


Advancements In Over-The-Air Testing of Multi-format Wireless Devices

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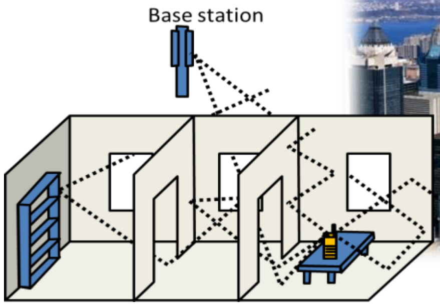
The Wireless Evolution

- More and more equipment becomes wireless
  - Increased need for capacity, speed & reliability
- Moore’s Law Hits at the Wireless Spectrum
  - “Domain Expansion”: Frequency, Time, Code, Spatial
  - MIMO and Rake Receivers
- Devices use multiple communication standards..
  - LTE, Wi-Fi, Bluetooth etc.
  - Often at the same time
- ..or multiple carriers/radios on the same standard
  - LTE Carrier Aggregation

Transmission Environment Shift

- Wireless communication used to be directional and line of sight
  - Antenna radiation patterns were verified in large and expensive anechoic chambers



- But that has changed with 2G, 3G, 4G…
  - No specific direction of the received radio signal
  - Multipath fading environment is the key enabler for MIMO systems like 4G (LTE, WiMAX) and WLAN (802.11n)

- System Design for a Rich Isotropic Multipath Environment:
  - Spatial Domain Leverage
  - High Throughput Expectations under challenging environments
  - Increased blending of digital chipsets with RF and packaging
  - LTE, WLAN and other MIMO devices measured as easy as 2G and 3G devices

Why Measure OTA Device Performance?

- The component manufacturer benefit
  - For antenna manufacturers:
    - Ensure maximized efficiency, diversity/MIMO gain and optimized antenna location
  - For chipset manufacturers:
    - Verify RF properties and transceiver algorithms

Why Measure OTA Device Performance?

- The device manufacturer benefit
  - RF performance of the complete device can be optimized from chip to antenna
  - Increase end user satisfaction by ensuring best possible receiver, transmitter and throughput performance
  - Comply with regulator and operator requirements

Why Measure OTA Device Performance?

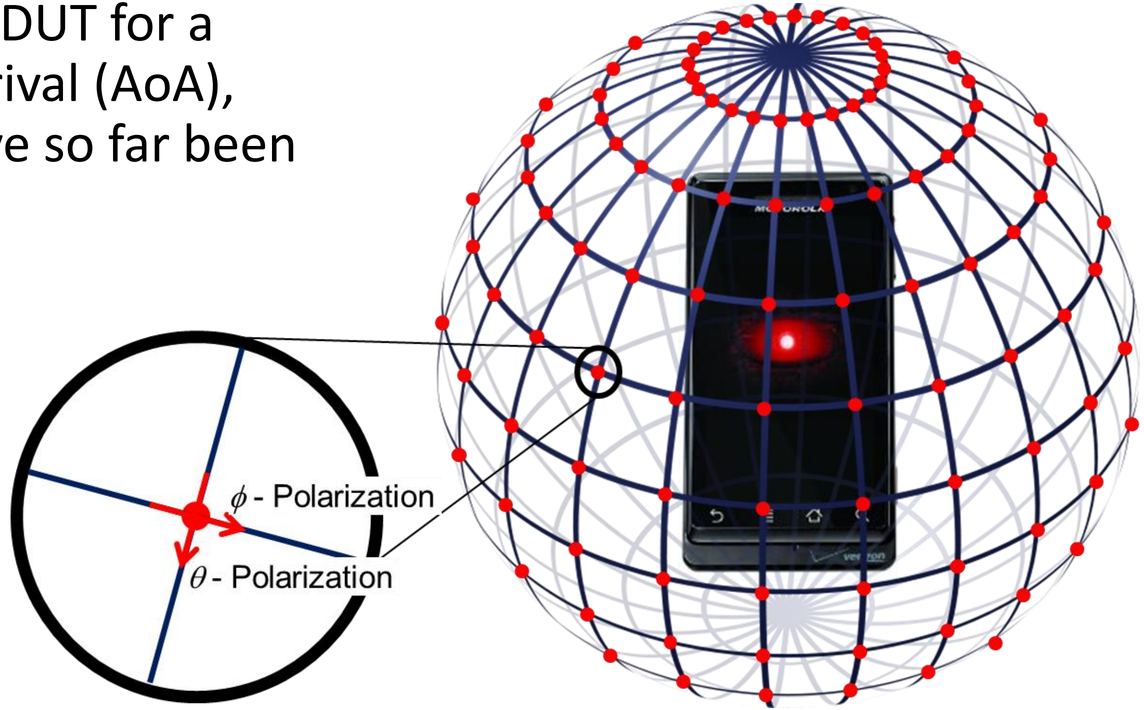
- The operator benefit
  - Select what devices and accessories to endorse/promote
  - A better performing device can reduce network load as much as 10-20% => Increased network capacity and revenue!
  - A better performing device increase end user satisfaction and reduce customer complaints

