Understanding MIMO OTA Testing: Simple Solution to a Complex Test

Moderated by
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ETS-Lindgren

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Microwave Journal
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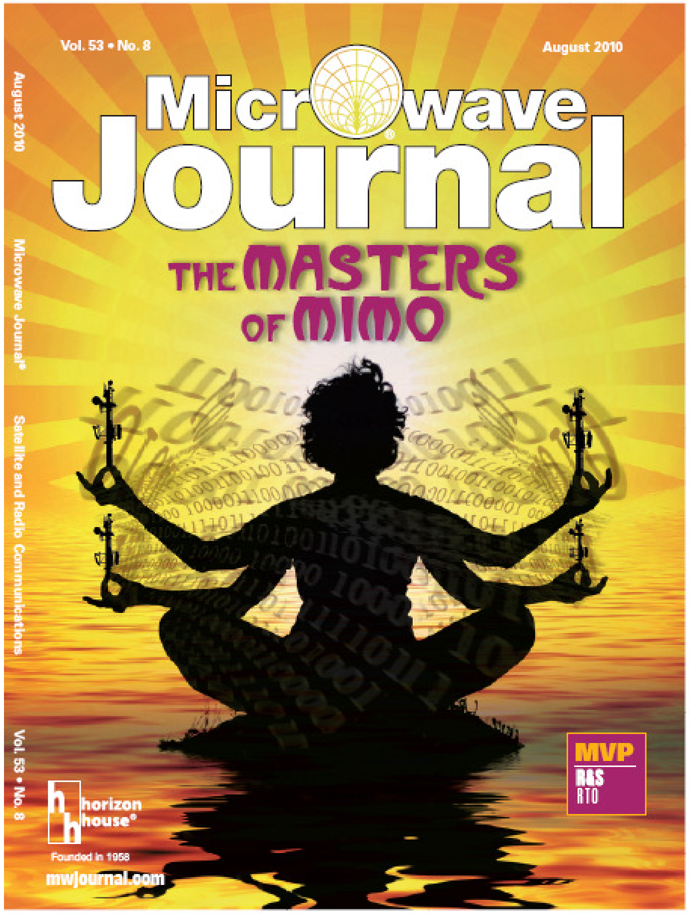
The Growing Importance of the Mobile Phone Antenna

August 2010 MWJ Cover feature:

- MIMO multiplies the number of required antennas, 2x, 4x...
- Multi-band phones multiply the number of antennas
- Devices sizes are shrinking
- Antenna design is getting very hard!
- And yet there are no MIMO test methods or performance targets



Testing MIMO Performance OTA "Over The Air"

CTIA, COST273 and RAN WG4 developed test methods and performance requirements for SISO

The work on SISO OTA took many years to finalize. The figures of merit are:

TRP - Total Radiated Power

TIS – Total Isotropic Sensitivity (TRS)

CTIA, COST2100 and 3GPP RAN WG4 are now investigating methods for testing the radiated performance of MIMO devices

MIMO performance is much more complicated than SISO!
It is a function of the complex antenna patterns, the propagation channel, baseband algorithms, noise and interference

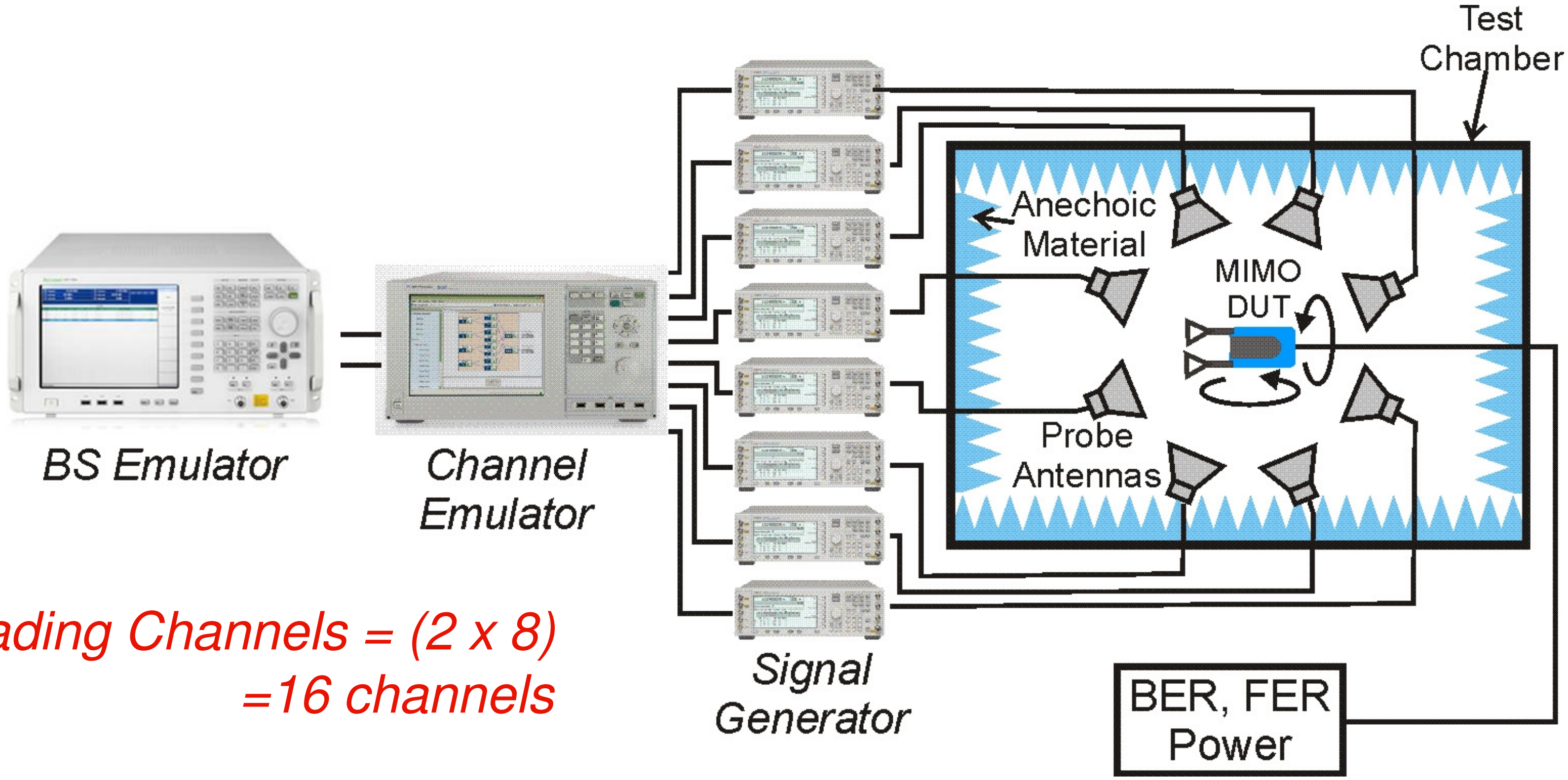
MIMO OTA Test Methodologies

Many test methodologies have been proposed for the study item

They can be grouped into three main methods:

1. Multi-antenna anechoic chamber methods
   - Configurations vary from simple two antenna up to as many as 16 dual polarized antennas
2. Reverberation chamber methods
   - These vary from simple single chamber to more complex multi-chamber with or without the addition of a fading emulator
3. Antenna pattern method and two-stage method
   - Antenna-only methods and the more advanced two-stage method involving throughput measurement

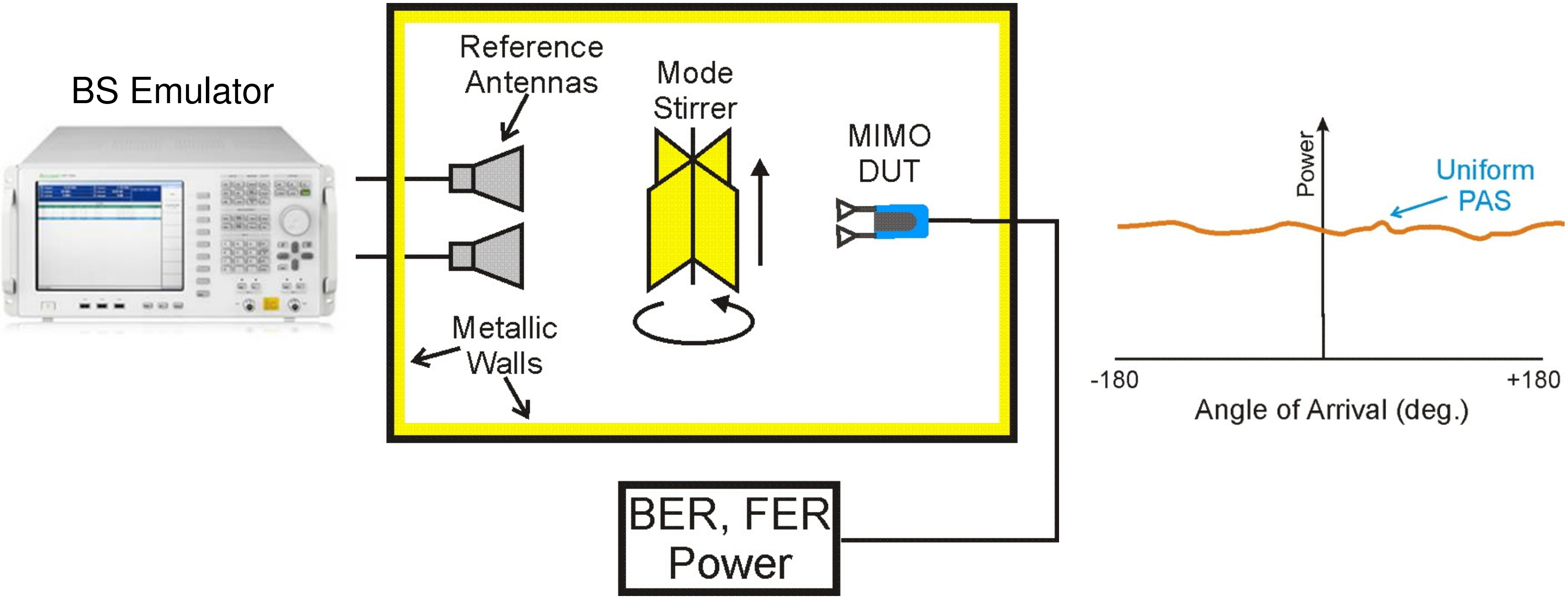
Multi-antenna Anechoic Methods



Fading Channels = (2 x 8)
=16 channels

- Conceptually simple
- Requires precise system calibration
- Many probes (16?) in full circle required for arbitrary channel emulation
- Full circle requires large chamber (single cluster is smaller)
- Full 3D channel emulation is a challenge, partial 3D may be possible

Reverberation Chamber Methods

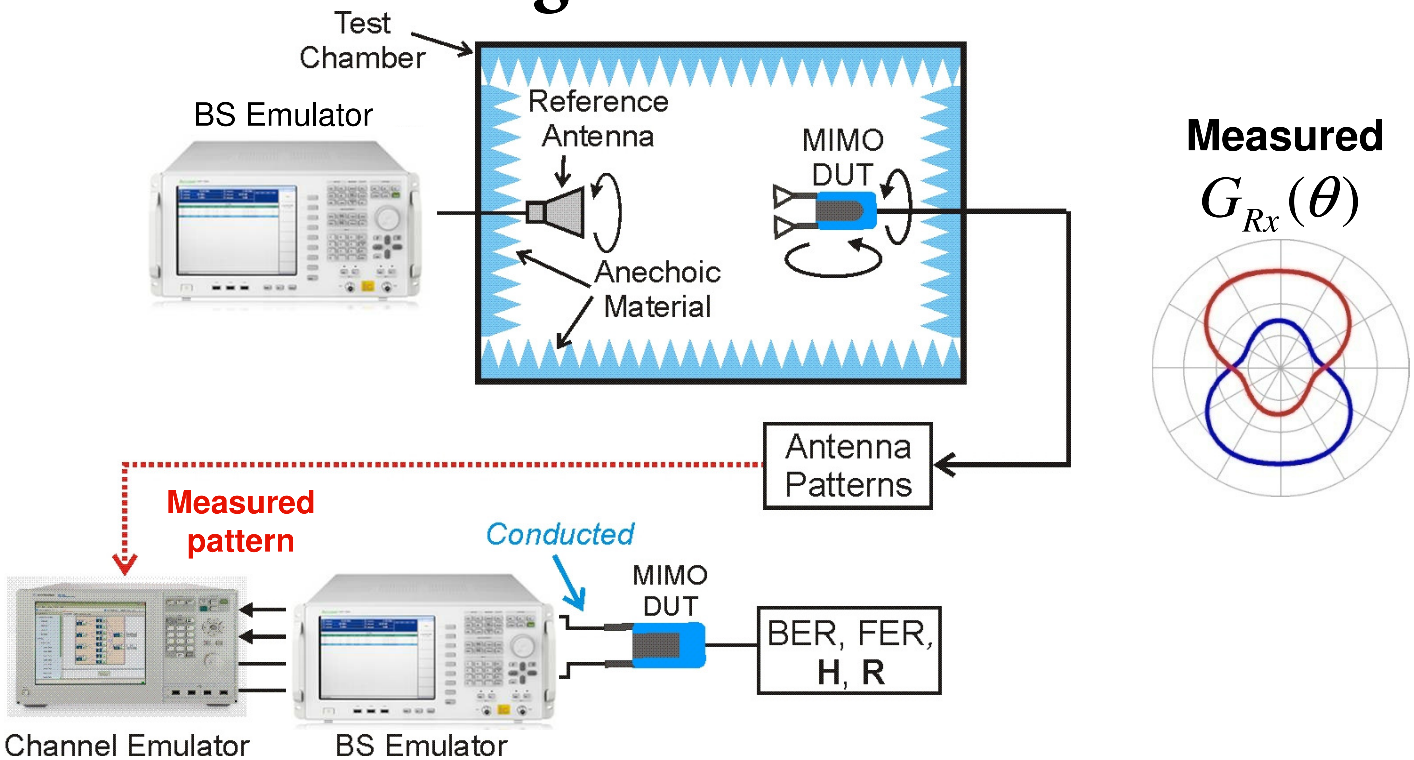


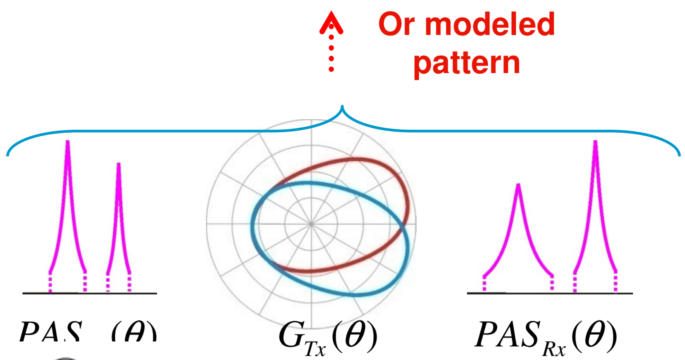
- The basic power delay profile (PDP) is modified using absorbers
- Adding a channel emulator can further modify the PDP
- Chambers can also be cascaded to create directional content
- Cost effective
- Good for assessing self-blocking
- Limited ability to generate standard channel profiles

Antenna Pattern and Two-stage Method

Stage 1
Antenna pattern measurement

Stage 2
Throughput measurement





- Fast and very cost effective
- Uses standard SISO anechoic chamber
- Can models any 2D or 3D channel using correlation or geometry methods
- Does not currently measure self-blocking
- Requires UE test mode for non-intrusive

Today's Program

- **MIMO OTA Antenna Measurements**

  Doug Reed, Solutions Architect, Spirent Communications

- **Radio Channel Aspects**

  Jukka-Pekka Nuutinen, Research Manager, Elektrobit

- **Multi-path Environment Simulator**

  Michael Foegelle, Dir. Of Technology, ETS-Lindgren

- **OTA Test Challenges and the Two-stage Methodology**

  Moray Rumney, Lead Technologist, Agilent

- **30 minute panel discussion with Q&A from live and webcast audience members**

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Introduction to OTA Testing of MIMO Devices and the AMS-8700 Multipath Environment Simulator

