EDI CON 2018
Electronic Design Innovation Conference & Exhibition
October 17-19 2018
Santa Clara Convention Center
Santa Clara, CA

Realistic Antenna Array Modeling for 5G Communications

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ANSYS Inc.

The Evolution of the Network*

*https://www.akuaroworld.com/wp-content/uploads/2016/09/2do-arte-1.jpg

So what do we expect from 5G?

- 5G will be everywhere
- 5G and IoT go hand in hand
- 5G must handle more users and even 4K data transfer

New Frequency (28 GHz)…. New Band …. New Problems!

Interference and Jamming

Thermal issues and overheating

Loss of connectivity and Network outage

New infrastructure

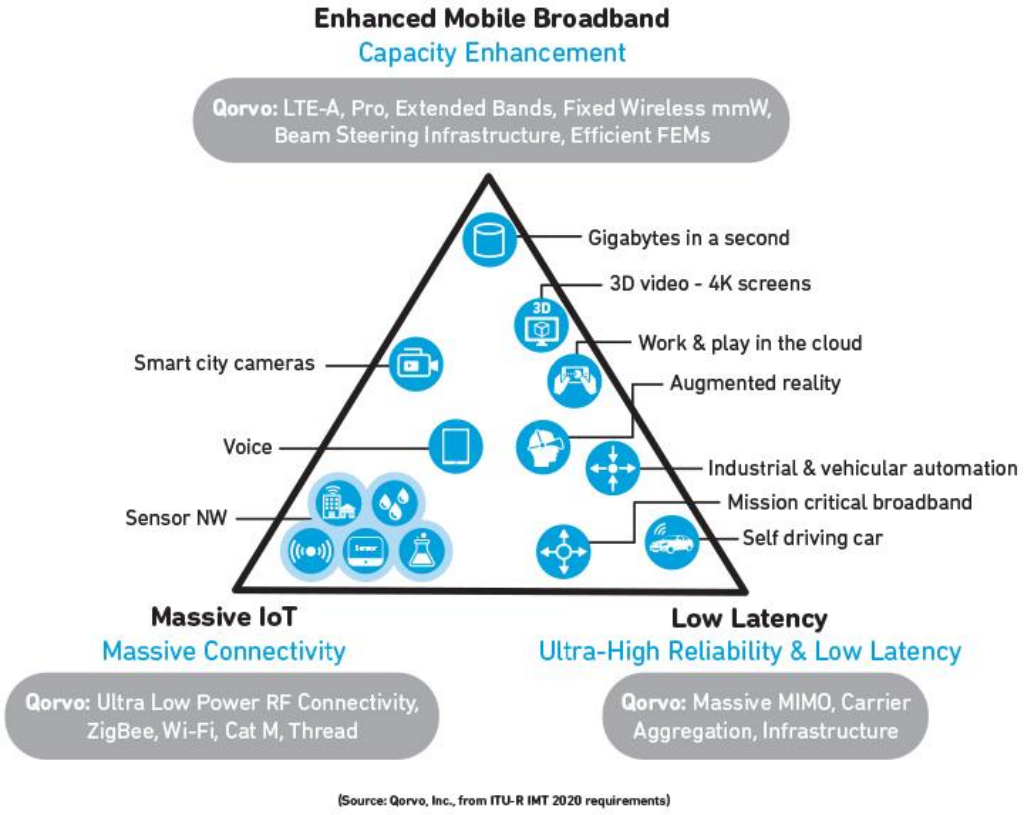
Detuning

Sensitivity to weather

Line of sight

2020s+
- New infrastructure
- High speed and capacity

Three Dimensions of 5G



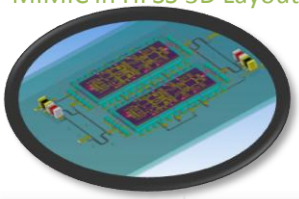
(Source: Qorvo, Inc., from ITU-R IMT 2020 requirements)

- Enhanced Mobile Broadband
  - Cellular in office, industrial parks, malls, sports venues.
  - High volumes in localized areas with lower cost
- Massive Internet of Things
  - Economy of scale for IoT and M2M
  - Low power
- Mission Critical Services
  - New market for high reliability, ultra-low latency, security, availability
  - Supports autonomous vehicles and remote operation of equipment

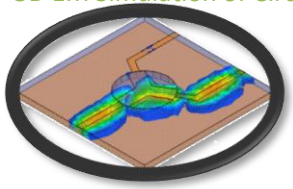
*The 5G Economy, IHS.com

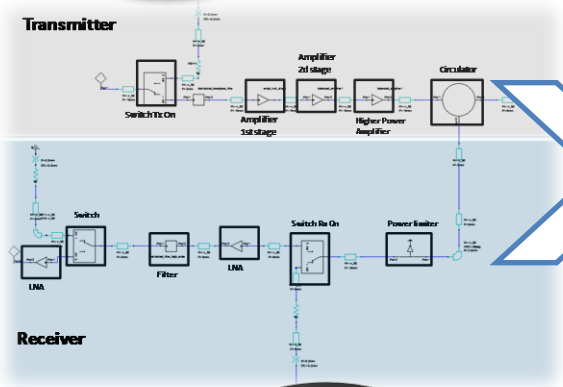
5G Active Antenna System: Multi-Scale + Multi-Domain

