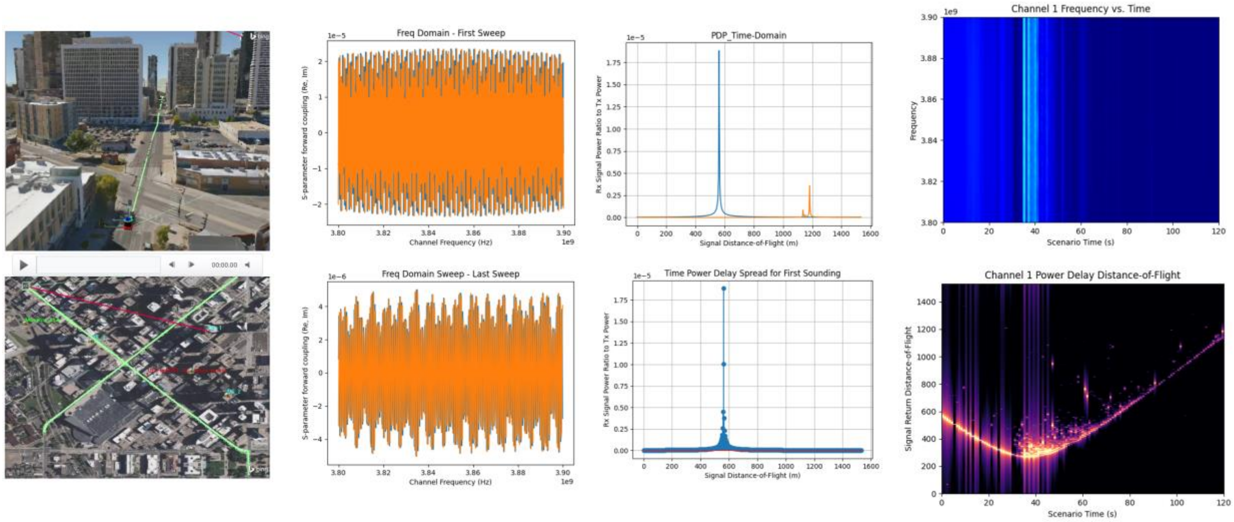
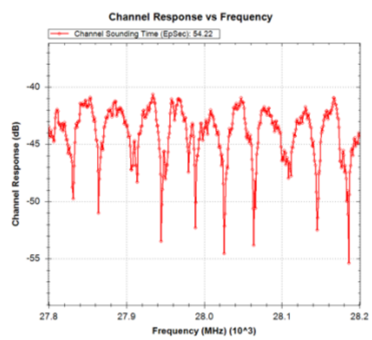
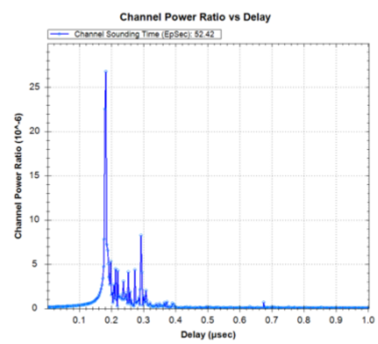


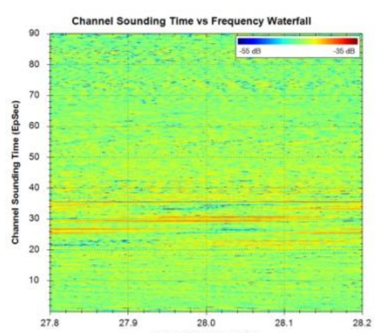
Figure 5. Interactive Plots – Channel I/Q Frequency Data, Complex Impulse Response and Spectrograms.



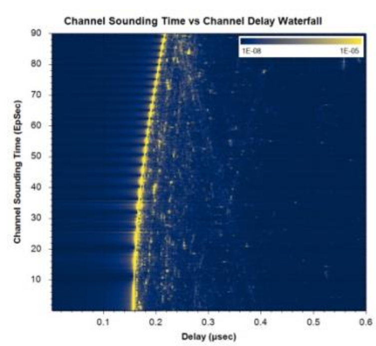
Frequency response for a single wireless channel at an instance of time. Shows the frequency selectivity of the channel across the band of interest. This is a 28 GHz 5G channel simulation.



Time domain response for the same channel at the same instance of time. Shows the delay spread of signals transmitted through this channel. First spike indicates the incident wave arrival, subsequent peaks indicate delayed wavefront arrivals at the receiver.



Waterfall plot showing the frequency response of the same channel, showing frequency response across the band as a function of scenario time. This gives a single view on the frequency selectivity of the channel throughout the scenario.



Waterfall plot showing the time domain response of the same channel, indicating channel delay spread of the channel as a function of scenario time. This provides a single view on the time delay characteristics of the channel across the band.

Figure 6. Example output plots.

What's Next?

You can extend the value of RF Channel Modeler with complementary Ansys products. For example, engineers that want to determine how to optimize antenna parameters can introduce Ansys optiSLang and ModelCenter into the workflow, allowing them to run trade studies using network KPIs such as outage probability orcumulative distribution of coverage in order to optimize physical parameters of the base station array.

The telecommunications 5G/6G wireless market is the first of many that Ansys believes will benefit from the RF Channel Modeler. The integration of STK and GPU-SBR is a universal capability that allows customers across numerous adjacent markets to generate raw radar and communications data as well as synthetic representations of sensor (e.g., SAR, EOIR) scenes. More information regarding the further development of this technology to support additional use cases across domains is forthcoming.