REMCOM®

Electromagnetic Simulation Software

mmWave Ray-Tracing Simulation With Diffuse Scattering in an Office Environment

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Author: Tarun Chawla, Remcom, Inc.

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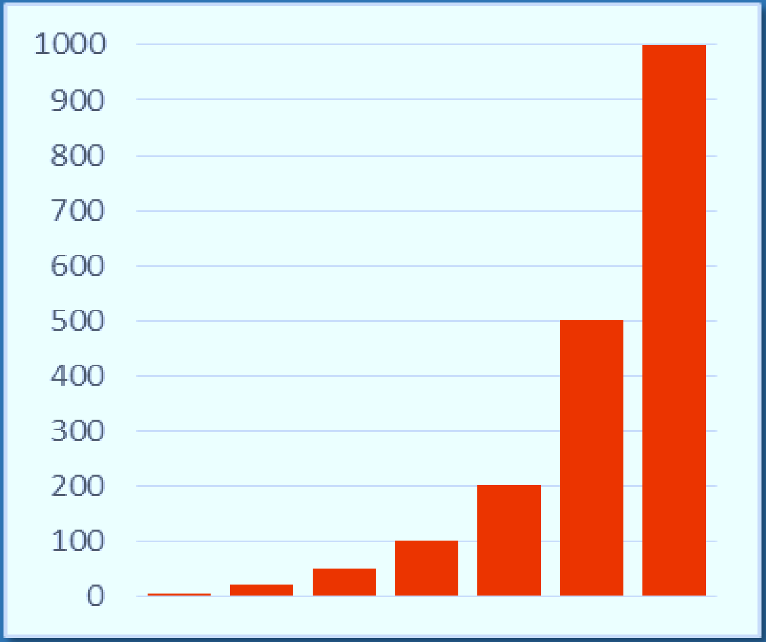
315 S. Allen St., Suite 416 | State College, PA 16801 USA | +1.814.861.1299 phone | +1.814.861.1308 fax | sales@remcom.com | www.remcom.com

Why Millimeter Wave?

5G: Predict 1000x Growth In Mobile Data Demand



5G must address expected growth over next decade

- 10-100 more connected devices
- 10-100 higher data rates
- 1000x+ increase

mm-wave is one of the many solutions planned for 5G

- Adds significant new spectrum
- Potential for much higher bandwidths

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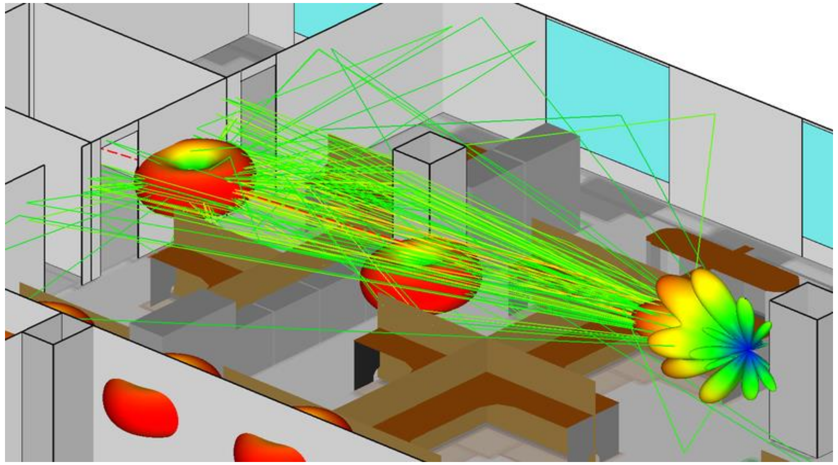
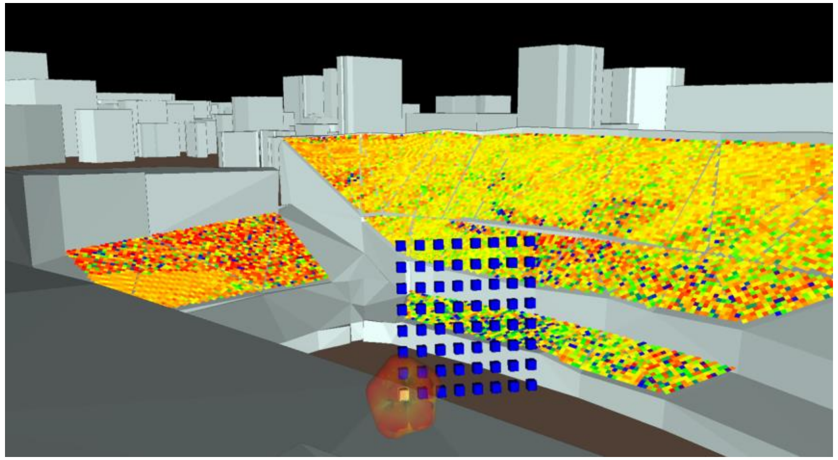
Modeling mm-wave using Wireless InSite

- Atmospheric absorption loss
- Highly directional antennas
- Details of polarization and phase
- Arrays and MIMO systems
- Diffuse Scattering



Predicting channel characteristics for macrocells, small cells, and indoor Wi-Fi



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Wireless InSite's Scattering Model

Implemented methods described by Degli-Esposti, et. al. [1-2]

- Extended with cross-polarization scattering terms described in [3]
- Option to include phase to support 5G/MIMO and other applications