Why Measure OTA Device Performance?

- With OTA tests, the <u>entire</u> TX and RX chain is evaluated for performance
  - Conducted tests evaluate pass/fail conformance but stop at the conducted ports of the device
- Every wireless enabled device with cellular functionality needs to be thoroughly tested and certified
  - Devices with pre-certified radio modules do not need to re-evaluated/certified for conducted conformance
- Some OTA solutions provide fast system performance metrics for design verification and optimization

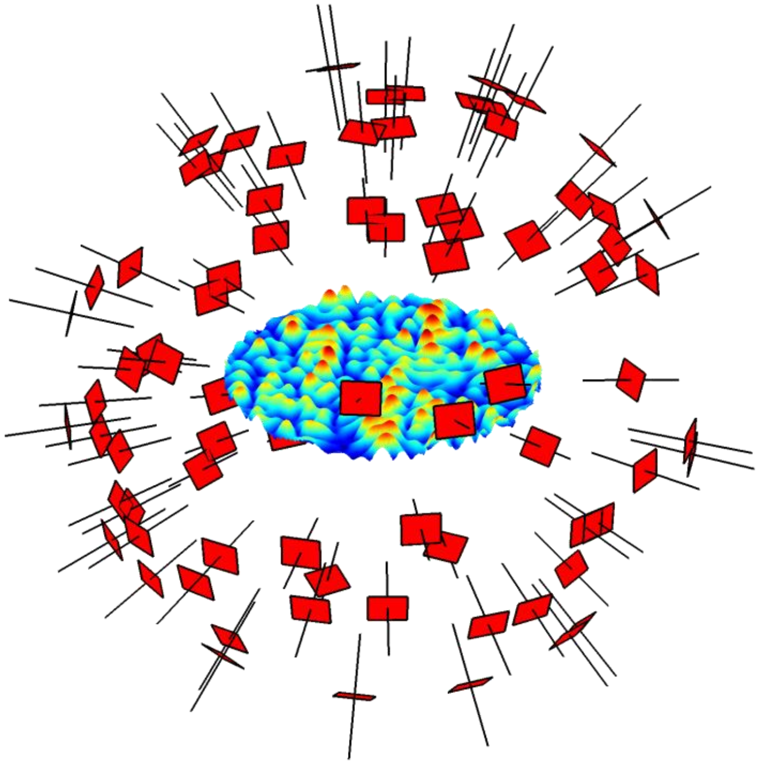
OTA Testing: 3D, Anechoic Evaluation

- In order to characterize the DUT for a large variety of angles of arrival (AoA), radiation characteristics have so far been captured in a full 3D fashion
  - Elevation
  - Azimuth
  - Polarization
- Test environment:
  - Anechoic chambers



