



Electromagnetic Simulation Software

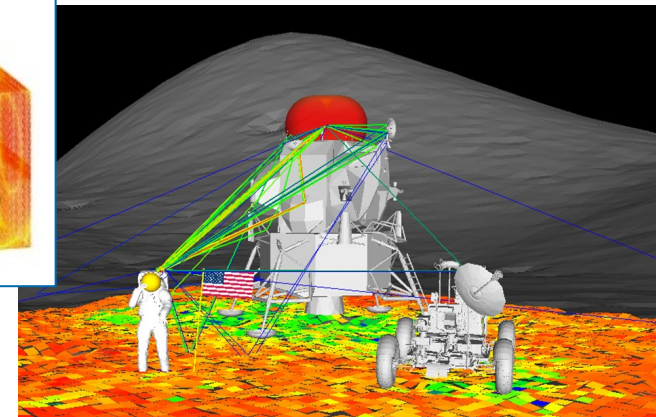
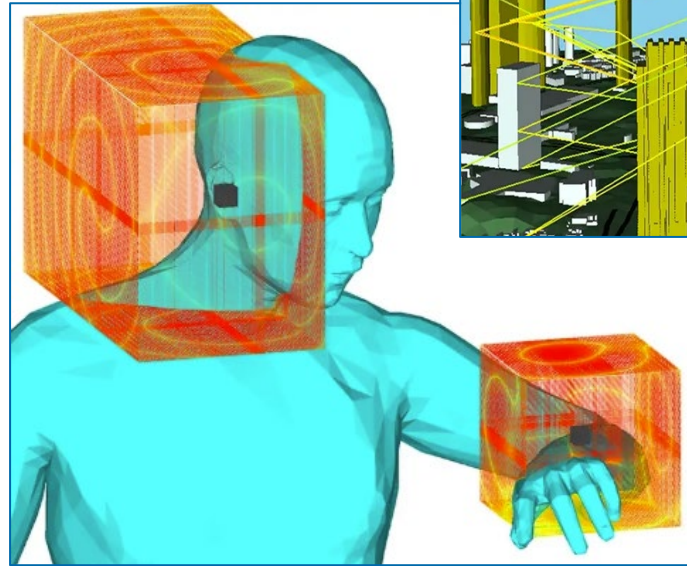
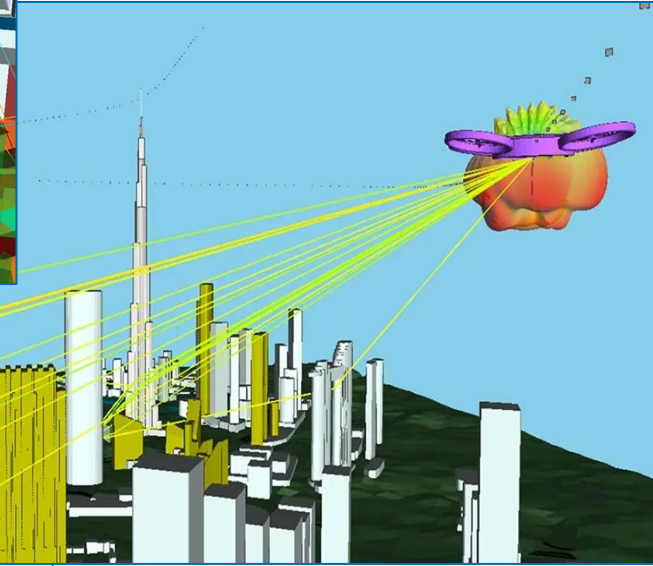
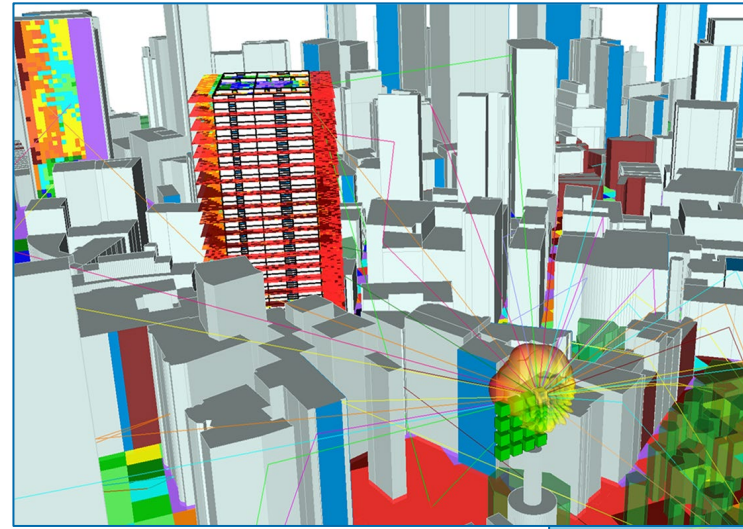
# Time-Based Mobility of RF Systems in Wireless InSite®



## New Features in Wireless InSite 4.0

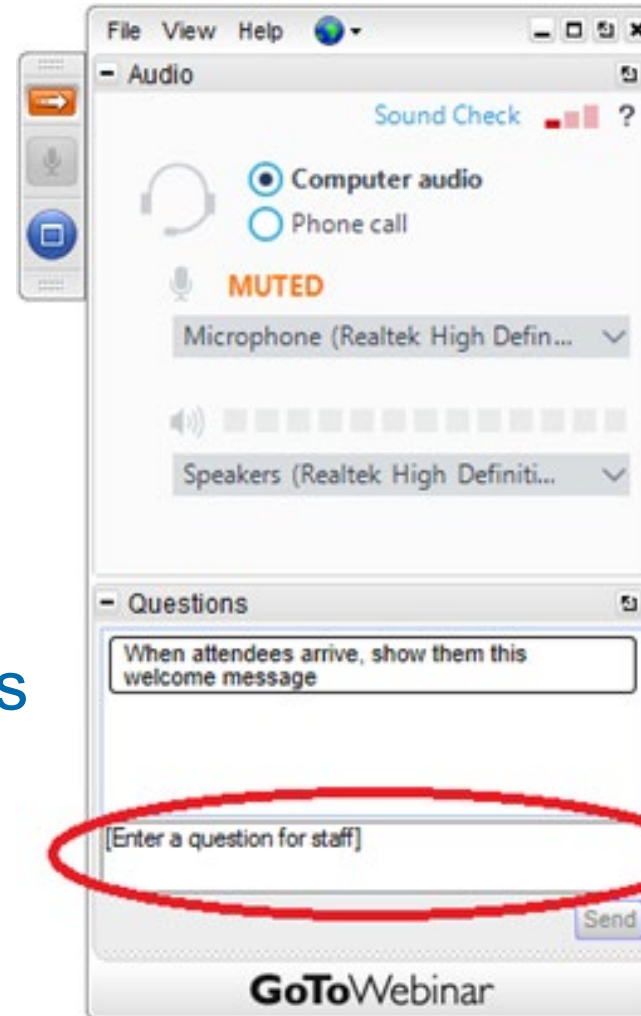
# Overview

- Wireless InSite Capabilities
- Wireless Mobility
- Broadband Simulations
- Hybrid EM: Full Wave to Ray-Tracing using Huygens surfaces
- Lunar Propagation
- Questions



# Overview

- Wireless InSite Capabilities
- Wireless Mobility
- Broadband Simulations
- Hybrid EM: Full Wave to Ray-Tracing using Huygens surfaces
- Lunar Propagation
- Questions



Can be undocked and expanded for easier use.

Questions may be entered into the dialogue on the webinar panel



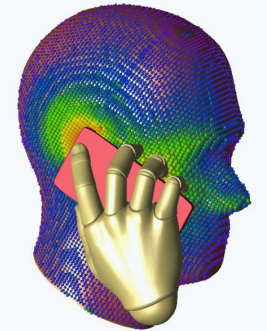
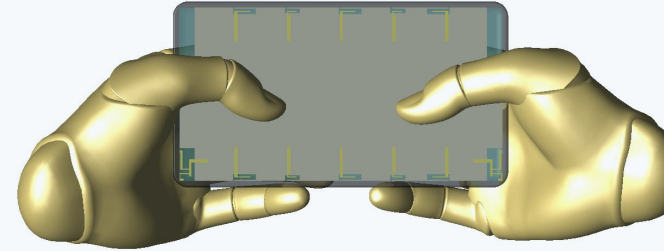
# Wireless InSite Capabilities



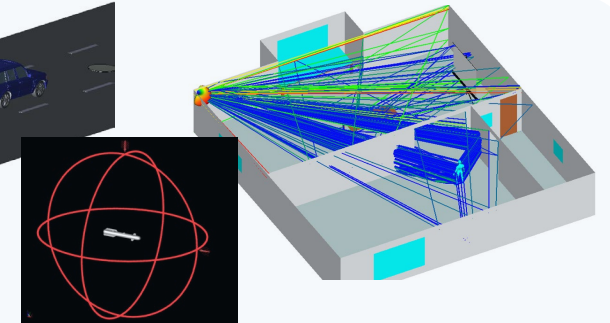
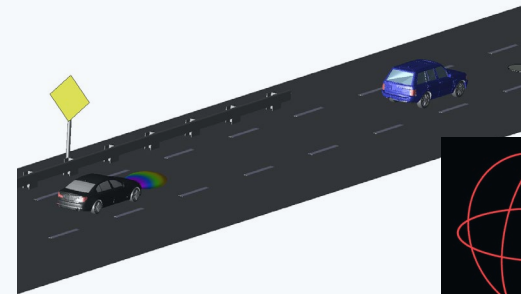
# Remcom Products



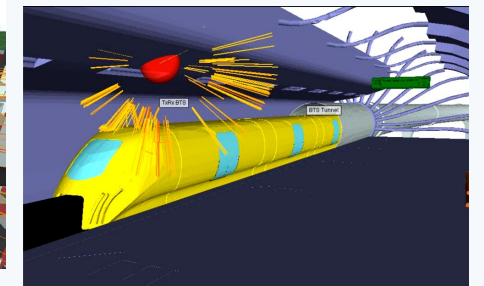
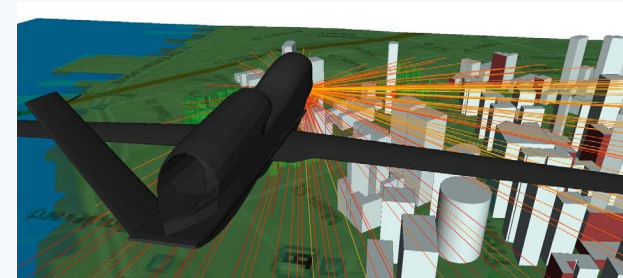
3D GPU Full-Wave Solver:  
Antennas, RF, EM Scattering,  
BioEM, RCS; Enterprise HPC  
Enabled for NN Datasets



3D GPU EM Ray Casting:  
Mobile Sensing Scenarios for  
RADAR and RCS; HPC  
enabled for NN for Sensing



3D GPU EM Ray Tracing:  
Mobile platforms for  
broadband propagation  
analysis; HPC Enabled for  
NN Dataset for Comms



# Wireless InSite: 3D Wireless Prediction

## 3D Wireless Prediction Software

- Suite of propagation models and comms post-processing (MIMO/throughput)
- Validated, deterministic models
  - GPU-accelerated, 3D ray-tracing in complex urban and indoor environments
  - 2D (long-range) and real-time alternatives
- 5G/MIMO beamforming, spatial multiplexing, diversity
- Extensions for mmWave, diffuse scatter

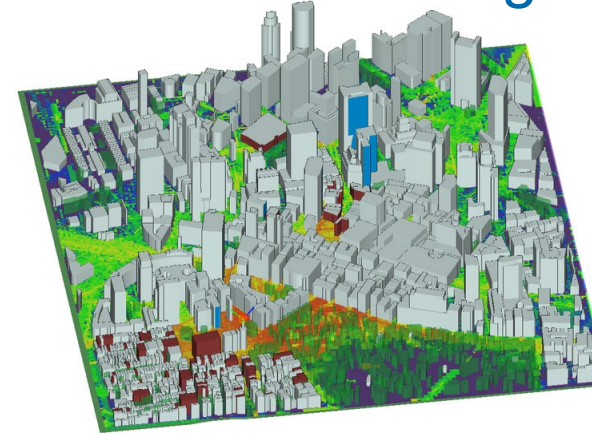
## Applications

- 5G/6G Coverage (SINR, throughput) in dense urban outdoor, indoor, out-to-in
- WiFi or BT coverage in complex indoor
- Multipath fading, mobility

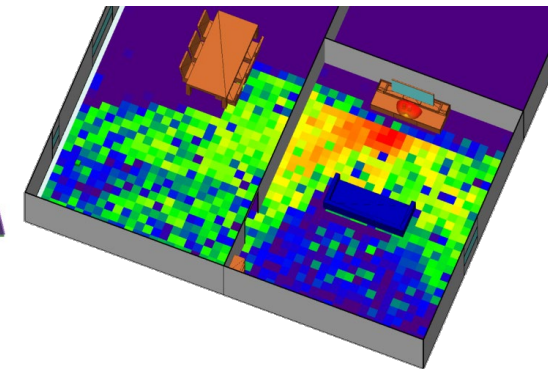
## Digitize RF System analysis

- Replace need for measurement
- Channel Emulation
- Generate synthetic data for ML