Dr. Michael D. Foegelle
Director of Technology Development
ETS-Lindgren

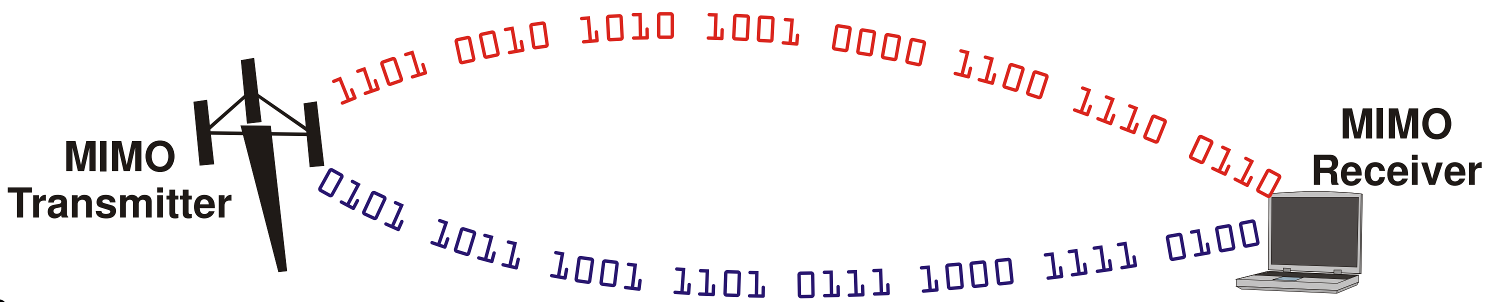
3/24/2011

Outline

- Multiple Antenna Technologies
- Spatial Environment Simulation
- System Validation
- Throughput Measurement Results

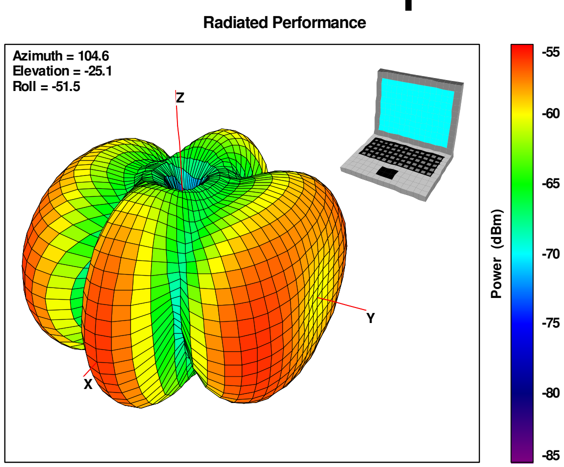
Multiple Antenna Technologies

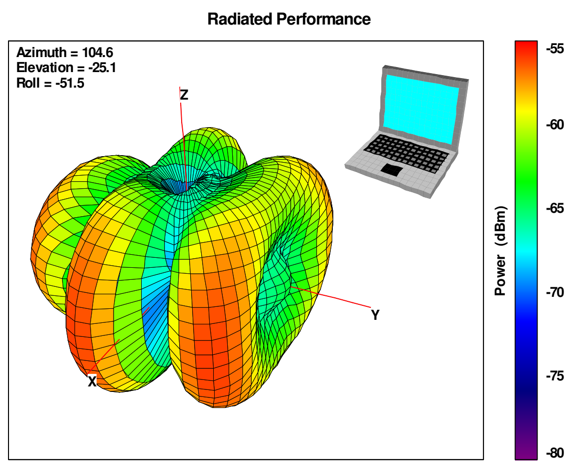
- New wireless technologies use more than one antenna on the same radio to improve performance.
- “Smart” software algorithms combine the signals to create the best performance.
- MIMO stands for *Multiple Input, Multiple Output* and refers to multiple TX and RX antennas used to increase bandwidth.

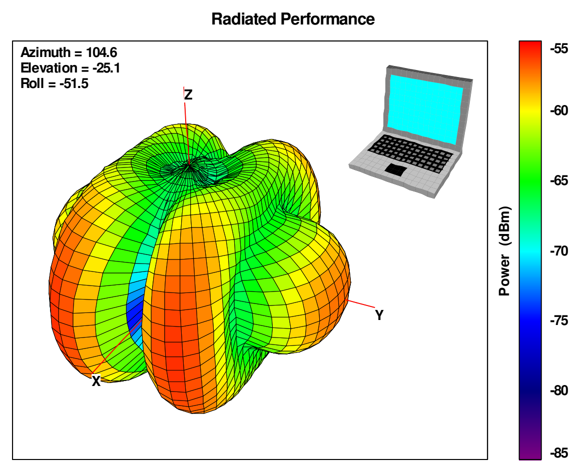


MIMO and the RF Environment

- All of these multiple antenna technologies share one thing in common – their performance is a function of the environment in which they're used.
- The device adapts to its environment through embedded algorithms that change its (effective) radiation pattern.

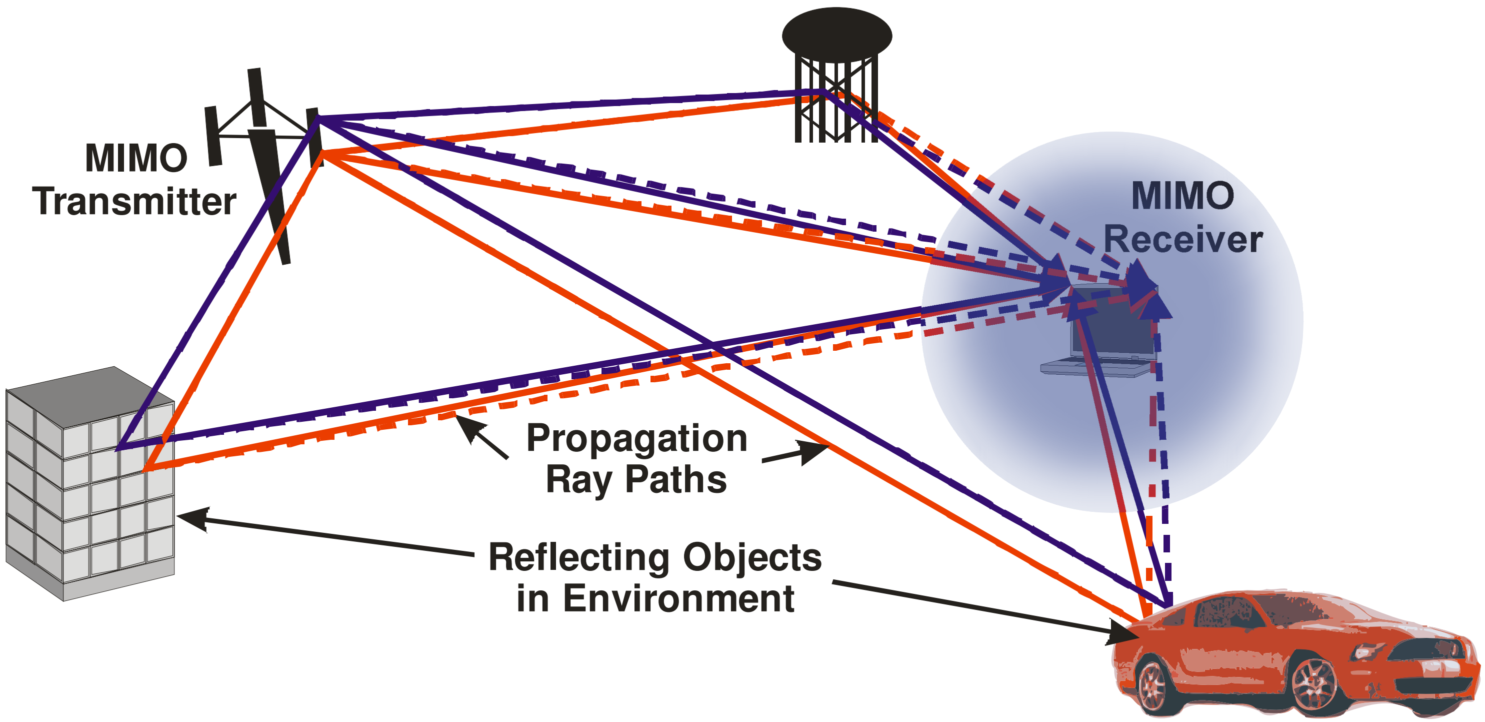






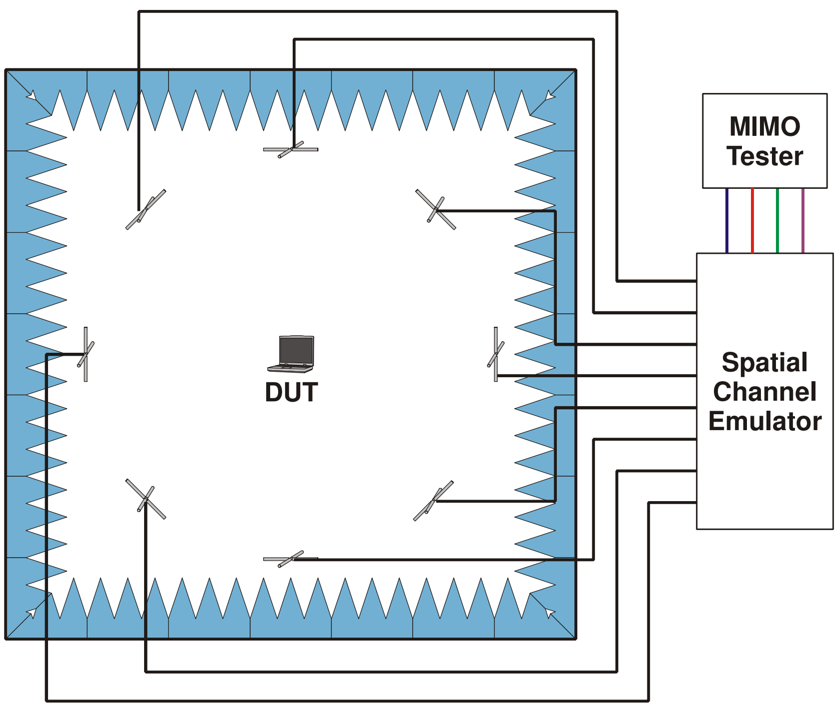
Spatial Environment Simulation

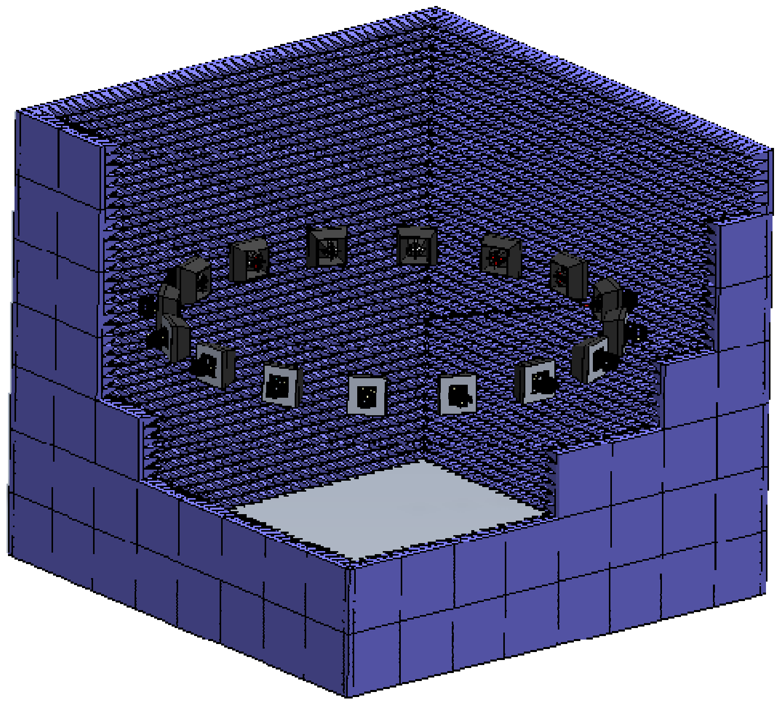
- The goal of the OTA Environment Simulator is to place the DUT in a controlled, isolated near field environment and then simulate everything outside that region.



Spatial Environment Simulation

- A spatial channel emulator (a channel emulator with modified channel models) simulates the desired external environment between BSE and DUT.

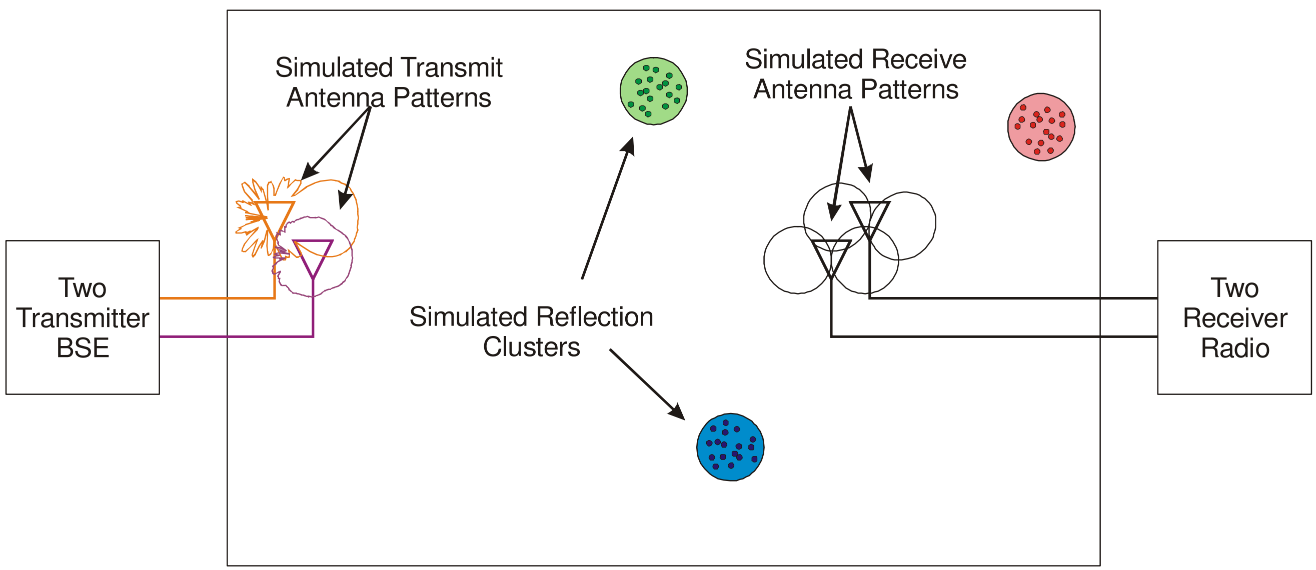




Spatial Environment Simulation

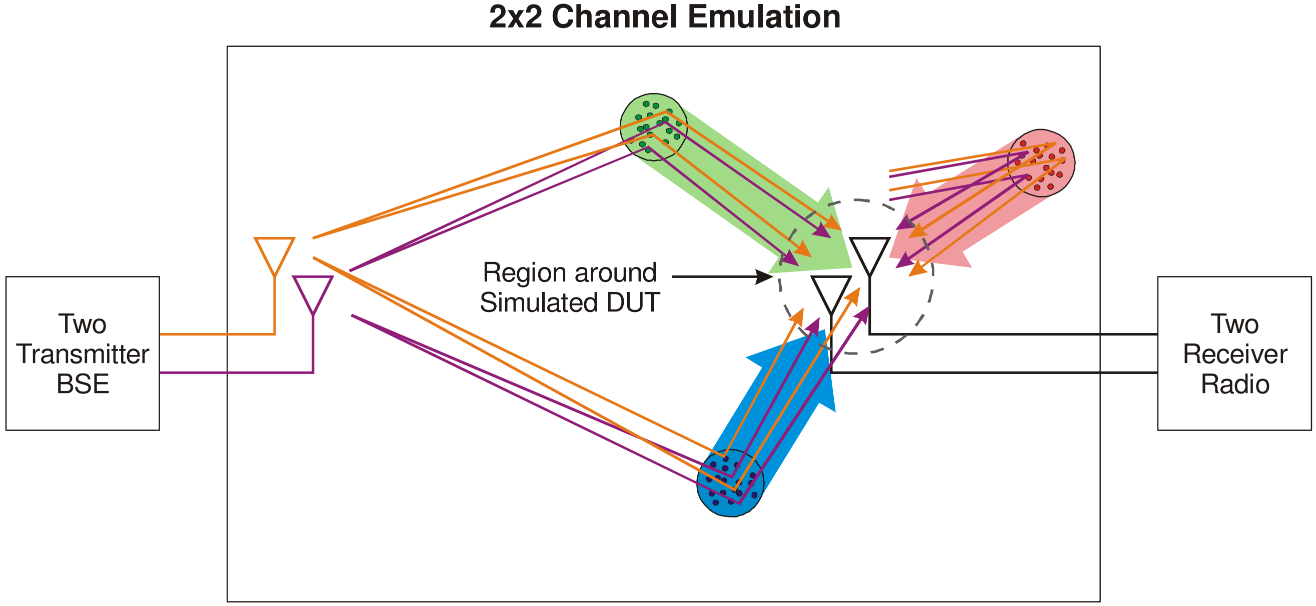
- Converting a conducted channel model to an OTA channel model:
  - Conducted model simulates TX and RX antennas.