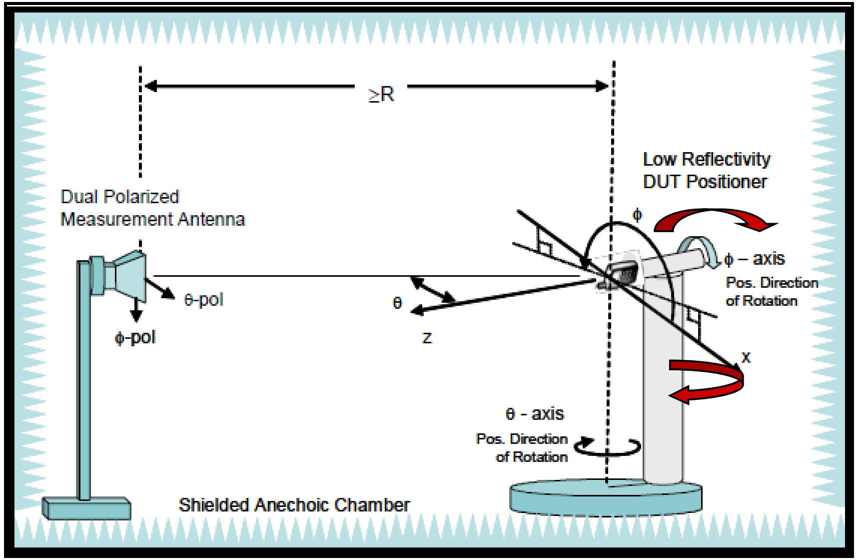
Definition: Isotropy

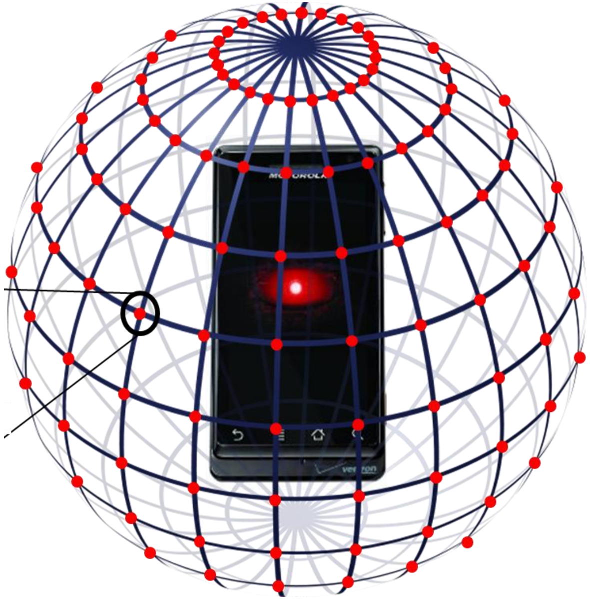
- Isotropic environment
  - Any angle of arrival equally probable
  - Any polarization equally probable
  - Average power equal in each direction and polarization
- Statistical Property:
  - Valid over the average of multiple incident waves
  - Instantaneous field not isotropic



History of OTA System Architectures

- Anechoic OTA testing started with Combined Axis Systems (Great Circle method)