MIMIC in HFSS 3D Layout



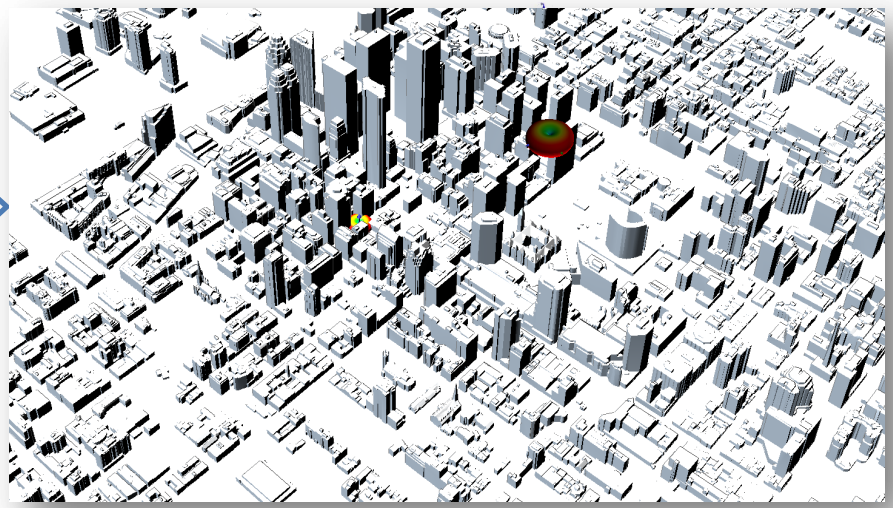
3D EM Simulation of Circulator





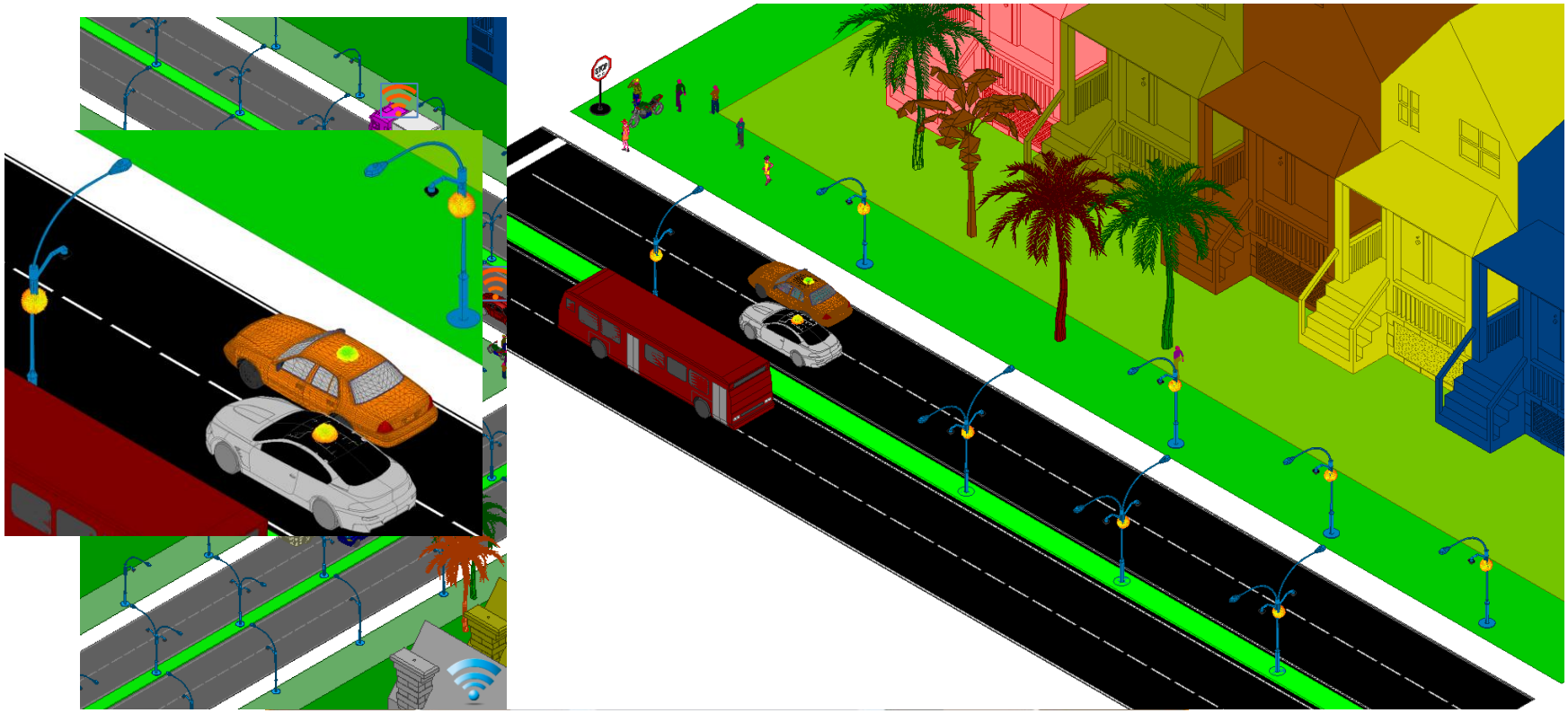
3D EM Simulation of Amp Package

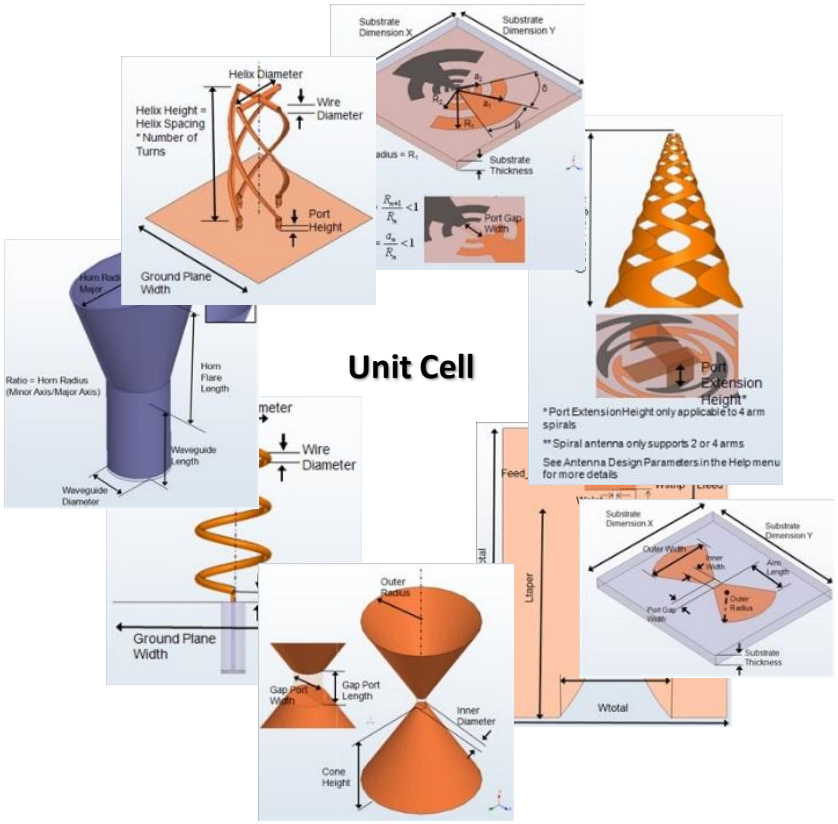
Antenna Element/Array



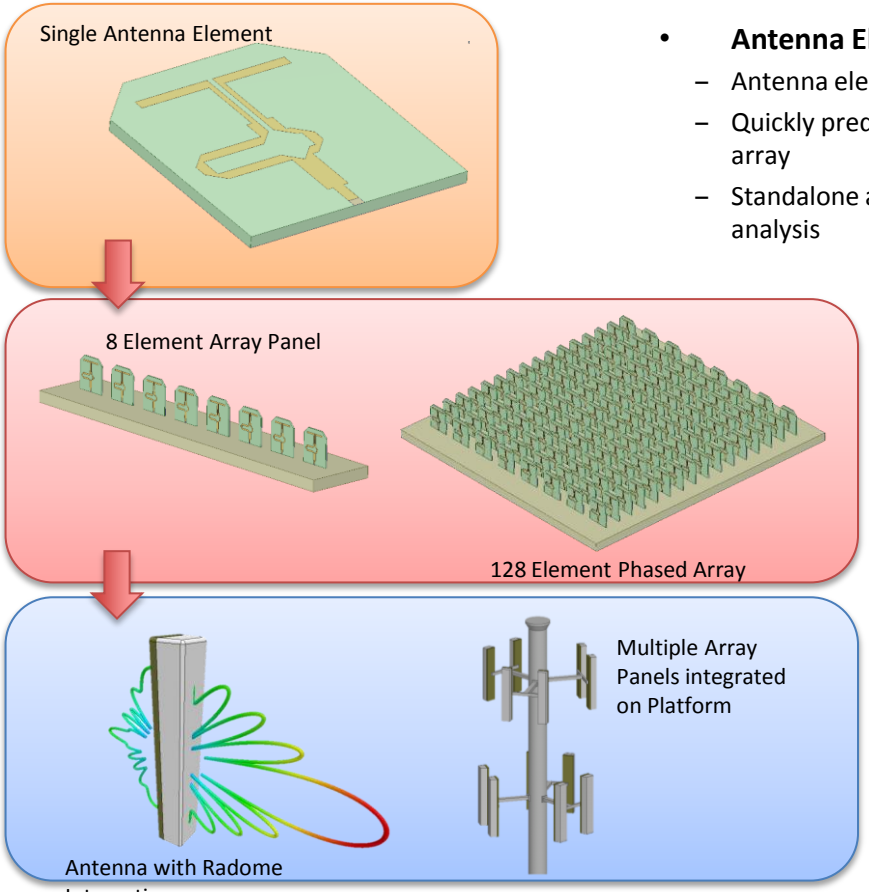
Building Smart Cities starts with Connected Street Infrastructure

Large Scale IOT Technology Adoption : Intelligent Street Lighting




Unit Cell
Helix Diameter
Wire Diameter
Helix Height = Helix Spacing * Number of Turns
Port Height
Ground Plane Width
Substrate Dimension X
Substrate Dimension Y
Substrate Thickness
Port Gap Width
Port Extension Height*
* Port Extension Height only applicable to 4 arm spirals
** Spiral antenna only supports 2 or 4 arms
See Antenna Design Parameters in the Help menu for more details
Horn Flare Length
Ratio = Horn Radius (Minor Axis/Major Axis)
Waveguide Length
Waveguide Diameter
Outer Radius
Gap Port Length
Gap Port Width
Inner Diameter
Cone Height
Feed
Loops
Wtotal
Outer Width
Inner Width
Arm Length

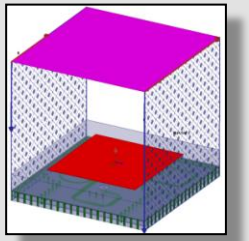
Array Design Methodology



- **Antenna Element Design**
  - Antenna element design
  - Quickly predict performance when integrated into finite array
  - Standalone antenna element, or unit cell (infinite array) analysis
- **Finite Array Analysis**
  - Analysis of finite array to accurately capture all effects
  - Edge effects, mutual coupling, active S-parameters
- **Array Platform Integration and Performance**
  - Real world phased array performance including platform effects

Unit Cell

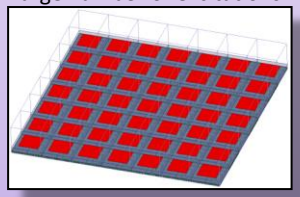
- Models a single element as if it were in an infinite array environment
- Low computational resources
- Infinite Array Approx.
  - Edge affects ignored
  - Uniform magnitude excitation
  - Single scan angle solved at a time



Finite Array

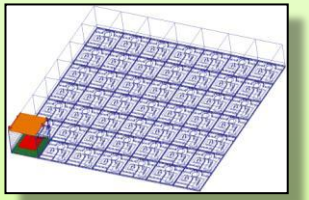
Explicit

- Entire array analyzed
  - Edge affects and edge treatments
  - Mutual coupling terms
  - Arbitrary excitations
- Most flexible
  - Fewest assumptions
- Complex Geometry
  - Every element needs to be drawn
  - Large number of excitations



Finite Array DDM

- Entire array analyzed
  - Edge affects
  - Mutual coupling terms
  - Arbitrary excitations
- Very efficient simulation
- Uses Domain Decomposition to minimize and distribute compute resources



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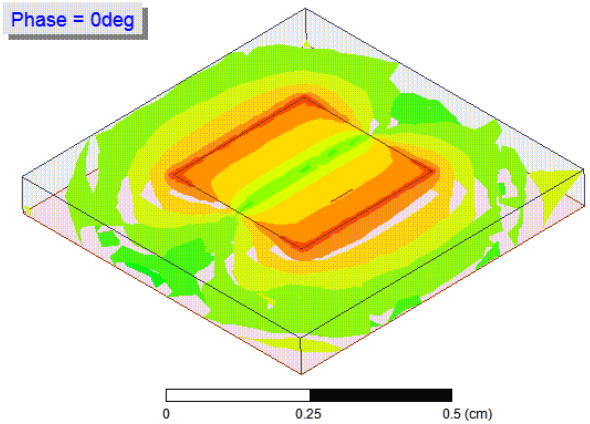
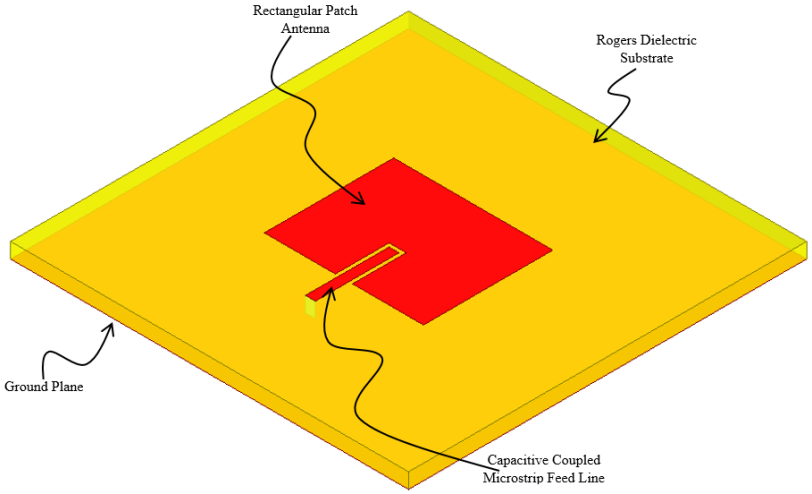
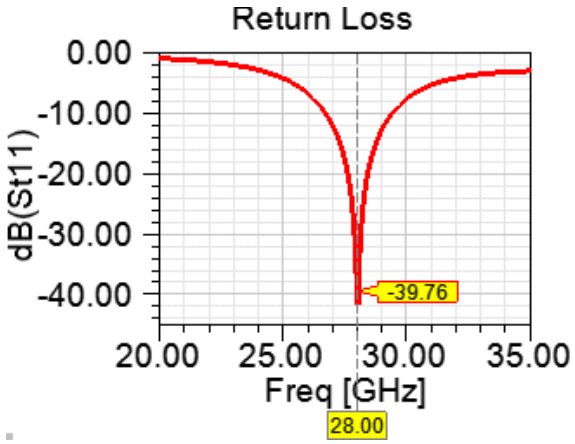
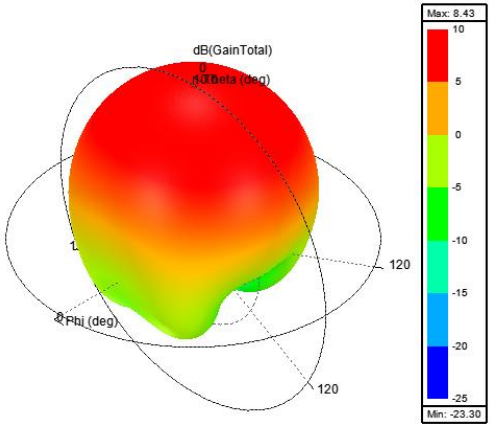
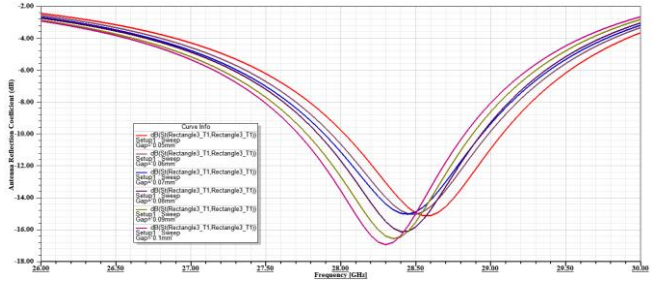
Unit Cell