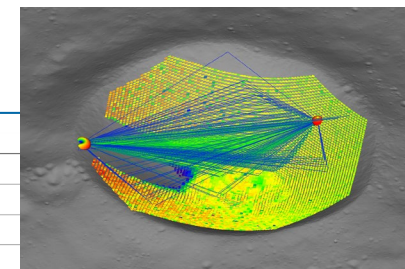
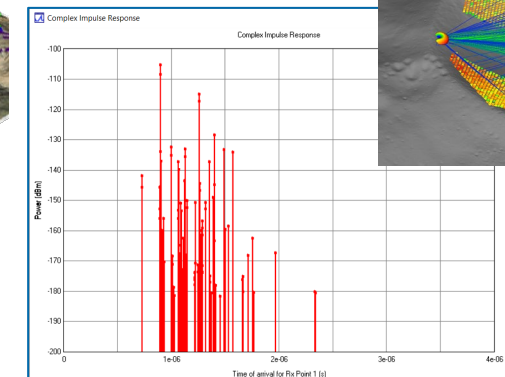
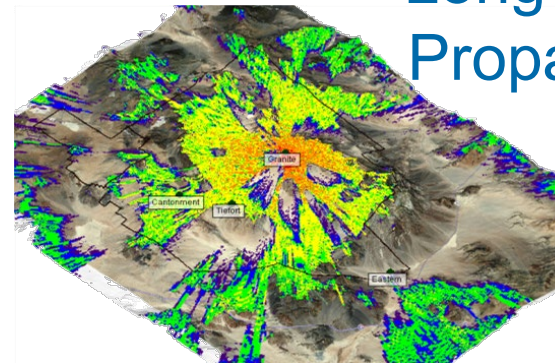
## MIMO/5G Coverage



## Indoor WiFi



## Long-Range Propagation



## Detailed Path Data

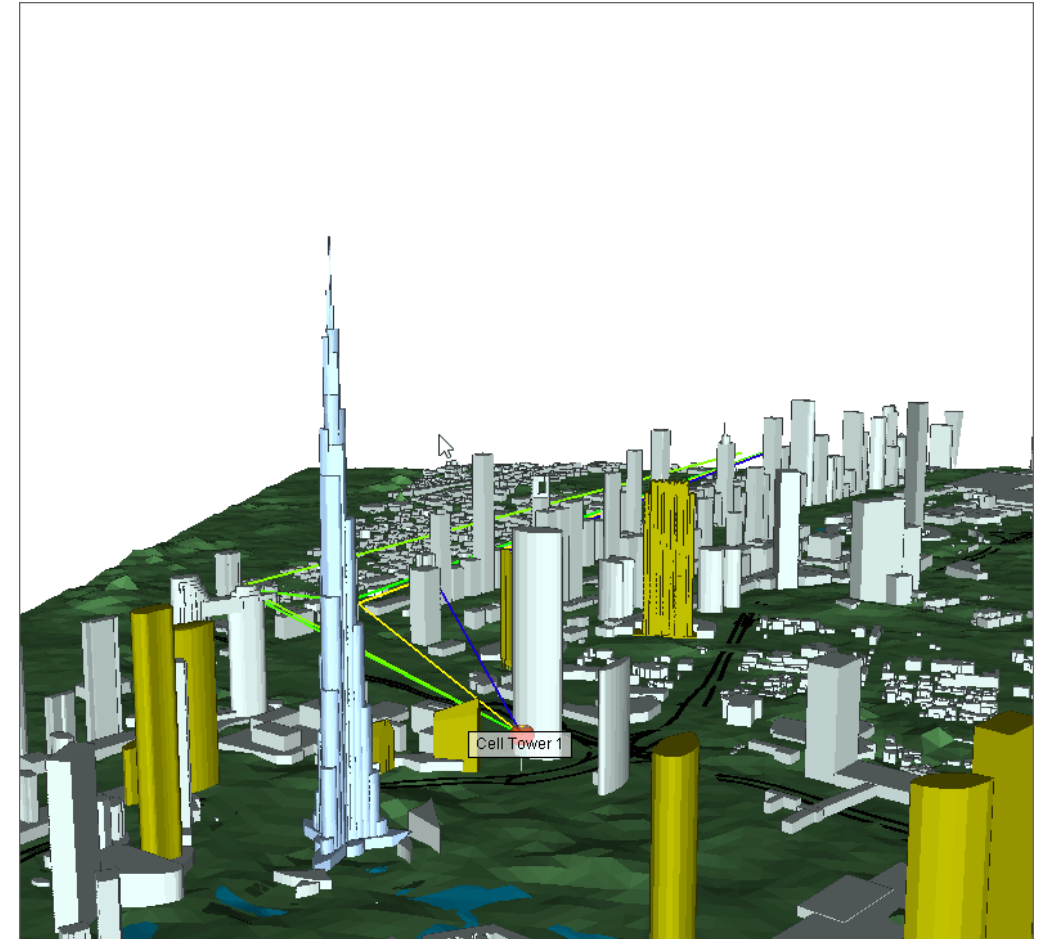


# Wireless Mobility

# Wireless Mobility

Create dynamic scenarios and simulate how movement of devices and vehicles affects multipath, coverage, and wireless communications

- Mobile platforms model assemblies of objects and transceivers as they move through a scene
- Visualize the multipath within views of the scenario
- Evaluate how time-varying shadowing and fading impact communication link performance
- Plot or view time-based outputs and automatically generate animations
- Generate accurate path data for each timestep





# Mobile Platforms

- Position transceivers and geometry relative to one another
- Maintain relative positions as the platform moves through the environment



## In Platform Editor

- Edit platform: (Car-UE)

Short Description: Car-UE

Migrate Objects/Transceivers From Static Scene

M...	Active	Geometry
<input checked="" type="checkbox"/>	A	Car UE (Initial Time)(2)

M...	Active	Transceiver	ID
<input checked="" type="checkbox"/>	A	RxB(2)	19
<input checked="" type="checkbox"/>	A	RxD(2)	20
<input checked="" type="checkbox"/>	A	RxF(2)	21
<input checked="" type="checkbox"/>	A	RxH(2)	22

☒ Grid spacing (m): 10

X: 69.26 m  
Y: 116.24 m

OK

Cancel

- Edit waypoints
- Define segment style (Linear or Spline)
- Define Constant speed vs. Time-based waypoints
- Define Exit condition (Remain stationary vs. Exit)

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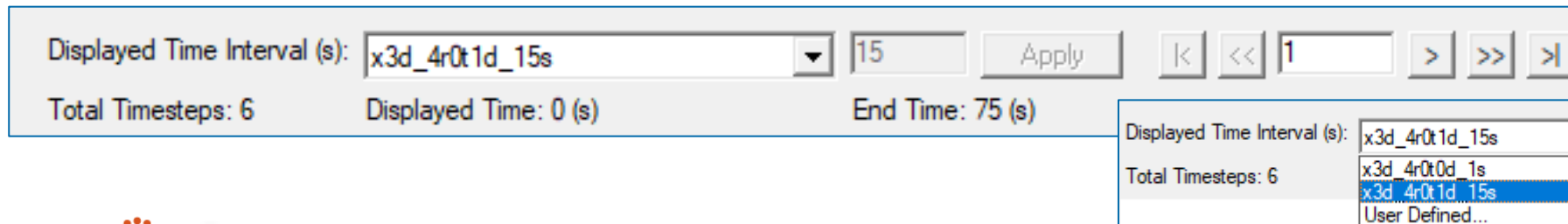
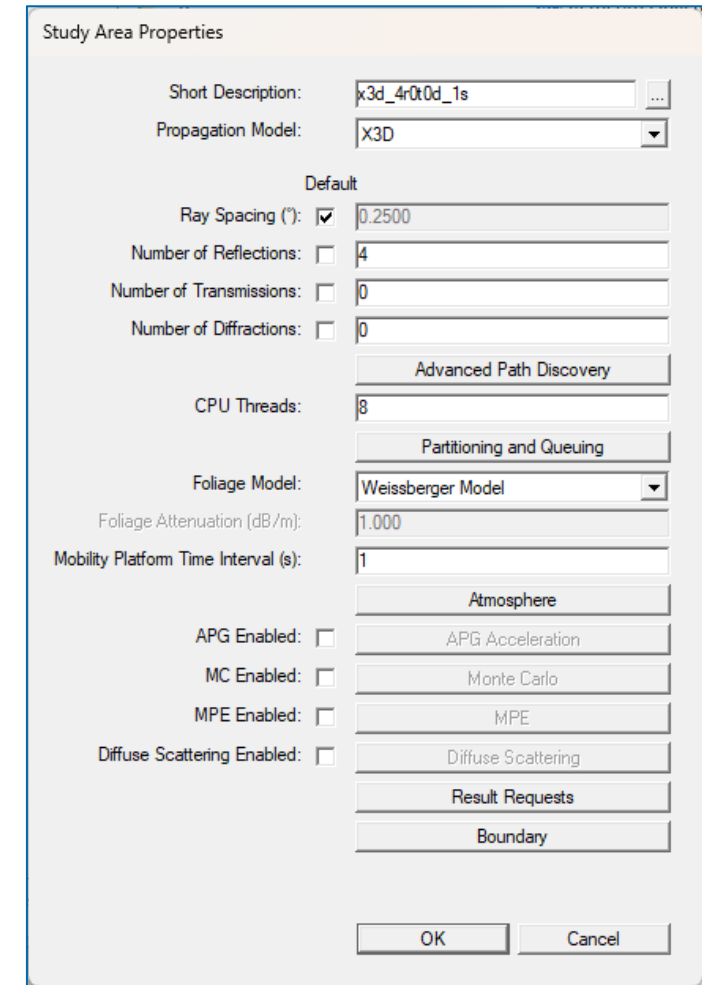
# Sampling Rate

## Study Area Property:

- Mobility Platform Time Interval

## Platform Tab:

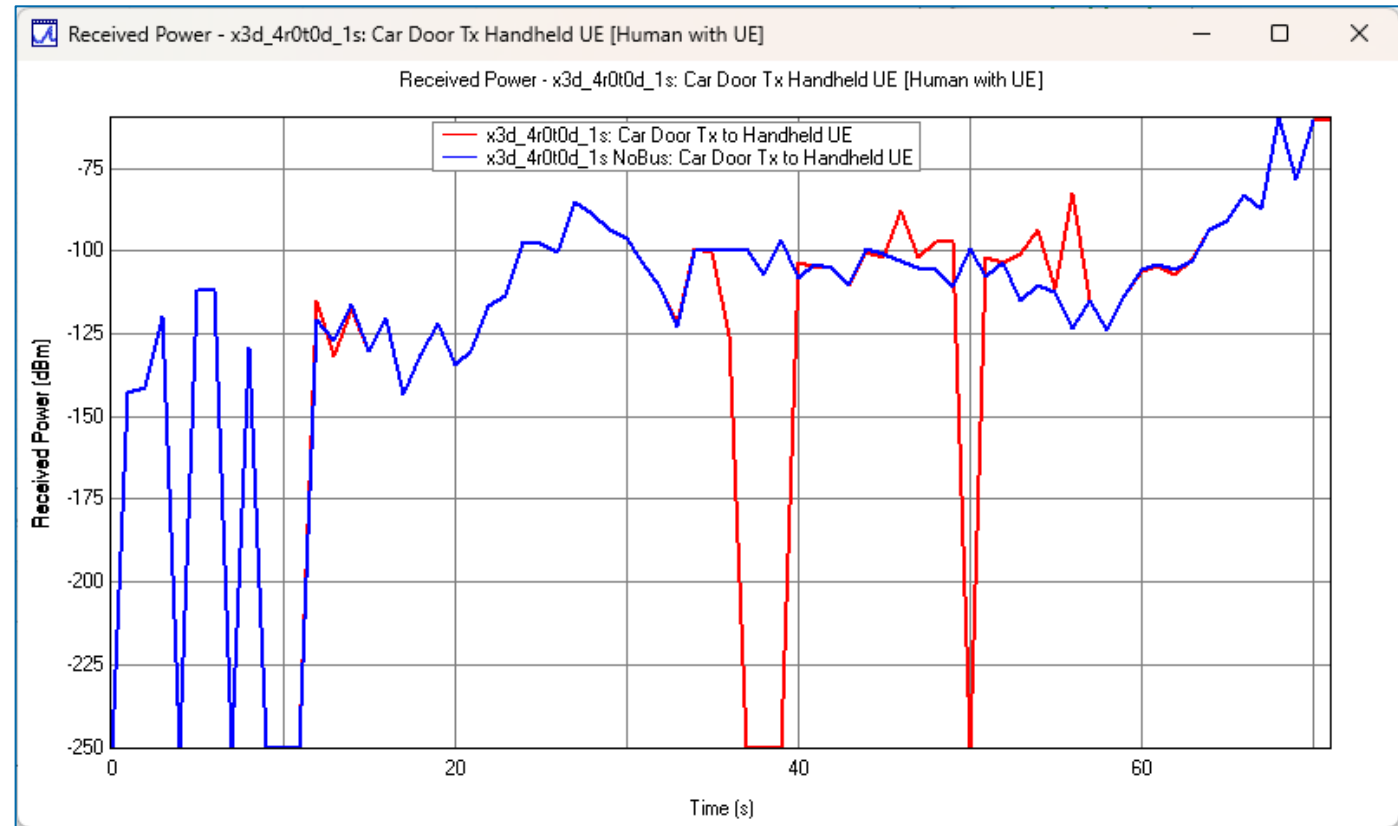
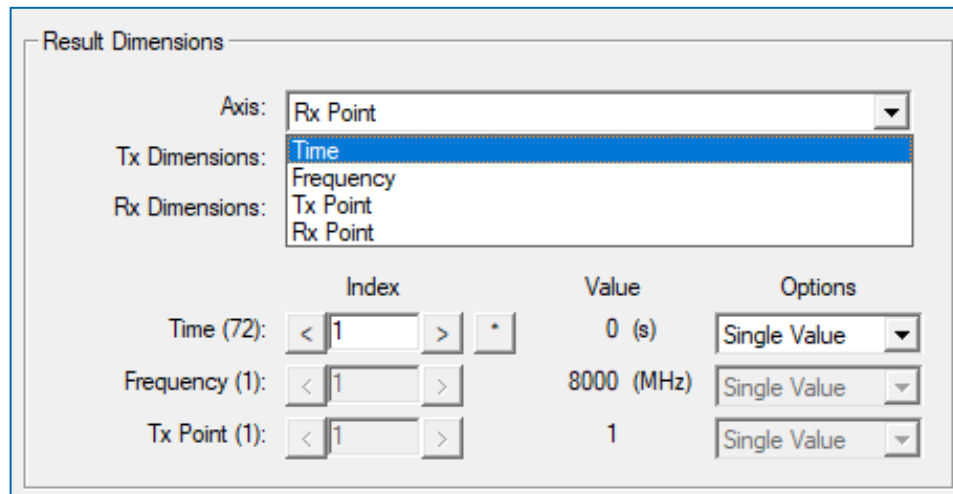
- Displayed Time Interval
  - Per study-area or custom
- Preview Total Timesteps
- Preview Position in Geometry view