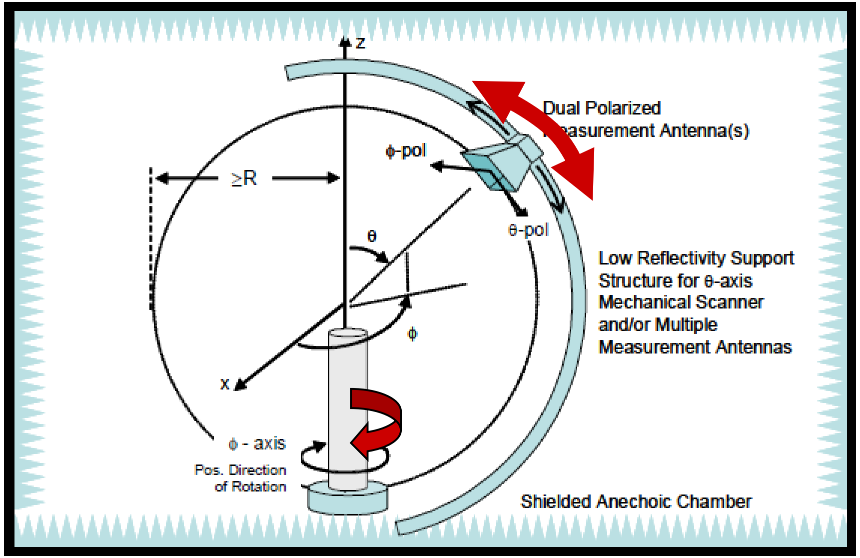


Test antenna is fixed

DUT is turning in azimuth and elevation

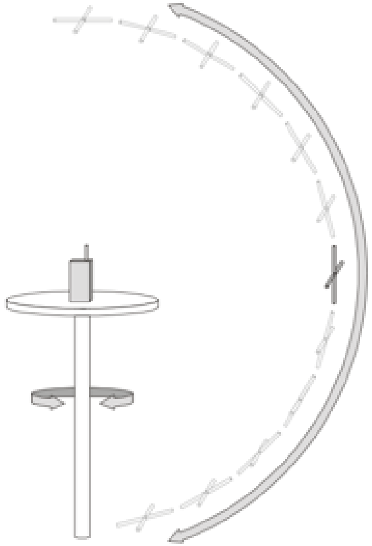
History of Anechoic System Architectures

- Later, Distributed Axis System (Conical Cut method) became more popular



DUT is turning in azimuth

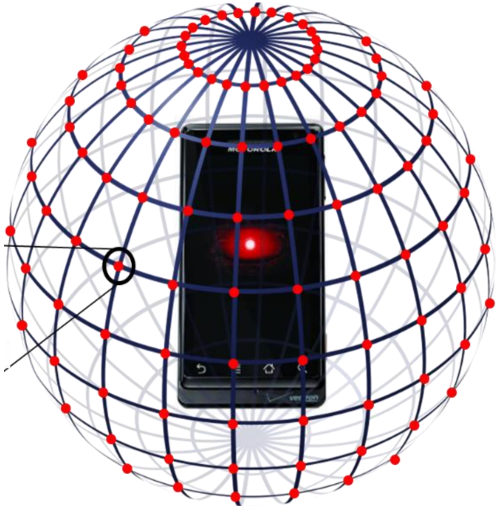
Single test antenna moving along elevation plane



Multiple probes along elevation plane

Base OTA Tests

- **TRP** Total Radiated Power
  - How well does my transmitter and transmitter antenna design work?
- **TIS** – Total Isotropic Sensitivity
  - How well does my receiver and receiver antenna work?



MIMO OTA Testing: Biggest Model Shift

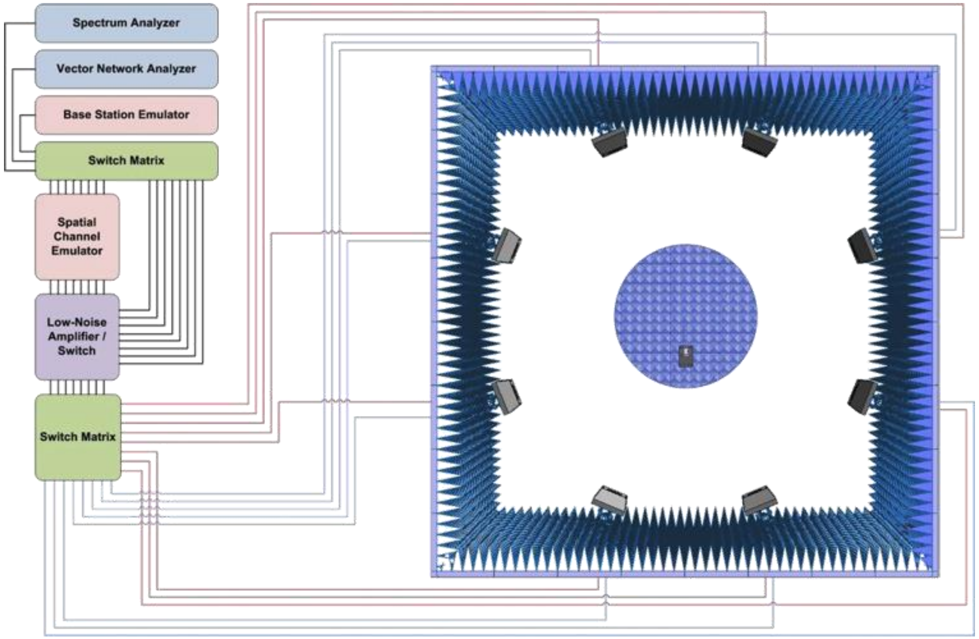
- The industry felt that new measurement approaches were required for MIMO OTA performance evaluation
  - Introduction of multipath radio channels was considered necessary to accurately determine the system performance of antennas and spatial diversity receiver
- A variety of standardization groups, e.g., CTIA and 3GPP RAN4, have been working on suitable techniques for several years