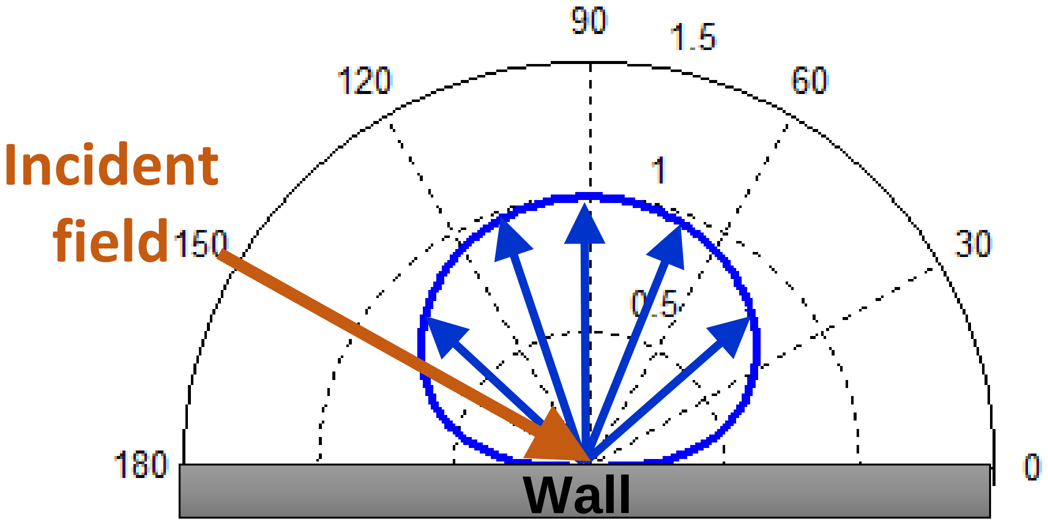
For each material, define nature of scattering by selecting from three possible scattering models (or "none" if smooth):

1. Lambertian
2. Directive
3. Directive with backscatter

Define parameters that characterize strength of scattering, as well as its direction and directivity

Model 1: Lambertian

Lambertian Scattering Pattern

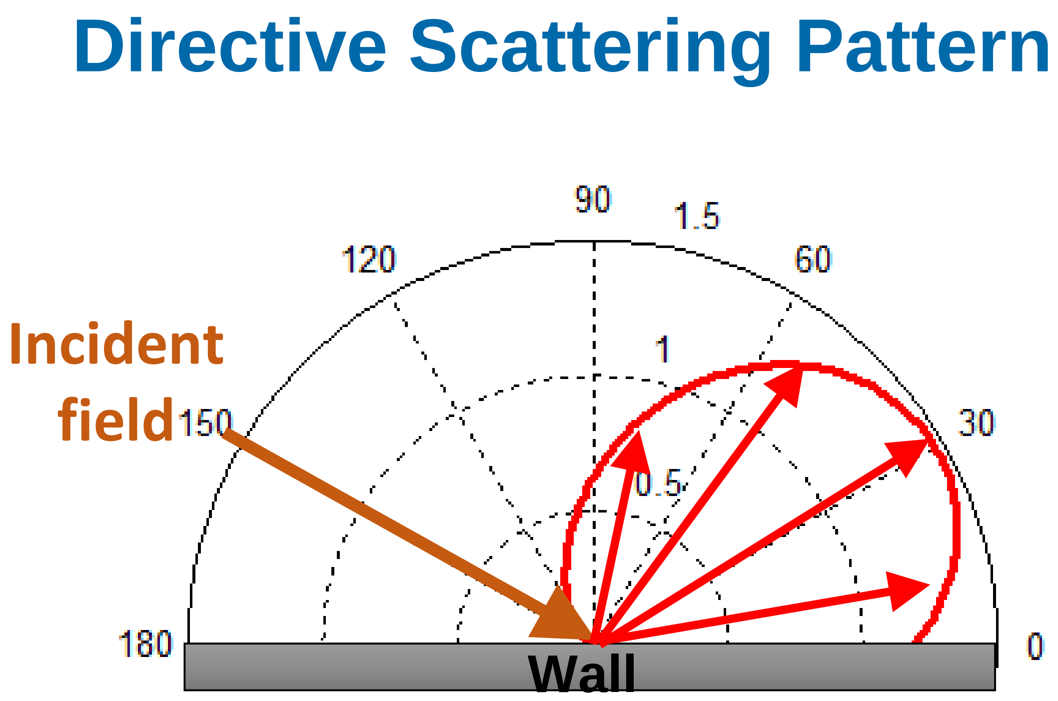


Scattering centered around surface normal

Parameters:

Scattering Factor	Fraction (0-1) of incident field that scatters diffusely
Cross-pol Fraction	Fraction (0-1) of scattered field that is cross-polarized

Model 2: Directive



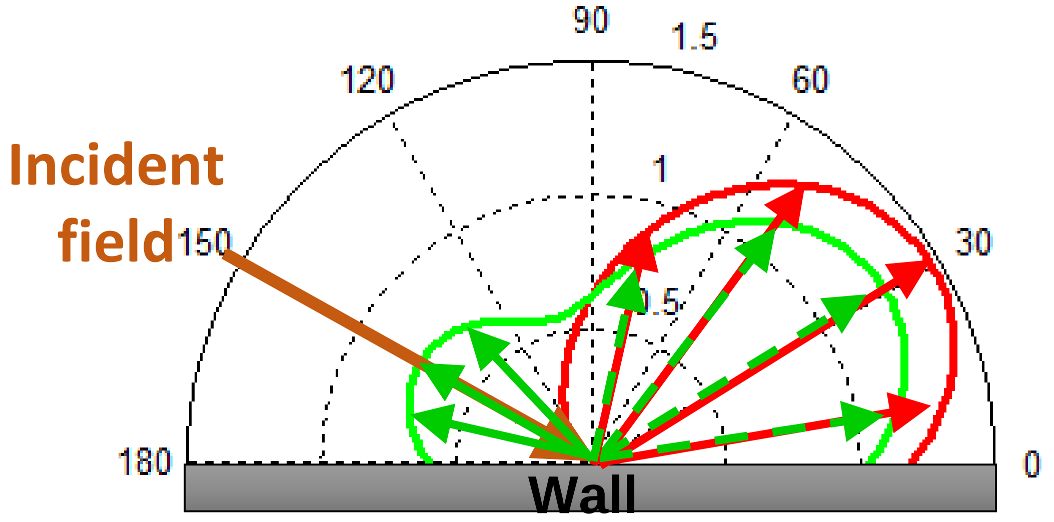
Scattering centered around reflection angle

Parameters:

Scattering Factor	Fraction (0-1) of incident field that scatters diffusely
Cross-pol Fraction	Fraction (0-1) of scattered field that is cross-polarized
Alpha	Value (1-10) defines how broad forward beam will be