# Plotting Results vs. Time

Result browser offers several options for defining the plot's independent variable:

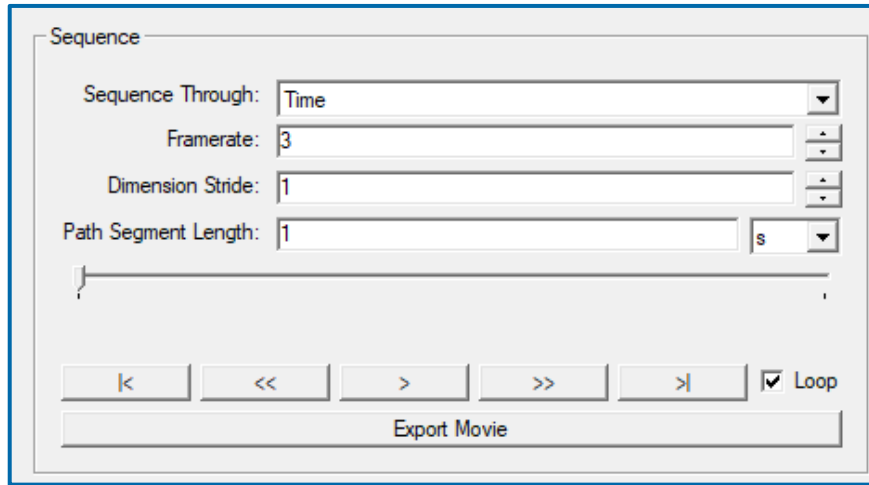
- Vs. Rx point
- Vs. Time
- Vs. Frequency
- Vs. Tx point



Received Power vs. Time: (Red) with bus; (Blue) without bus



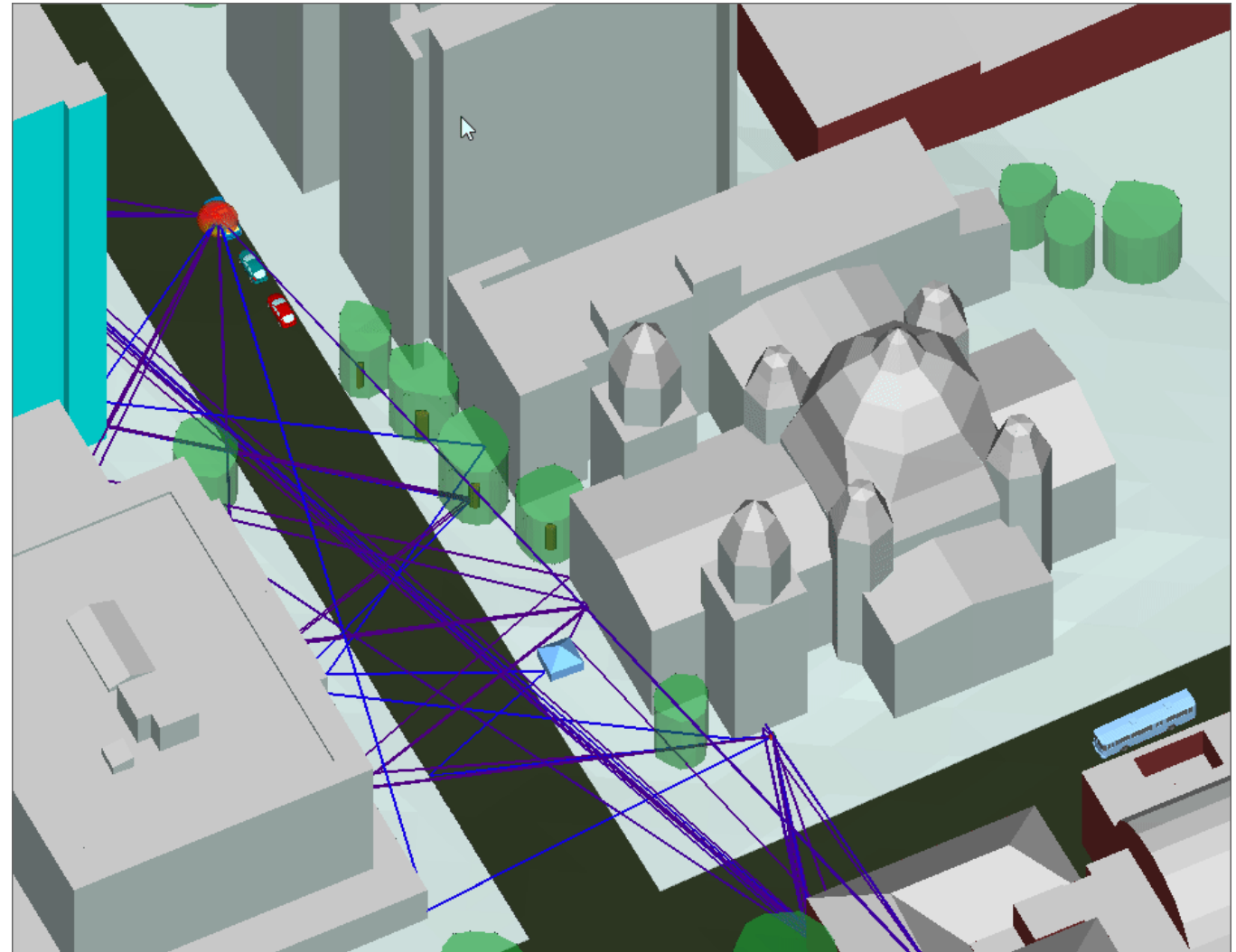
# Viewing Results vs. Time



## Sequence through time

- Render in geometry view
- Control frame rate

Analyze path interactions in dynamic scene





# Multi-Frequency & Broadband Simulations



# Multi-Frequency & Broadband Analysis

Multi-frequency definitions: define a single project for multiple bands

- Multi-frequency antennas
- Frequency-based atmospheric effects
- Multi-frequency materials
- Multi-frequency MIMO S-parameters

Optimized frequency-sweep simulation

- Ray-trace once to find paths, then only recalculate field results for each frequency
- **Key benefits**: adjusts antenna gains and material properties for each frequency in the sweep – improves accuracy while simplifying setup (single project rather than project for each frequency band) and reducing runtime

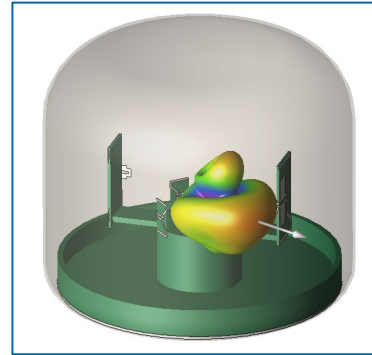
Broadband Analyzer Post-Processing Utility

- Calculate frequency spectrum, broadband CIR

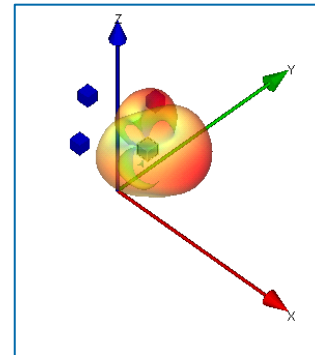
# Multi-Frequency Antenna Patterns

Import multi-frequency antenna gain patterns from full-wave or measured data:

- MIMO antennas, including radiation patterns, and element positions
- Frequency-specific radiation patterns across 1 or more bands
- Codebooks (beamforming weights)
- Multi-port S-parameters (touchstone file)



Antenna Sim  
in XFDTD®



Antenna Imported  
Into Wireless InSite

Includes direct import from XFDTD®; benefits:

- Easy to load, and saves time by automatically setting up MIMO arrays and antenna patterns
- Realistic patterns and tuned beamforming coefficients to match

Multi-frequency user defined antenna properties

Short description: 5 GHz Component 1

Receiver Threshold (dBm): -250

Polarization: Total ge Edit gain range

☐ Show max gain arrow

☐ Render as sphere

Antenna Patterns

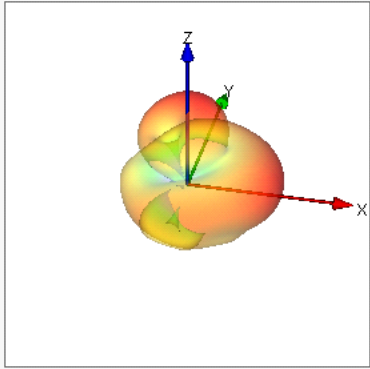
Freq.	UAN filename	Max G...	Cabl...	VS. ^
2412 MHz	/5 GHz Component 1/p1_f0(3)...	1.2488...	0 (dB)	1
2449.999870...	/5 GHz Component 1/p1_f1(3)...	1.2303...	0 (dB)	1
2481.999870...	/5 GHz Component 1/p1_f2(3)...	1.3268...	0 (dB)	1
5000 MHz	/5 GHz Component 1/p1_f3(3)...	5.0992...	0 (dB)	1
5099.999740...	/5 GHz Component 1/p1_f4(3)...	5.0041...	0 (dB)	1
5200 MHz	/5 GHz Component 1/p1_f5(4)...	4.6824...	0 (dB)	1
5299.999740...	/5 GHz Component 1/p1_f6(3)...	5.1358...	0 (dB)	1
5400 MHz	/5 GHz Component 1/p1_f7(3)...	5.5449...	0 (dB)	1
5500.000259...	/5 GHz Component 1/p1_f8(3)...	5.9170...	0 (dB)	1
5600 MHz	/5 GHz Component 1/p1_f9(3)...	6.2659...	0 (dB)	1
5699.999739...	/5 GHz Component 1/p1_f10(3)...	6.5929...	0 (dB)	1
5800 MHz	/5 GHz Component 1/p1_f11(3)...	6.8857...	0 (dB)	1
5900.000259...	/5 GHz Component 1/p1_f12(2)...	7.1194...	0 (dB)	1
6000 MHz	/5 GHz Component 1/p1_f13(2)...	7.3042...	0 (dB)	1
6099.999740...	/5 GHz Component 1/p1_f14(2)...	7.4337...	0 (dB)	1
6200 MHz	/5 GHz Component 1/p1_f15(2)...	7.5140...	0 (dB)	1
6299.999740...	/5 GHz Component 1/p1_f16(2)...	7.5556...	0 (dB)	1
6400 MHz	/5 GHz Component 1/p1_f17(2)...	7.5681...	0 (dB)	1
6499.999740...	/5 GHz Component 1/p1_f18(2)...	7.5433...	0 (dB)	1
6600 MHz	/5 GHz Component 1/p1_f19(2)...	7.5212...	0 (dB)	1
6700.000259...	/5 GHz Component 1/p1_f20(2)...	7.4759...	0 (dB)	1

