MIMO OTA in a Small Anechoic Chamber

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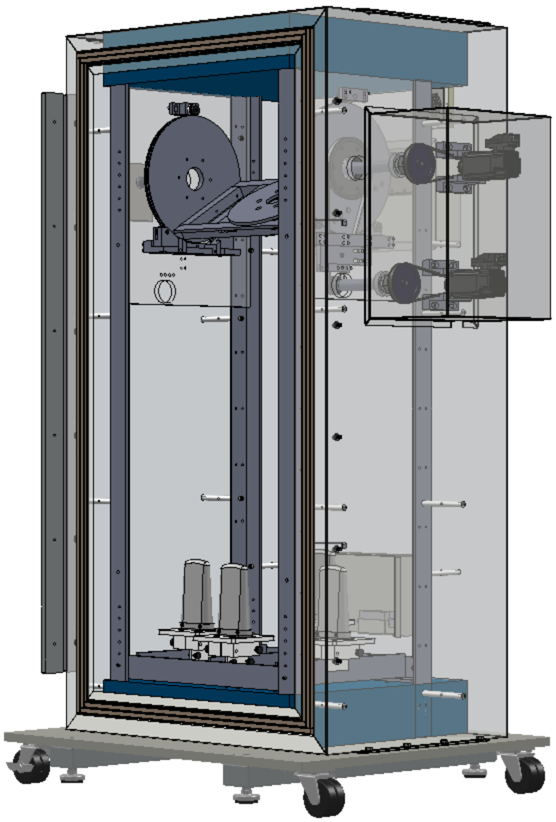
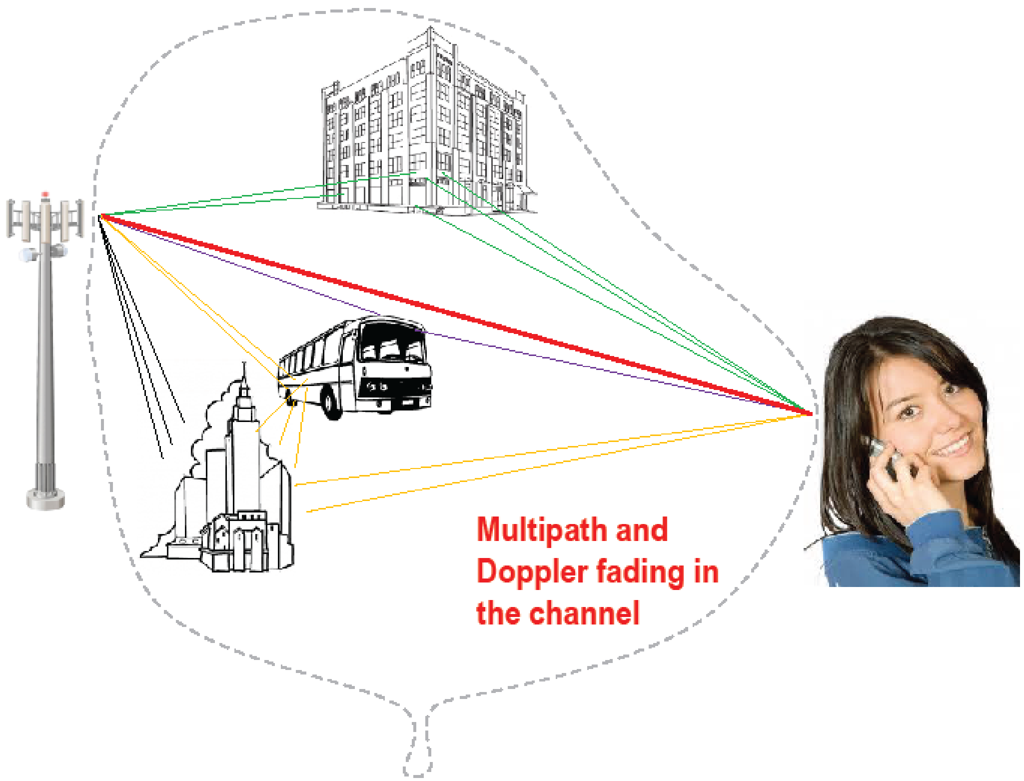


Motivation

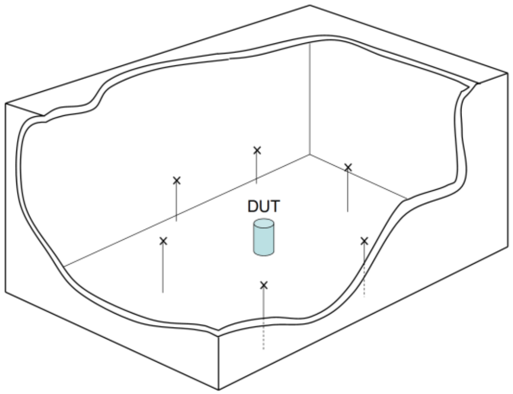
- NSF Enhancing Access to the Radio Spectrum (EARS)
  - Wireless system tests, measurements, and validation
- Next generation wireless standards use multiple antenna systems to increase connectivity and spectral efficiency.
- Certification of next generation devices is an expensive and time consuming process.