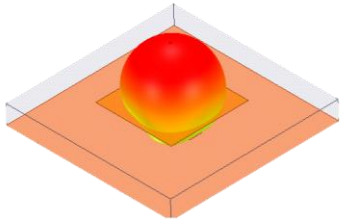




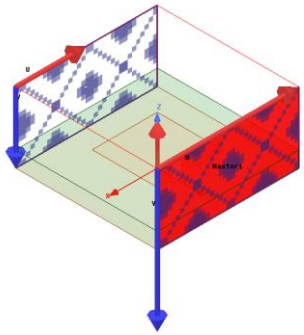


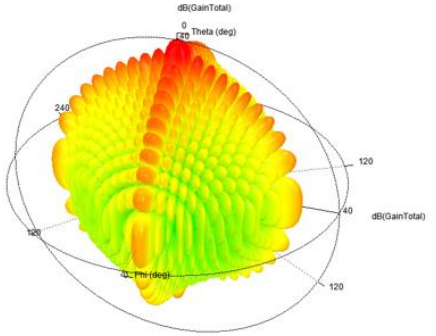


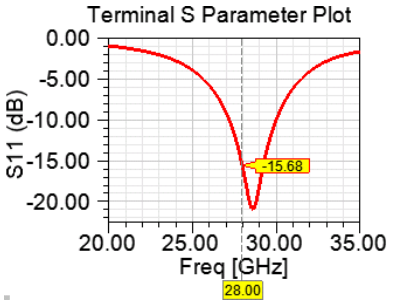
Unit Cell

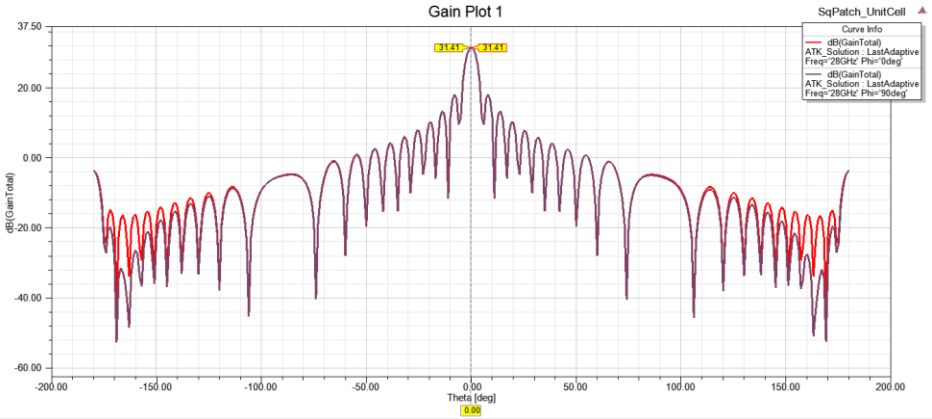


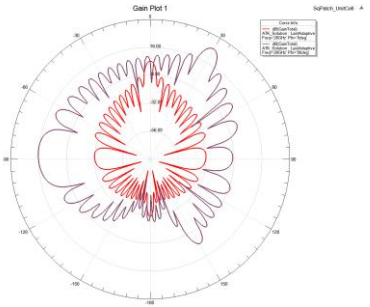
Infinite Array

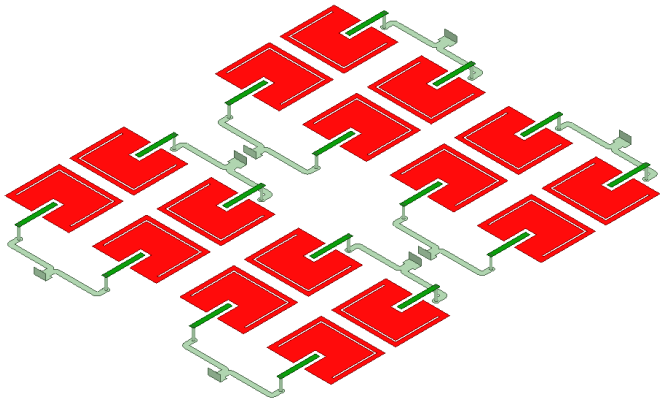




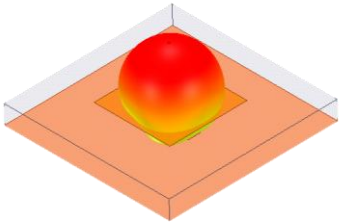




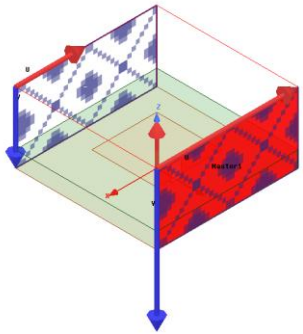




Unit Cell



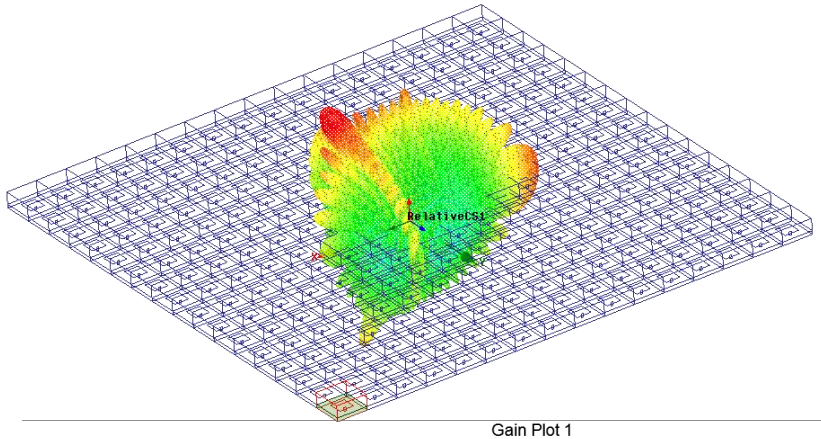
Infinite Array

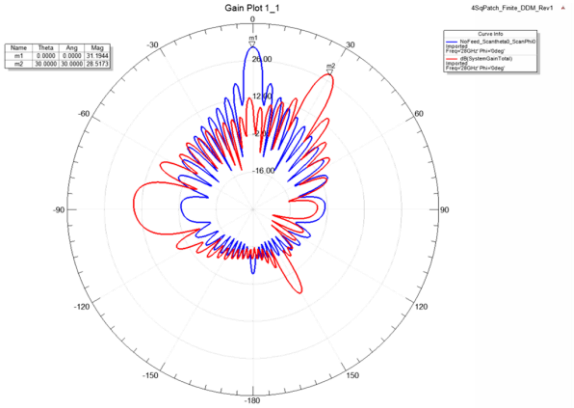


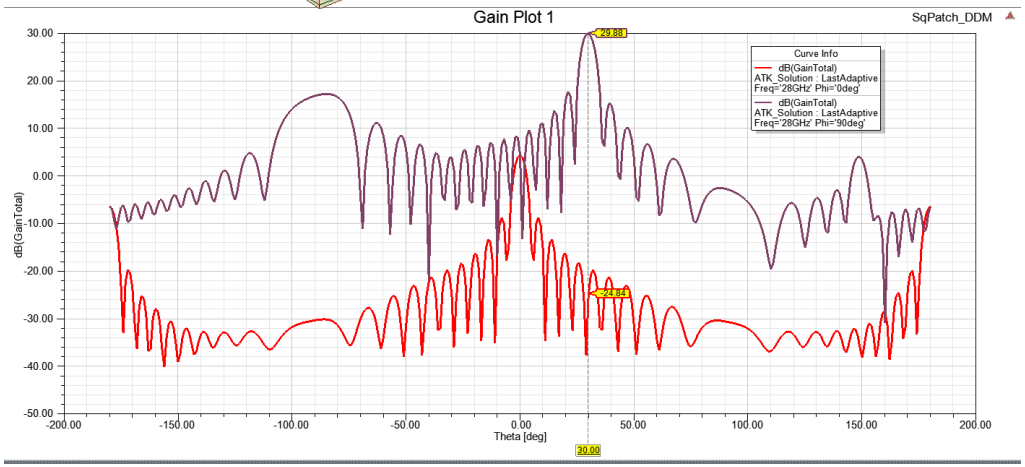
Finite Array DDM

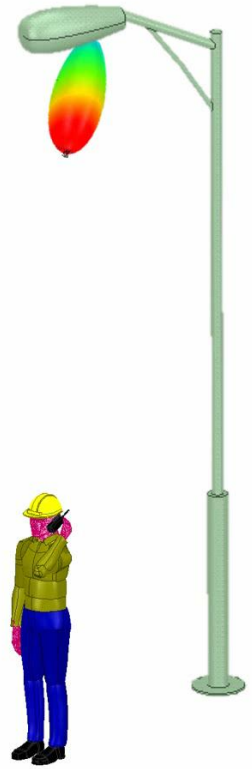
256 element array

Finite Array with Steering Using Domain Decomposition