Set Common Cable Loss Set Common VSWR

Add Remove

OK Cancel Apply

Scalebar properties

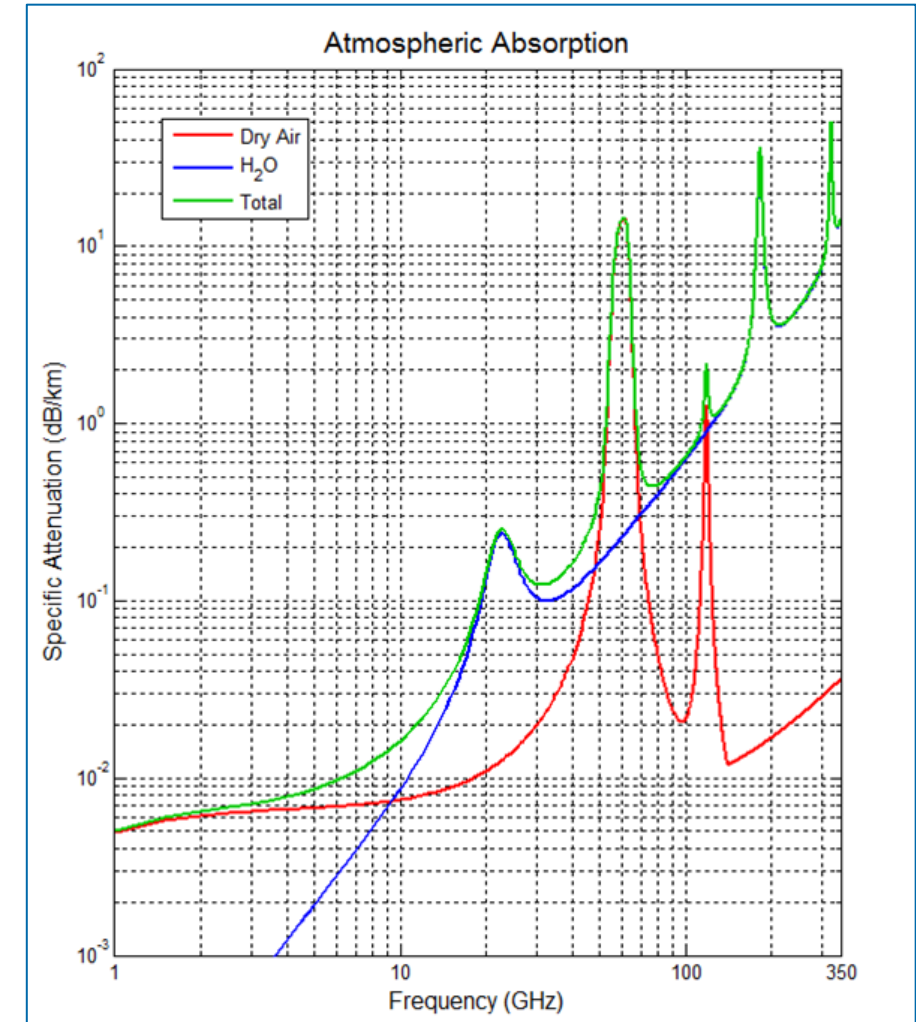


## Frequency-Specific Patterns



# Atmospheric Absorption

- Define temperature, pressure and humidity
- Wireless InSite incorporates key absorption bands due to oxygen and water vapor resonances
  - Examples: 22, 60 GHz, etc.
- Absorption is defined up to 1 THz, allowing for LOS calculations (direct path only) above mmW



Specific Attenuation as predicted by Wireless InSite's X3D

# Multi-Frequency Material Definitions

Material properties can be defined per facet

Database provides ground and wall materials from ITU recommendations and other references

Modeled via electrical & physical properties

- Electrical properties:
  - Permittivity and conductivity
  - Reflection/transmission coefficients; can vary with frequency and angle
- Physical properties:
  - Thickness: half-spaces (ground), finite-thickness (walls) or multilayer materials (e.g. 2-pane glass)
  - Roughness: specular or diffuse scattering

Analytically include multipath between multiple layers to predict resonances

Example: Concrete (1-100 GHz)

Layer Properties

Layer Name:  ...

Thickness (m):

Type:  ▼

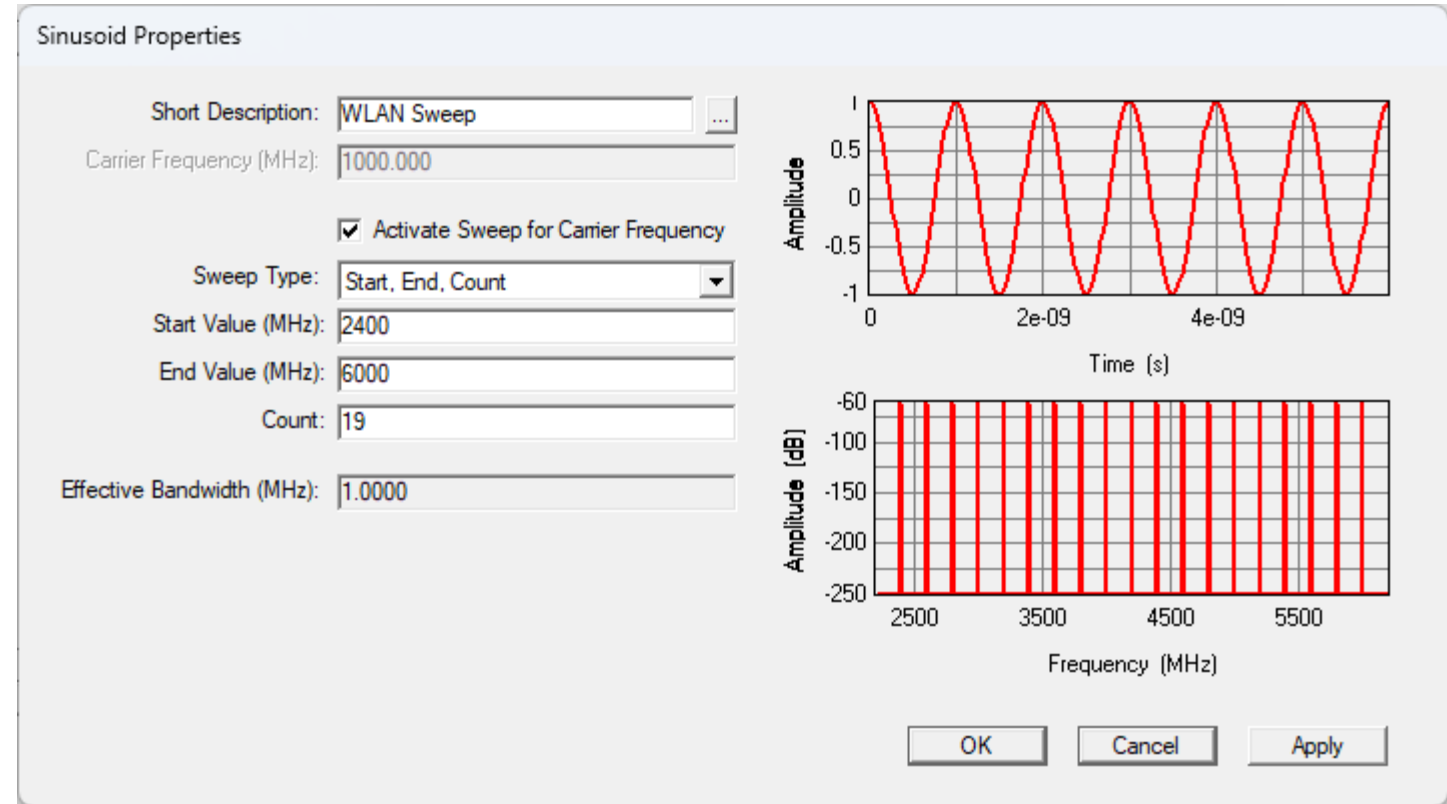
Frequency	Permittivity	Conductivity	
1000 MHz	5.24	0.0462 S/m	
1100 MHz	5.24	0.049776 S/m	
1200 MHz	5.24	0.053282 S/m	
1300 MHz	5.24	0.056724 S/m	
1400 MHz	5.24	0.06011 S/m	
1500 MHz	5.24	0.063443 S/m	
...			
94000 MHz	5.24	1.61444 S/m	
95000 MHz	5.24	1.62786 S/m	
96000 MHz	5.24	1.64125 S/m	
97000 MHz	5.24	1.65461 S/m	
98000 MHz	5.24	1.66793 S/m	
99000 MHz	5.24	1.68123 S/m	
100000 MHz	5.24	1.6945 S/m	

OK Cancel

# Frequency Sweeps

Define waveform with a frequency sweep

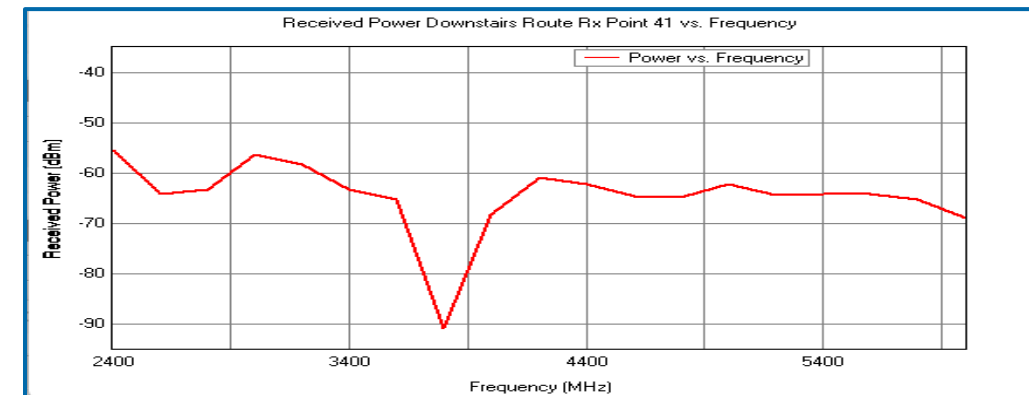
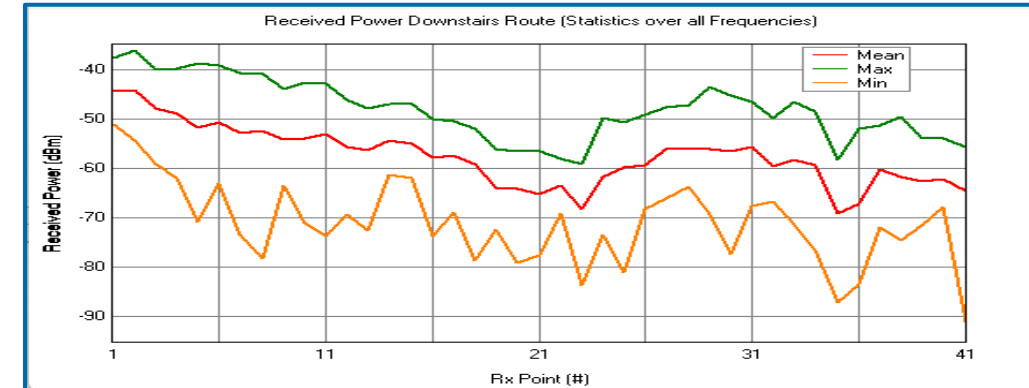
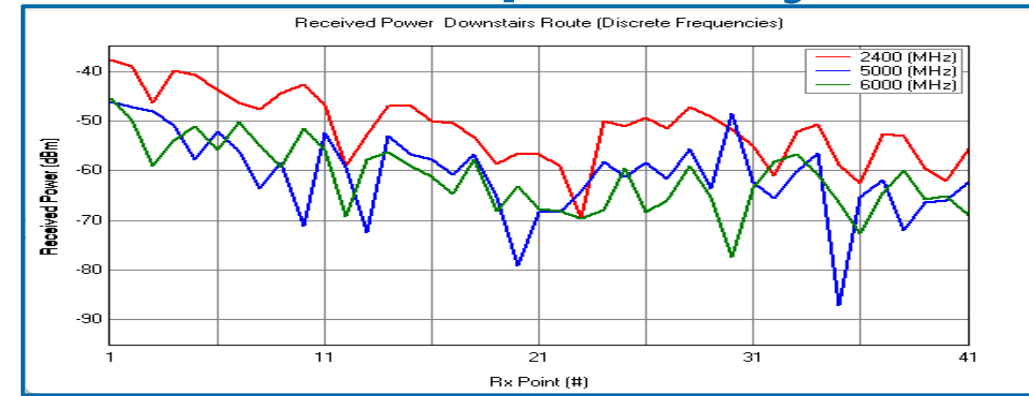
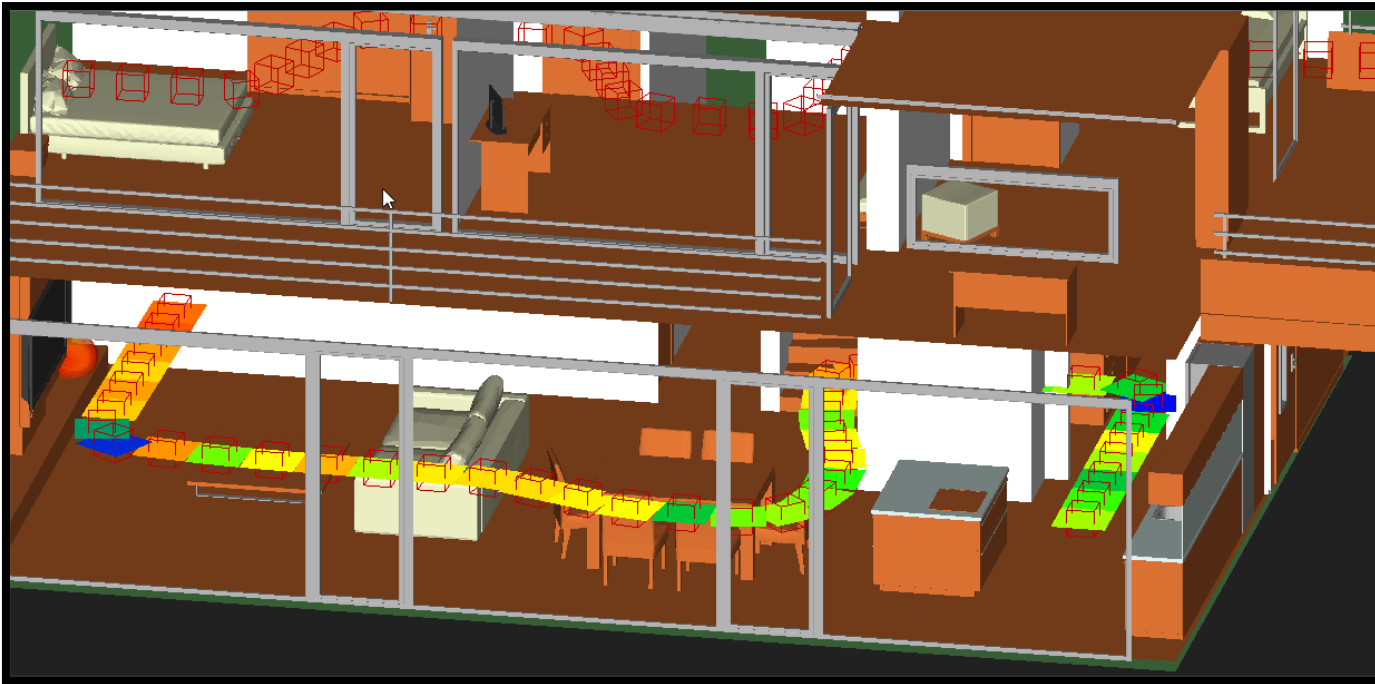
- Start, End, Count
- Start, Increment, Count