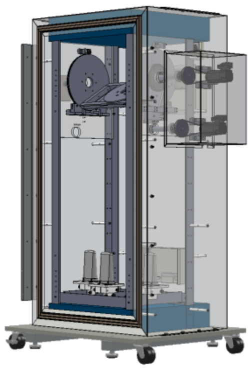
Multipath Channel

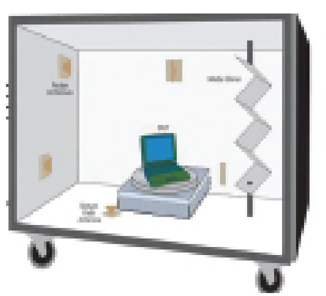


MIMO OTA Test Methods

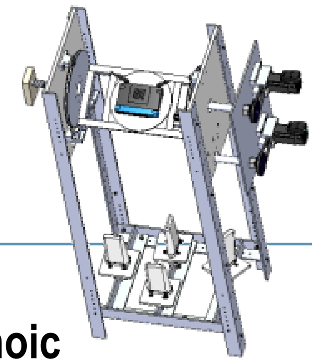
- MIMO OTA test metrics are being standardized by 3GPP [1] and CTIA [5]
- Large anechoic chamber
  - DUT is surround by multiple antennas inside the chamber
  - Multi-cluster 2D measurements on a plane
- Small anechoic chamber
  - Single cluster 3-D measurements indicating DUT's MIMO performance vs. orientation
  - 2-Stage method whereby antennas are measured in the chamber and then modeled using a traditional conducted fader
- Reverberation chamber
  - Uniform isotropic (3D) propagation is achieved via reflections from metal walls and mechanical stirrers
  - An external channel emulator is used to provide power delay profiles, Doppler and multipath fading