2x2 Channel Emulation



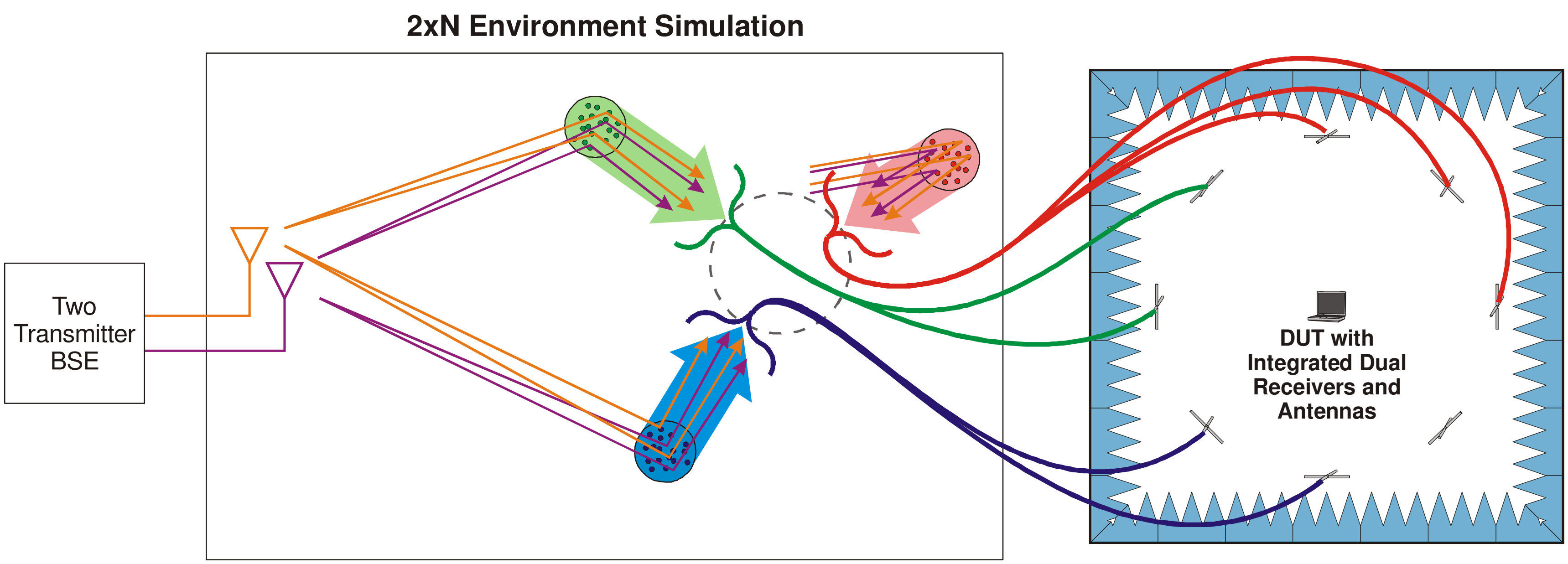
Spatial Environment Simulation

- Converting a conducted channel model to an OTA channel model:
  - Grouping AOAs, we can remove virtual RX antennas.



Spatial Environment Simulation

- OTA channel model:
  - 2xN channel emulator used to feed N antennas for AOA simulation around DUT with real antennas.

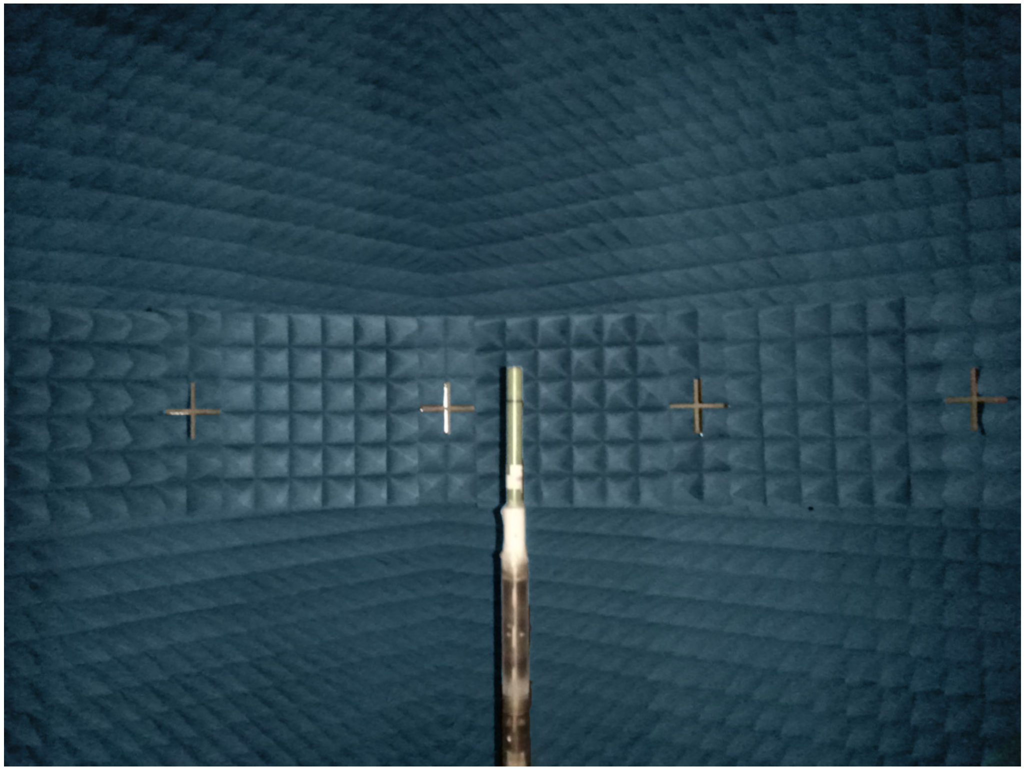


Spatial Environment Simulation

- Ideally, the sphere around the DUT would define a perfect boundary condition that exactly reproduces the desired field distribution inside the test region.
- Practicality and physical limitations impose restrictions that create a less than ideal environment simulation.
- The chosen number of antenna positions limits the available range of "Real" propagation directions.
- Splitting clusters across discrete antennas does not produce true plane wave behavior in test region.
  - Results in an interference pattern with wave-like distribution in center of test region.

System Validation

- A re-configurable MIMO OTA system with 16 dual polarized antennas and two 8-output channel emulators was evaluated.



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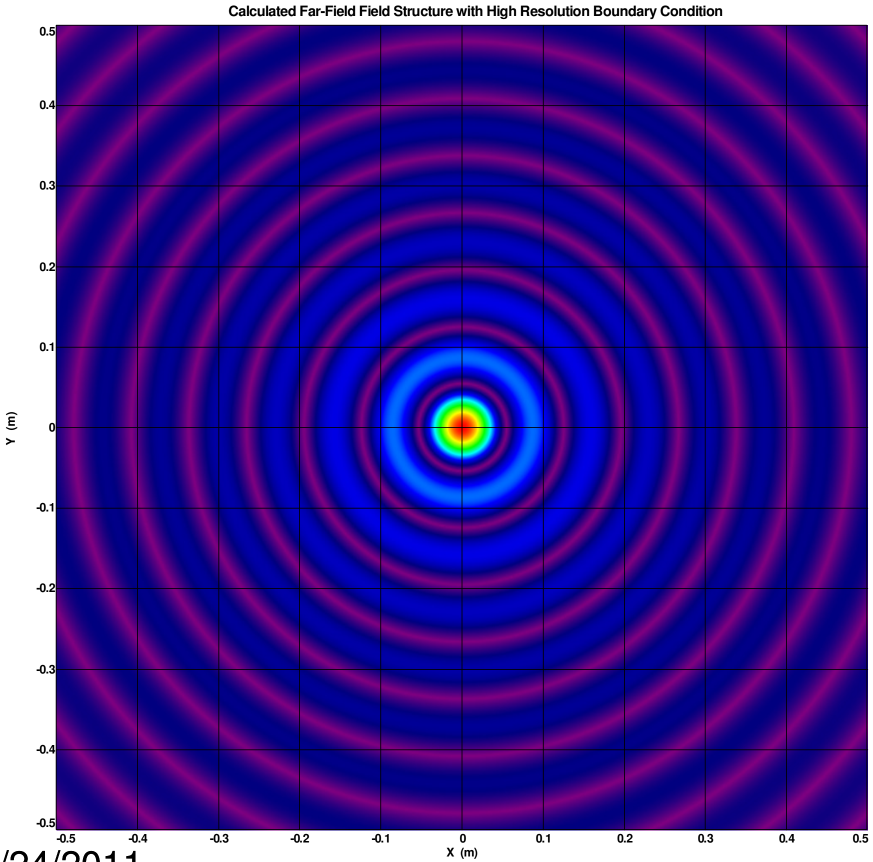
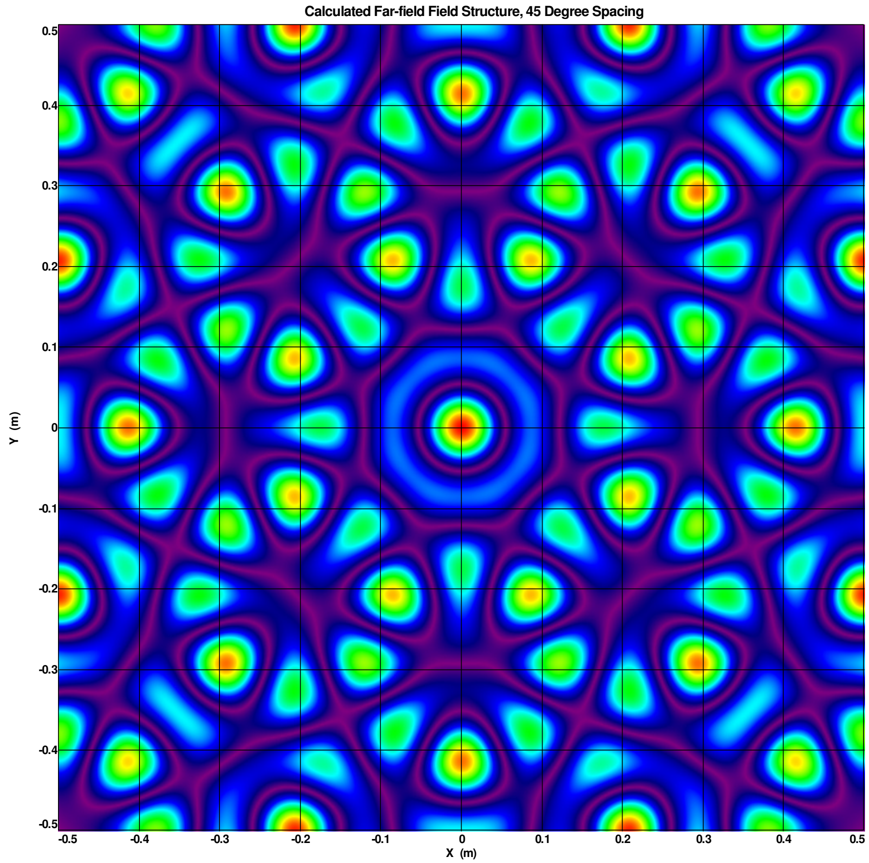
System Validation

- Spatial Field Mapping is used to compare the measured environment to a theoretical model.

Ideal Free-Space or Continuous Boundary Condition



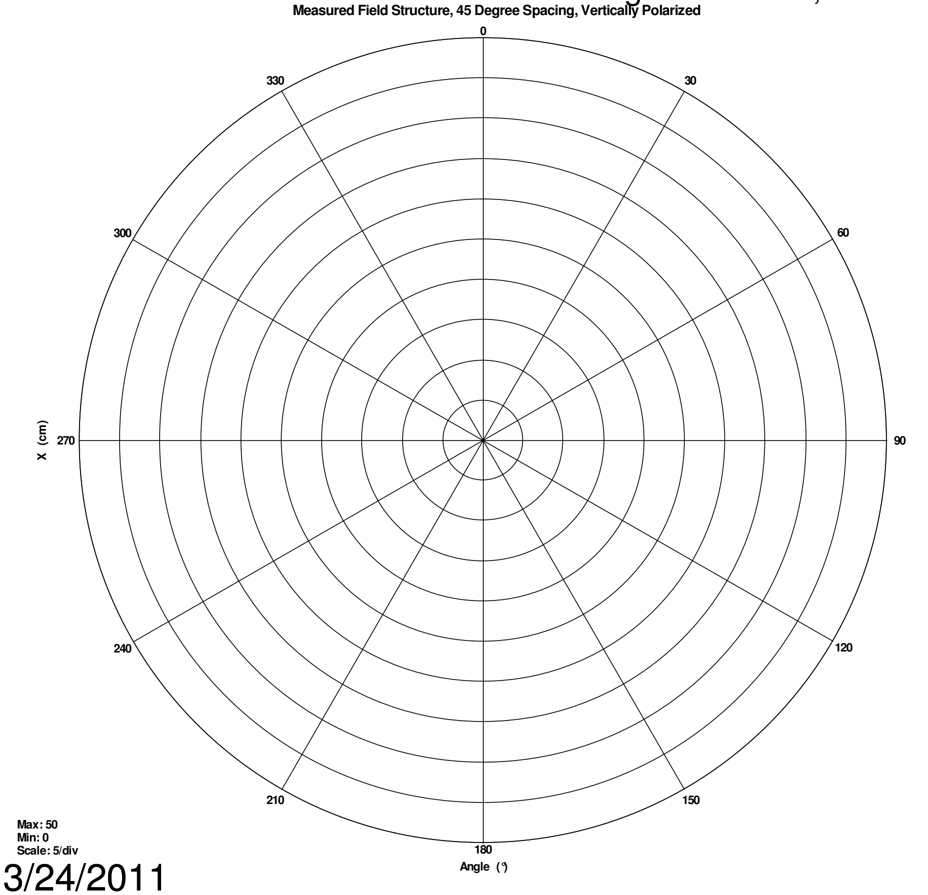
Interference Pattern from Eight Evenly Spaced Plane Waves



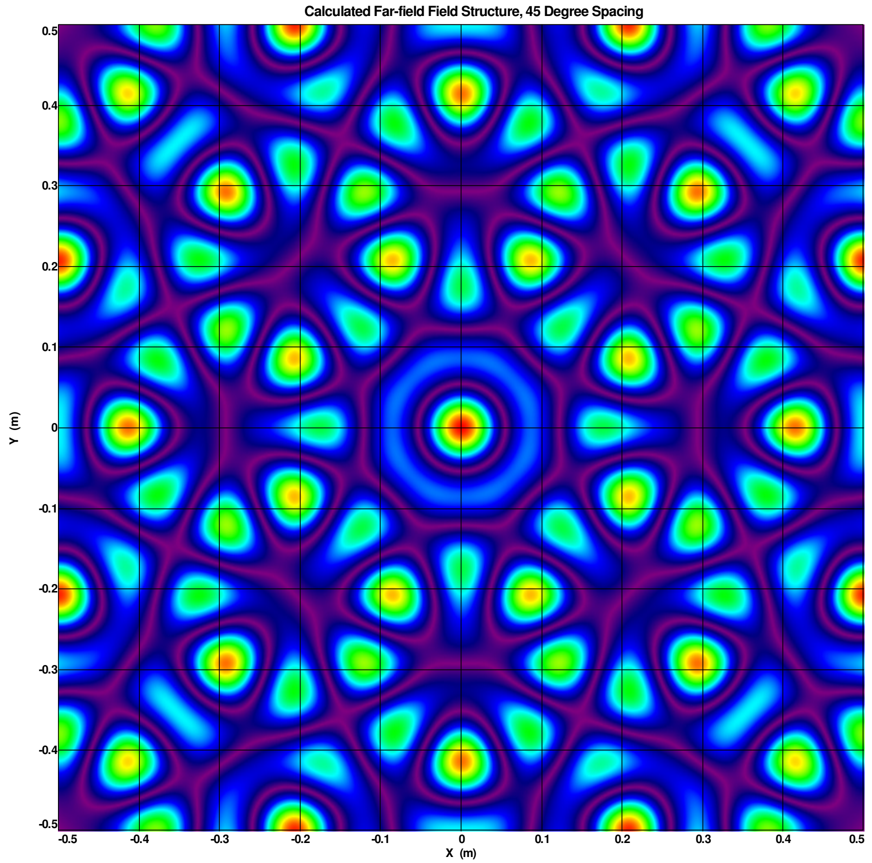
System Validation

- Measurement shows differences from plane wave interference pattern.