MIMO OTA Testing: Biggest Model Shift

- The industry proposed a variety of approaches that directly and indirectly measured the device MIMO OTA performance
  - Direct Measurement Techniques:
    - Anechoic Chamber Multi-Probe Methods
    - Reverberation Chamber Methods
  - Indirect Techniques
    - Decomposition Method
    - Two-Stage Method

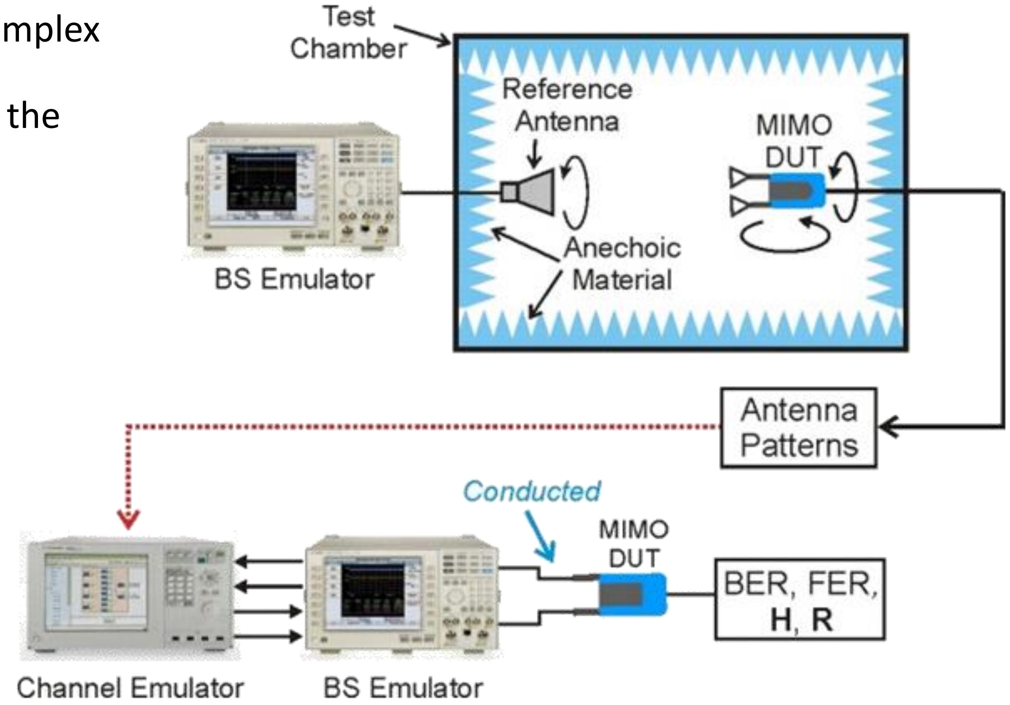
MIMO OTA Techniques

- One of the most prominent approaches is the multi-probe approach
  - Ring of dual-polarized probes surrounding the DUT
  - Generate channel model within the test zone



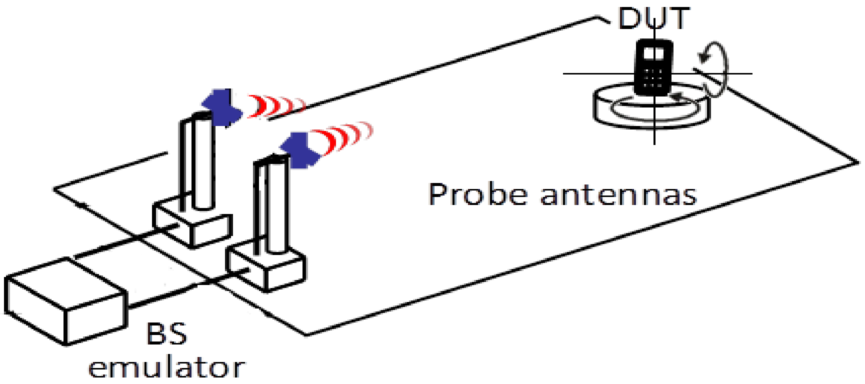
MIMO OTA Techniques

- Two-stage Method
  - During the first stage, the DUT records complex receiver antenna patterns and during the second stage convolves that pattern with the desired channel model