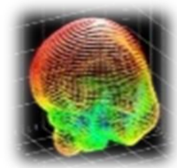




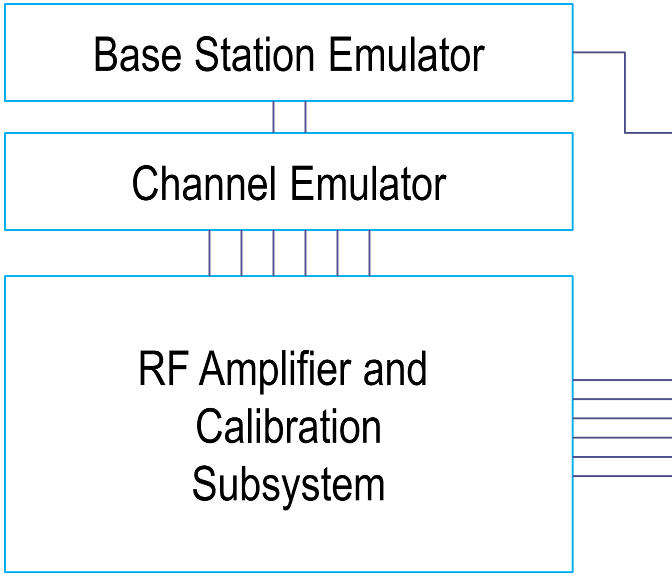


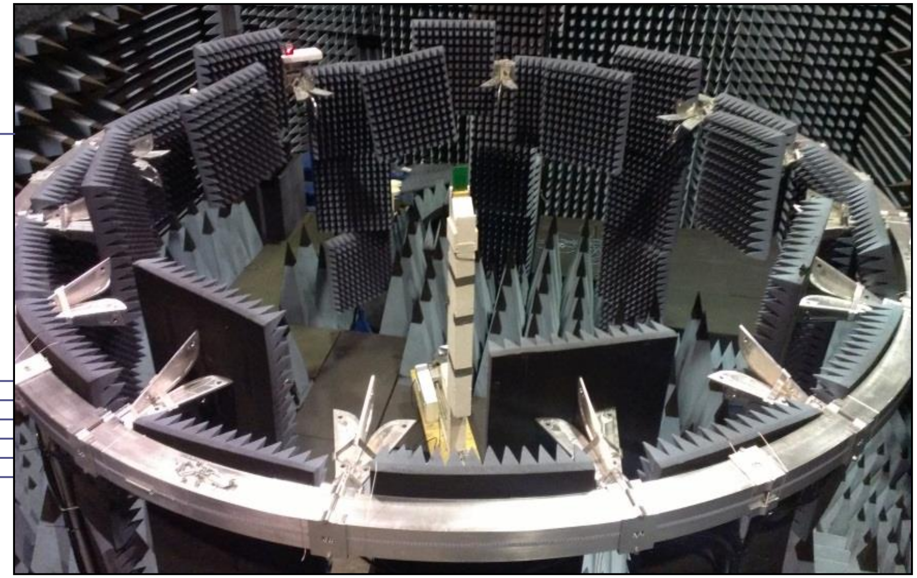
Comparison of MIMO-OTA Methods

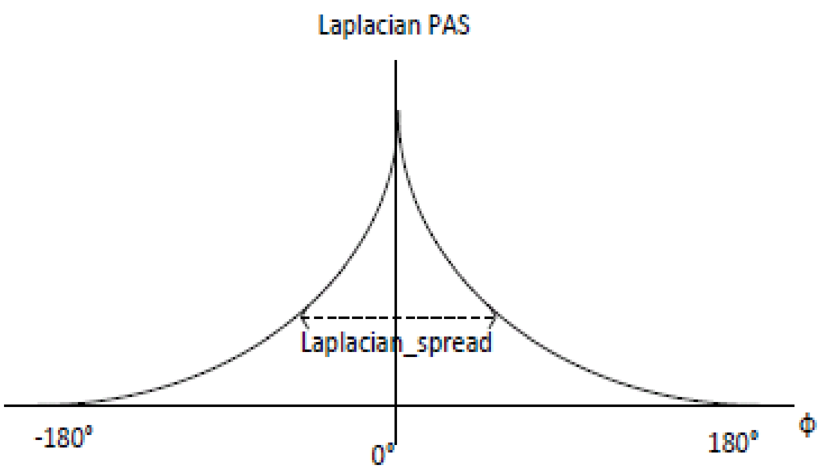


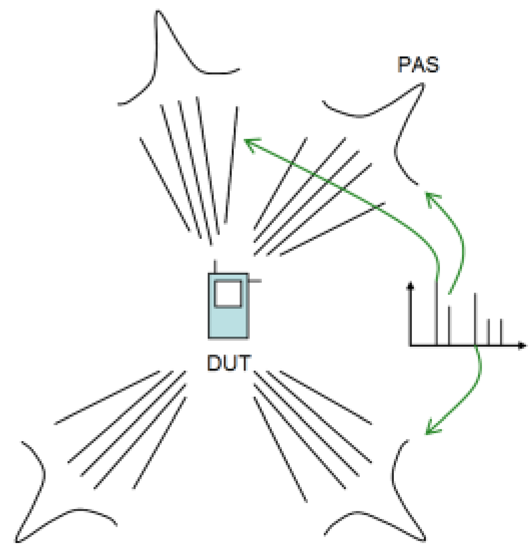
Full sized anechoic	Reverberation chamber	Single cluster anechoic
• Provides 2D performance information with 360° multi-cluster propagation • Requires a lot of space	• Less expensive and smaller than full sized anechoic chamber • No information on where the nulls are in the antenna field	• Provides 3D performance information  • Supports single cluster anechoic and 2-stage methods • Takes little space