Measured Interference Pattern from Eight Antennas, r = 2 m



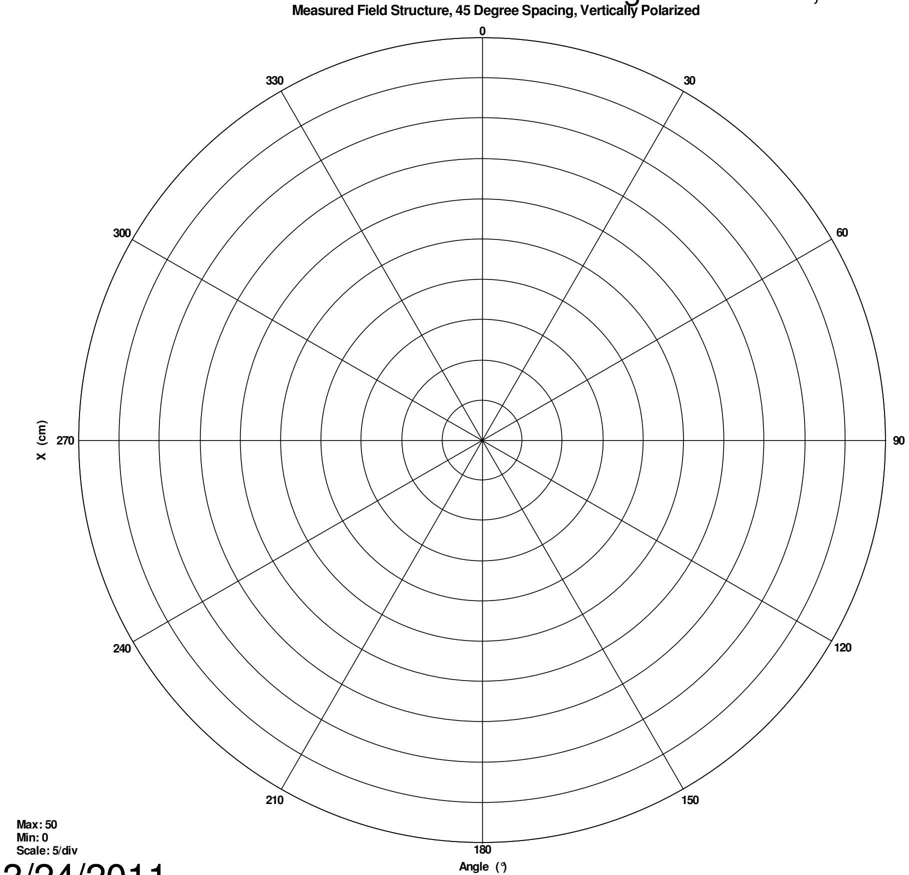
Interference Pattern from Eight Evenly Spaced Plane Waves



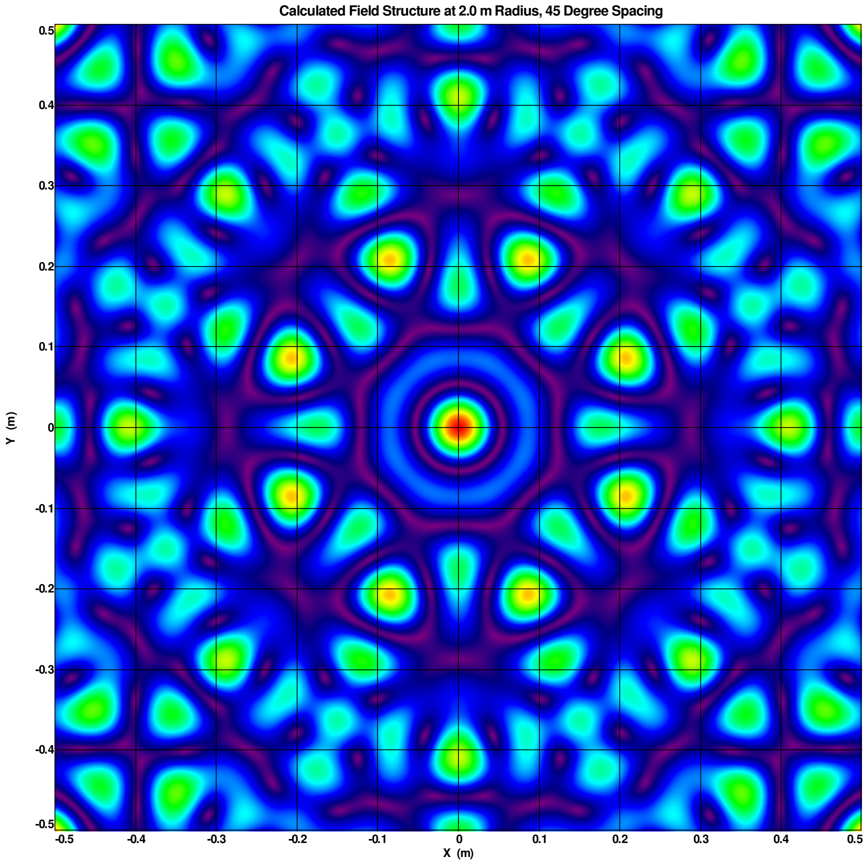
System Validation

- Modeling a 2 m range length instead of a plane wave shows excellent correlation.

Measured Interference Pattern from Eight Antennas, r = 2 m



Calculated Interference Pattern from Eight Antennas , r = 2 m



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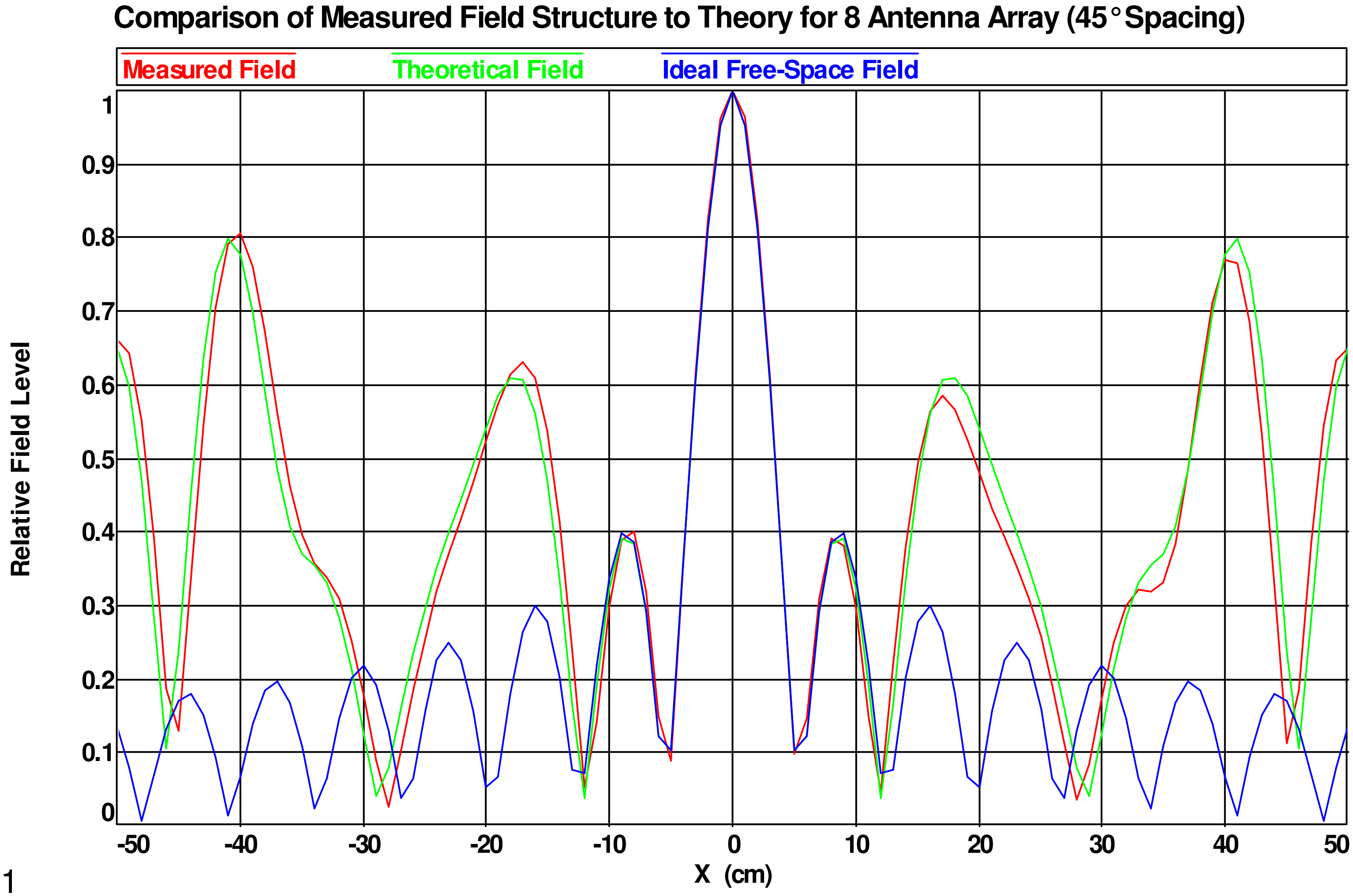
System Validation

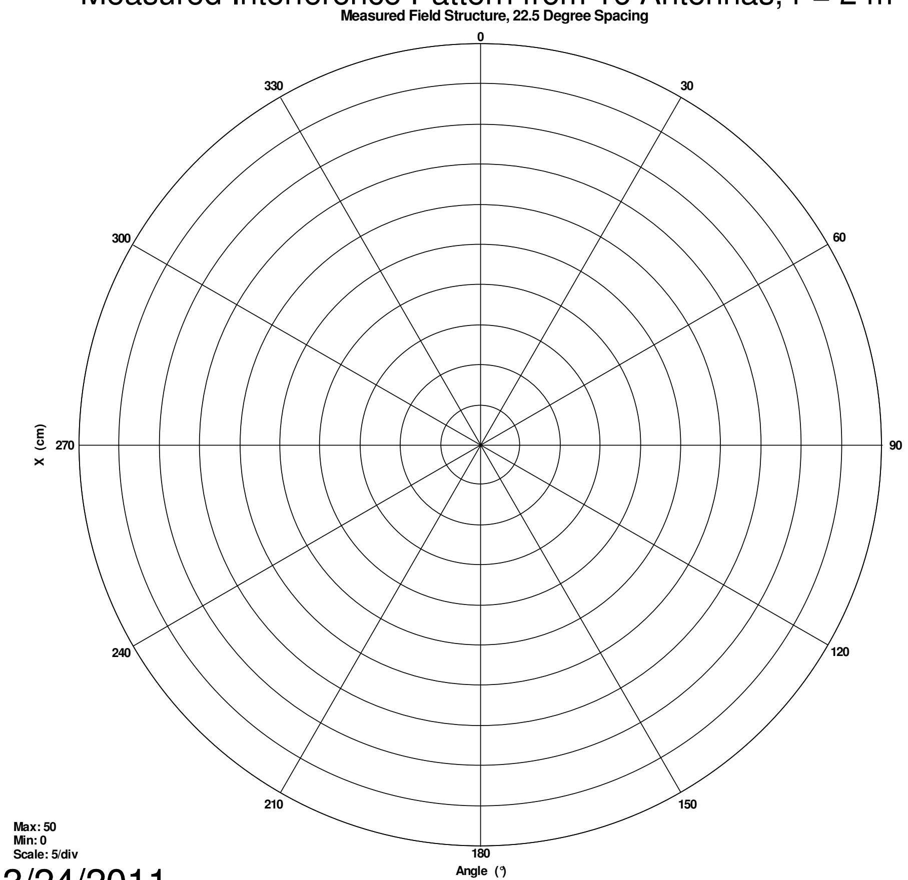
- Comparing a single cut through the test volume.



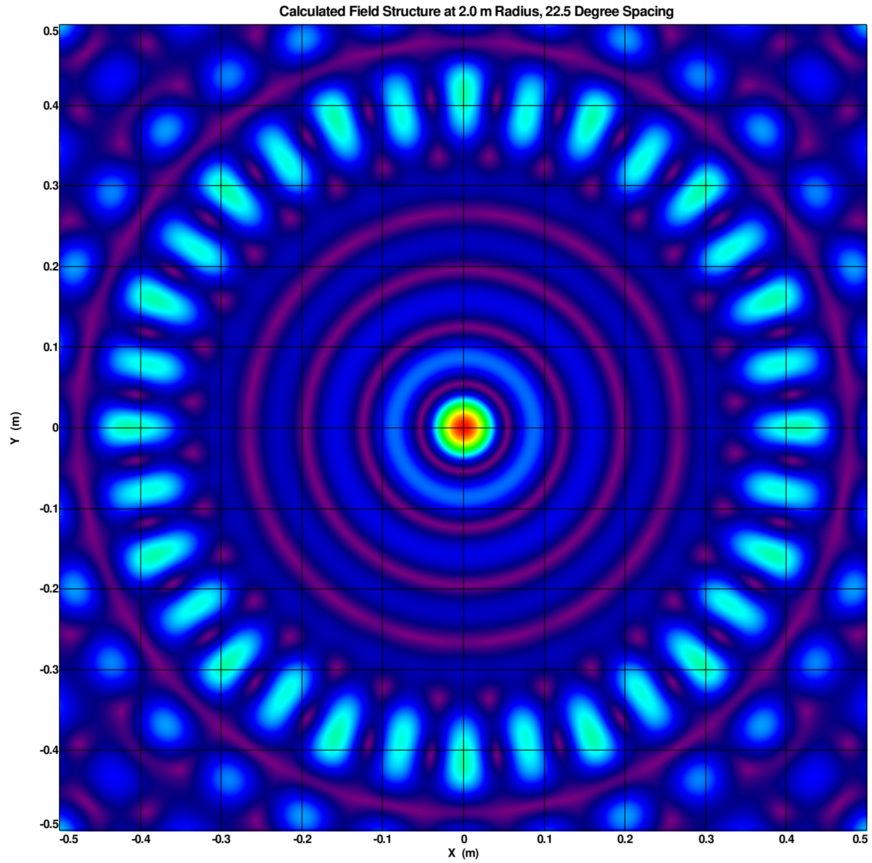
System Validation

- Increasing the resolution of the boundary condition from 8 to 16 antennas increases usable test volume.