Model 3: Directive w/Backscatter

Directive w/Backscatter



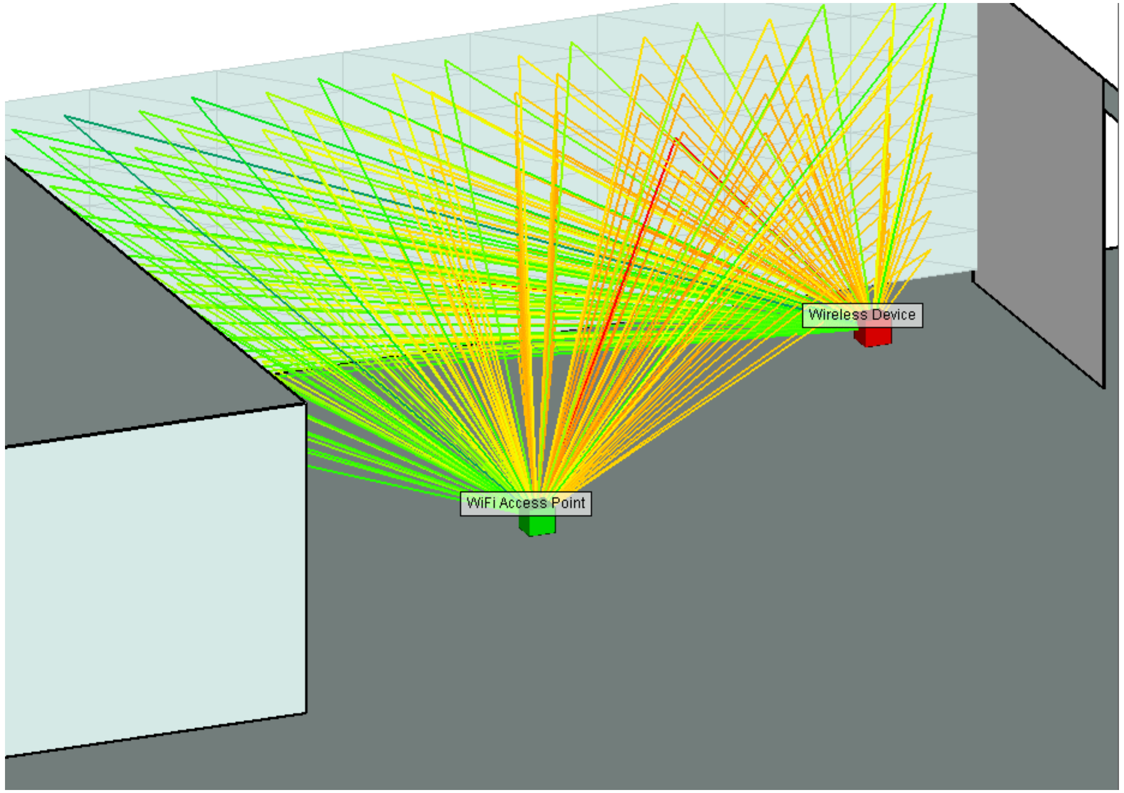
Directive scattering in forward and reverse directions

Parameters:

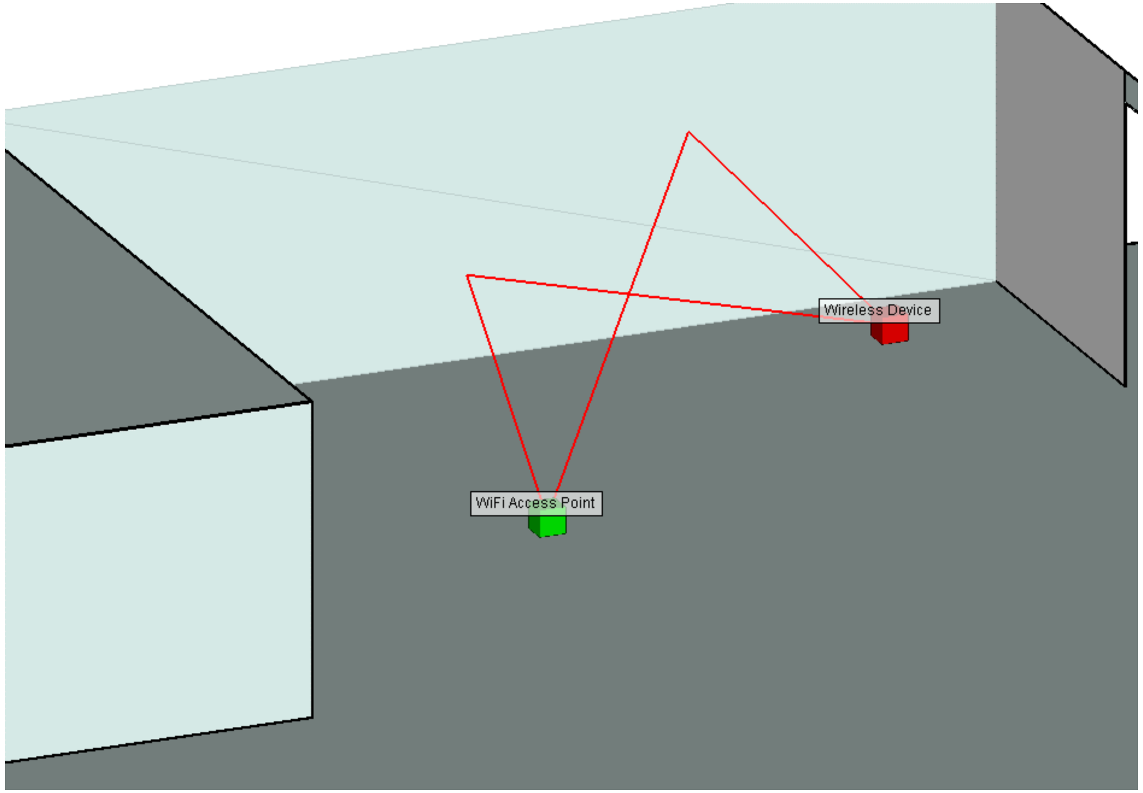
Scattering Factor	Fraction (0-1) of incident field that scatters diffusely
Cross-pol Fraction	Fraction (0-1) of scattered field that is cross-polarized
Alpha	Value (1-10) defines how broad forward beam will be
Beta	Value (1-10) defines how broad backscatter beam will be
Λ	Fraction (0-1) of power that scatters in forward direction (vs. backscatter)