Conventional Chamber MIMO-OTA Testbed



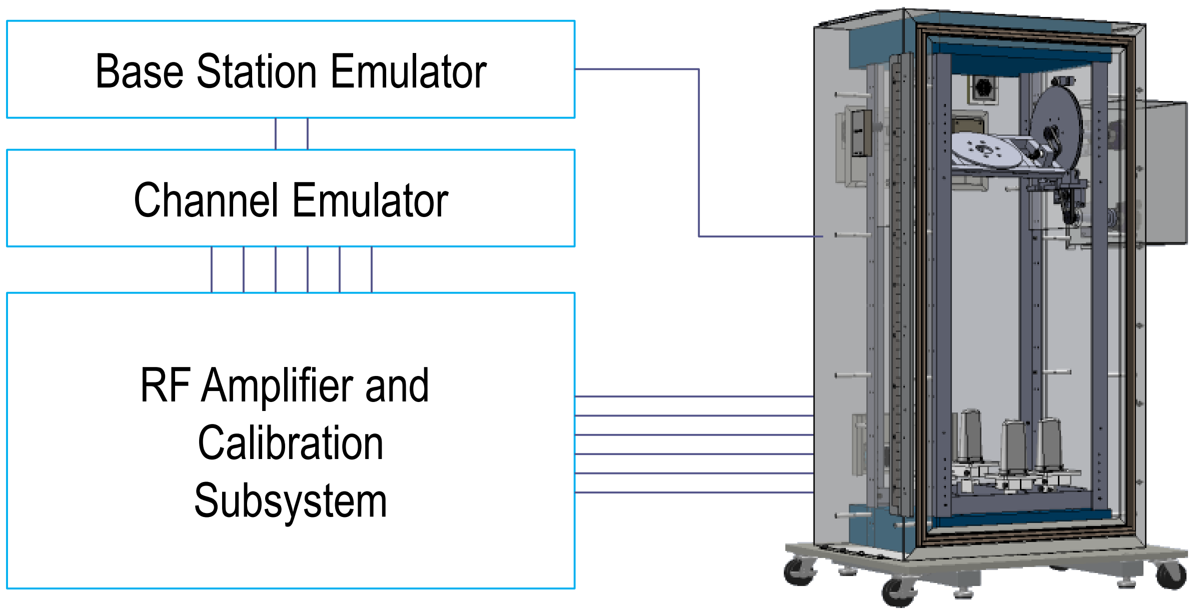






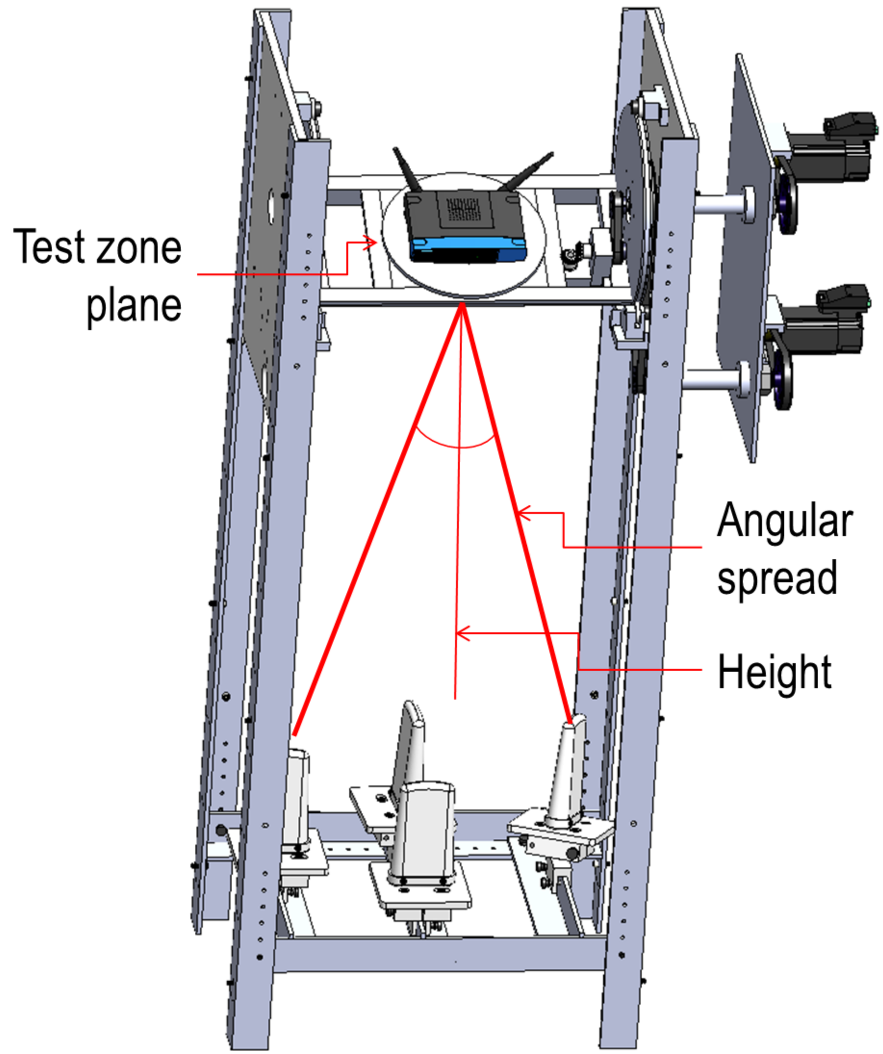
Small Chamber MIMO-OTA Testbed

Single cluster UMa/UMi models



NSF Phase I: Accomplishments

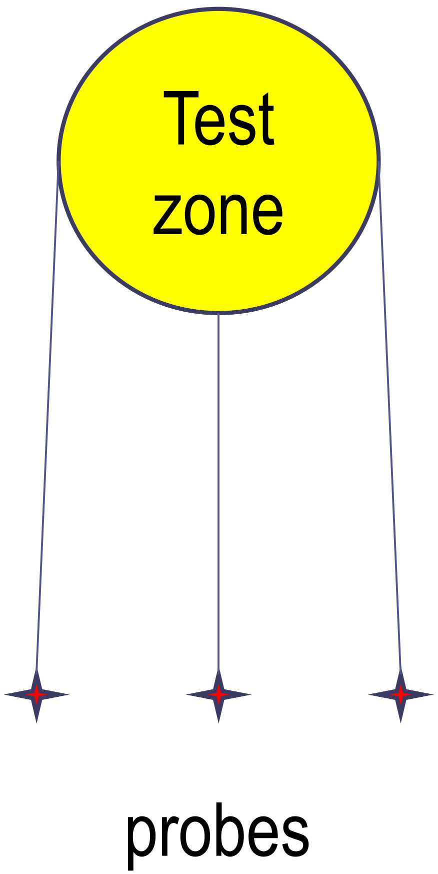
- Goal is to analyze accuracy of the measurement as a function of angular spread of test antennas and number of antennas
- Developed synthesis algorithm to produce Laplacian PAS clusters in the test zone based on:
  - The wavelength used in the measurement
  - Test zone radius
  - Geometry of chamber and probe locations
  - Shape of probe field
- Algorithm calculates error of synthesized field vs. theory – Reflectivity [8]



PAS = power angular spread

Method – Plane Wave Synthesis

- Widely used *spherical wave theory* models 3D antenna radiation [8]
- *Plane wave synthesis* technique is based on spherical wave theory [8] and enables synthesis of Laplacian PAS cluster field
- Team created synthesis algorithm to generate Laplacian PAS



Field synthesis

- From spherical plane wave theory we can reduce the number of probe antennas

$$K = 4\pi r/\lambda + 1$$

- With plane wave synthesis, a target field can be approximated

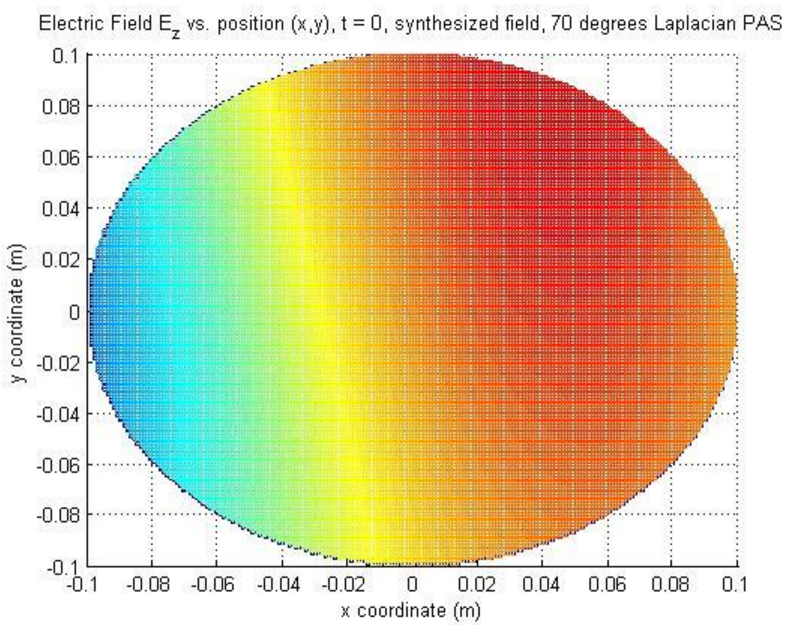
$$\vec{E}_{Target}(r_0, \phi) \approx \vec{E}_{Synth}(r_0, \phi) = \sum_{n=1}^{N} c_n \vec{E}_n(r_0, \phi)$$