Measured Interference Pattern from 16 Antennas, r = 2 m

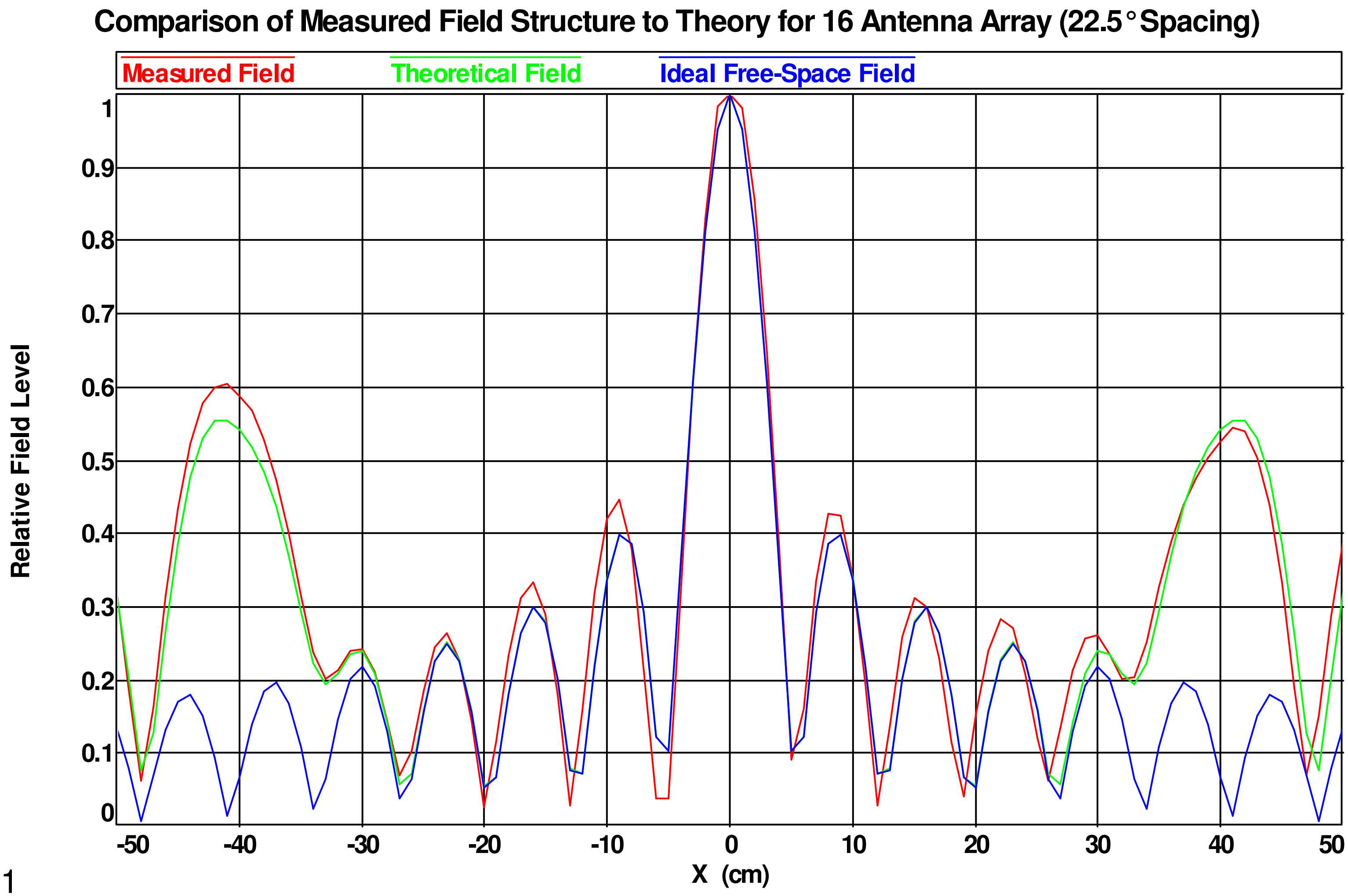


Calculated Interference Pattern from 16 Antennas , r = 2 m



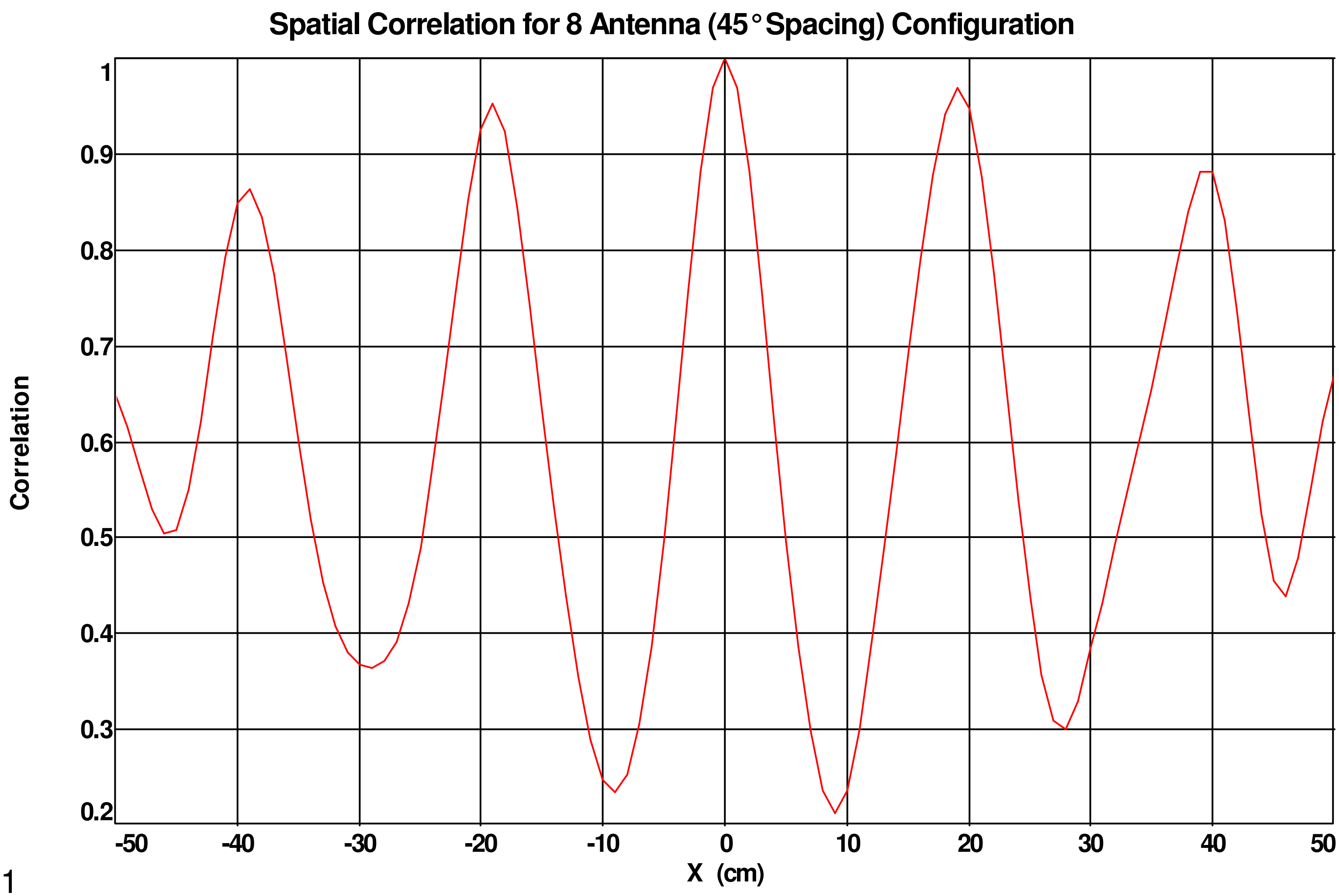
System Validation

- Comparing a single cut through the test volume.



System Validation

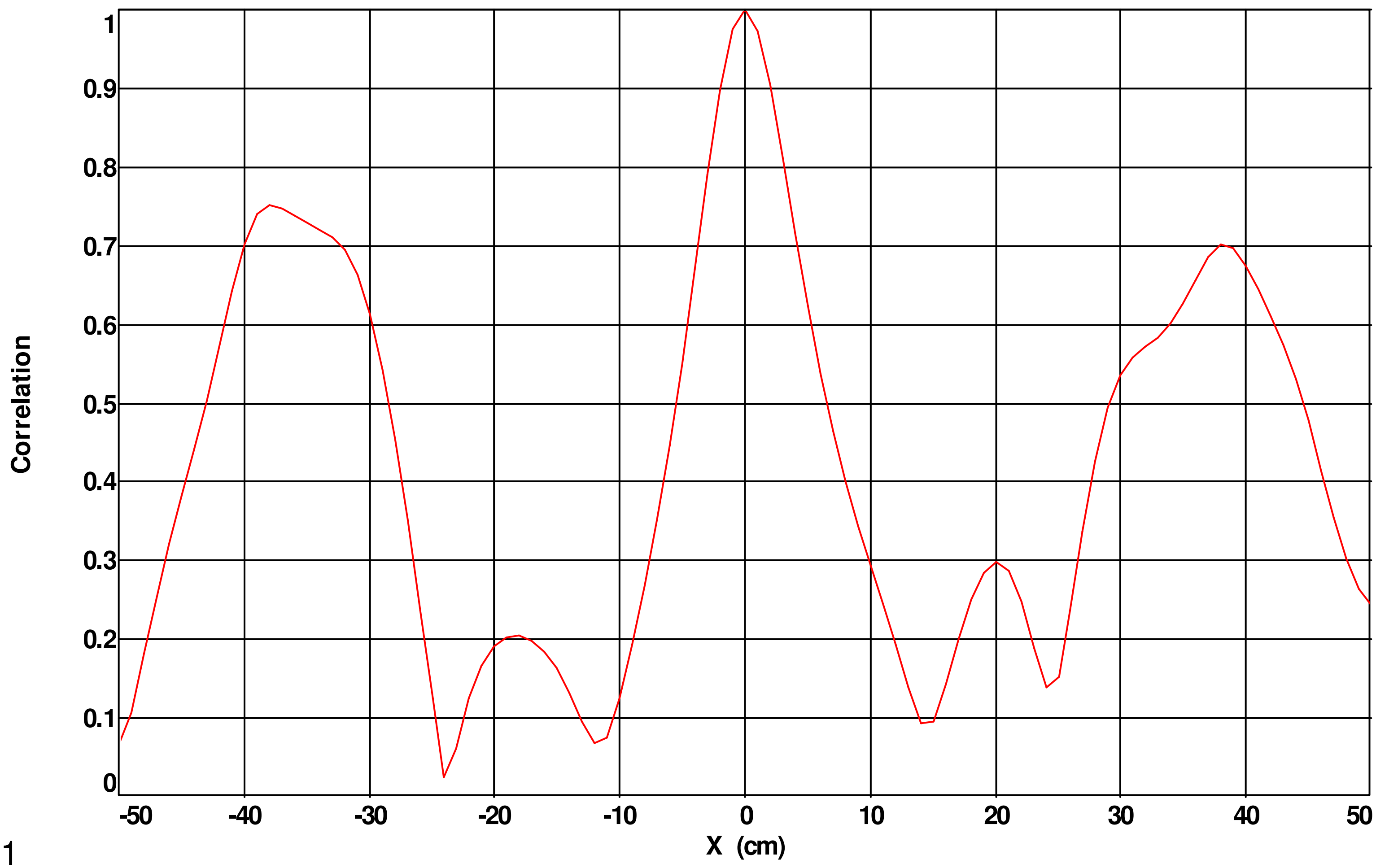
- Spatial Correlation evaluates RF system + emulation.



System Validation

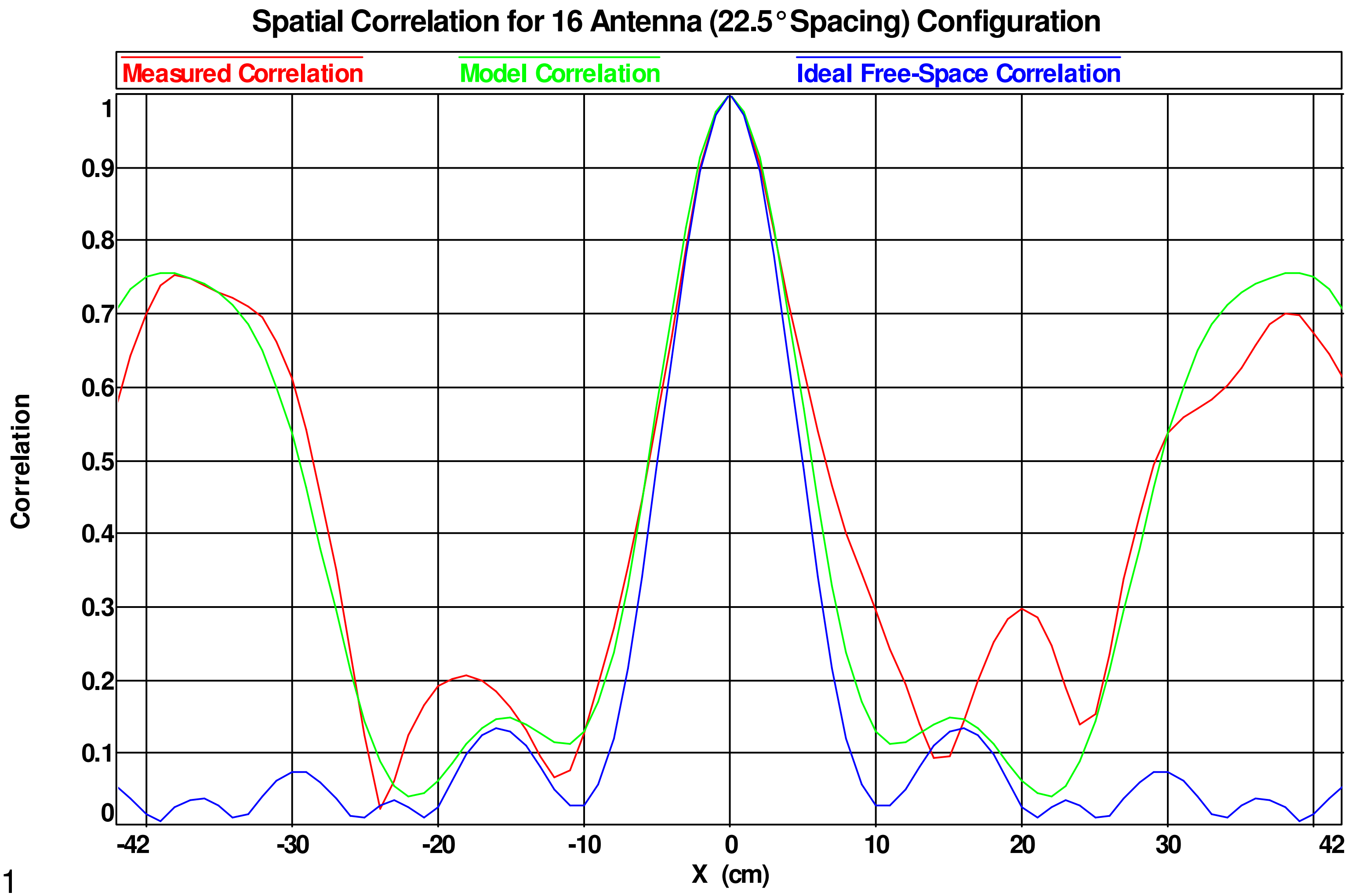
- Single cluster model produces known correlation.

Spatial Correlation for 16 Antenna (22.5° Spacing) Configuration



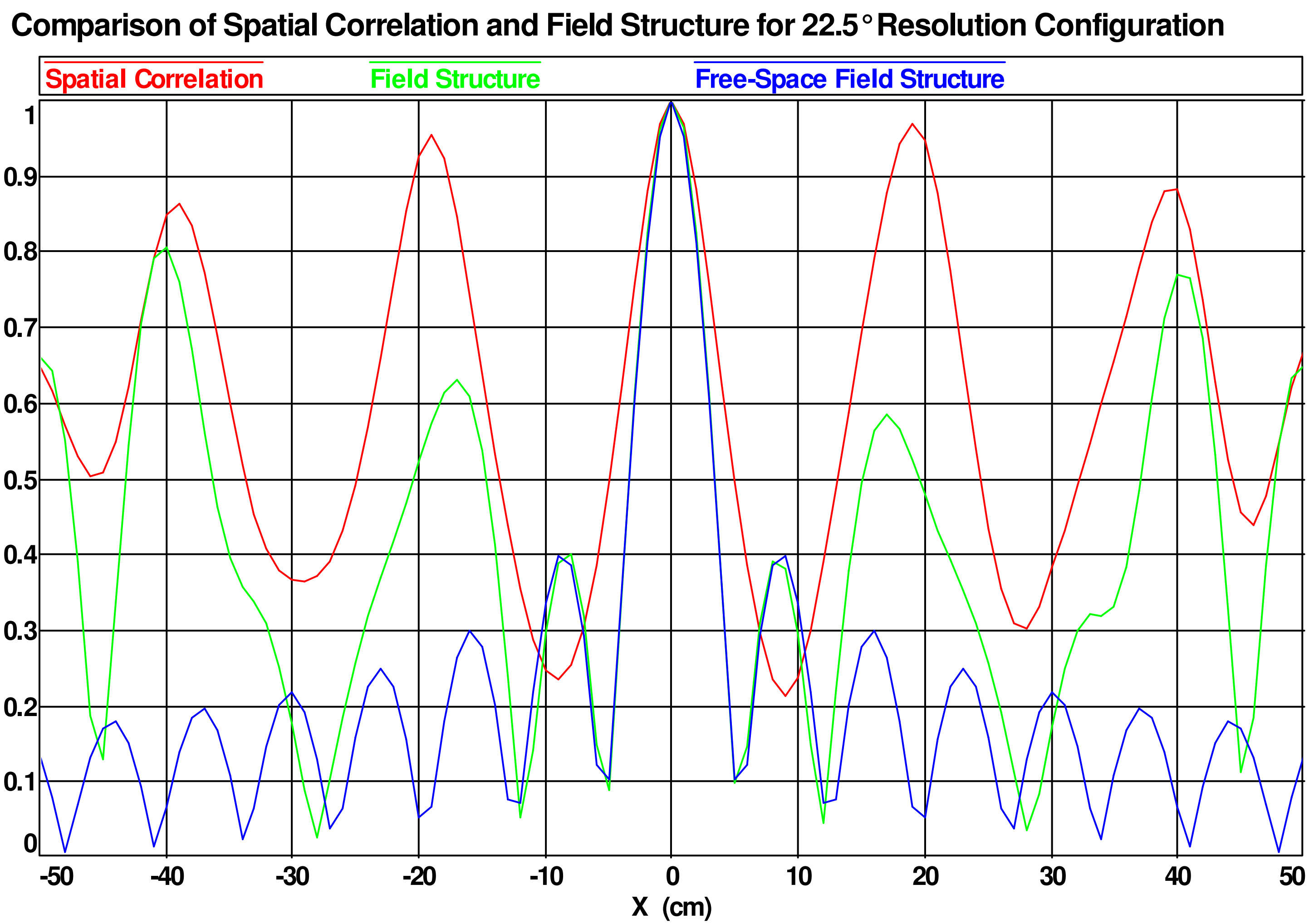
System Validation

- Comparing to theory for the same channel model.