MIMO OTA Techniques

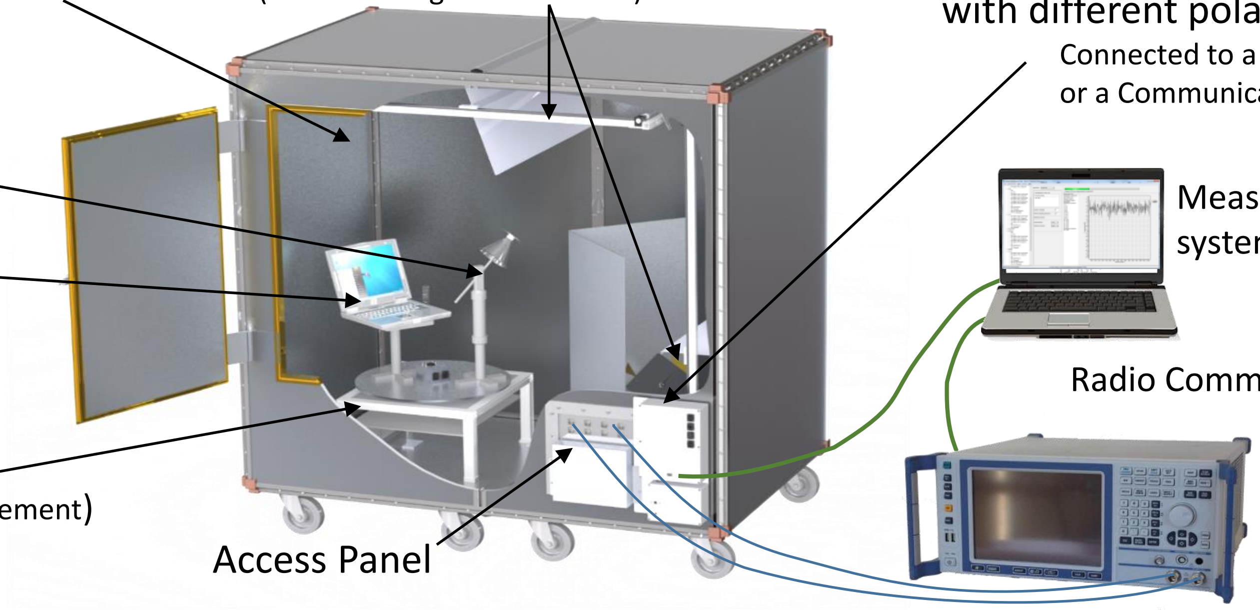
- Decomposition Method
  - Conducted test determines figure of merit of the receiver for desired channel models while the radiated test determines the figure of merit for the MIMO antenna pair. The combination of results from each test yield a figure of merit for overall device performance



MIMO OTA Techniques

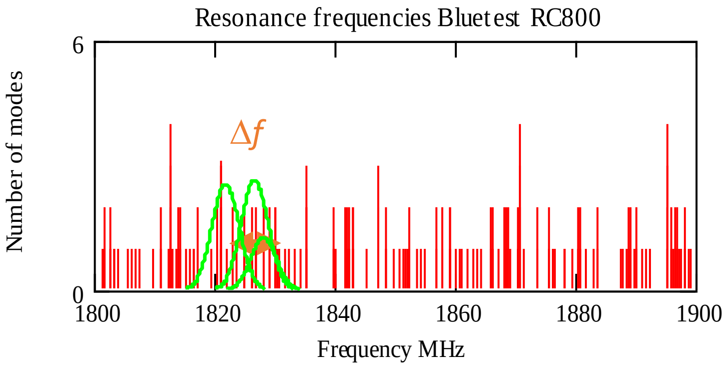
- In comparison, alternative approaches offer much simpler, less complex, and significantly cheaper solution
  - Two-stage Method
  - Decomposition Method
  - Reverberation Chamber Method