- Error or reflectivity between the desired and synthesis

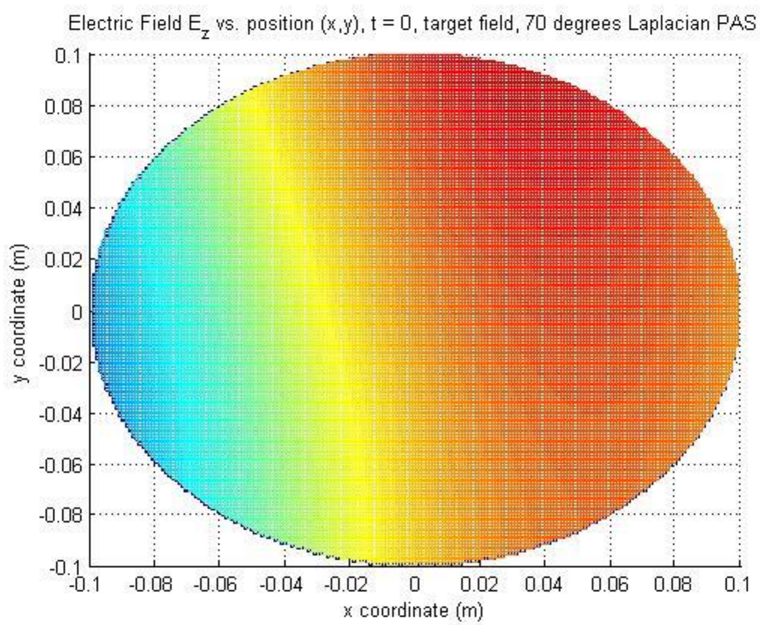
$$e(r_0) = 20\log_{10}\left(\max_{0^\circ \le \phi < 360^\circ}\left(\frac{\left|\vec{E}_{Synth}(r_0, \phi) - \vec{E}_{Target}(r_0, \phi)\right|}{\max_{0 < r \le r_0, 0^\circ \le \phi < 360^\circ}\left|\vec{E}_{Target}(r, \phi)\right|}\right)\right)$$

E-field Over Test Zone

Synthesized by Model



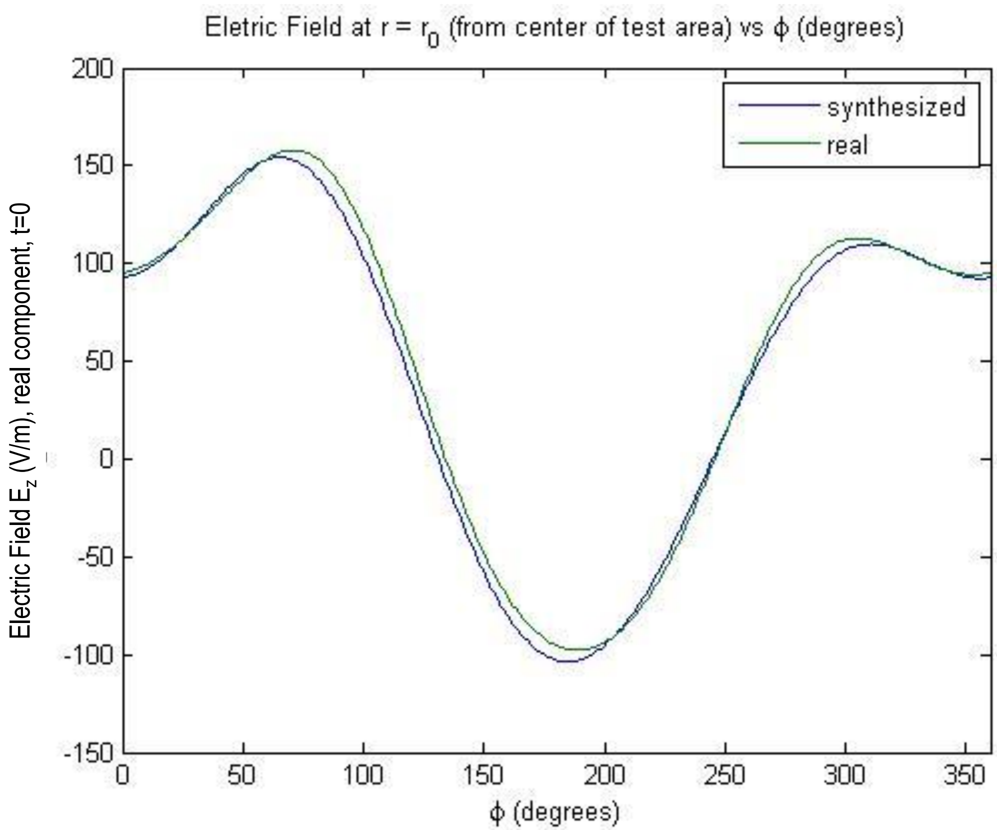
Theoretical



Synthesized electric field levels across the test zone agree with the theoretical field levels for the desired Laplacian PAS.