Paths for Surface Integration

Actual Paths: breaks down facets, finds & verifies paths to many integration points

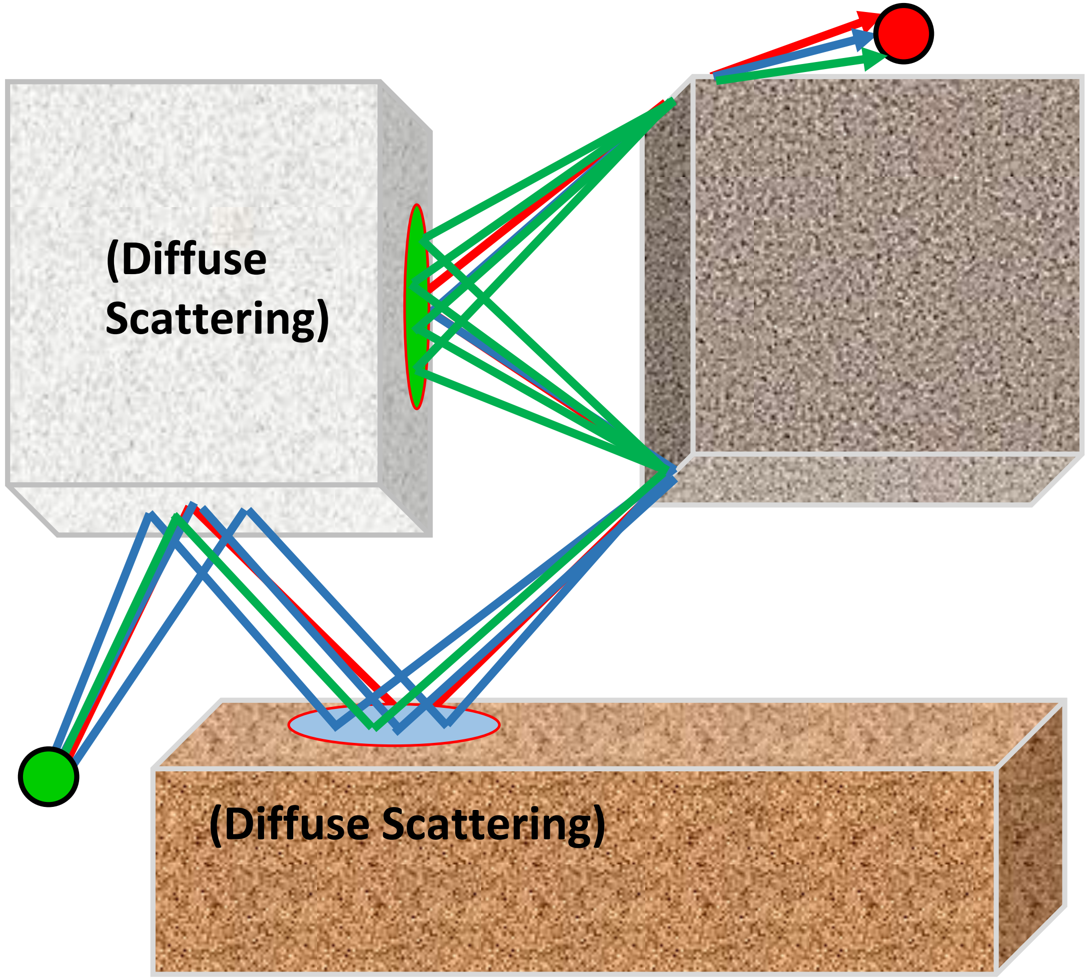


Stores Aggregate Paths: path data consolidated & displayed at power weighted average points



Diffuse Scattering and Multipath

- A path can include up to one diffuse scattering interaction
  - Can be at any point along path
  - Can result in many paths interacting with same structures
- Paths that interact with scattering surfaces will also scatter in many other directions



Outputs from Sims with Diffuse Scattering

Path Data

- Interactions with structures
- Time of arrival
- Directions of arrival & departure
- Complex impulse response

Received Power

- Specular power
- Diffuse Scattered power
- Total Power
  - Power sum (incoherent)
  - Summed coherently
- Derived: Path loss/gain, etc.