MIMO OTA: The Reverberation Test System

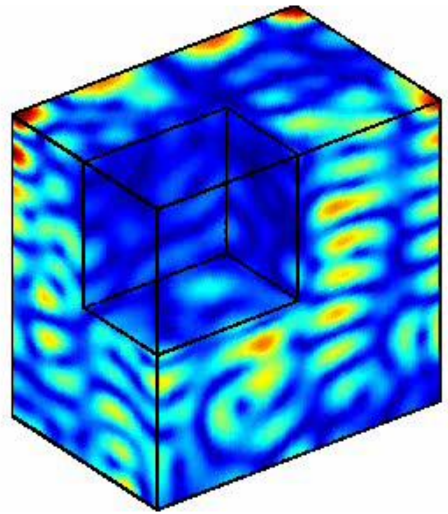


Stirring Effects Reverberation Chamber

- Stirring change boundary conditions and thus shift the eigenfrequencies of the resonant modes
  → Stirring increases the mode density at measurement frequency
- The more effective the stirring, the higher the mode density

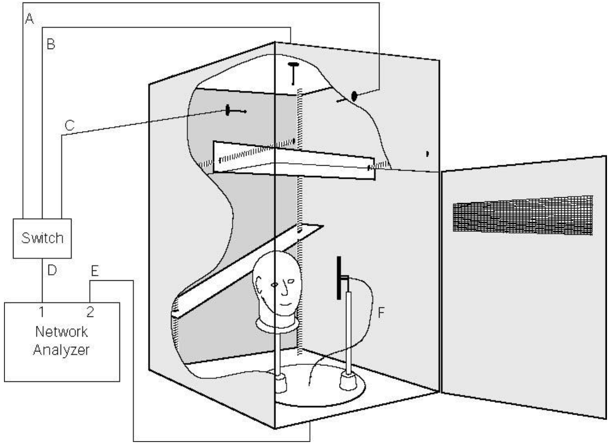


Simulated Rayleigh Field Distribution



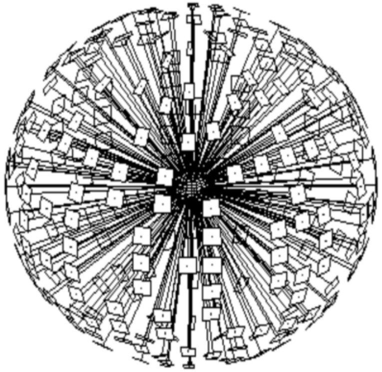
- Instantaneous signal level will differ over time and with position in the chamber (Rayleigh faded signal) but the average over time is the same regardless of position in the chamber (within certain limits)

Useful Properties of the Reverberation Chamber



- Isotropic field environment when averaged over large number of independent field samples

- Creates scattering environment
- Average transmission level in chamber proportional to
  - Total radiated power
  - Radiation efficiency of antenna



Inherent Chamber Environment

- Reverberation Chamber: NIST Channel Model
  - Pedestrian speeds
  - Low delay spread
  - Low correlation between MIMO channels
  - Full 3D evaluation with polarization balance
  - With or without interference
  - Conditions often found for example in indoor environments

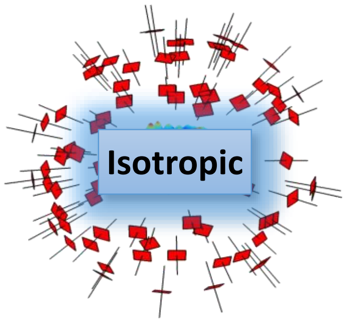
Adding a Channel Emulator

- Reverberation Chamber + Channel Emulator (RC+CE)
  - Can be used to emulate more advanced situations
  - For example:
    - Introduce high speed Doppler shift
    - Modify the power delay profile (PDP)
    - Adjust Base Station antenna configuration and correlation
    - 3GPP UMa-IS/UMi-IS channels