Note: Results are shown for a single instance in time

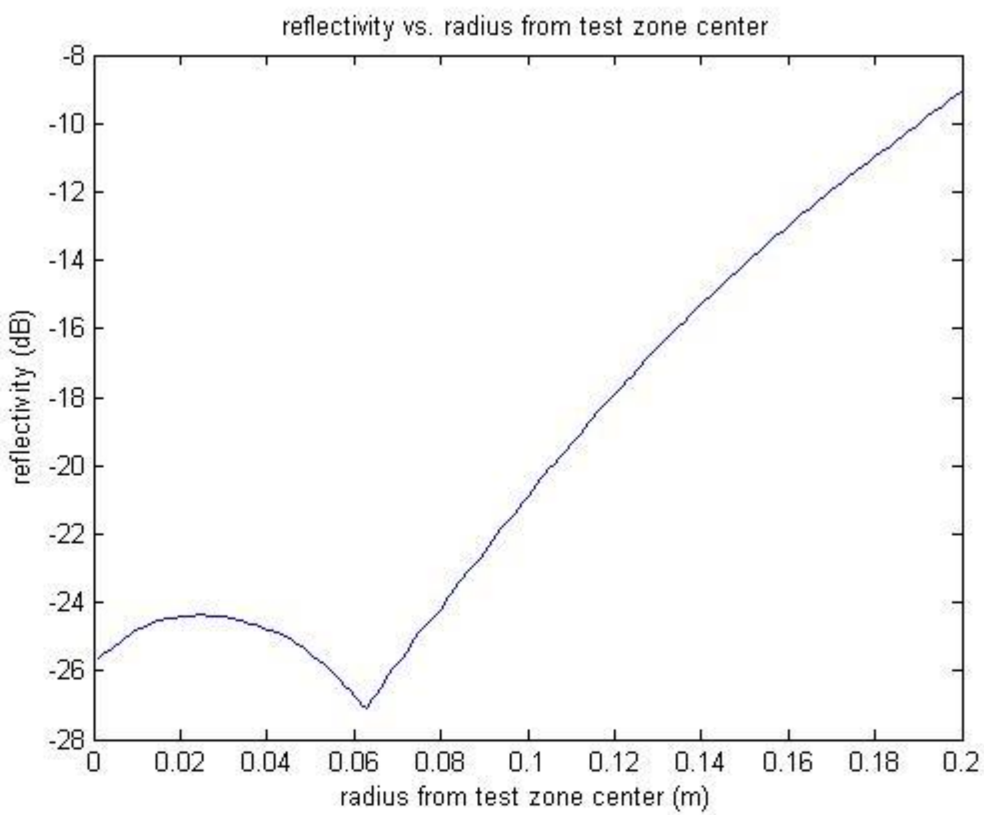
E-field at Max Test Zone Boundary



Synthesized electric field levels around the circumference of the test zone agrees with the theoretical field levels for the desired Laplacian PAS

Note: Results are shown for a single instance in time

E-field Error vs. Test Zone Radius



Reflectivity (error) is < 20dB up to 0.1m from the center of the test zone

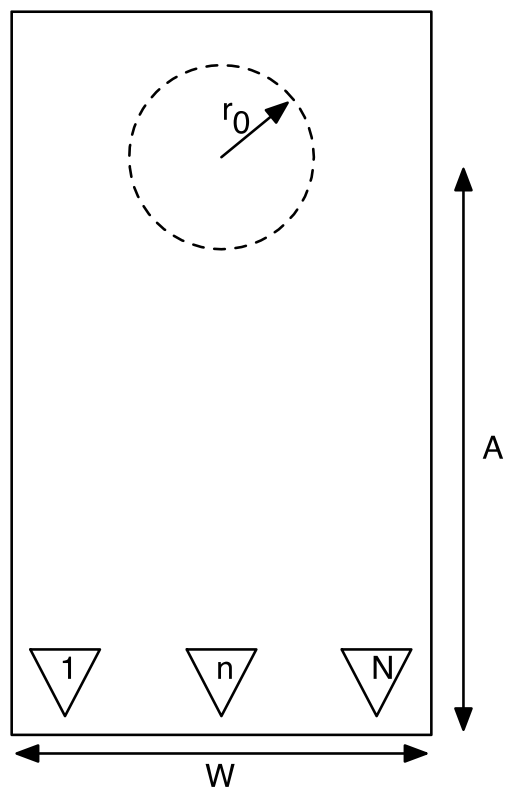
Reflectivity indicates the maximum E-field error at a given radius relative to the peak field over the entire test zone plane.