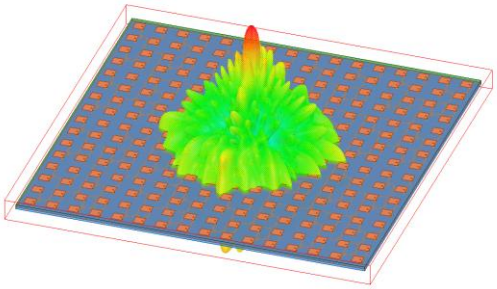




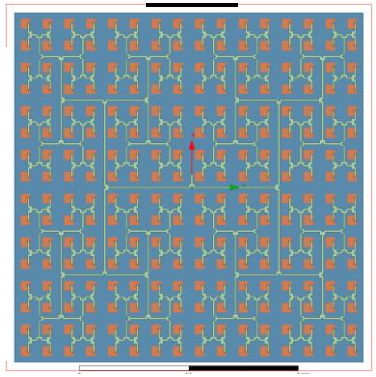


Wrapping option in SpaceClaim
Performance before and After

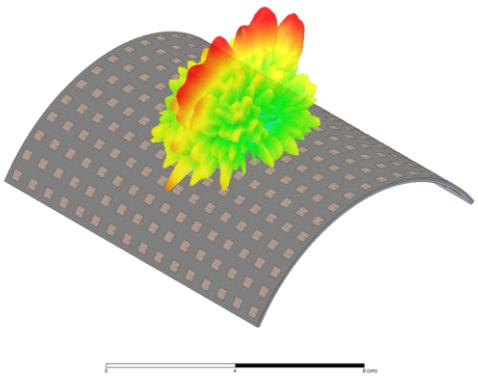
Front



Back



Front



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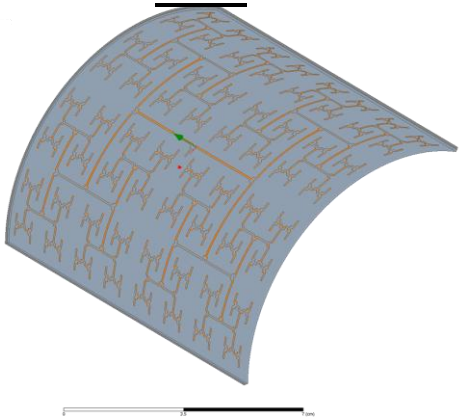
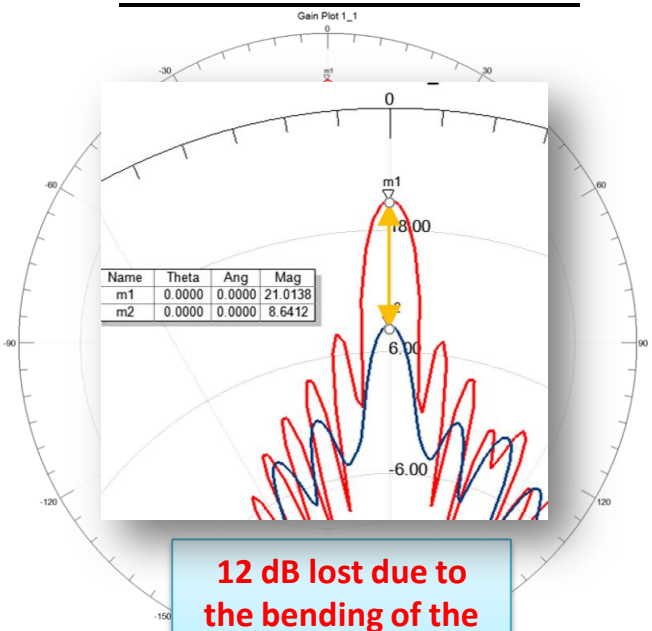
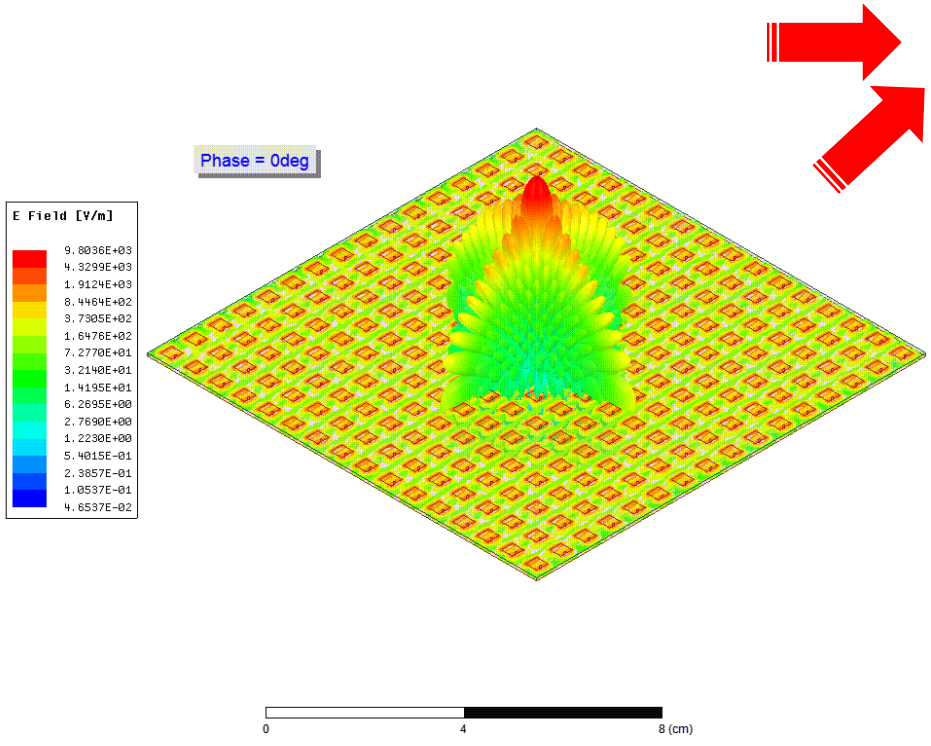


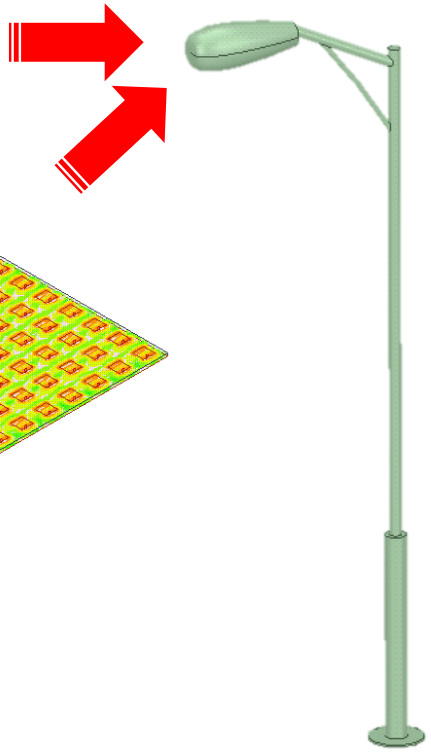
Radiation Pattern Effect



12 dB lost due to the bending of the array to conform to the light pole

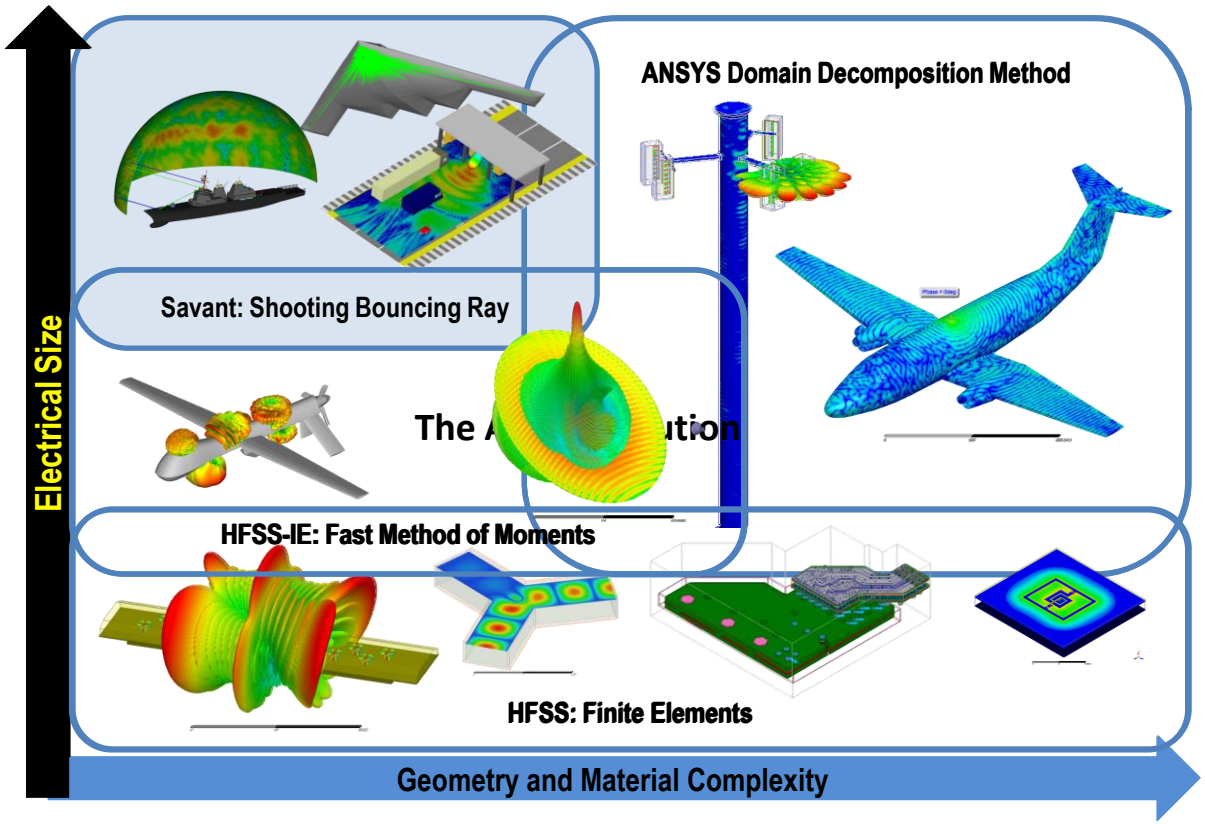
Array on Platform



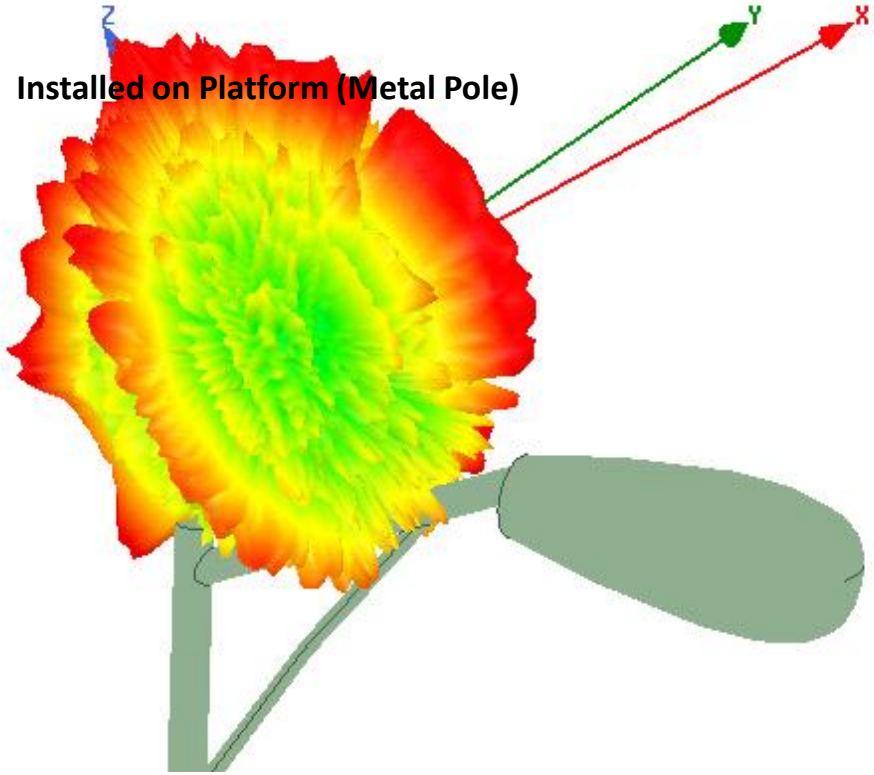


Electrically large environment (1400 λ)