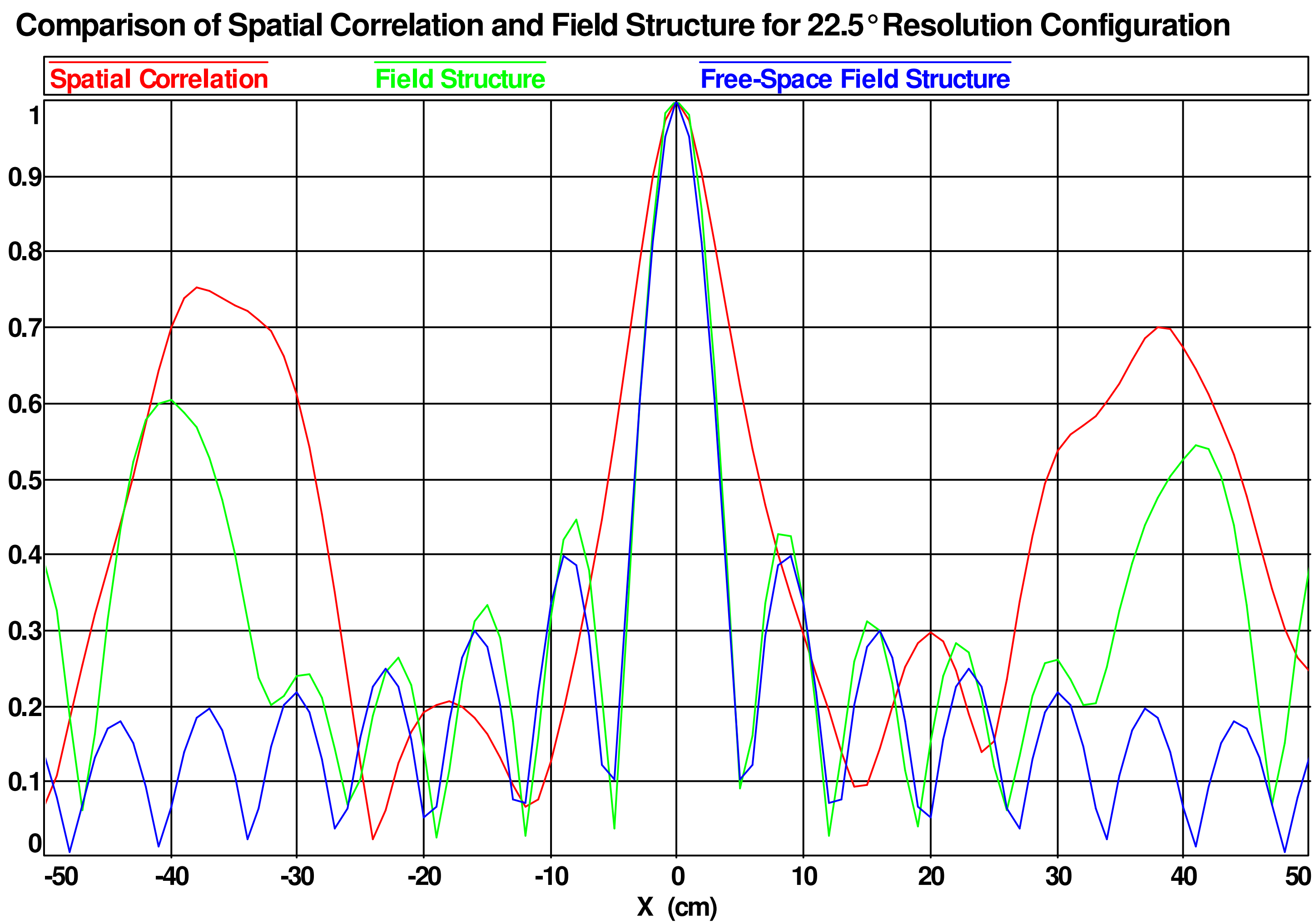
System Validation

- Both tests show similar system performance results.



System Validation

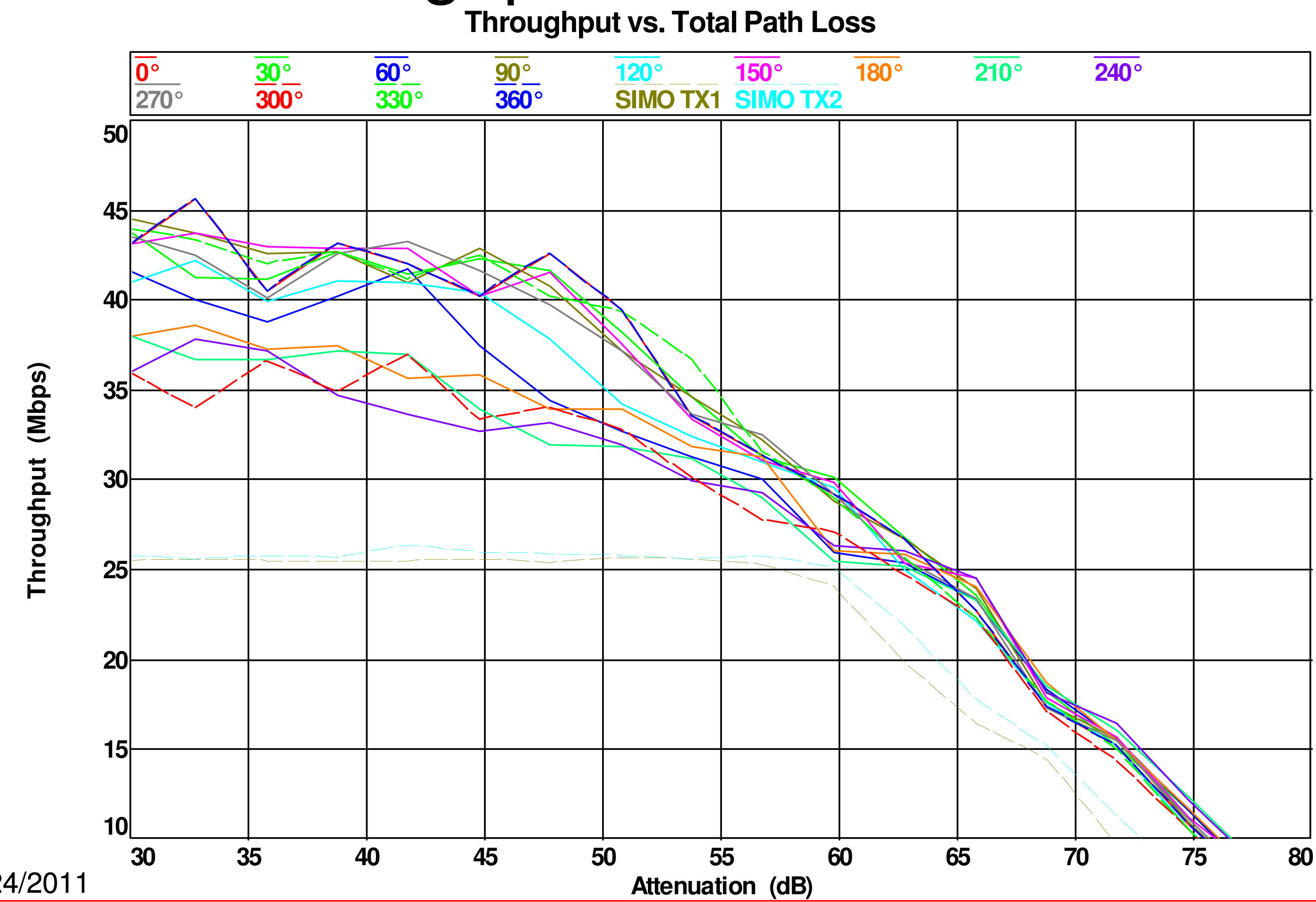
- When field deviates from ideal, so does correlation.



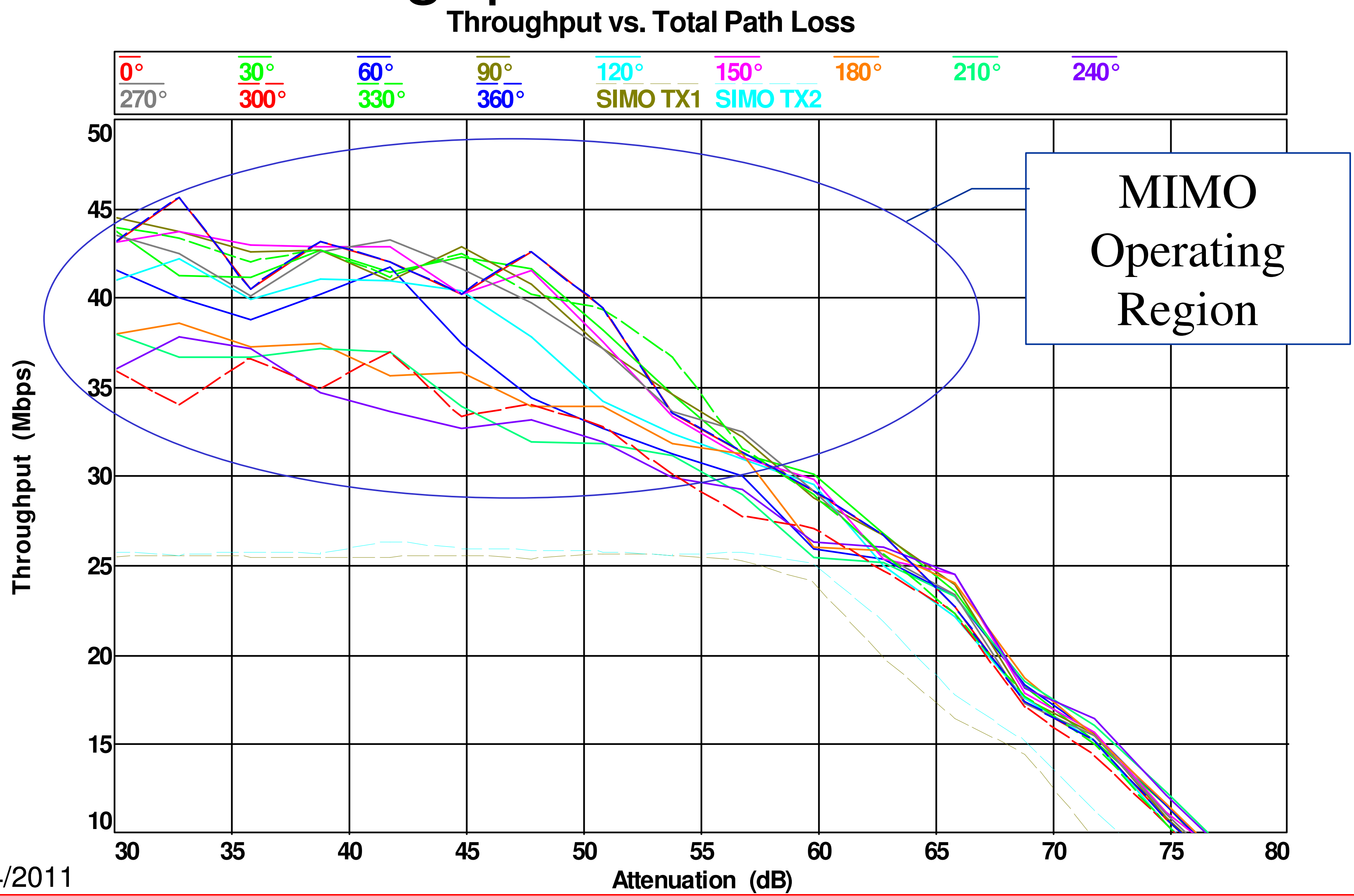
Throughput Measurement Results

- Unlike traditional TRP/TIS tests, which provide edge of link performance metrics, MIMO performance is all about high bandwidth with large SNRs.
- The corresponding metric for measuring bandwidth is throughput, and the equivalent evaluation would be to determine when the throughput begins to fall off.
- Initial tests were performed with 802.11n devices supporting 2x2 MIMO, to prove the capabilities of the system and methodology.
- Now that LTE communication testers are available, it is possible to show the first LTE MIMO OTA results.

Wi-Fi Throughput Measurement Results



Wi-Fi Throughput Measurement Results



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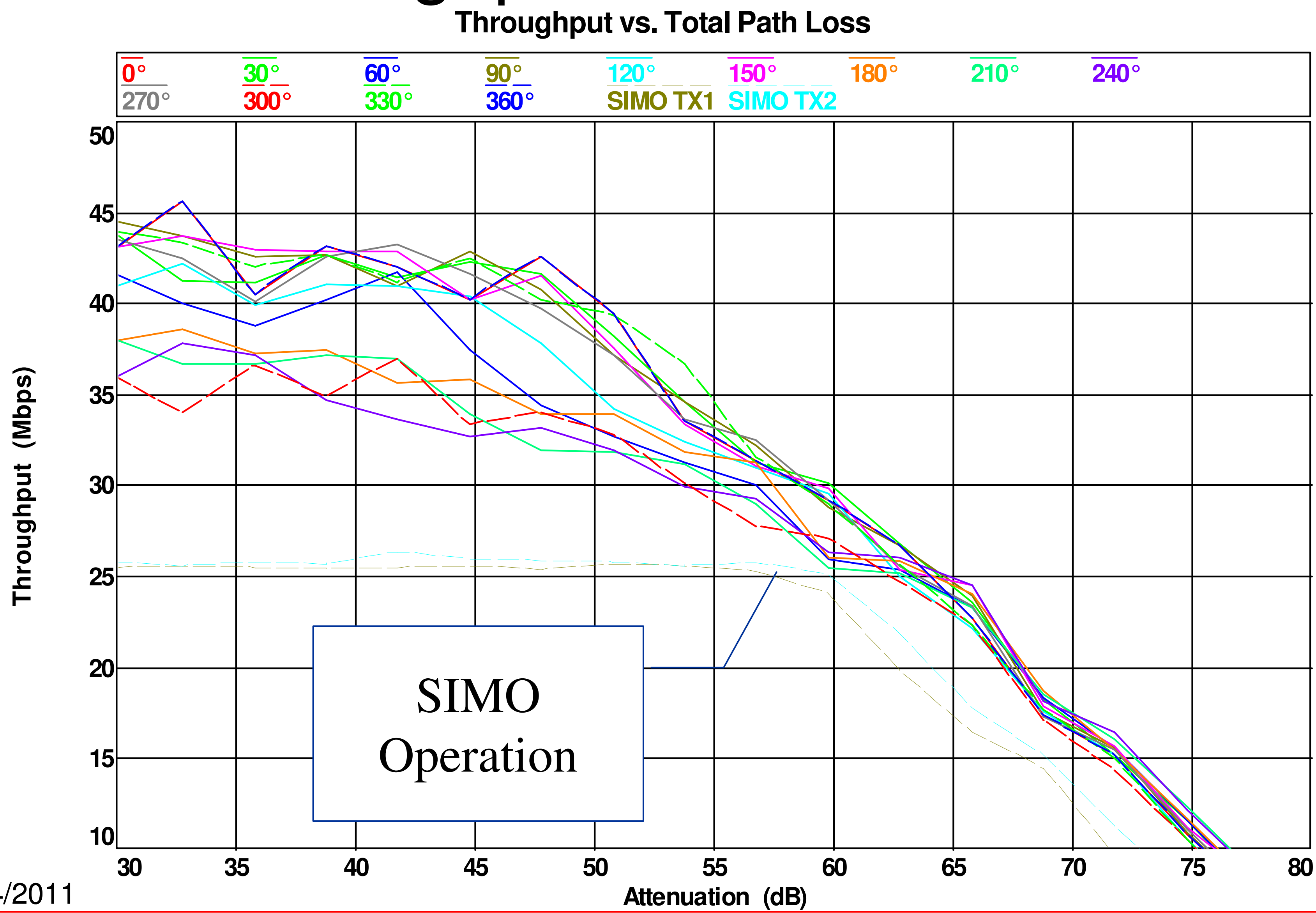
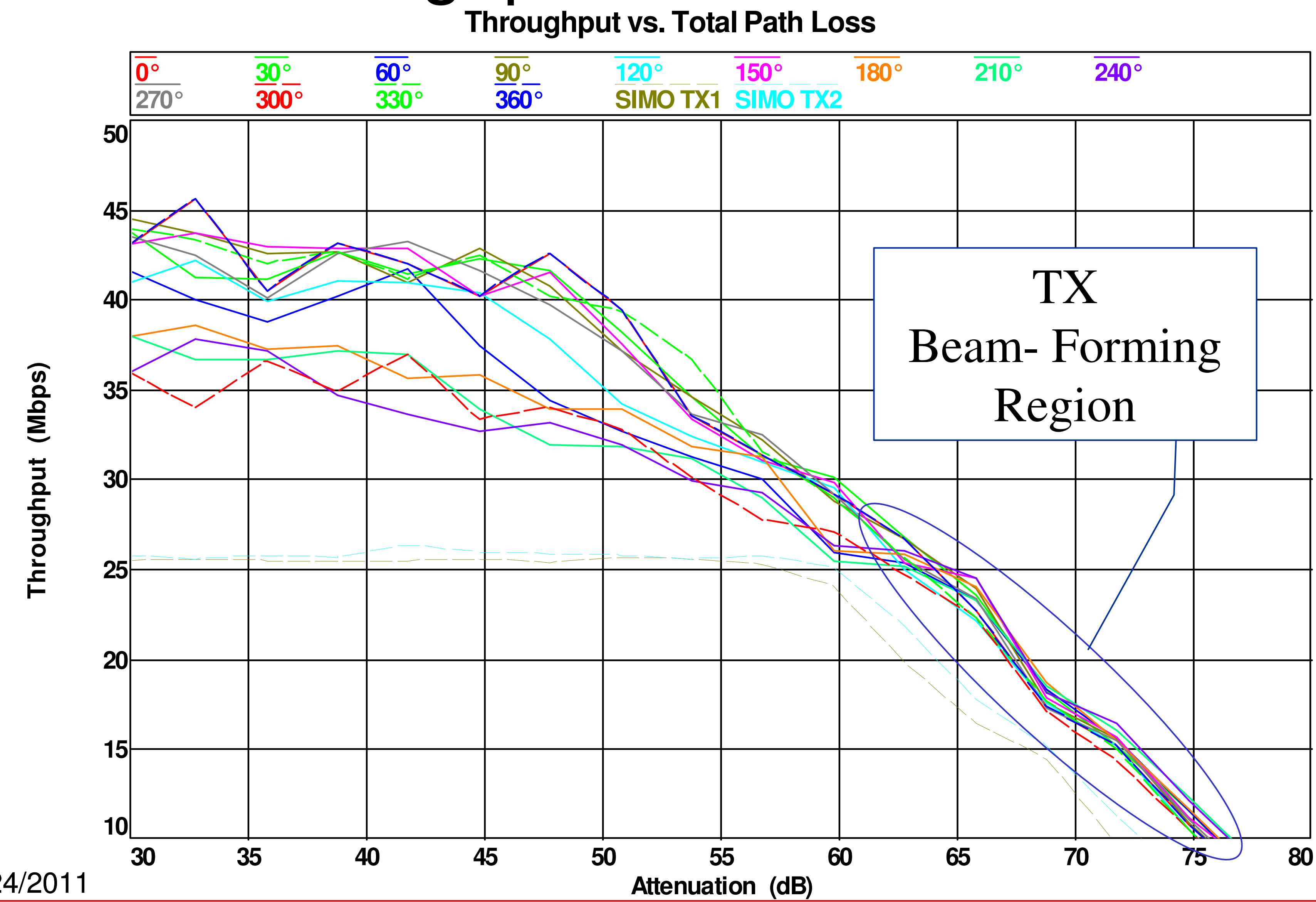
Wi-Fi Throughput Measurement Results