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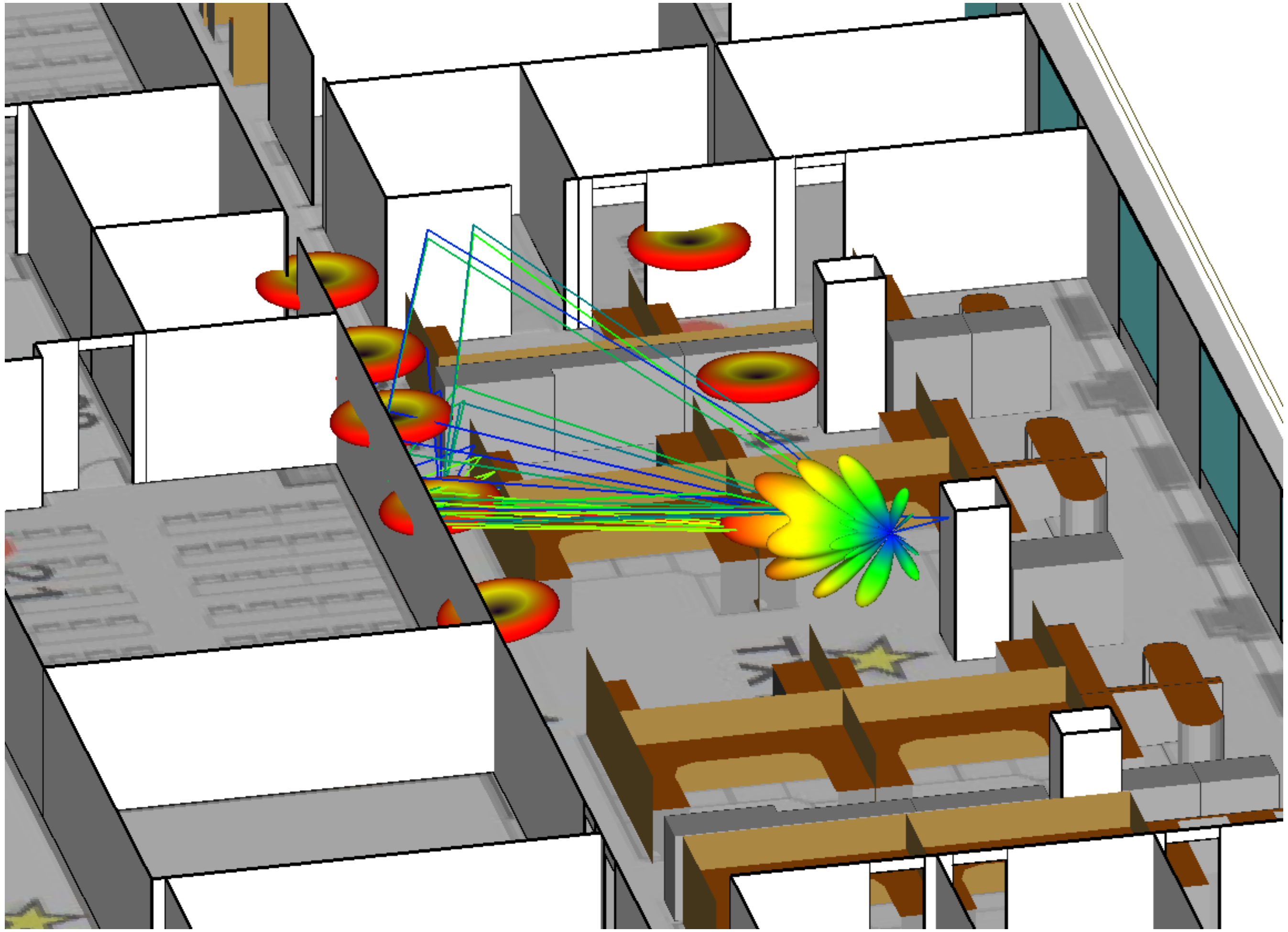
Advantages of Remcom's Approach

- Ability to scatter from any interaction along a ray path appears to be unique
- Verification of paths and scattering from individual integration points across surface provides more accurate result
- Scatter in all directions (no bounding of ray-tracing using beam pattern)
- Handling of polarization and phase supports MIMO and arrays

Diffuse Scattering Example



Replicated Measurements from IEEE Paper

Office floorplan

- 9th floor of office bldg. in Brooklyn
- Construction primarily drywall
- Cubicles, desks, cabinets

Transmitter

- Tx1 in diagram; just below ceiling
- Directional antenna pointed at each receiver (15º beamwidth)

9 Receivers (labeled 1-9)

- LOS and NLOS points in room & hallway
- Antennas rotated over measurement series to emulate omnidirectional

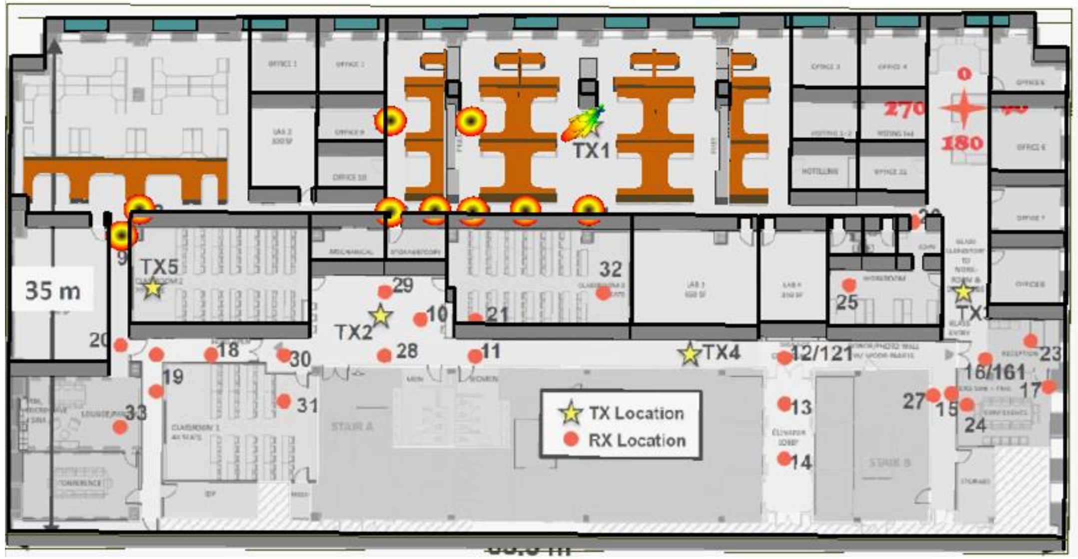


Image used with permission from IEEE. Reference:

G. MacCartney, T.S. Rappaport, S. Sun, and S. Deng, "Indoor Office Wideband Millimeter-Wave Propagation Measurements and Channel Models at 28 and 73 GHz for Ultra-Dense 5G Wireless Networks," IEEE Access, Vol. 3, Dec 7, 2015, pp. 2388 - 2424.