HFSS Solver Overview



Array on Platform Results

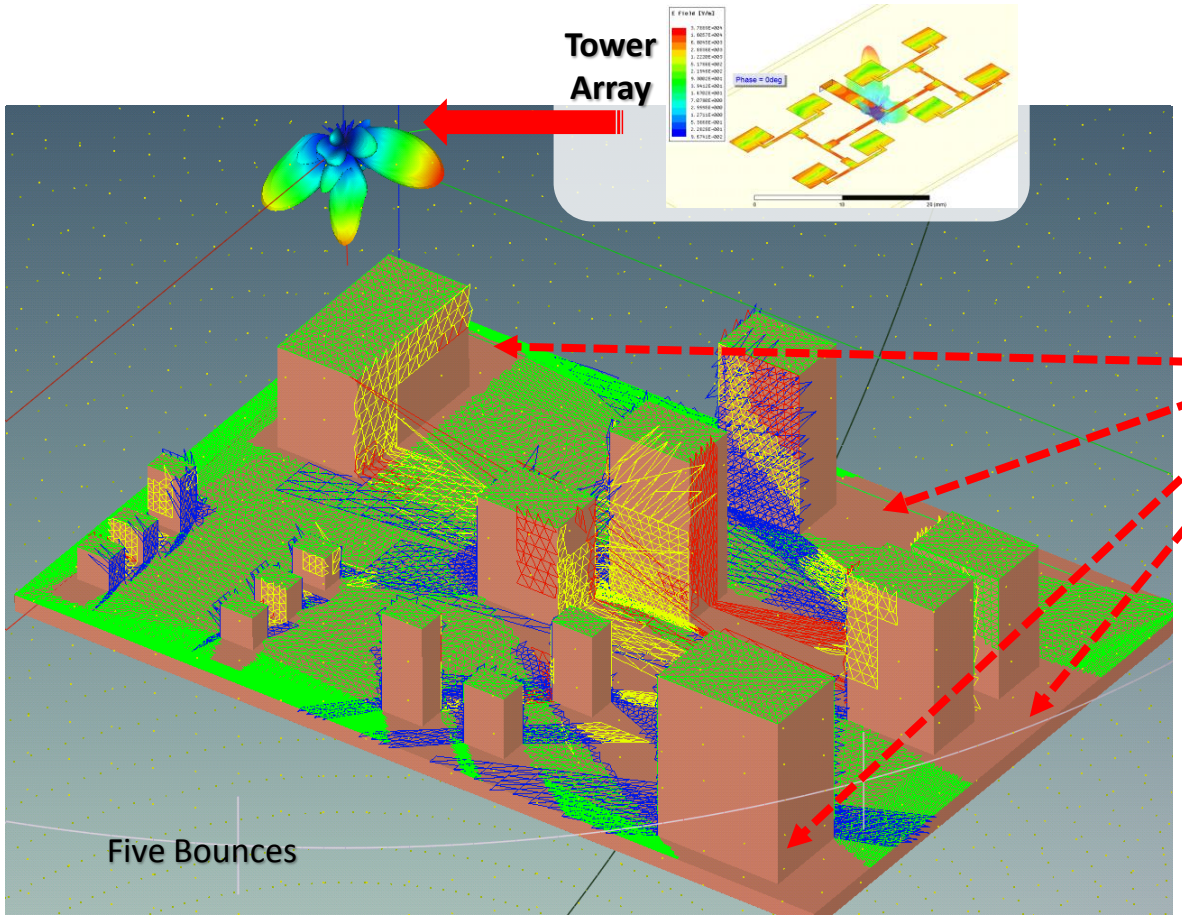


Installed on Platform (Metal Pole)

Far Field Link

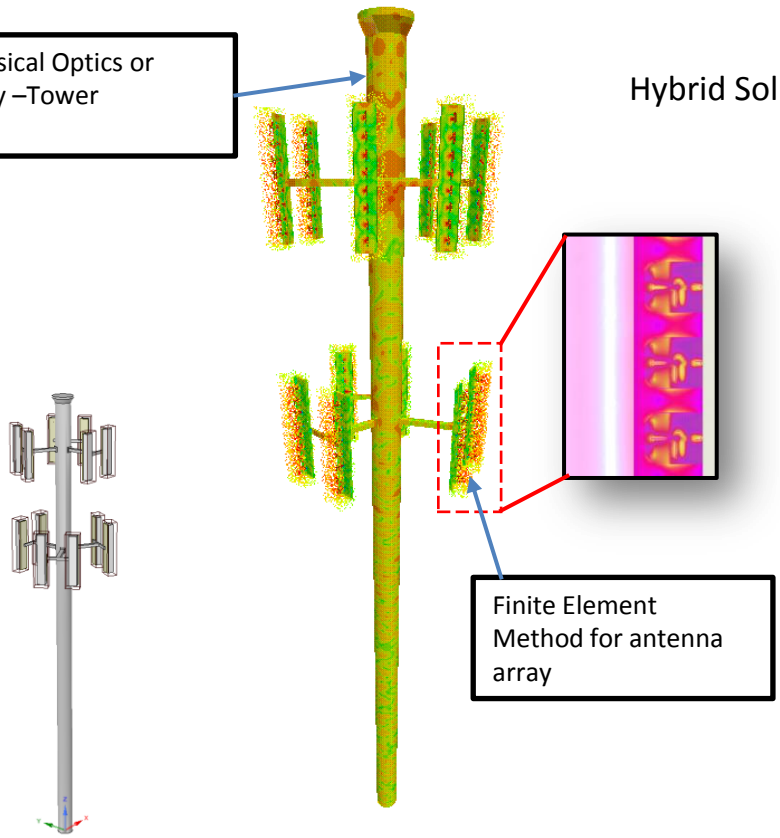
with SBR+

and GPU Accelerated


Tower Array
Dead Zones = No Coverage
Five Bounces

Advanced Electromagnetic Solution for Electrically Large Geometry: Fully Coupled Hybrid Solution

Integral Equation, Physical Optics or Shooting Bouncing Ray –Tower Geometry

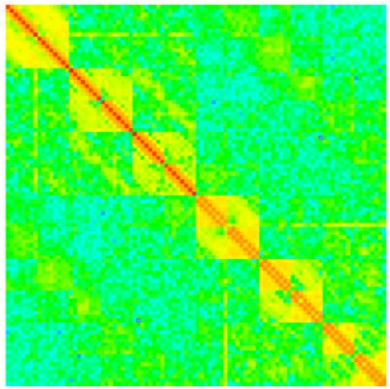


Finite Element Method for antenna array

Hybrid Solution

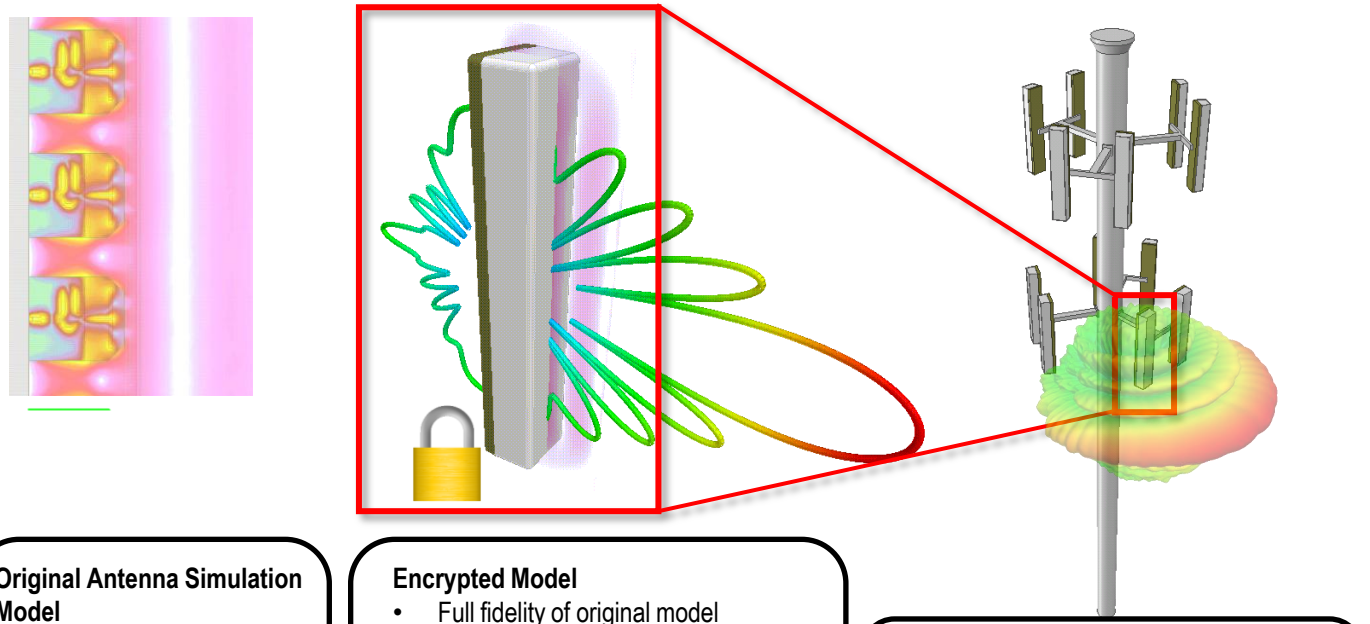
Combining multiple numerical techniques in a hybrid solution allows for most efficient solution to this electrically large complex problem

Fully coupled solutions



Coupling Matrix

Encrypted 3D Components



Original Antenna Simulation Model

- Geometry may contains sensitive IP that may make it difficult/undesirable to share with others

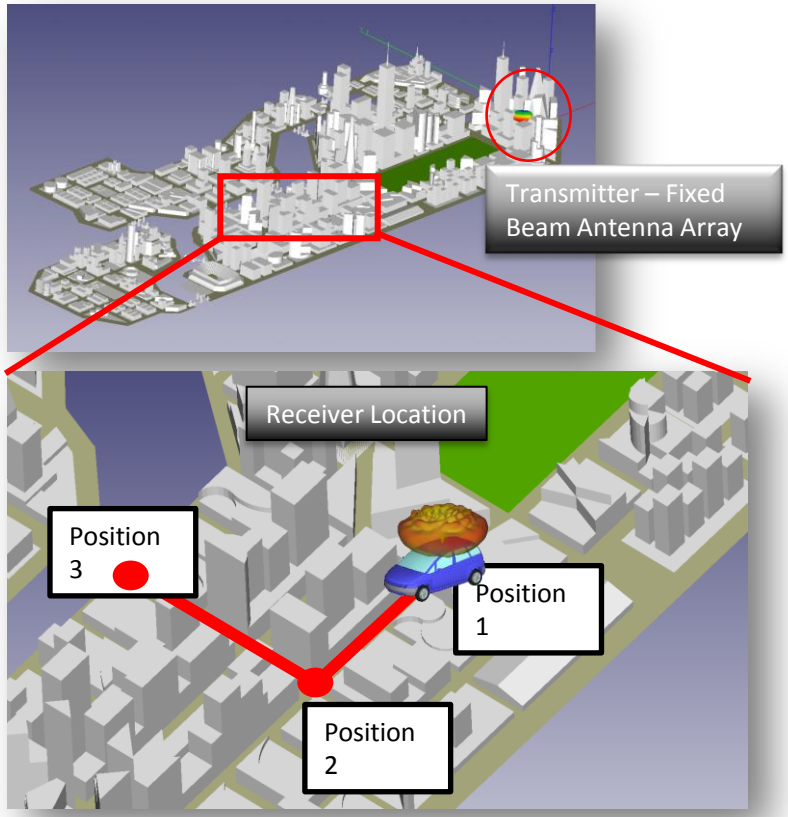
Encrypted Model

- Full fidelity of original model encapsulated and encrypted
- Visibility of geometry and fields are defined by original model creator
- 3D EM simulation