# Plotting and Viewing Results vs. Frequency

View and Plot results:

- For specific frequencies
- For statistics aggregated over frequency
- vs. frequency







# Hybrid EM: Full Wave to Ray-Tracing using Huygens surfaces

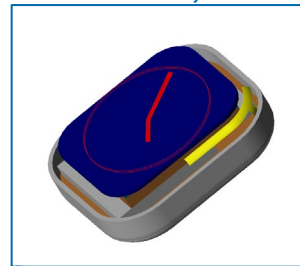
# Huygens Equivalence Principle & Reciprocity



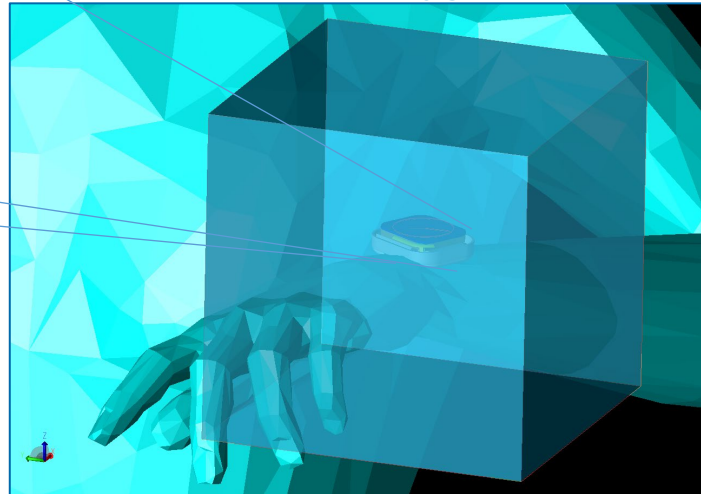
Christiaan Huygens (1629-1695)

Tangential components of E & H Fields on a closed surface are used to find the power transmitted from (Tx) and/or to (Rx) antenna systems that are modeled inside the respective Huygens surfaces.

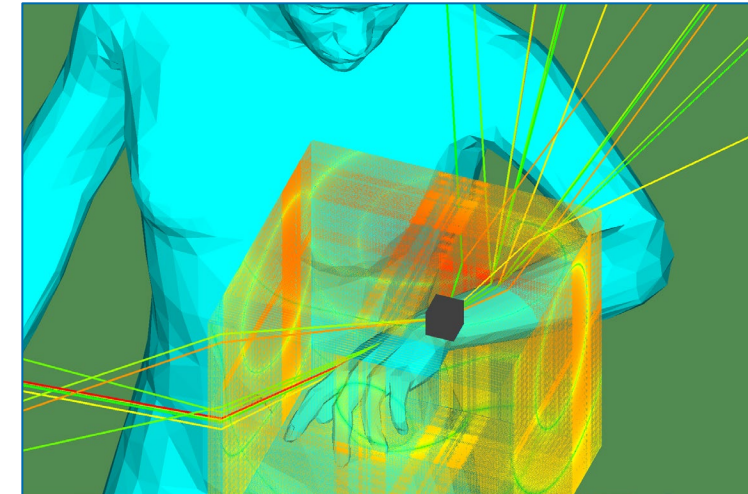
CAD with PCB,  
Antenna, etc.



Full wave simulation in XFDTD® to  
capture Fields on Huygens surface



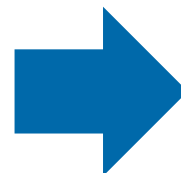
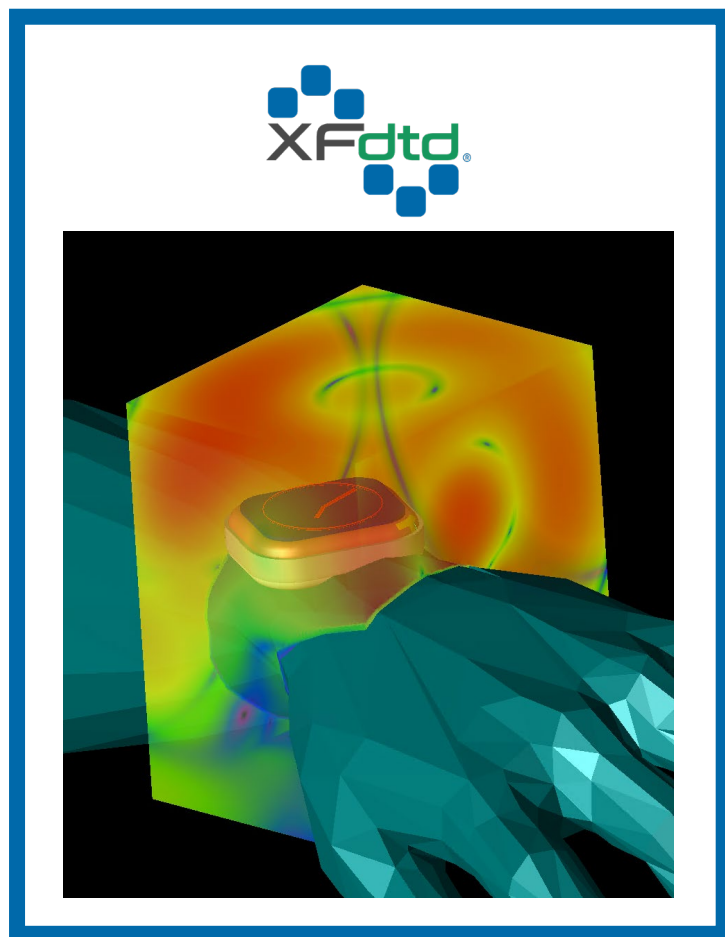
Huygens Antenna in Wireless InSite®



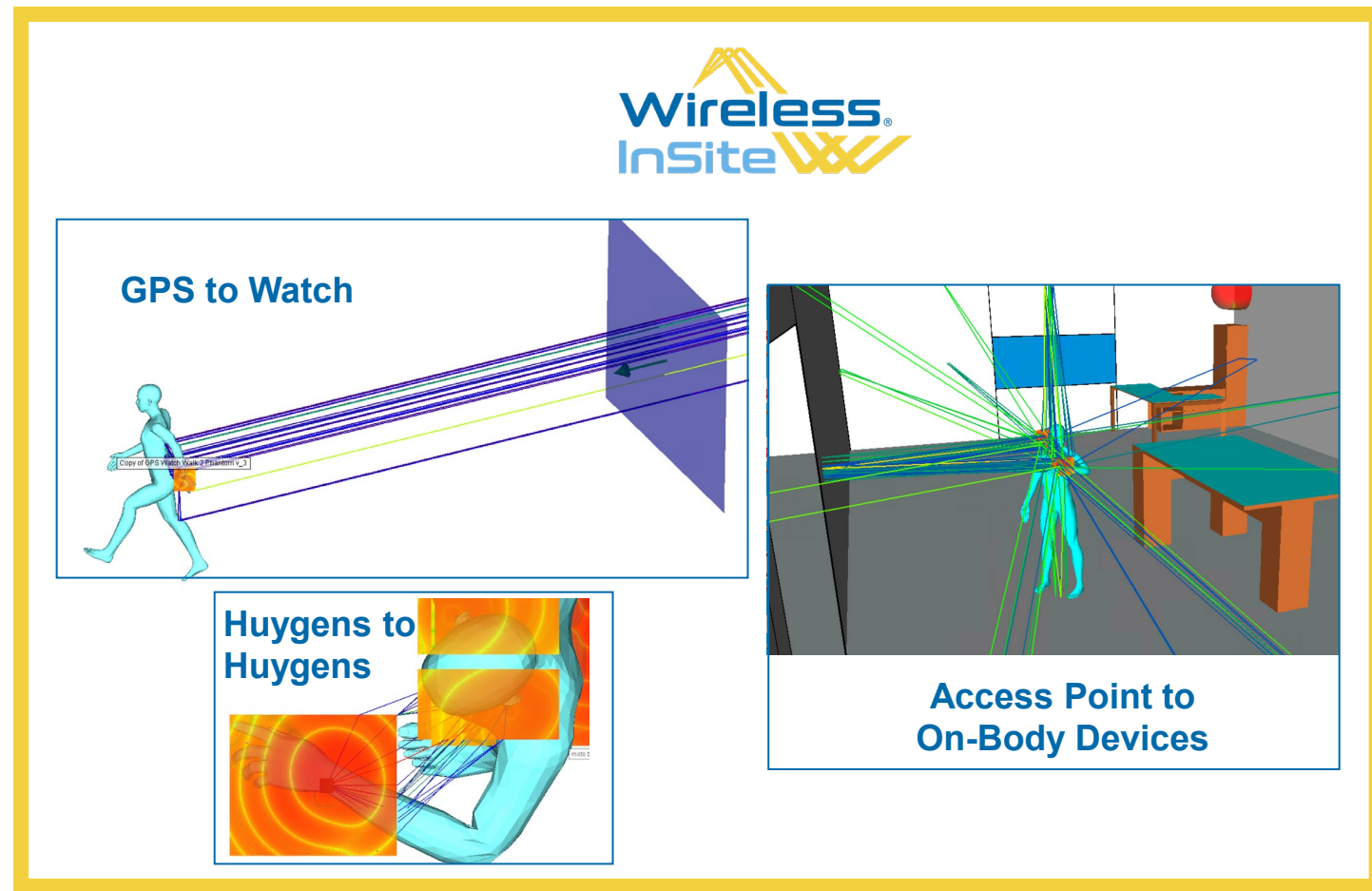
- Huygens Principle (1690)
- Huygens – Fresnel Principle (1819)
- Lorentz Reciprocity Theorem (1896)
- Stratton & Chu Formulation (1936)

# Full wave Near-field to 3D Ray-trace Environment

Capture near-field effects  
on Huygens surface



Capture multipath from larger environment



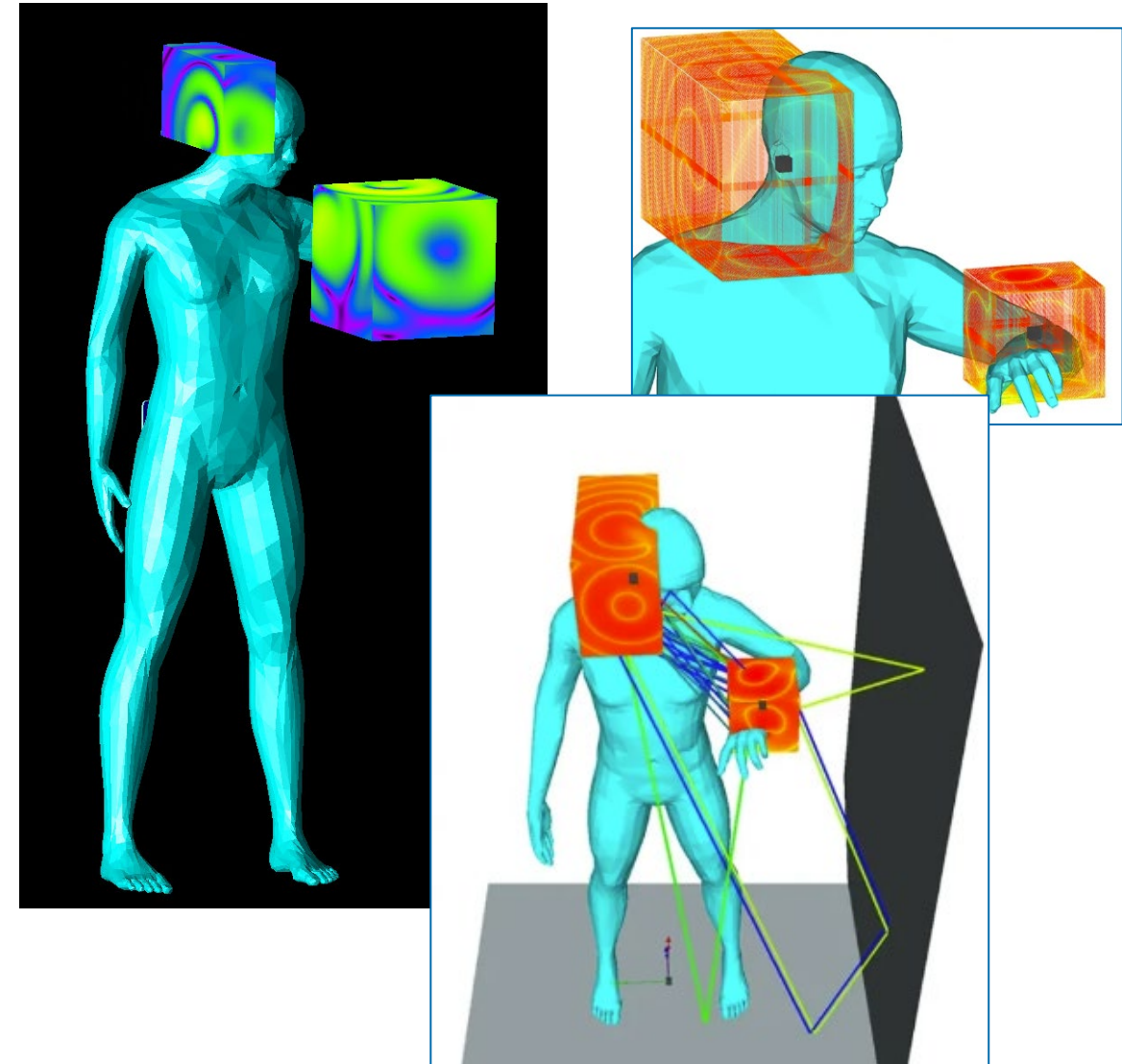
# Seamless Huygens Package Import

XF Huygens Platform package export & Import into Wireless InSite

- Huygens antenna field files
- Object files with material defined
- Relative positions defined