Materials

Structural materials

- Values from ITU[5] for drywall, concrete (ceiling & floor), glass windows

Office furniture

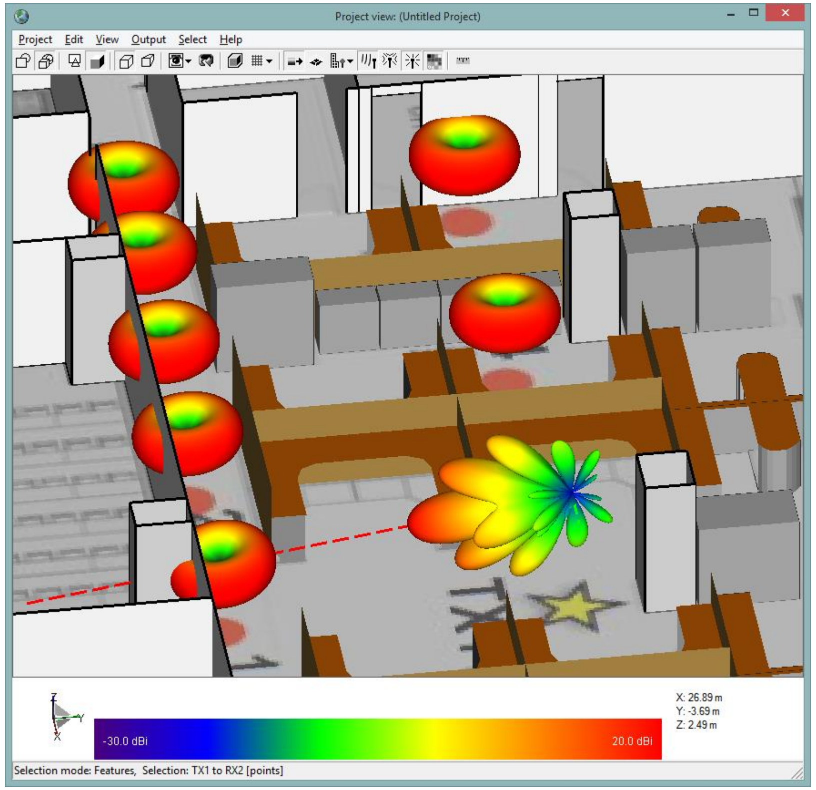
- Desktops: ITU chipboard [5]
- Cubicle walls: assumed FRP honeycomb core, extrapolating from [6]

Diffuse Scattering properties

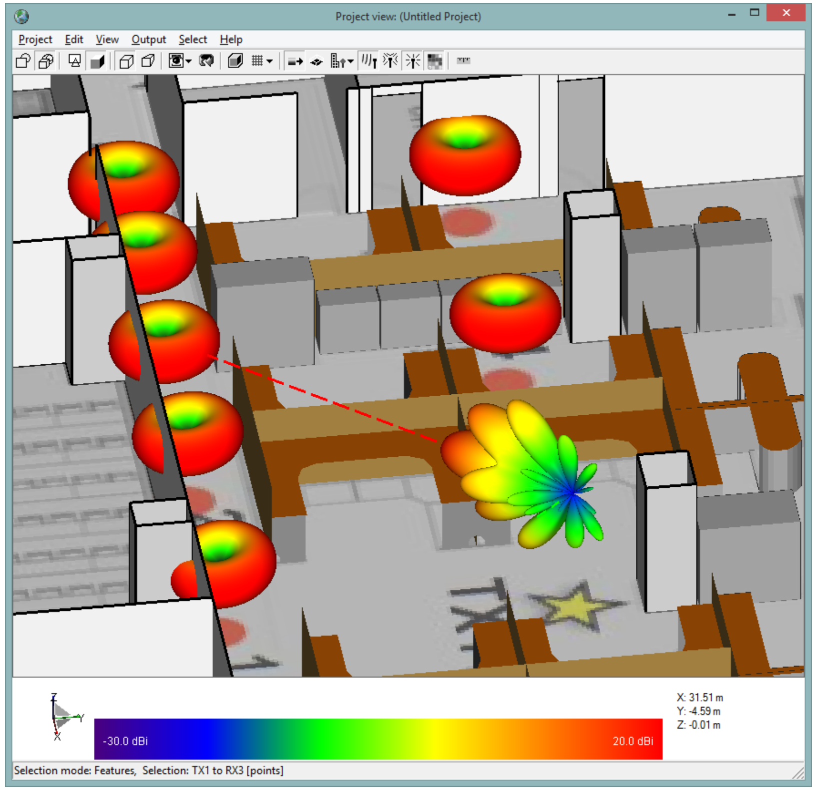
- Compared Lambertian and Directive models; found best agreement with Directive
- Specified scattering factor between 0.2 and 0.5 for walls, filing cabinets, ceilings and cube walls, depending on level of roughness (e.g., drywall is fairly smooth)
- Note: ref[7] suggests values from approximately 0.1 to 0.5 at 60 GHz