Installed Antenna Performance with Encrypted Model

- Maintains accuracy and details of original component, but without exposing sensitive IP

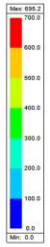
Large Scale Simulations with SBR: Received signal strength evaluation



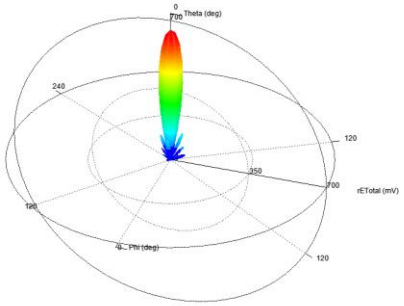
Electrically very large, multi-path environment

- **Observation of fading effects as receiver travels along path**
- **Reduced signal strength as receiver travels in direction with increased blockage**
- **Fixed antenna**

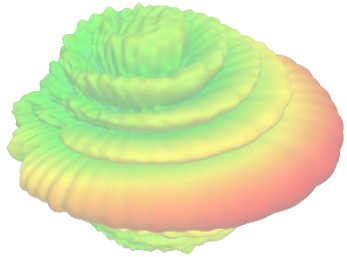
Adaptive Beamforming



Adaptive Phased Array Antenna for 5G



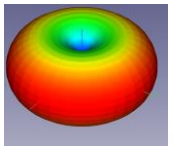
Fixed Beam Array Antenna typical in 4G



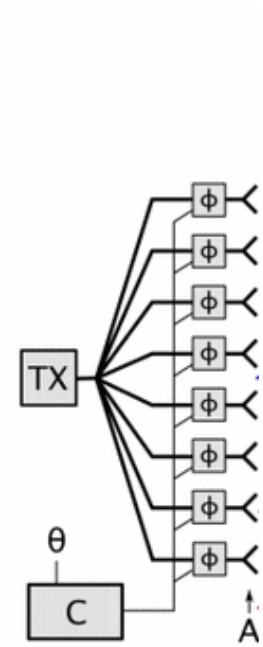
- 5G utilizes adaptive beamforming
  - Enabling technology multi-user massive MIMO
  - More efficient usage of radiated power

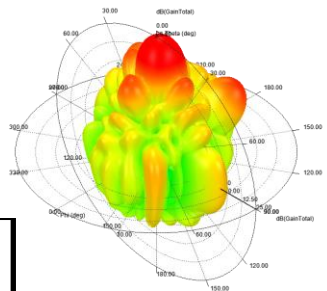
- **Fixed beam antenna systems**
  - **Limiting factor of many 3G/4G networks**

Adaptive Beamforming for 5G Applications



User Equipment (or terminal)



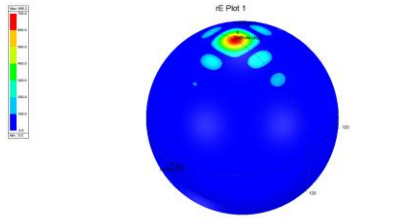


Phased Array

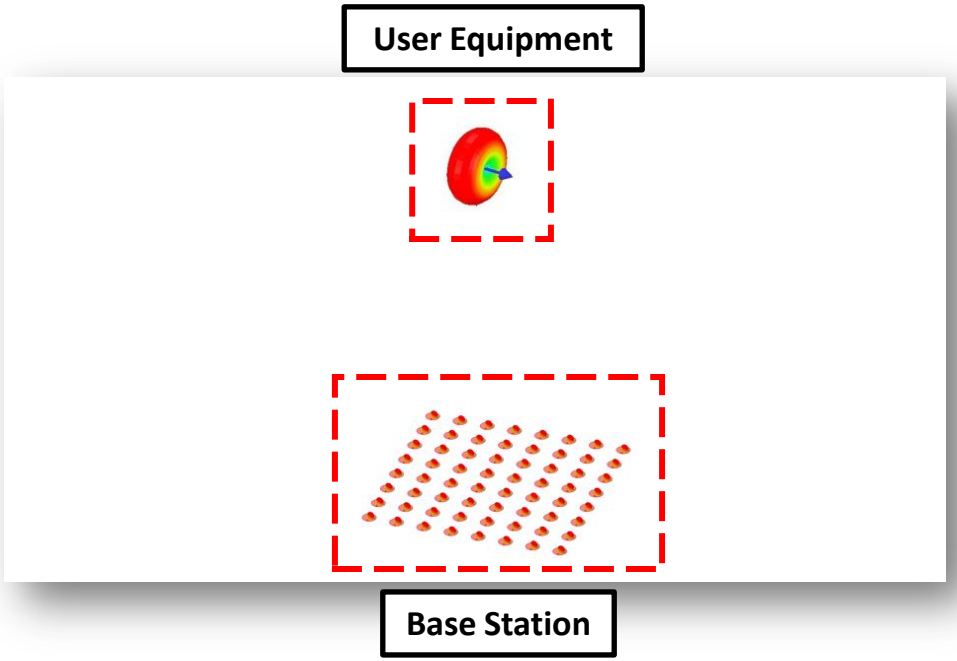
- Single User Beamforming Example
  - Channel State Information (CSI) simulated and captured from pilot signal from terminal (UE)
- Apply beamforming algorithm to drive phased array (including null steering if needed)
- Simulation result: received power and beam pattern required for user coverage

Adaptive Beamforming: Line of Sight Example

- Demonstration of adaptive beamforming algorithm implemented using a hybrid FEM-SBR solution
  - Phased array (Base station) solved using faDDM
  - Separation between UE and Base Station simulated using SBR solver
    - 100 meter separation at 28GHz (10,000λ)

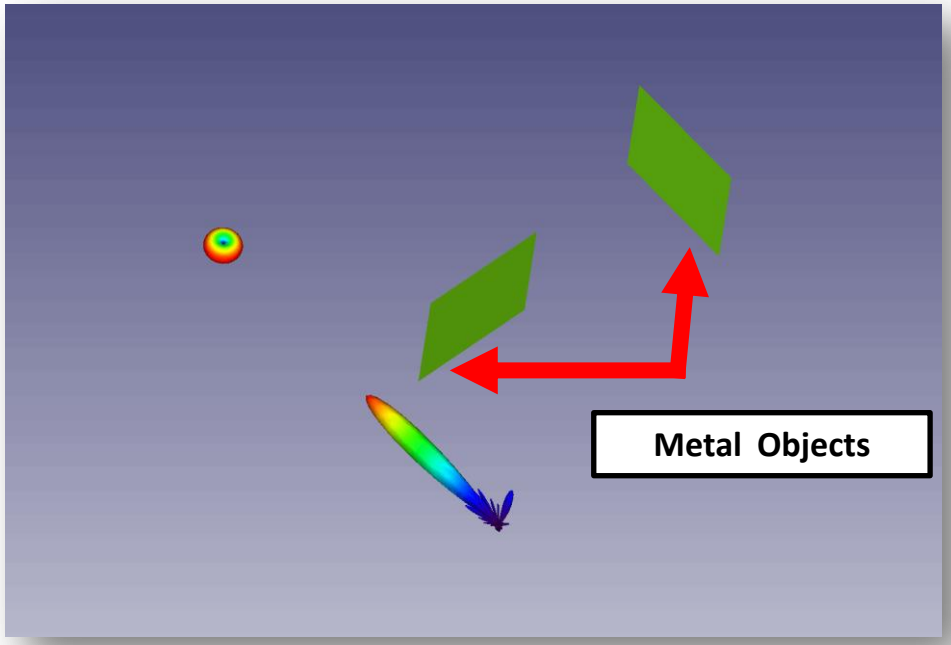


Base Station Gain Spherical Plot



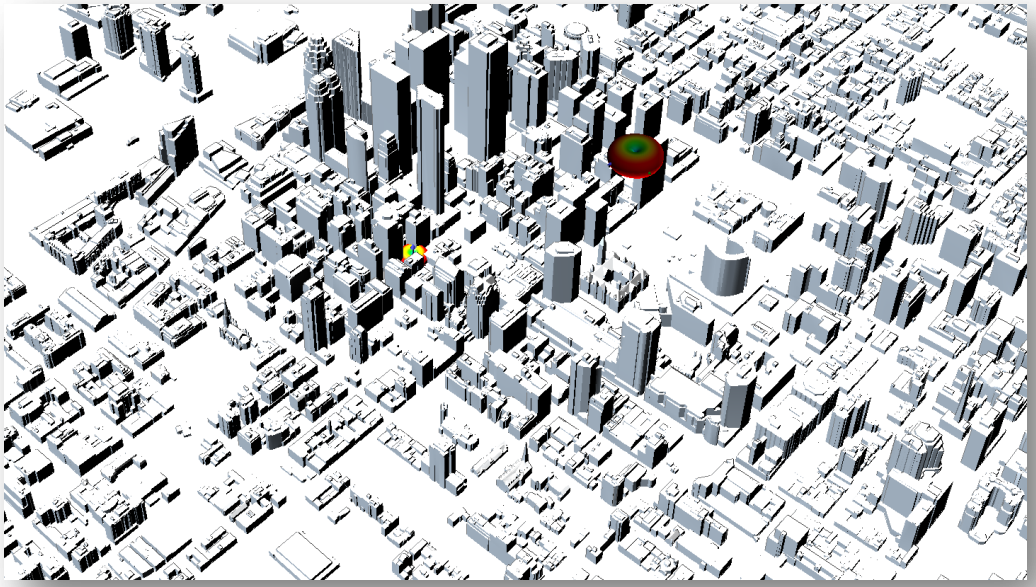
Adaptive Beamforming: Non-Line of Sight Example

- Demonstration of adaptive beamforming algorithm for dynamic scenario where LoS is temporarily blocked
  - Metal plate used to provide blockage and multi-path propagation potential
  - Secondary beam seen when plates transition across line of sight