Can be moved within the InSite scene without losing spatial relationships

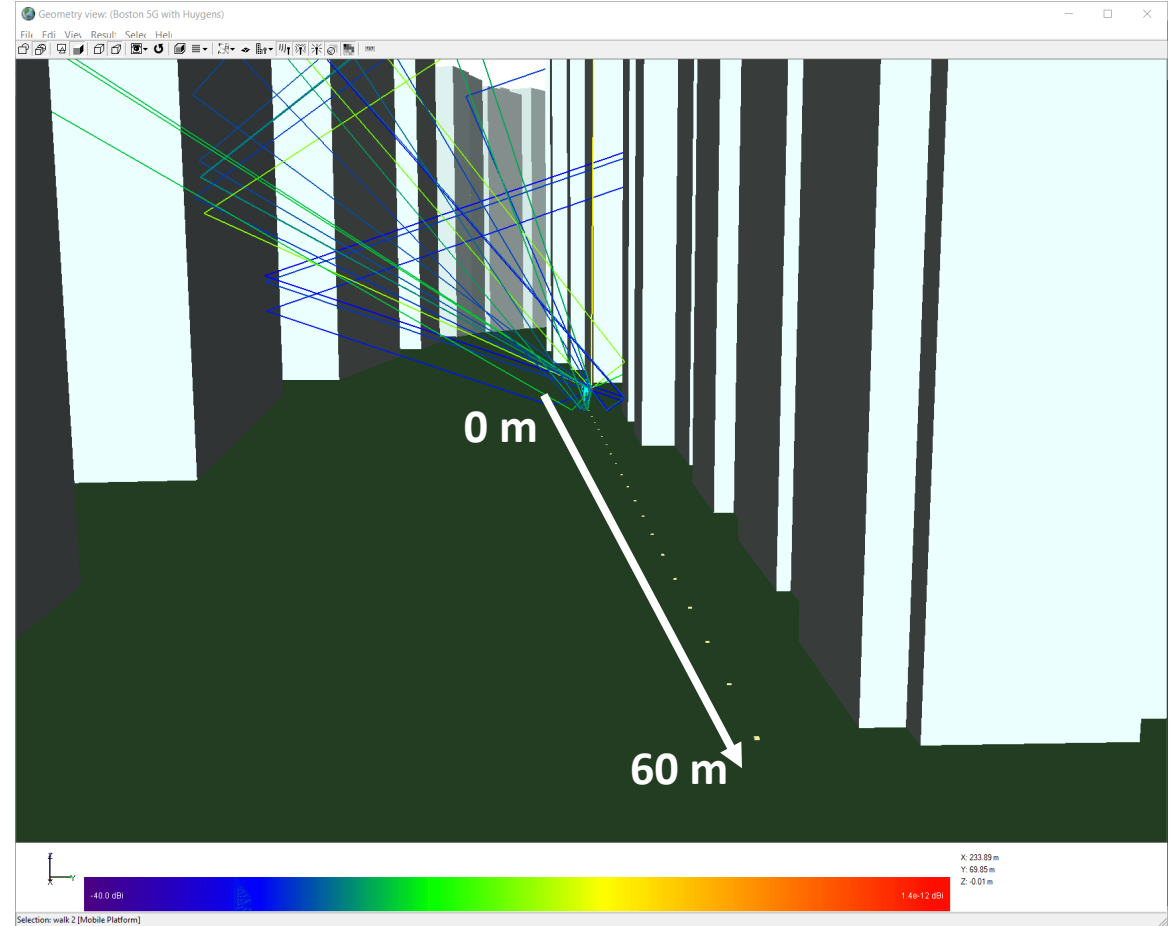
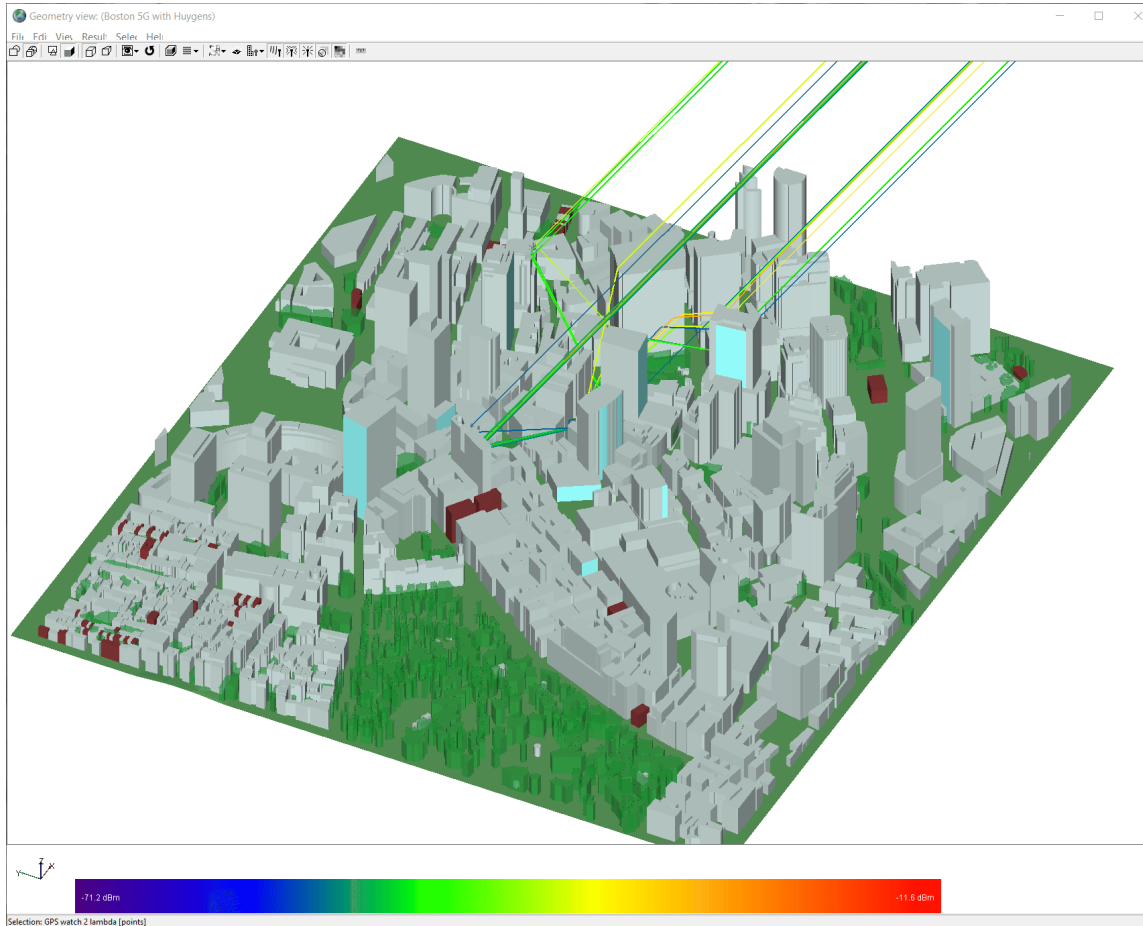
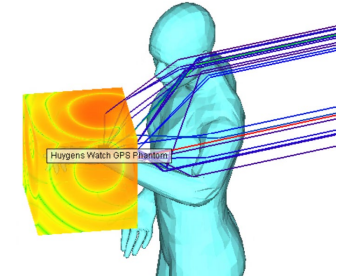
Hybrid EM solution allows analysis of chip/device system performance in larger scenario





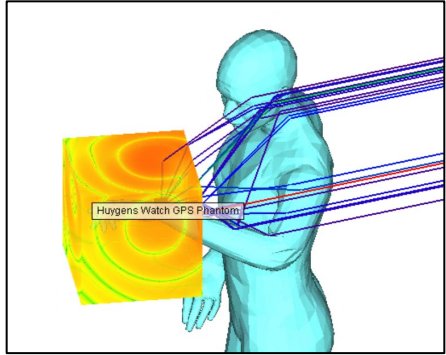
# GPS Signal in Boston

Plane Wave (V/m)	100
Power Density (W/m <sup>2</sup> )	13.26
Power Density (dBm/m <sup>2</sup> )	41.226
Theta AOA (degrees)	71
Phi AOA (degrees)	341

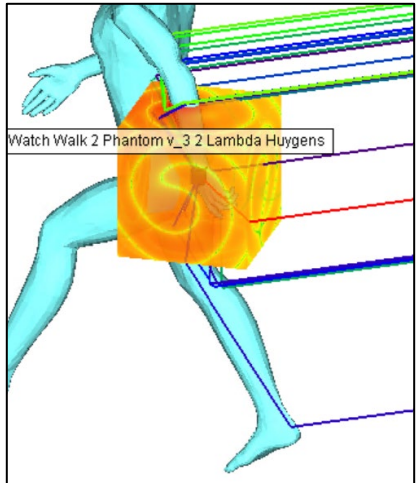




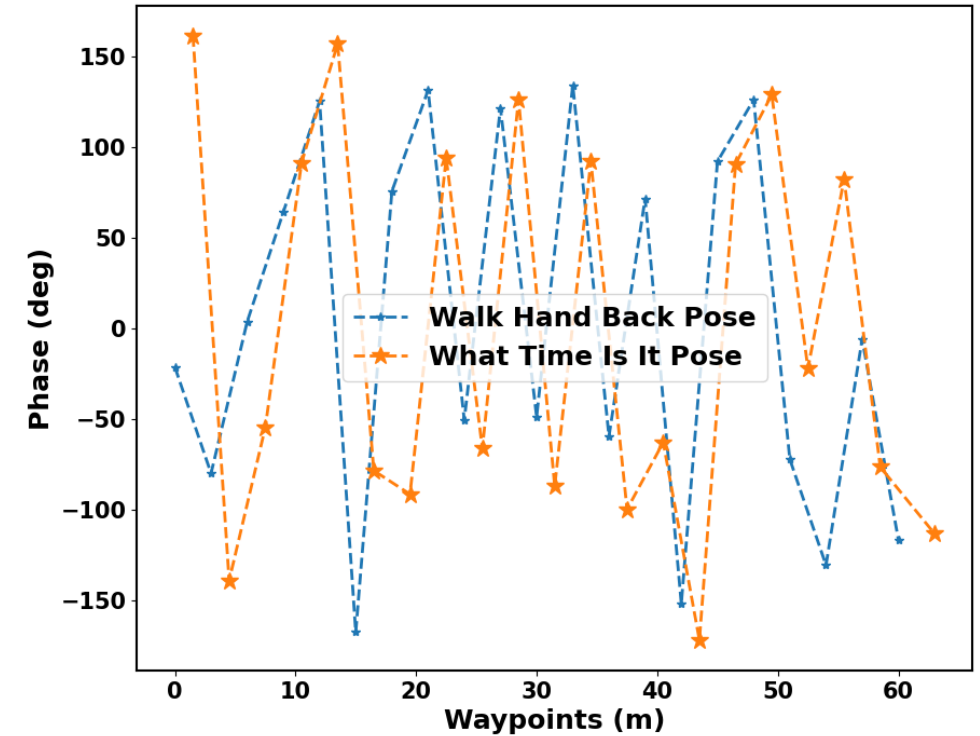
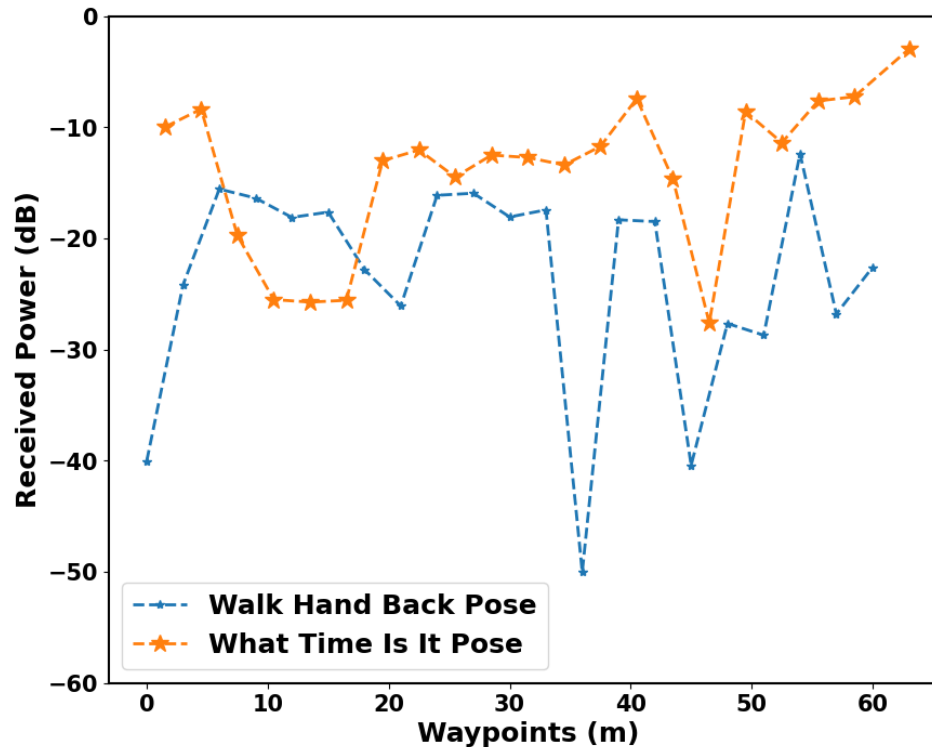
# GPS Signal in Boston