Note: Results are shown for a single instance in time

Simulation Technique

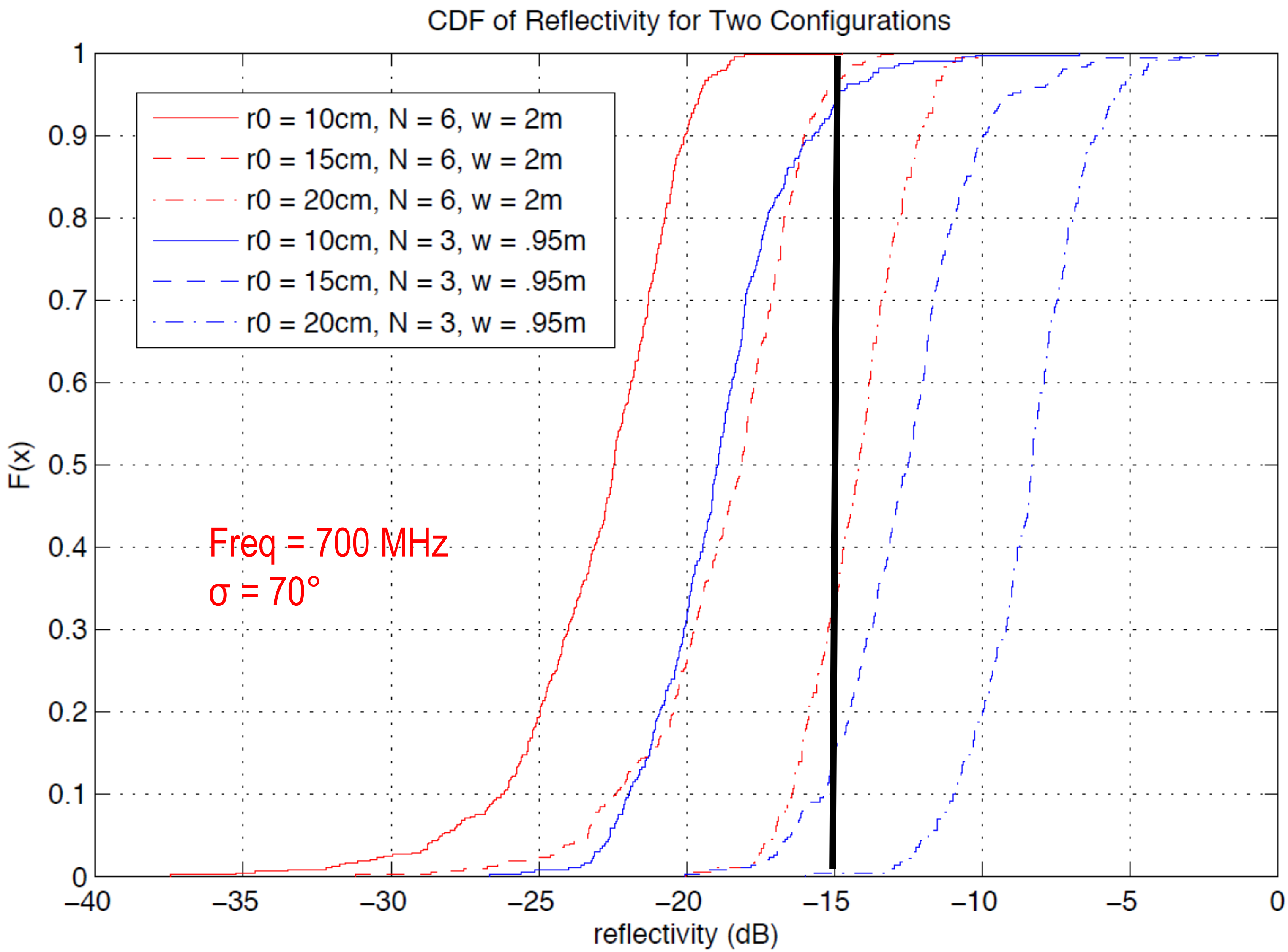
- Simulate the generation of a target electromagnetic field in a test zone with different small anechoic chamber dimensions/parameters
- The target EM field is a Laplacian-distributed Power Azimuthal Spectrum with a random phase a each angle $e^{j2\pi\beta}$ where β=[0…1].
- Monte Carlo simulations to determine the reflectivity in the test zone with 95% and 0.25 dB error.

Simulation Configuration Diagram



Number of antennas	Chamber height (m)	Chamber width (m)	PAS (σ in degrees)	Frequency (GHz)	Test zone radius (cm)
3,4,5,6	1	0.95, 1.5 2	50,70,90	0.7, 2.4, 5.9	10,15,20

Simulated Reflectivity vs. # Probes, r0, width



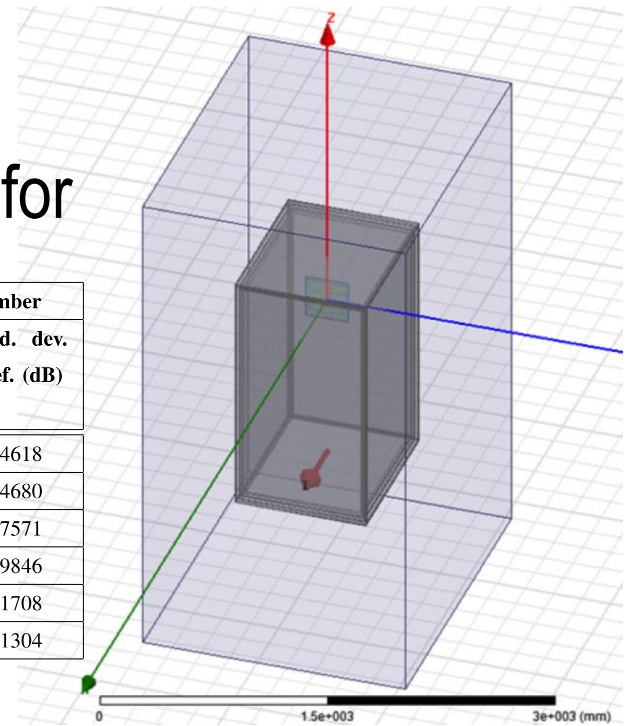
Summary of Simulation Results

- More probes required for bigger test zone radius to maintain the same accuracy (reflectivity)
- For a small laptop or pad sized test zone, 20cm test zone radius, it appears at least 6 probes are required to keep the error (reflectivity) below -15 dB
- Constraining the range of phase variation of the waveform will make this feasible
- Our effort has created a tool to help us optimize error vs. number of probes