Large Scale Simulation for 5G (28GHz) Base Station Performance

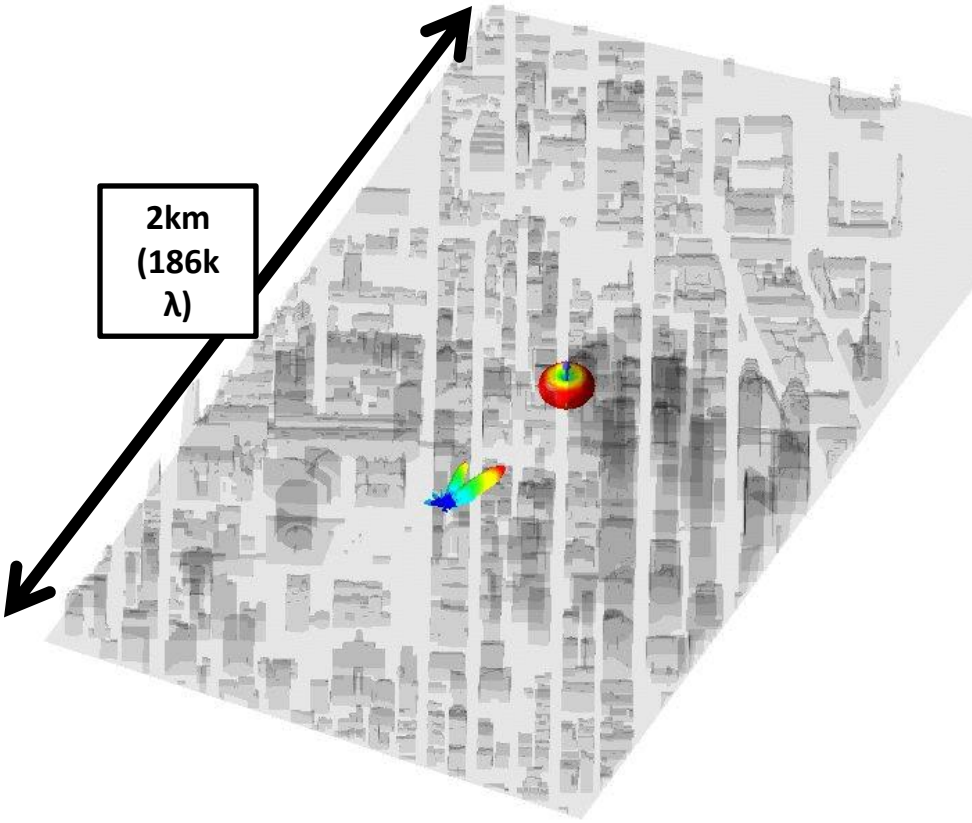
- Physics based simulation of large scale environments
  - Shooting Bouncing Ray (SBR) for efficient simulation of electrically large environment.
  - Accurate representation of antenna array through FEM simulation
- Evaluate system performance
  - Antenna Array
  - Site evaluation
  - Beamforming, null steering algorithms
  - Received power at user equipment
  - Base station to base station interference or unintentional jamming



Single User Beamforming: Received Power

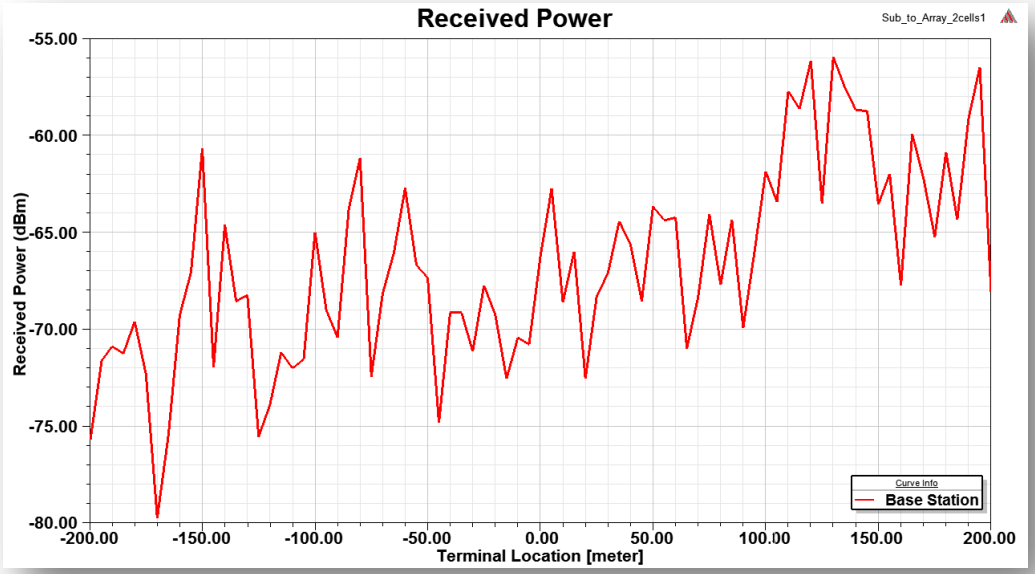
Adaptive beam for moving UE

- 64 Element Phased Array Antenna
  - 28GHz, microstrip path elements
- Line of sight and multi-path propagation contribute to received power
  - Smart antenna system beam steering
  - UE location ranges from 500 meters to 100 meters from base station



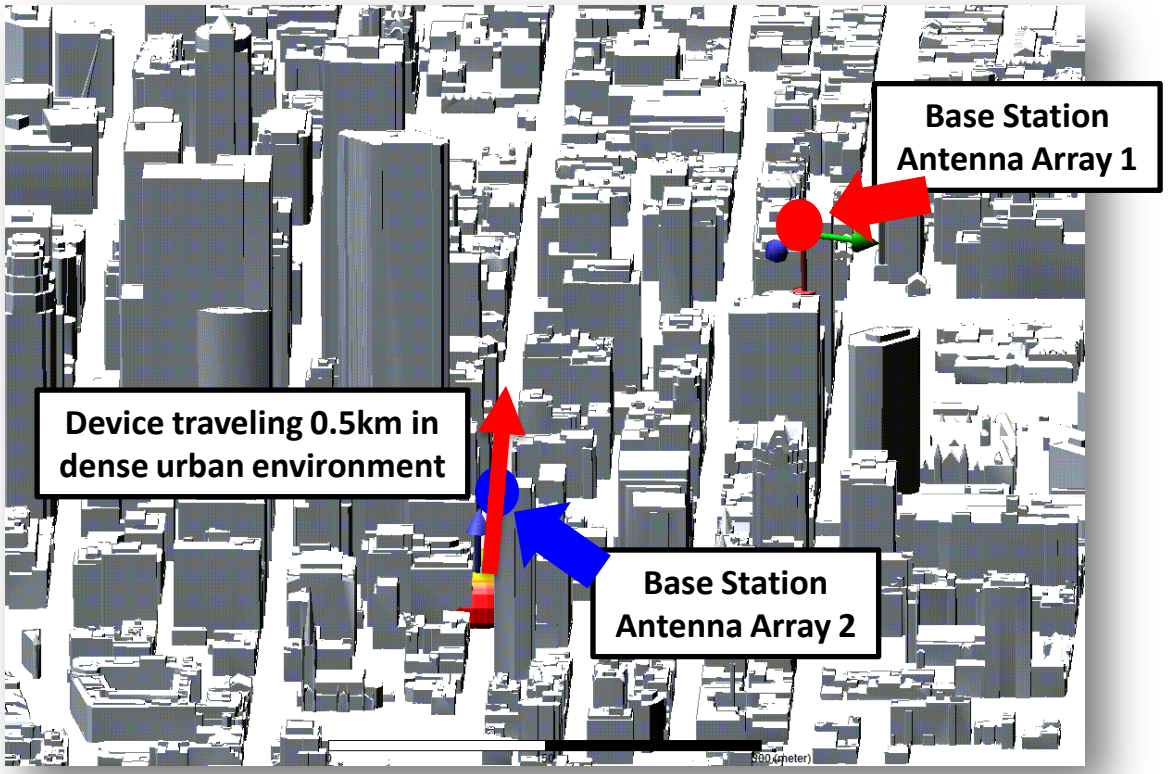
UE Received Power for Adaptive Antenna Array

- Power received by UE for path along city street
- Single user adaptive beamforming, no interference
  - Includes multi-path propagation
  - Up to 7 bounces (SBR solution setting)

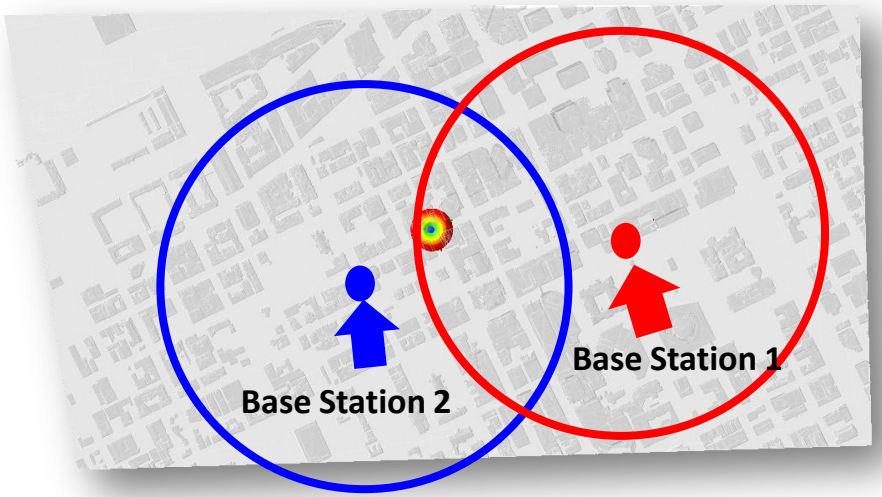


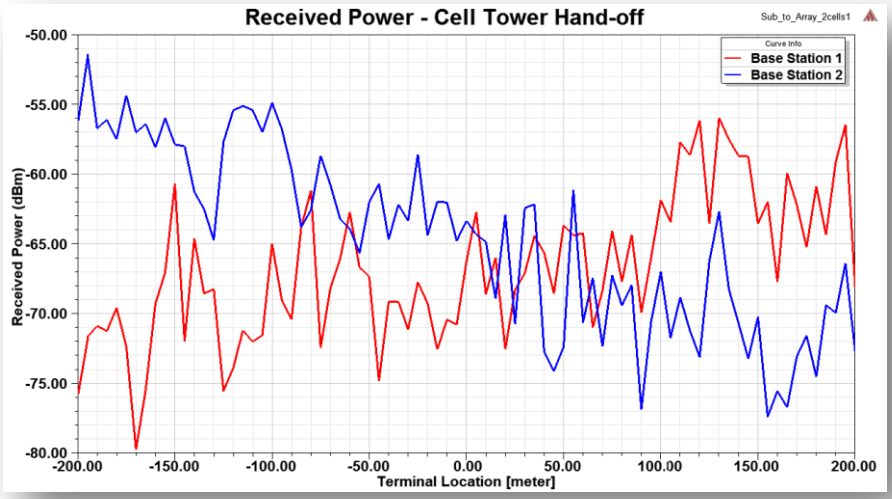
Base Station Handoff

- Device travels along street in dense urban environment
- UE travels between coverage zones of two base stations
  - Observe received power from both sites
- Site evaluation
- Base Station to Base Station Interference