What Time Is It Pose



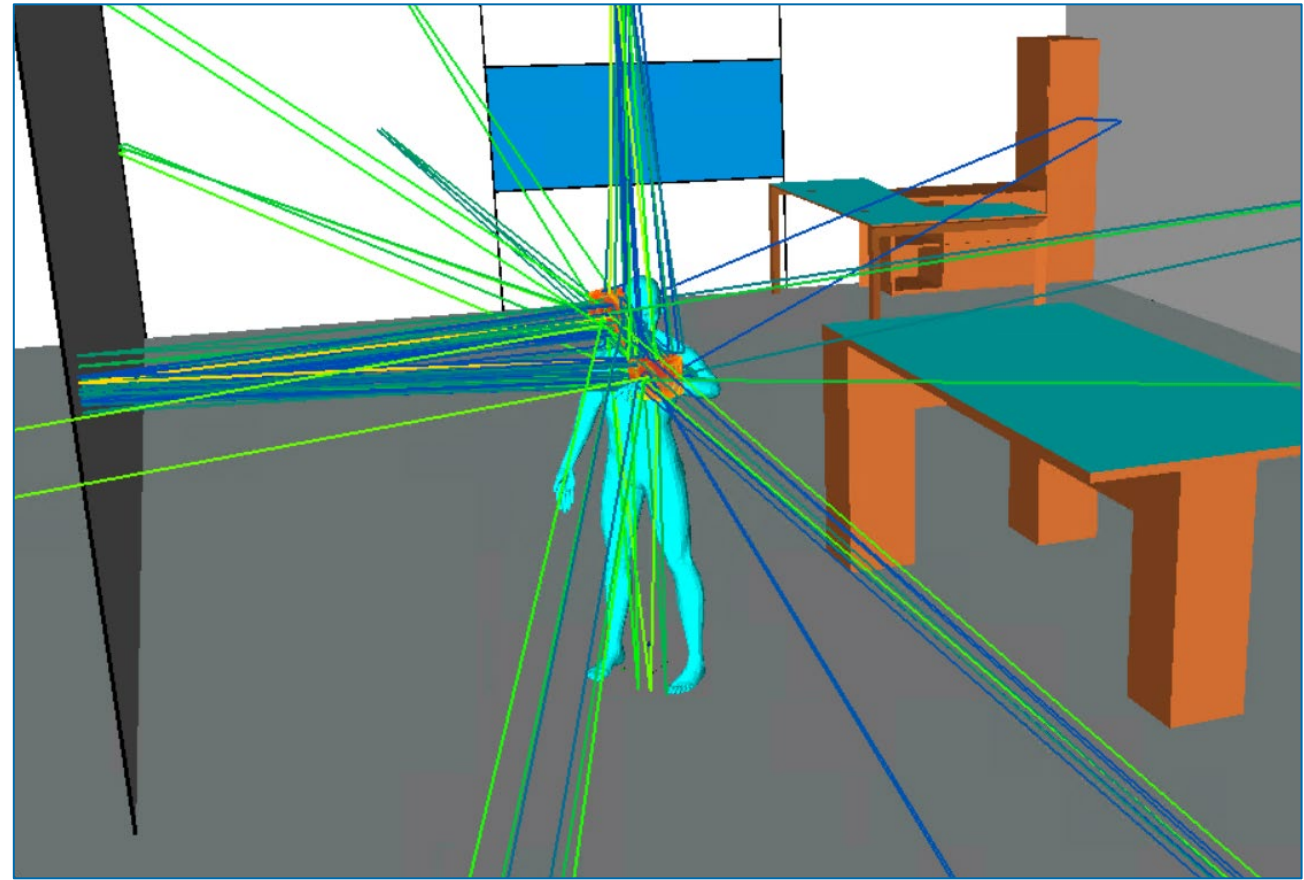
Walk Hand Back



- Near-field effects of on-body position
- Multipath effects as person moves through environment

# Benefits of Huygens Antennas

- Huygen's workflow captures near-field accuracy of XFDTD inside InSite's powerful ray tracer
- On-body/platform antennas simulated in electrically large scenes
- Huygen's workflow decreases the hardware requirements for simulation





# Lunar Propagation



# Lunar Propagation

- Import Lunar Reconnaissance Orbiter (LRO) Lunar Orbiter Laser Altimeter (LOLA) terrain datasets
- Accurately transform the coordinates of RF mobile systems upon lunar terrain
- Set appropriate defaults to no atmosphere (vacuum) for lunar environments
- Built-in lunar materials database

# Importing Lunar Terrain

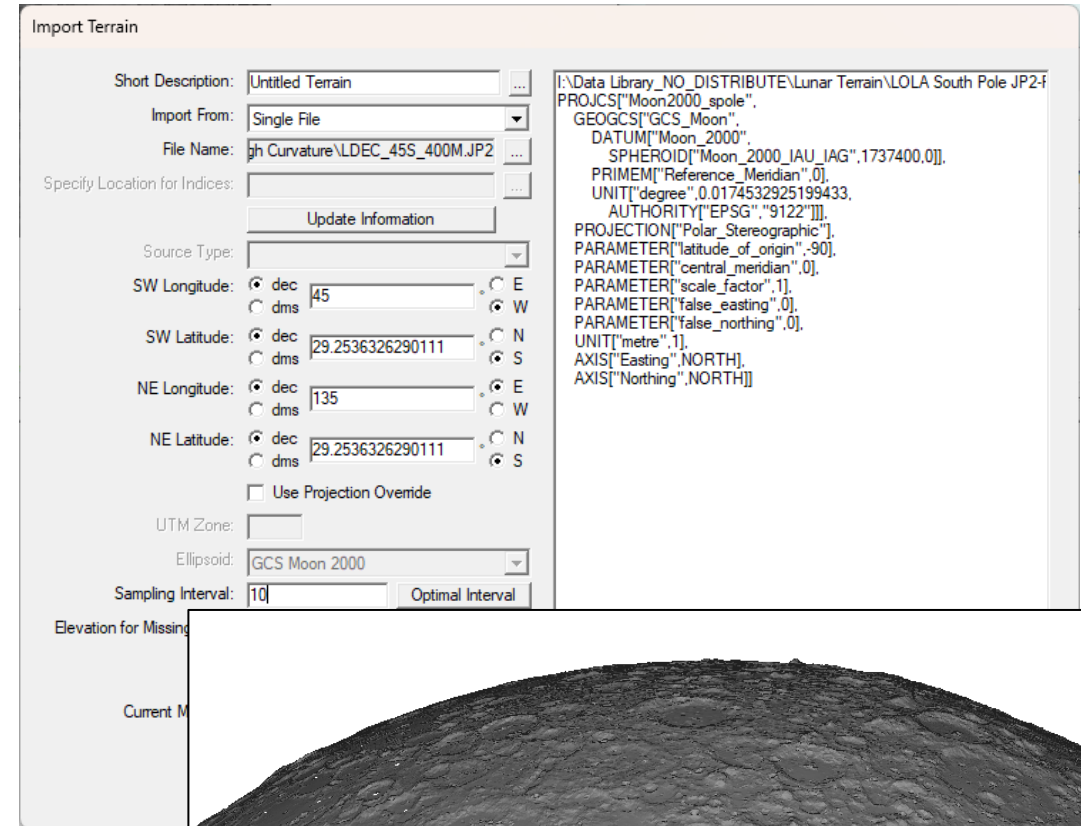
Additional terrain elevation formats supported:

- TIFF/BigTIFF/GeoTIFF
- JPEG-2000
- PDS/PDS4

View metadata from elevation source

Automatically set GCS Moon 2000 ellipsoid projection, or manually override

Automatically adjust atmospheric defaults for projects based on lunar terrain



Import Terrain

Short Description: Untitled Terrain

Import From: Single File

File Name: gh Curvature\LDEC\_45S\_400M.JP2

Specify Location for Indices:

Update Information

Source Type:

SW Longitude: ☒ dec 45 ☐ dms ☐ E ☒ W

SW Latitude: ☒ dec 29.2536326290111 ☐ dms ☐ N ☒ S

NE Longitude: ☒ dec 135 ☐ dms ☐ E ☒ W

NE Latitude: ☒ dec 29.2536326290111 ☐ dms ☐ N ☒ S

☐ Use Projection Override

UTM Zone:

Ellipsoid: GCS Moon 2000

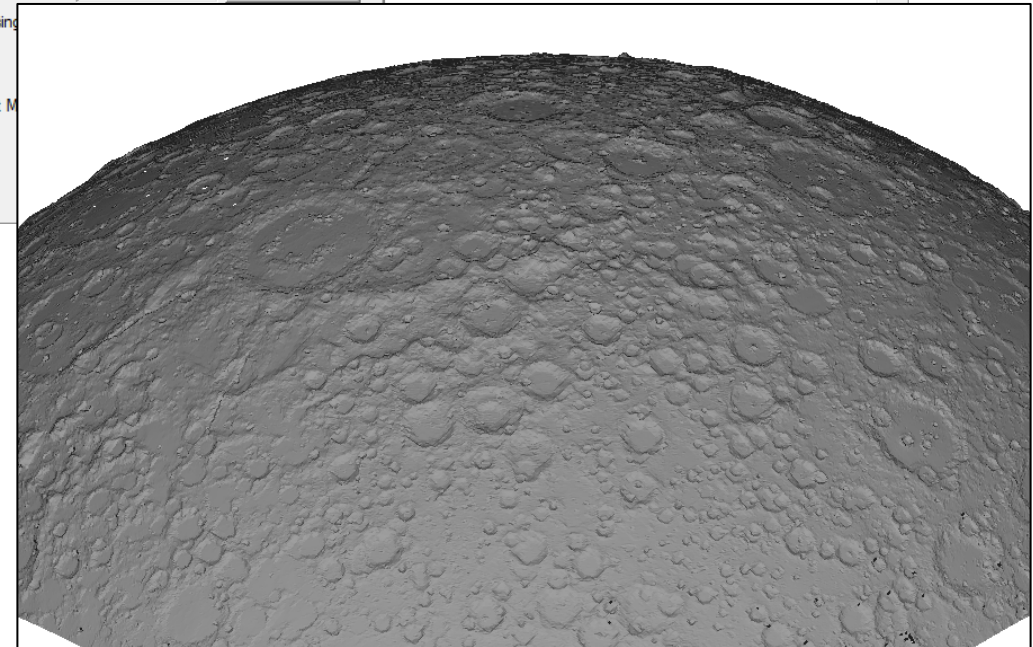
Sampling Interval: 10 Optimal Interval

Elevation for Missing

Current M

Metadata:

```
I:\Data Library_NO_DISTRIBUTE\Lunar Terrain\LOLA South Pole JP2-f
PROJCS["Moon2000_spole",
GEOGCS["GCS_Moon",
DATUM["Moon_2000",
SPHEROID["Moon_2000_IAG",1737400,0]],
PRIMEM["Reference_Meridian",0],
UNIT["degree",0.0174532925199433,
AUTHORITY["EPSG","9122"]]],
PROJECTION["Polar_Stereographic"],
PARAMETER["latitude_of_origin",-90],
PARAMETER["central_meridian",0],
PARAMETER["scale_factor",1],
PARAMETER["false_easting",0],
PARAMETER["false_northing",0],
UNIT["metre",1],
AXIS["Easting",NORTH],
AXIS["Northing",NORTH]]
```





# Lunar Surface Materials: Regolith & Bedrock

- Lunar regolith materials database
- Based on ITU working document ITU-R [LUNAR\_PERMITTIVITY]/3
- Predefined for a range of inputs
  - 189 materials
  - 21 frequencies
  - 3 regolith depths
  - 3 metal composition percentages

Parameter	Values	Units
Frequencies	WiFi: 2.4, 5.2, 6, 7, 60 4G/5G: 0.7, 2.5, 3.6, 5.2/6, 28 SATCOM: <ul style="list-style-type: none"><li>• L-Band: 1.55, 1.65, 1.7</li><li>• S-Band: 2.0, 2.1, 2.2</li><li>• X-Band: 8</li><li>• Ka Band: 18, 19, 20, 28, 29, 30</li></ul>	GHz
Regolith Depth	0 (exposed), 5, 10	m
Regolith & Bedrock $\text{TiO}_2 + \text{FeO}$	0%, 2%, 10%	% by weight