Wi-Fi Throughput Measurement Results



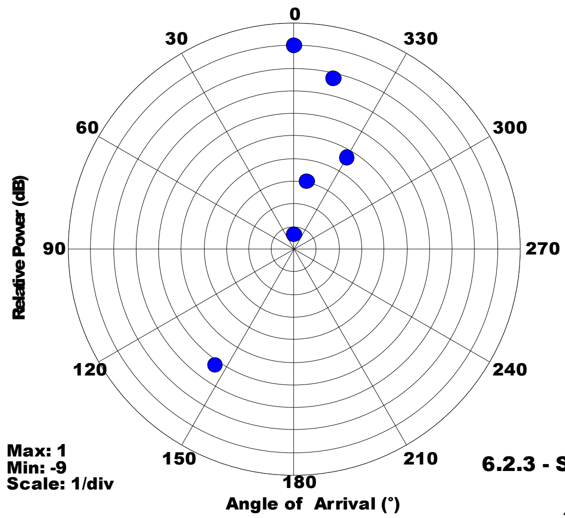
LTE Throughput Measurement Results

- LTE USB modem on test pedestal in middle of chamber

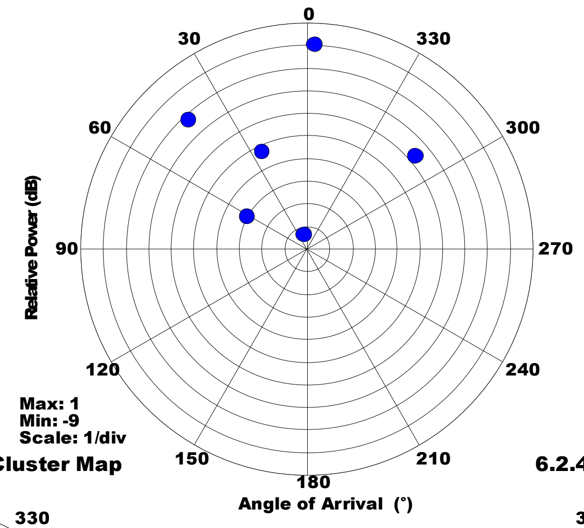
LTE Throughput Measurement Results

- Channel Model Definitions

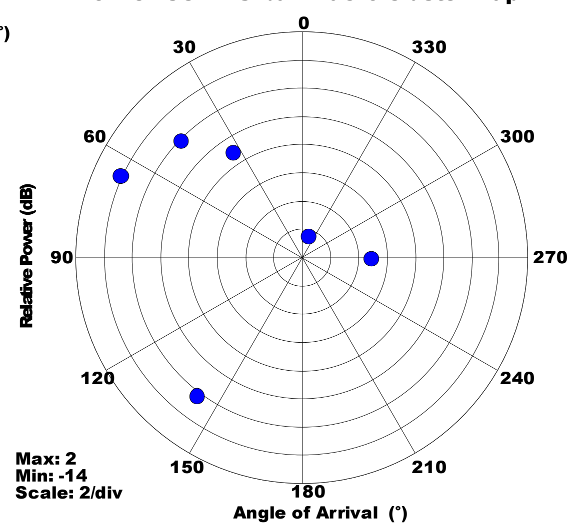
6.2.1 - SCME Urban Micro Cluster Map



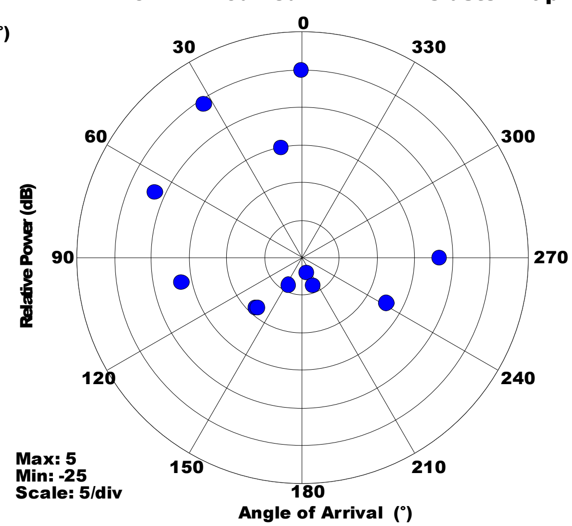
6.2.2 - Modified SCME Urban Micro Cluster Map



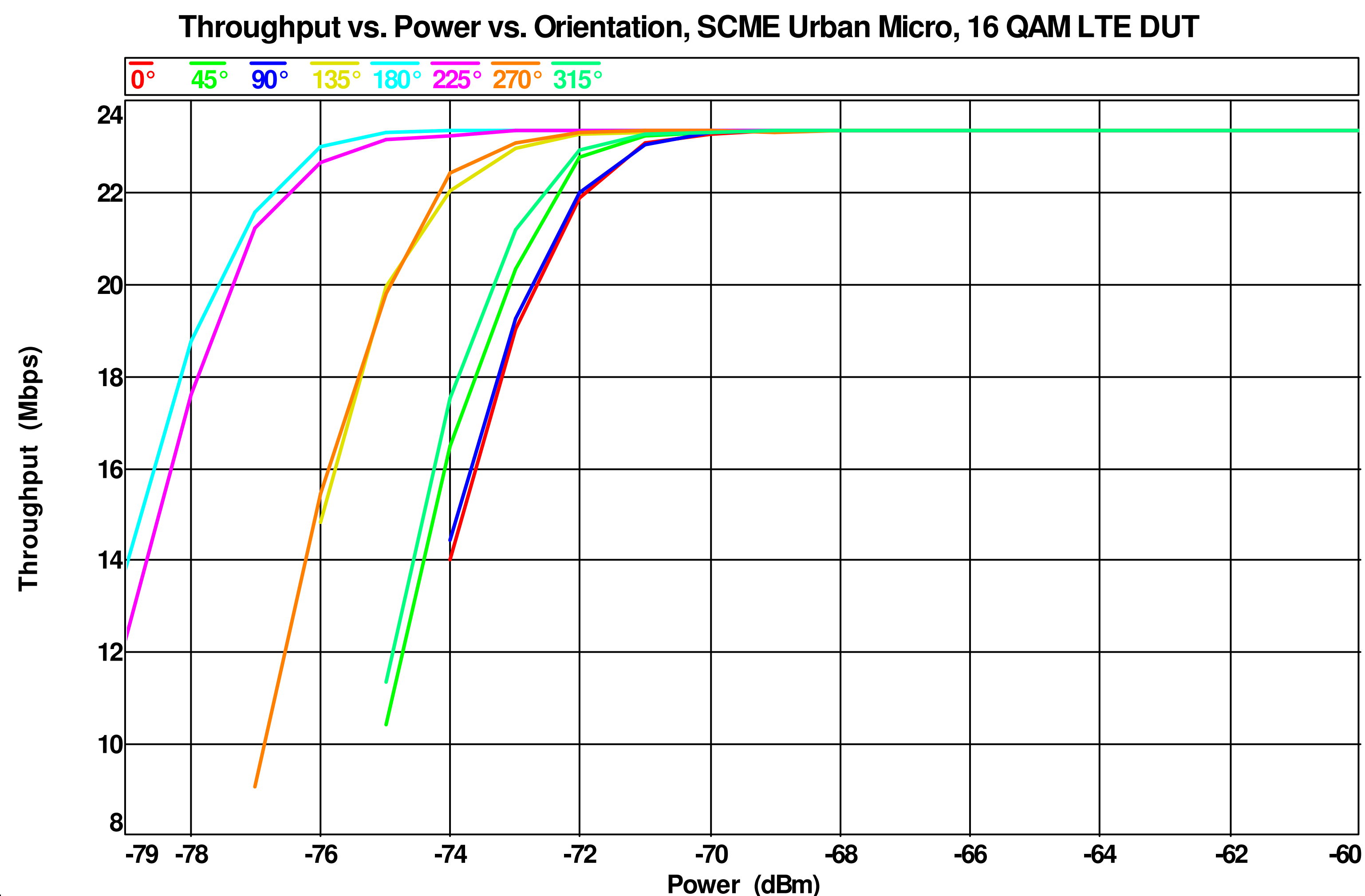
6.2.3 - SCME Urban Macro Cluster Map



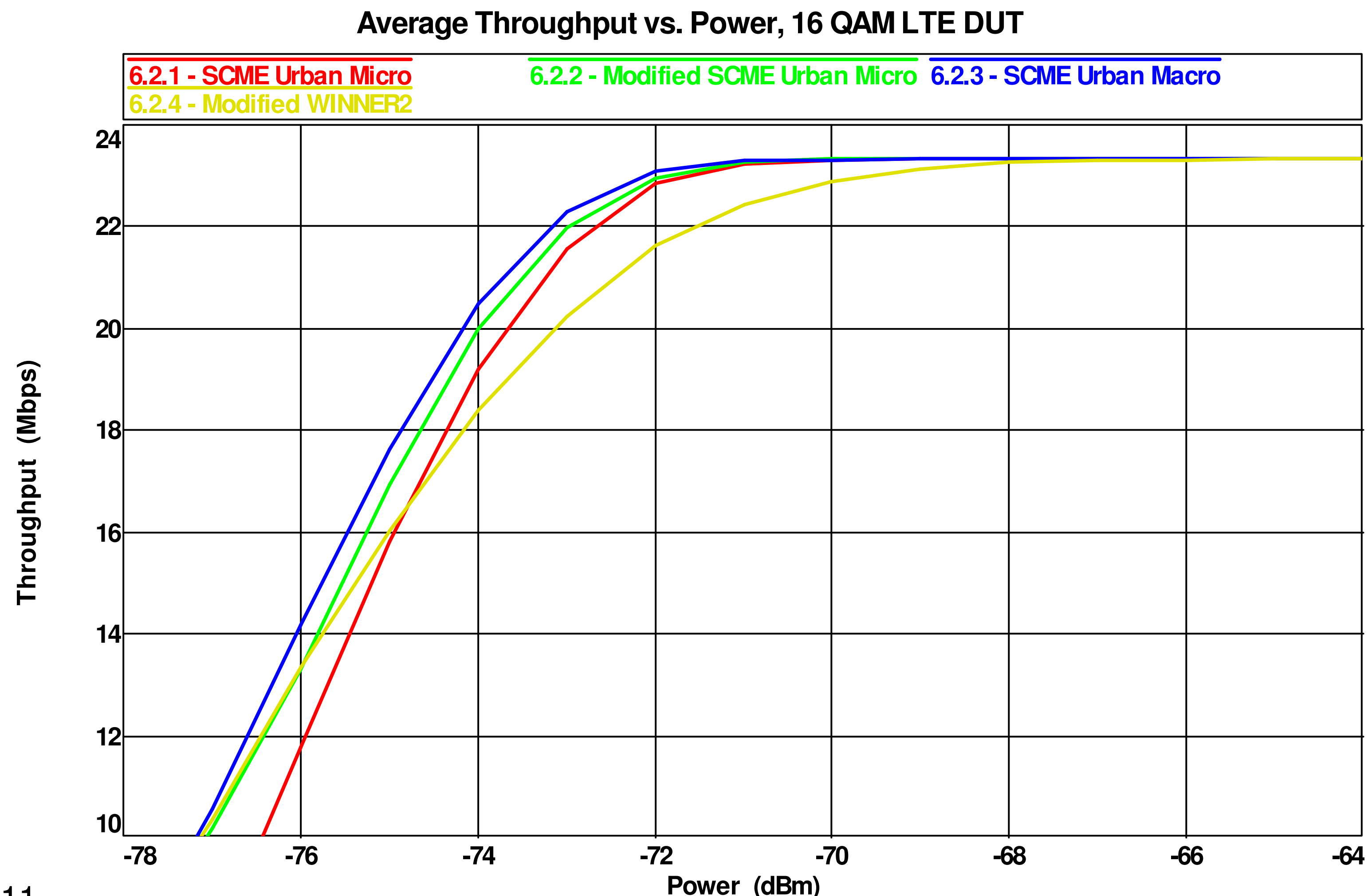
6.2.4 - Modified WINNER II Cluster Map



LTE Throughput Measurement Results



LTE Throughput Measurement Results



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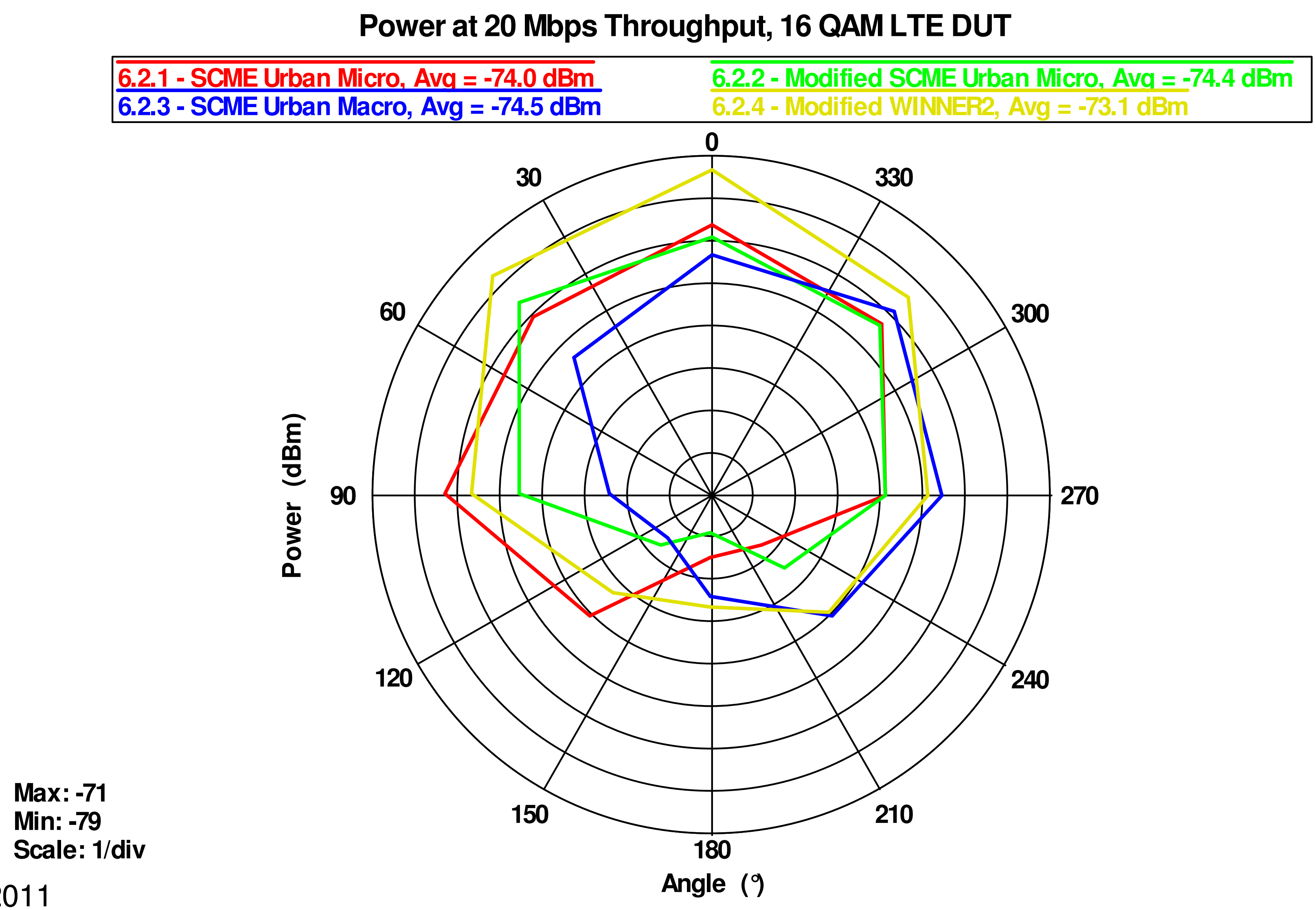