Base Station Handoff: Received Power and Coverage Zones





Base stations approximate cell coverage zones

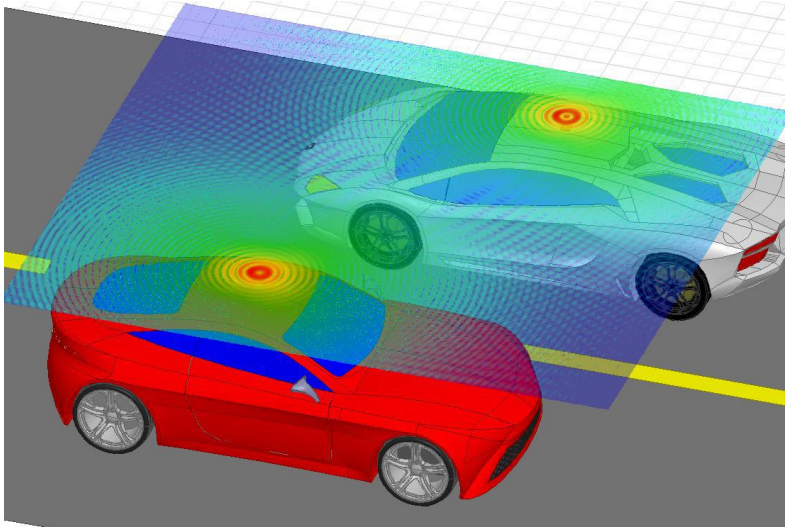
5G And Autonomous Vehicles

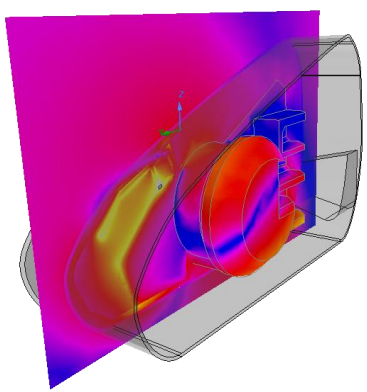
- According to Qualcomm CEO Steve Mollenkopf
  - Data from cameras and other sensors will be fused with V2X data, providing safer and improved autonomous operation.
  - 3D HD maps are an example. When combined with precise positioning, they'll be essential for safe navigation through changing environments.

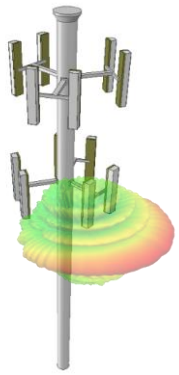
Steve Mollenkopf
CEO, Qualcomm

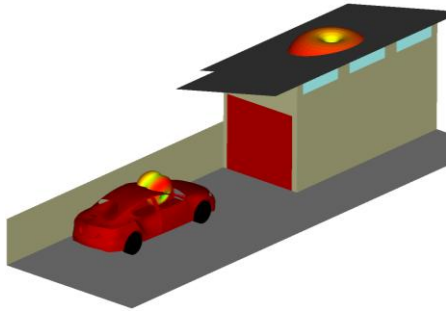
- Automotive V2V and V2I

Wireless Communications





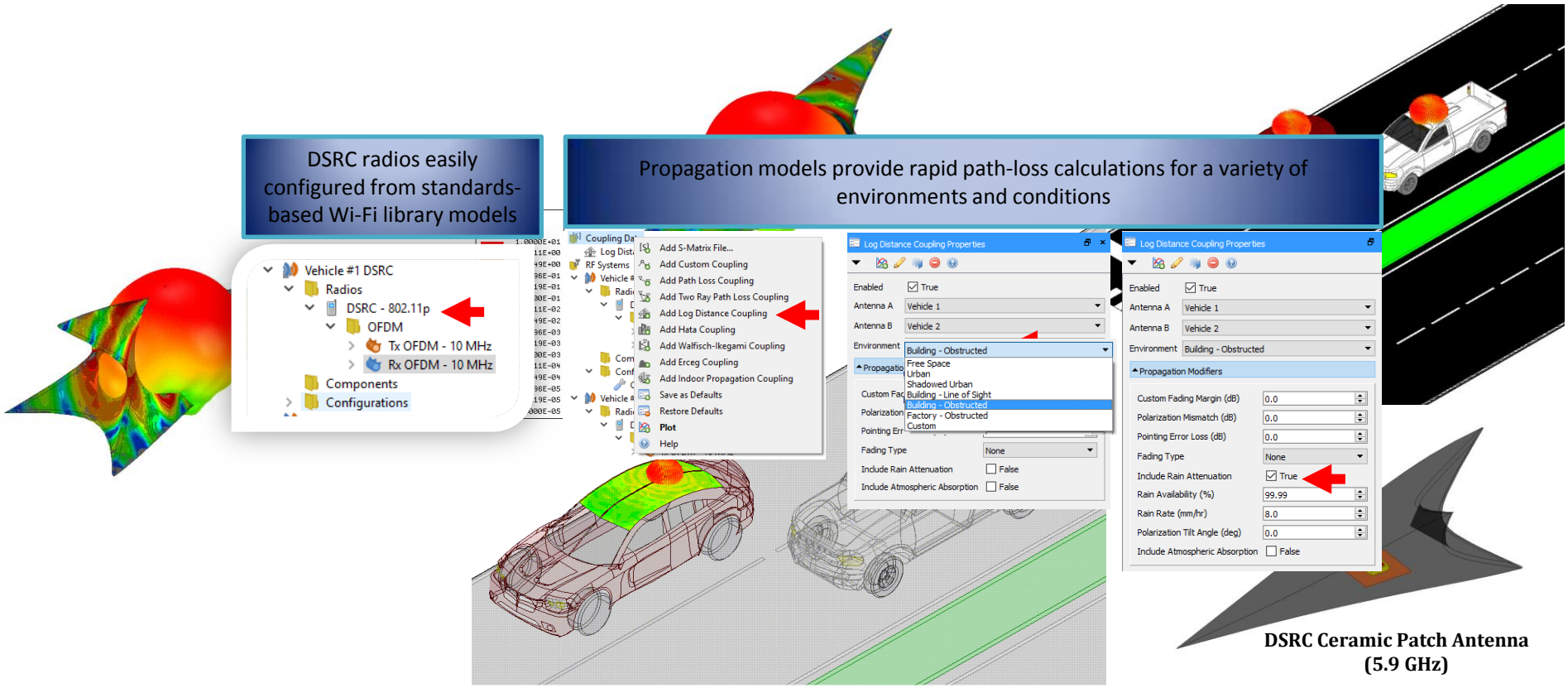




Engineering Design Challenges facing the IoT V2V Communication Systems …

DSRC radios easily configured from standards-based Wi-Fi library models

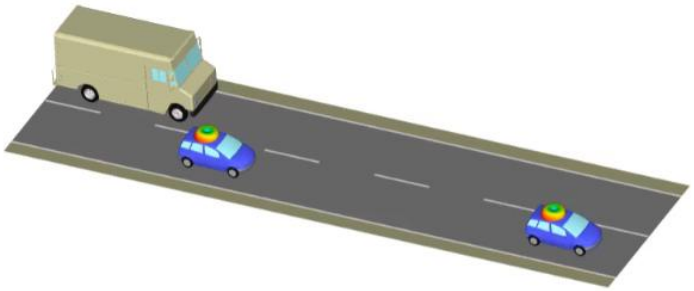
Propagation models provide rapid path-loss calculations for a variety of environments and conditions

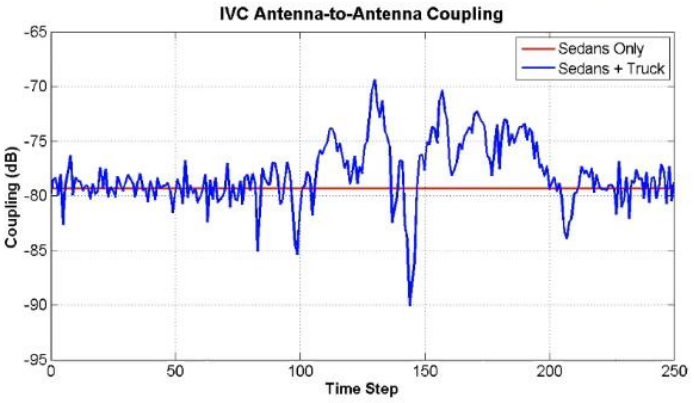


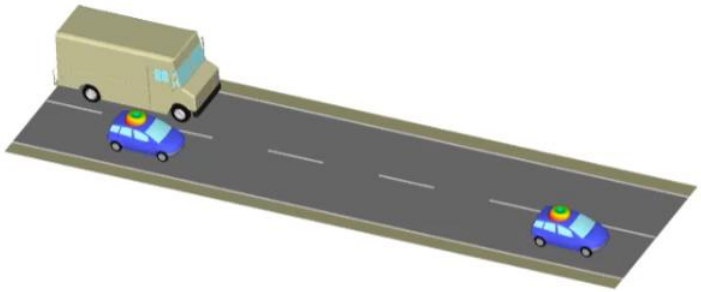
DSRC Ceramic Patch Antenna (5.9 GHz)

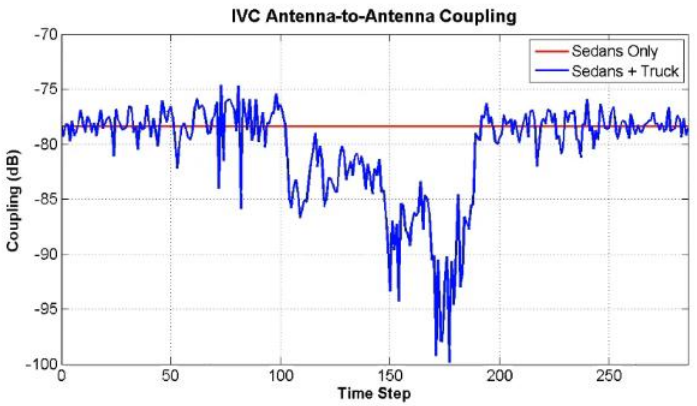
ANSYS AEDT HFSS / RF Option (EMIT)

5.9 GHz Antenna System Simulations

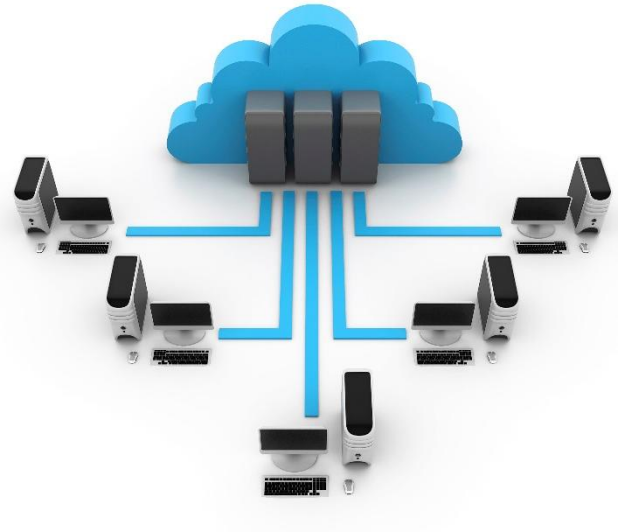








Thank You!!!



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