Choose Material

Choose a Material From the Current Project:

In Use	Type	Description	Geometry	Diffuse Scattering Model	Notes
Yes	11-layer dielectric	Lunar Regolith 5 m Depth 2% Metal Oxide 5.2 G...	Untitled Terrain [Terrain]	None	

Create a New Material

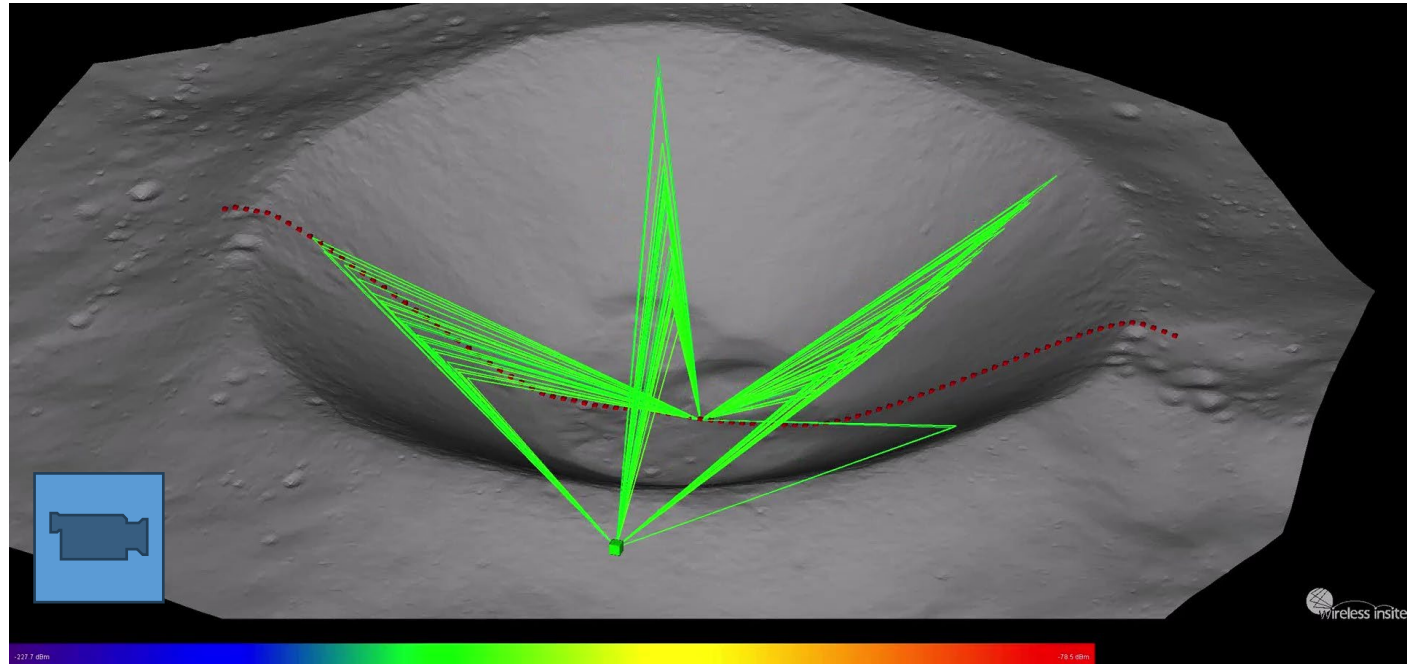
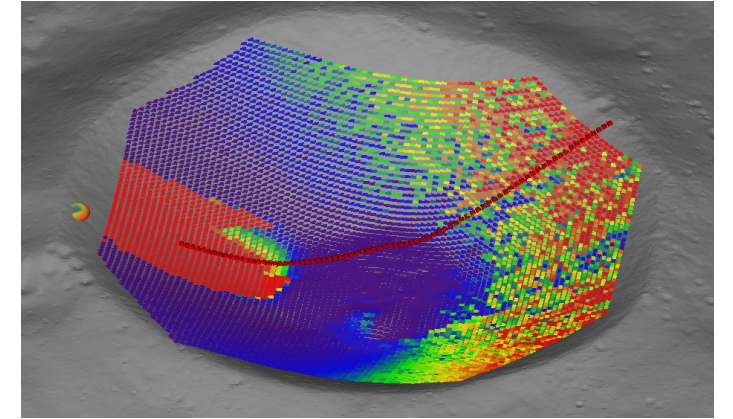
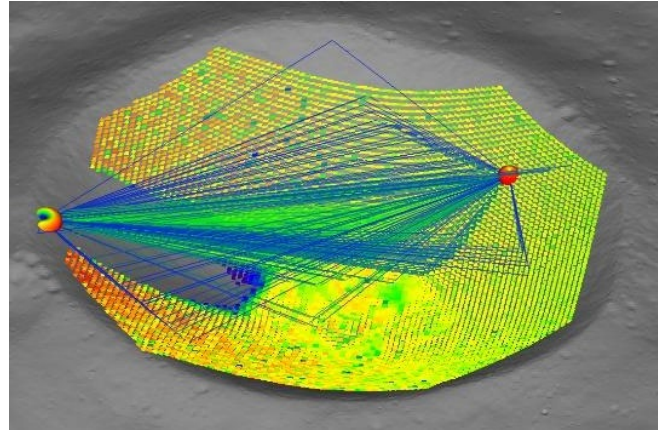
Or From the Material Database:

Type	Description	Location
12-layer dielectric	Lunar Regolith 10 m Depth 0% Metal Oxide 30 GHz	C:\Program Files\Remcom\Wireless InSite 4.0.0\materials\LunarSur
12-layer dielectric	Lunar Regolith 10 m Depth 2% Metal Oxide 30 GHz	C:\Program Files\Remcom\Wireless InSite 4.0.0\materials\LunarSur
12-layer dielectric	Lunar Regolith 10 m Depth 10% Metal Oxide 30 GHz	C:\Program Files\Remcom\Wireless InSite 4.0.0\materials\LunarSur
12-layer dielectric	Lunar Regolith 10 m Depth 0% Metal Oxide 60 GHz	C:\Program Files\Remcom\Wireless InSite 4.0.0\materials\LunarSur
12-layer dielectric	Lunar Regolith 10 m Depth 2% Metal Oxide 60 GHz	C:\Program Files\Remcom\Wireless InSite 4.0.0\materials\LunarSur
12-layer dielectric	Lunar Regolith 10 m Depth 10% Metal Oxide 60 GHz	C:\Program Files\Remcom\Wireless InSite 4.0.0\materials\LunarSur

OK Cancel

# Lunar Propagation

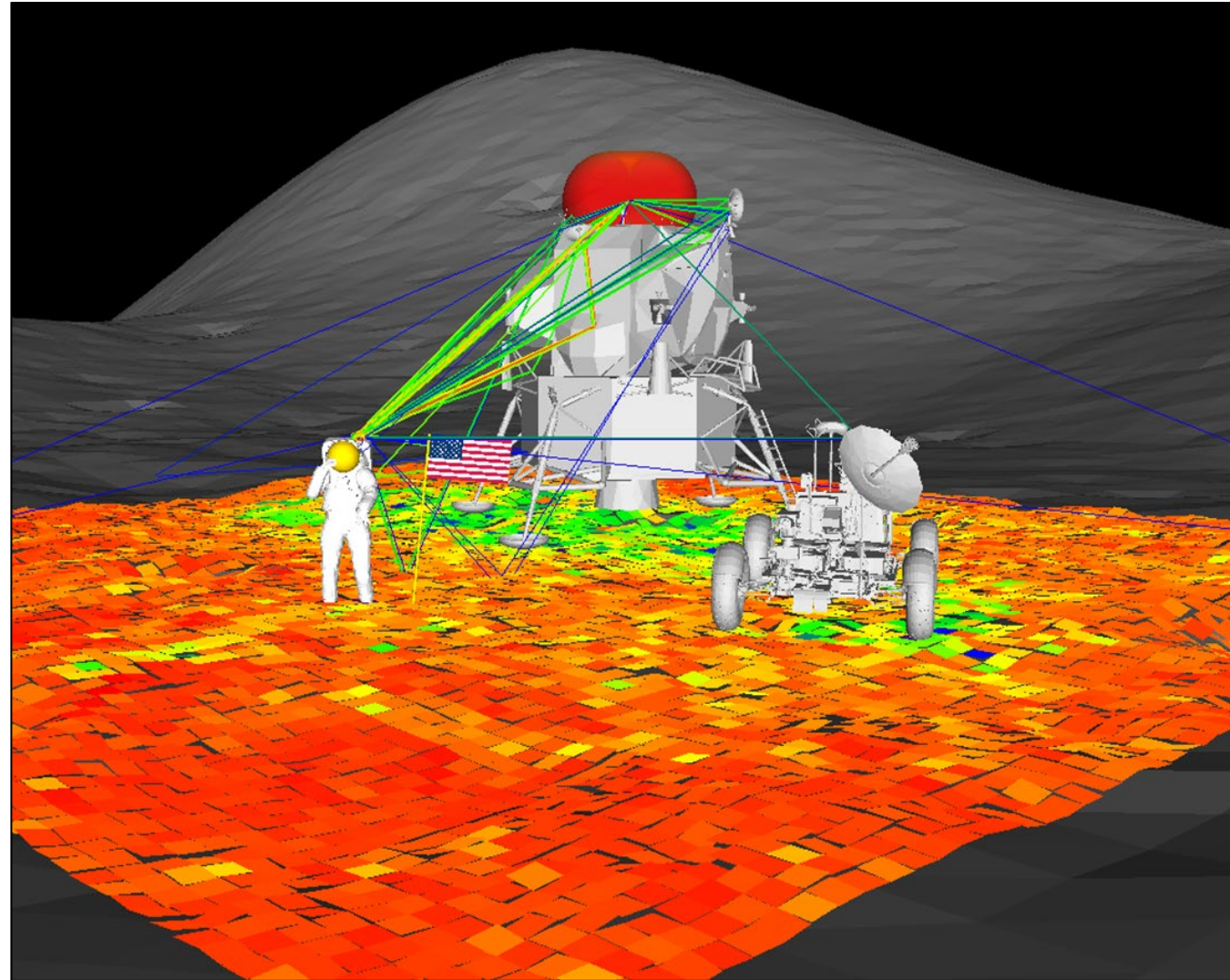
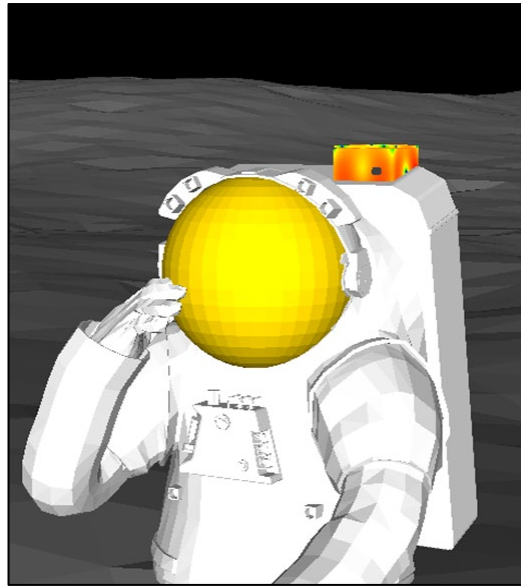
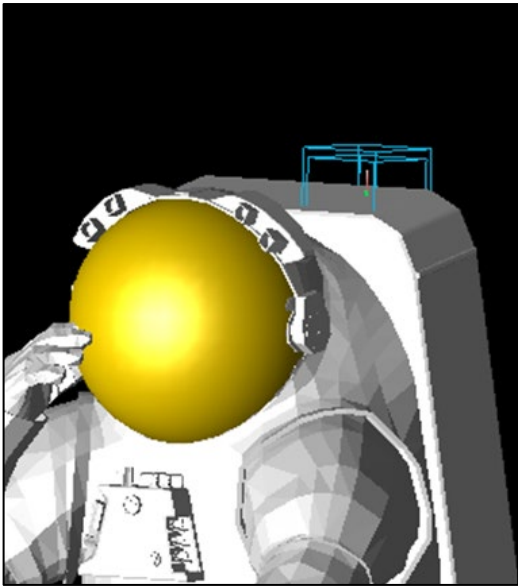
- Imported lunar terrain
- Regolith materials from Wireless InSite database
- X3D simulation showing coverage map, delay spread & animated ray paths





# Support NASA Lunar Artemis Missions

- Compatible with Mobility and Huygens
- Ongoing work to provide:
  - Lunar material generator
  - Improved 3D ray-tracing





# Summary

- Wireless InSite
  - Validated deterministic RF simulation in arbitrary environments
  - Accurate, detailed path data
- Mobility
  - Define motion for configurations of objects and transceivers
  - Time-based results
- Multi-frequency broadband analysis
  - Single project defines broadband scenario
  - Optimized multi-frequency analysis
- Huygens antennas
  - Near-field accuracy of full-wave solver with the ability to run in complex large-scale environments
  - Improved runtime, smaller resource footprint, and frequency-agnostic solution
- Lunar propagation
  - Terrain import and Lunar materials database
  - Optimized and enhanced ray-tracing for lunar environments



# Thank You!

## Questions?

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