Computation EM Simulations

- Field based simulations do not account for reflections and near-field effects
- Create a chamber model to analyze the performance of a realistic system
- Vacuum results are comparable
- Reflections and NF must be accounted for

r_0 (m)	N	Lap. σ (deg)	Freq	Width (m)	Matlab, vacuum		HFSS, vacuum		HFSS, chamber	
					mean ref. (dB)	std. dev. ref. (dB)	mean ref. (dB)	std. dev. ref. (dB)	mean ref. (dB)	std. dev. ref. (dB)
0.1	6	25	700 MHz	2.0	-36.7199	2.4177	-36.2777	2.2741	-21.5130	4.4618
0.1	6	35	700 MHz	2.0	-34.6884	3.5247	-34.2675	3.4109	-22.1664	4.4680
0.1	6	45	700 MHz	2.0	-30.7851	4.5645	-30.3239	4.5859	-22.4231	4.7571
0.1	3	25	2 GHz	0.95	-17.1502	3.6965	-17.3265	3.9848	-15.1249	2.9846
0.1	3	35	2 GHz	0.95	-14.3711	3.6514	-13.4716	3.5810	-12.9946	3.1708
0.1	3	45	2 GHz	0.95	-12.2670	3.5722	-11.3945	3.4241	-11.0843	3.1304



Verifying Laplacian Field

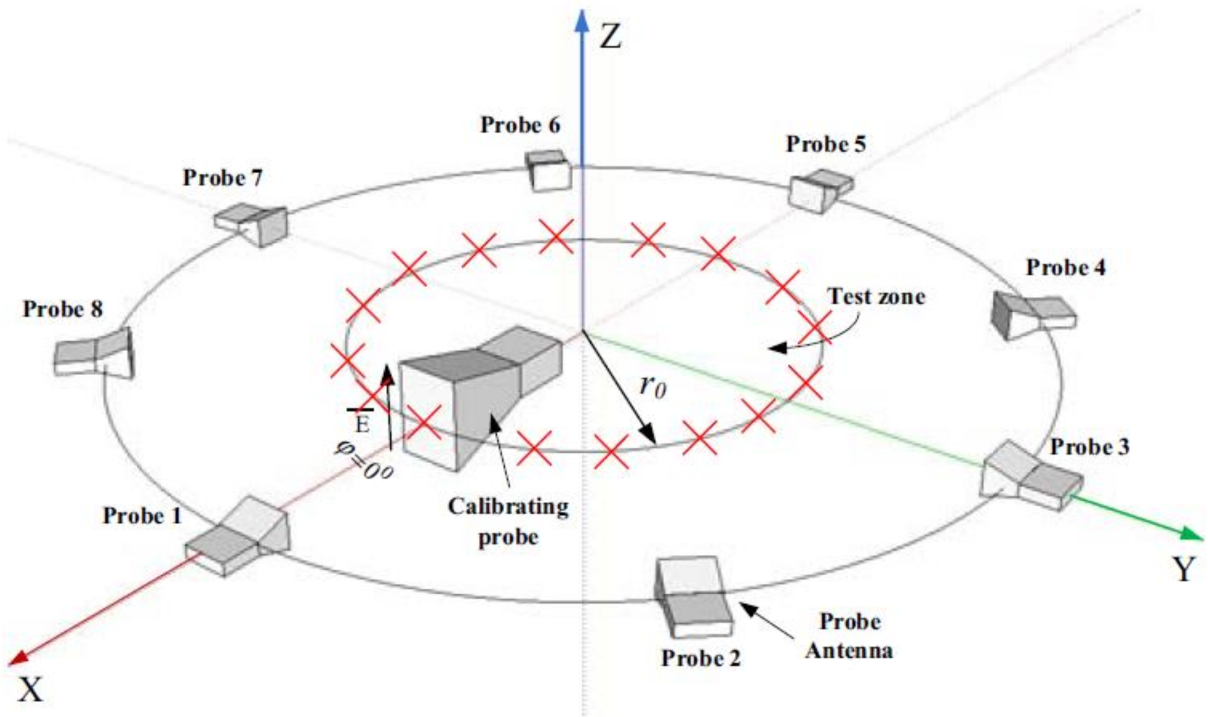


Fig. 3. The 2-D multi-probe system calibration setup of eight probes. The red crosses are the possible locations of the calibrating probe placed equidistantly with constant ϕ intervals ($\Delta\phi$) around the test zone of radius r_0.

Source: "Calibration Procedure for 2-D MIMO Over-The-Air Multi-Probe Test System", by D. Parveg et al

Contributions

- Document for the CTIA MIMO-OTA Subgroup
- Submission to IEEE Transactions of Instrumentation and Measurements

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5) CTIA, DRAFT “Test Plan for 2x2 Downlink MIMO Over-the-Air Performance”
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16) CITA MOSG130705, “Action Item Plan for Defining EUT Size and Test Zone for the Multi-Probe Anechoic Chamber Methodology”, by Anatoliy Ioffe et al.
17) “Calibration Procedure for 2-D MIMO Over-The-Air Multi-Probe Test System”, by D. Parveg et al