Transmitter Aimed Toward each Receiver

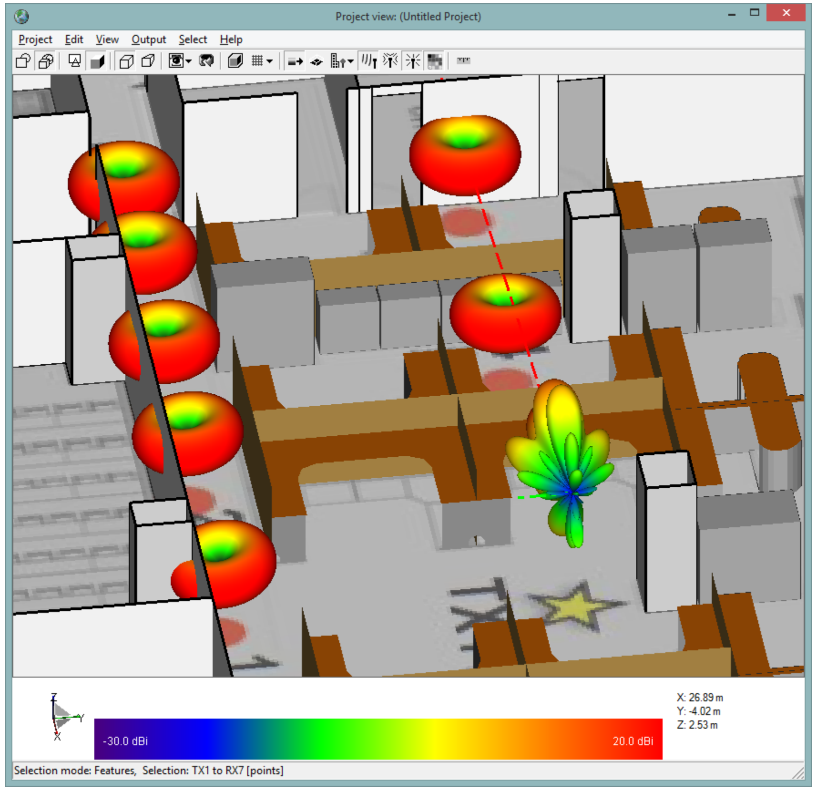
Receiver 1



Receiver 3

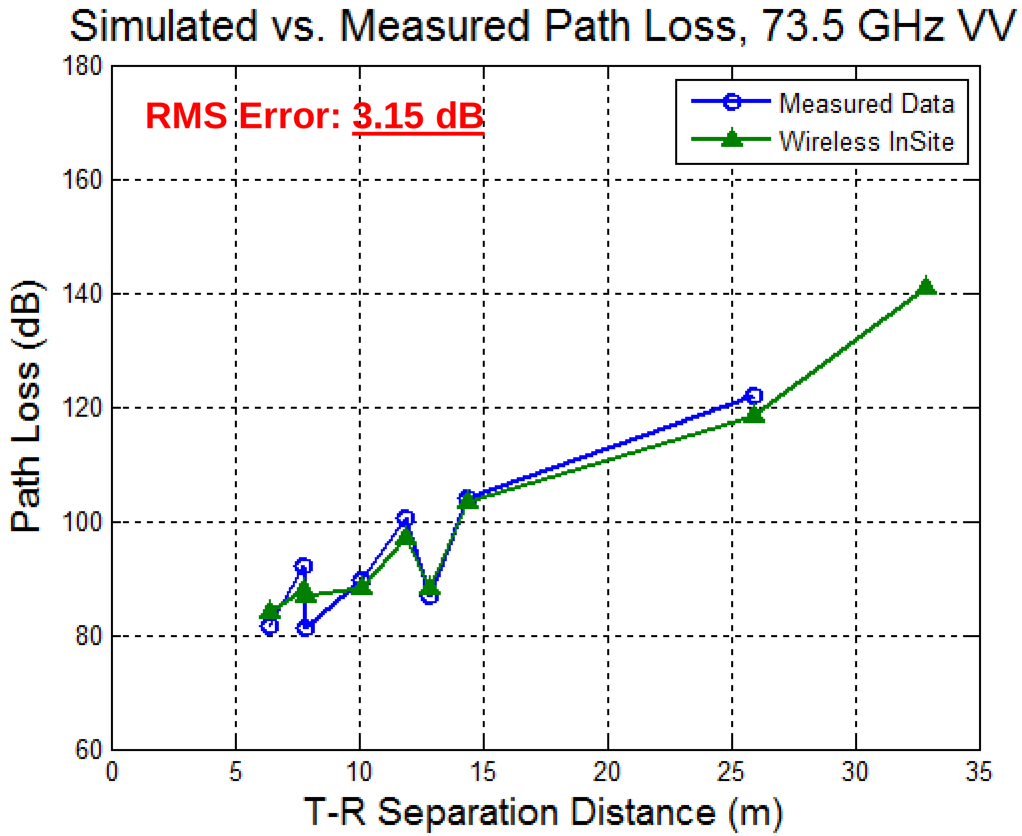


Receiver 7

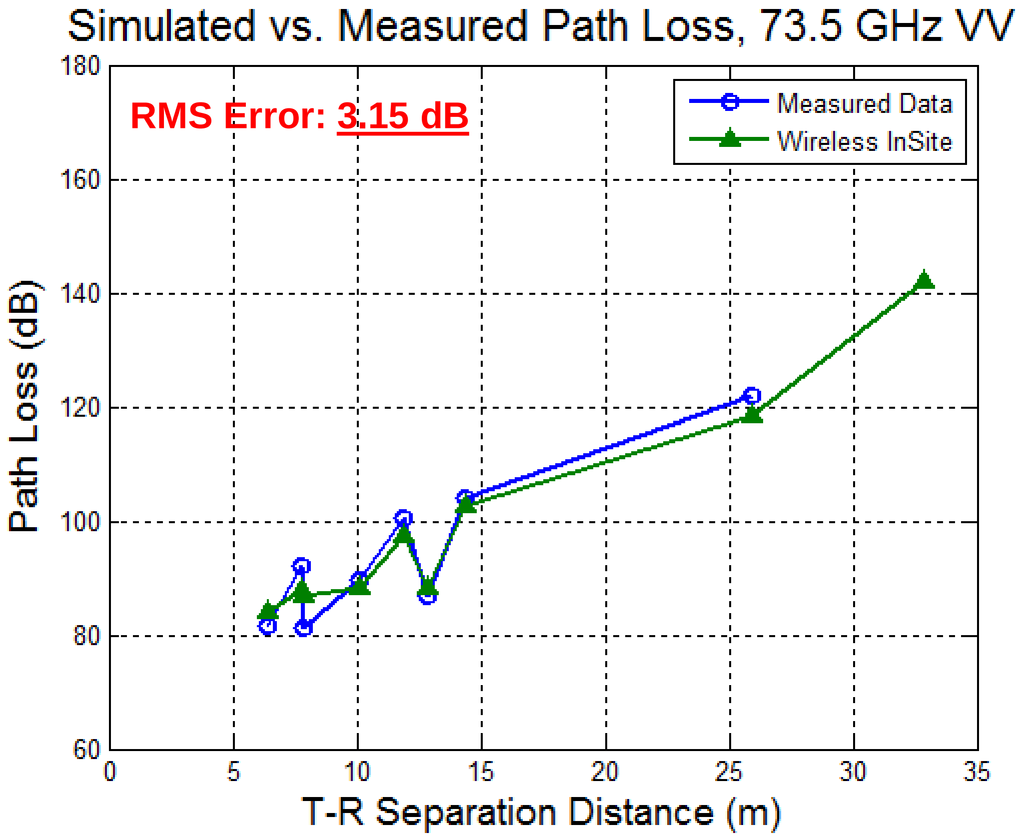


Co-Polarized Measurements (VV)

Received Power Ignoring Scattering



Received Power with Diffuse Scattering



For co-polarized results, agreement is good for both cases (diffuse scattering contributions are low compared to dominant path)