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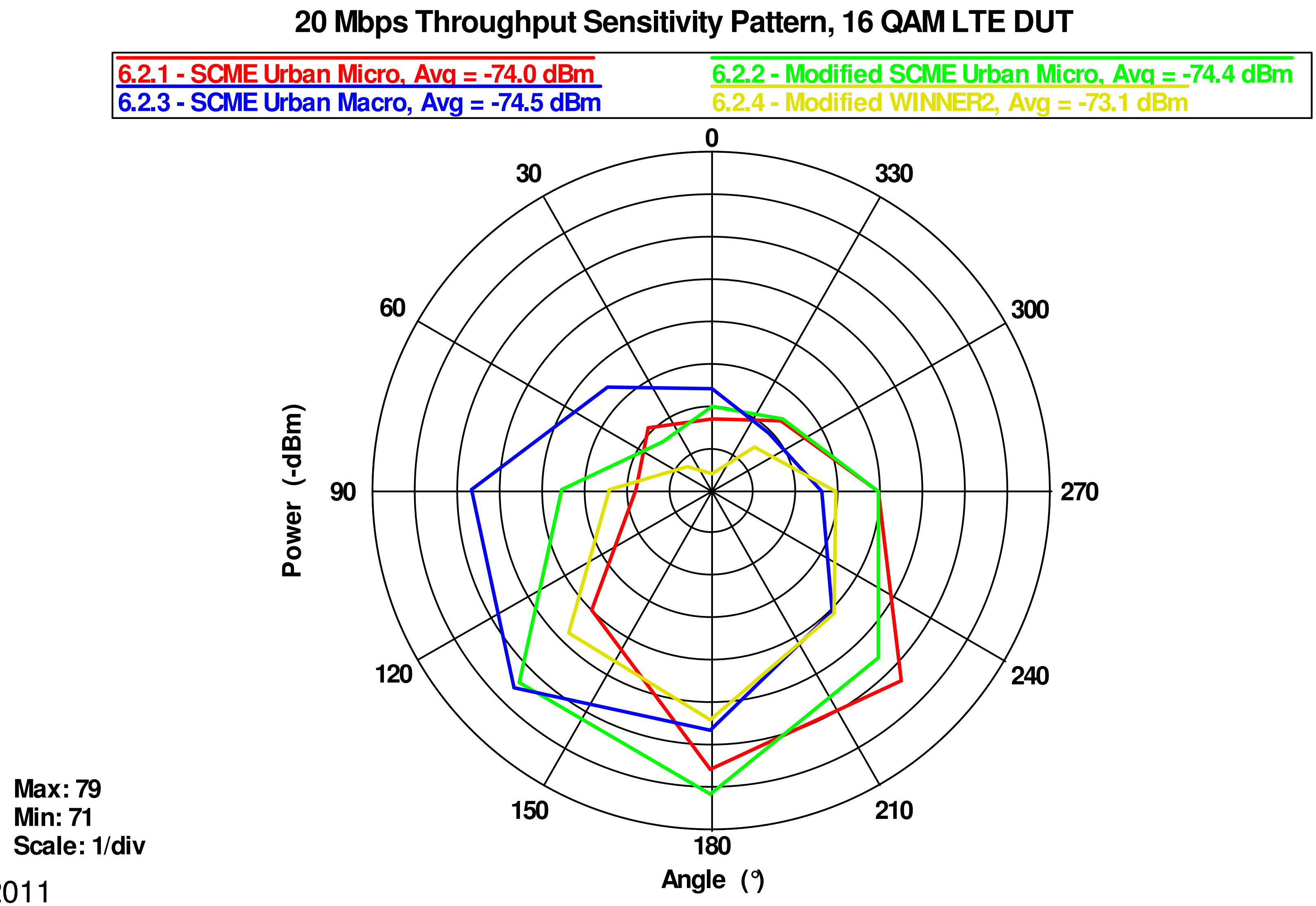

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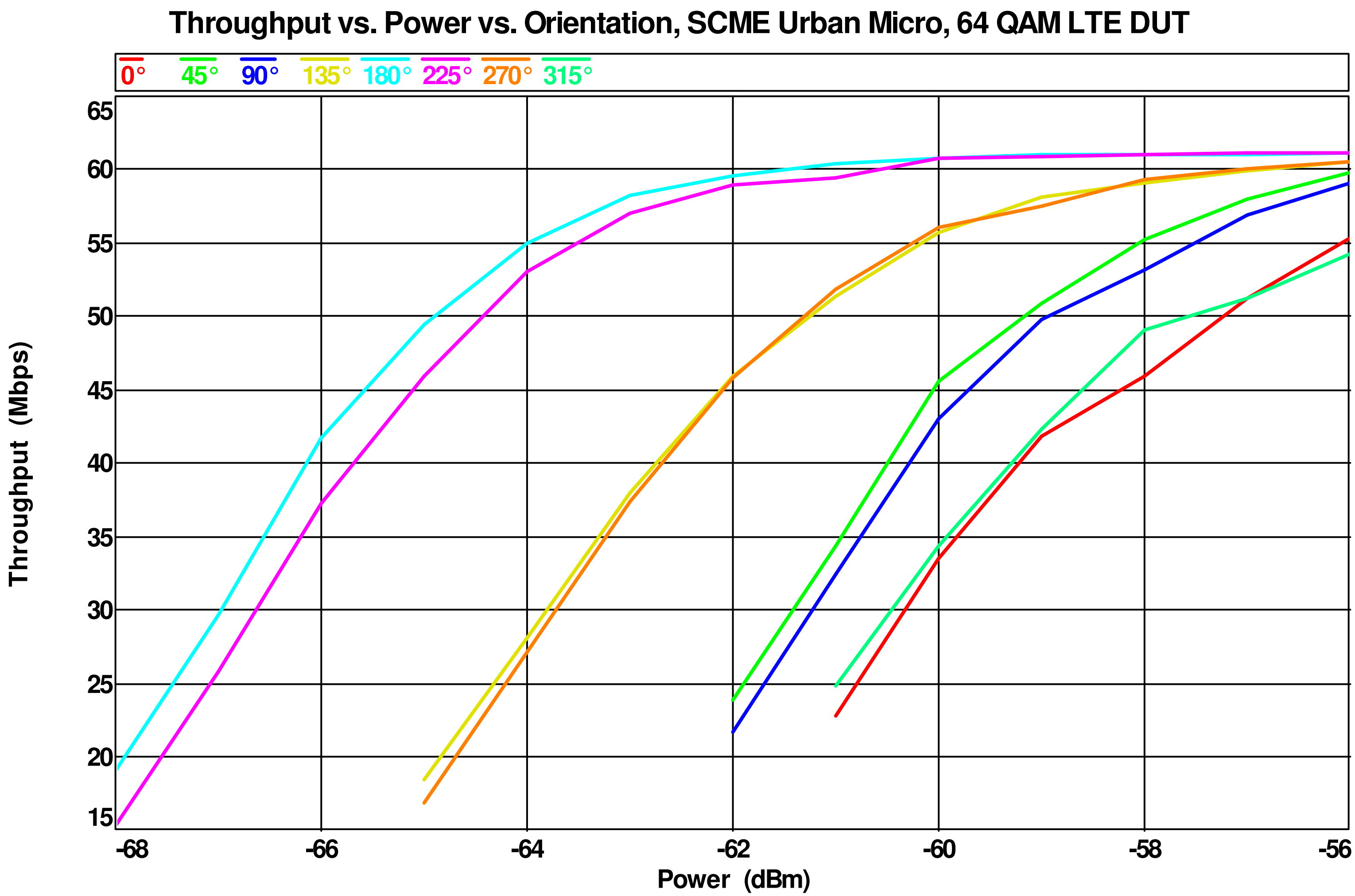

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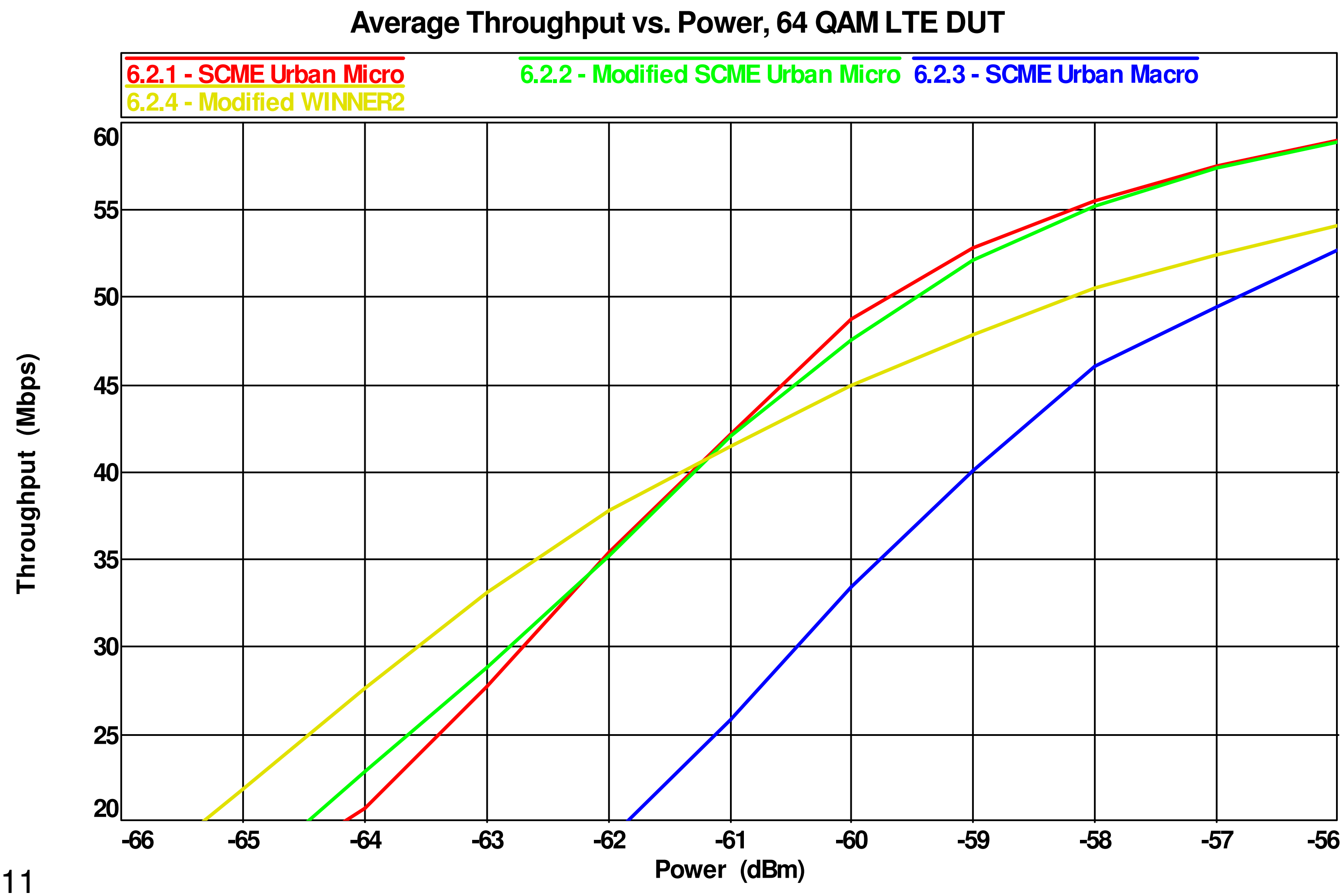

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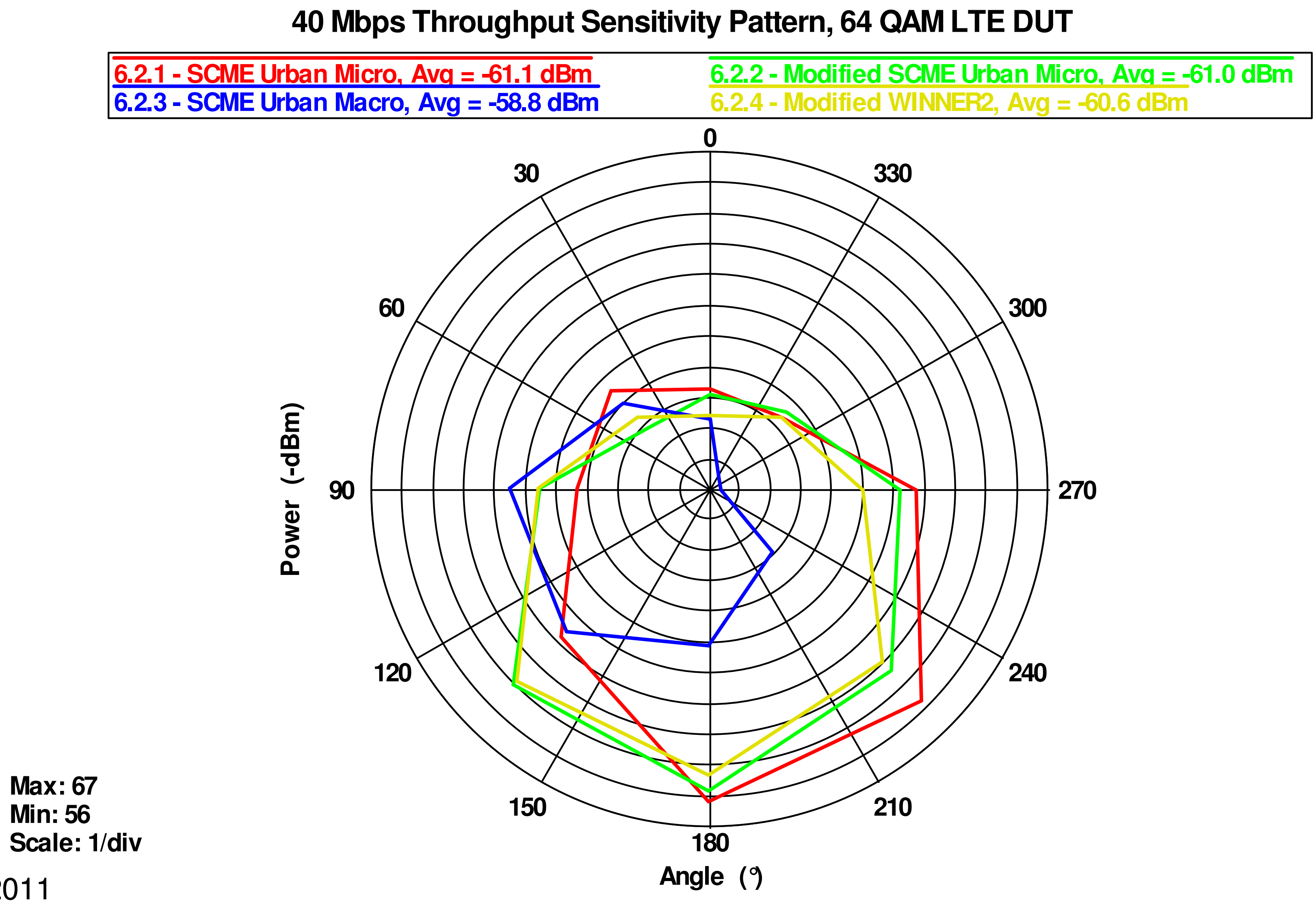

Conclusion

- Extensive efforts are underway to standardize on a next generation platform for wireless testing.
- The ability to perform realistic RF environment simulation and evaluate end user metrics in real-world scenarios is an invaluable resource to wireless technology developers.
- Detailed calibration and validation methods are required to ensure the validity of measured data.
- While a throughput related metric is the logical choice, the industry must still choose the desired target metric (e.g. throughput sensitivity).