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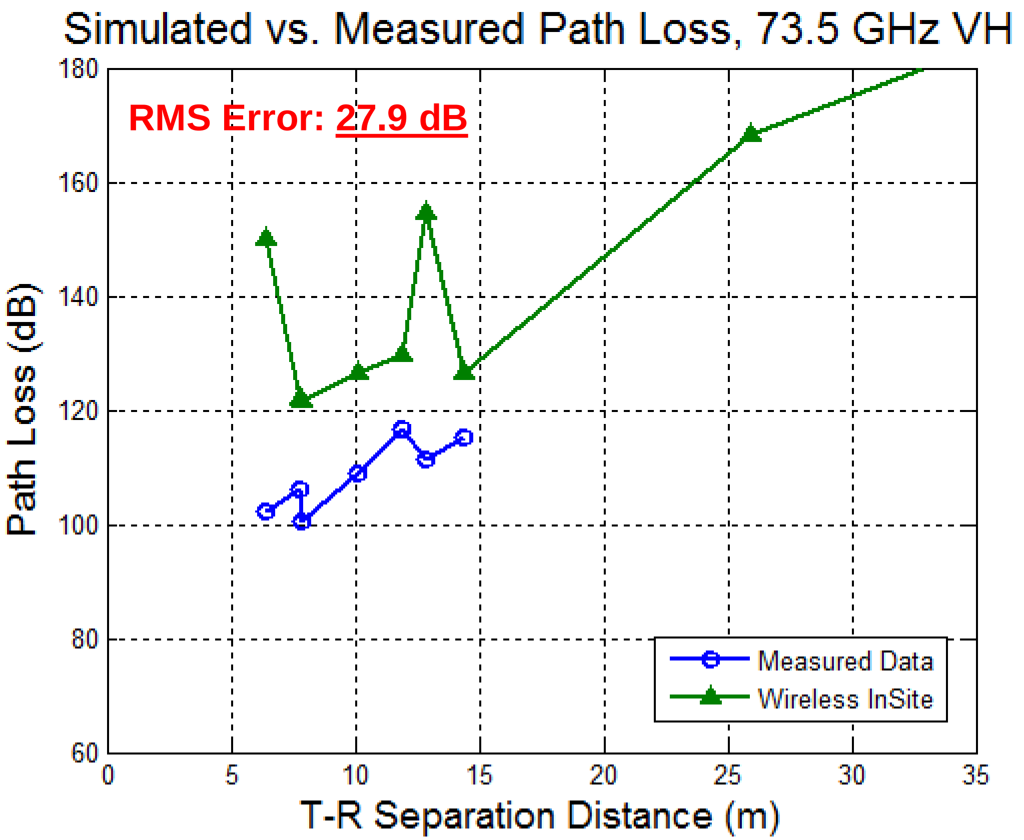
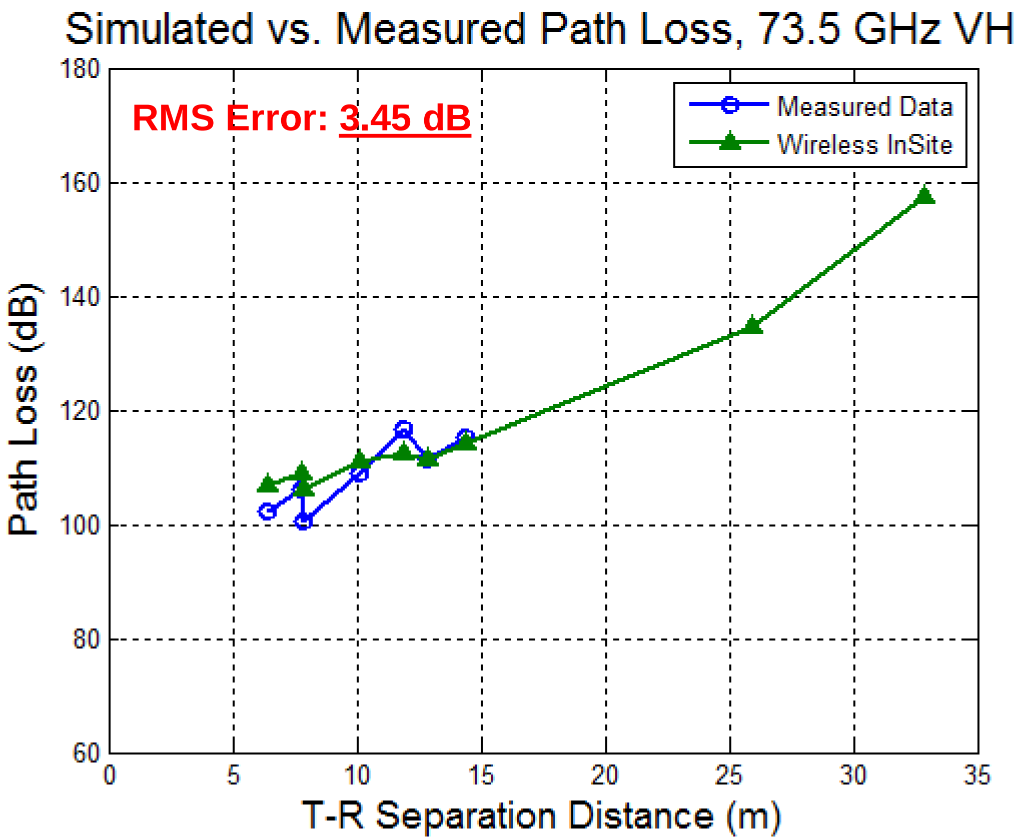
Cross-Polarized Measurements (VH)

Received Power Ignoring Scattering



Received Power with Diffuse Scattering



For cross-polarized results, diffuse scattering proves critical

Summary

- Introduced Wireless InSite®'s new diffuse scattering model
- Demonstrated how to set up a mm-wave scenario, by replicating a measurement campaign from an IEEE paper
- Shown how to define materials with surface characteristics that result in diffuse scattering
- Explained the settings for performing simulations that include diffuse scattering
- Presented a collection of simulation results, demonstrating the value of simulation, and through improvements to cross-polarization results, the importance of diffuse scattering

Questions?

Contact

Toll Free: 1-888-773-6266 (US/Canada)

Tel: 1-814-861-1299

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