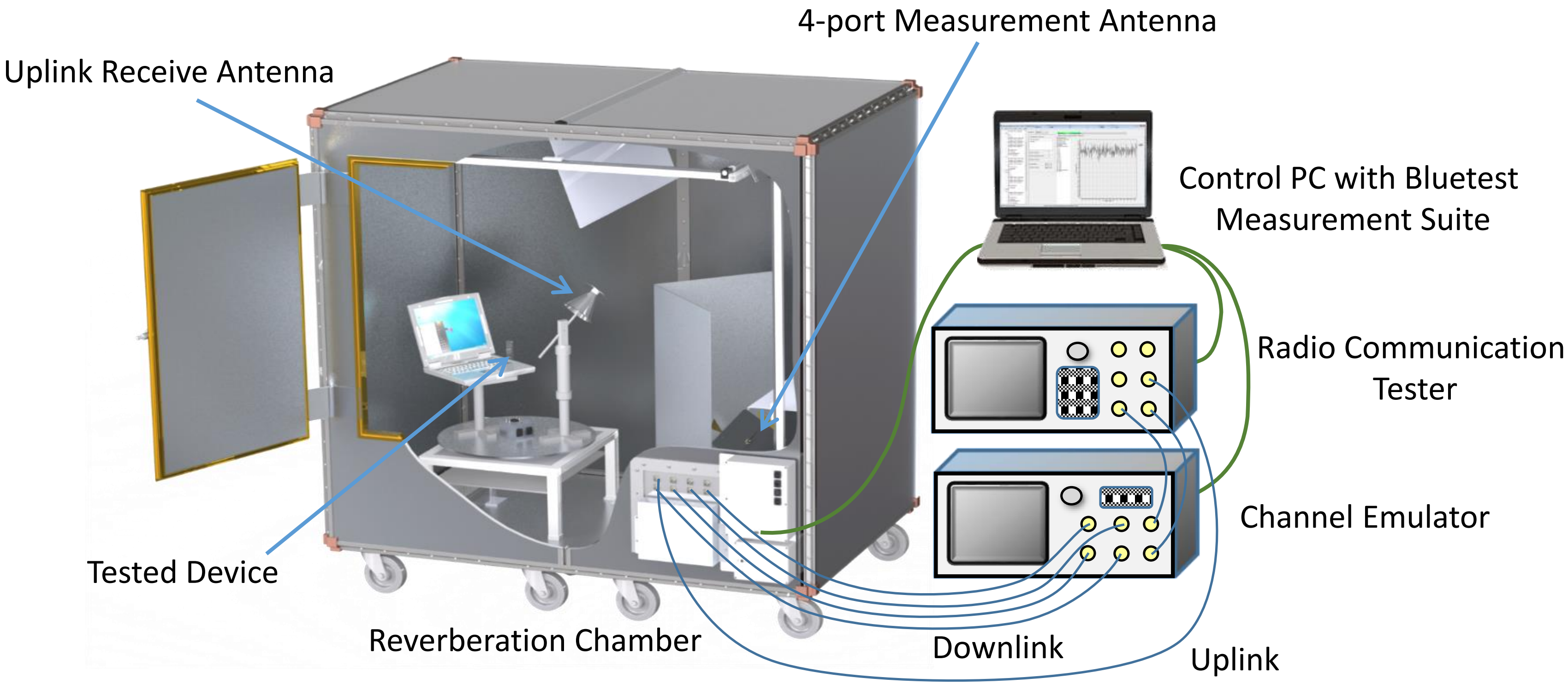
Angle Of Arrival

- The Angle of Arrival setting in the CE is not used
  - The RC automatically provides a full 3D evaluation of the device
  - The AoA in RC is isotropic in <u>average</u>, i.e over many samples
  - An individual sample will not be isotropic – it will have a distribution of AoA

- 3D Isotropic versions of UMa and UMi
  - UMi-IS: Isotropic short delay spread low correlation channel model
  - UMa-IS: Isotropic long delay spread high correlation channel model



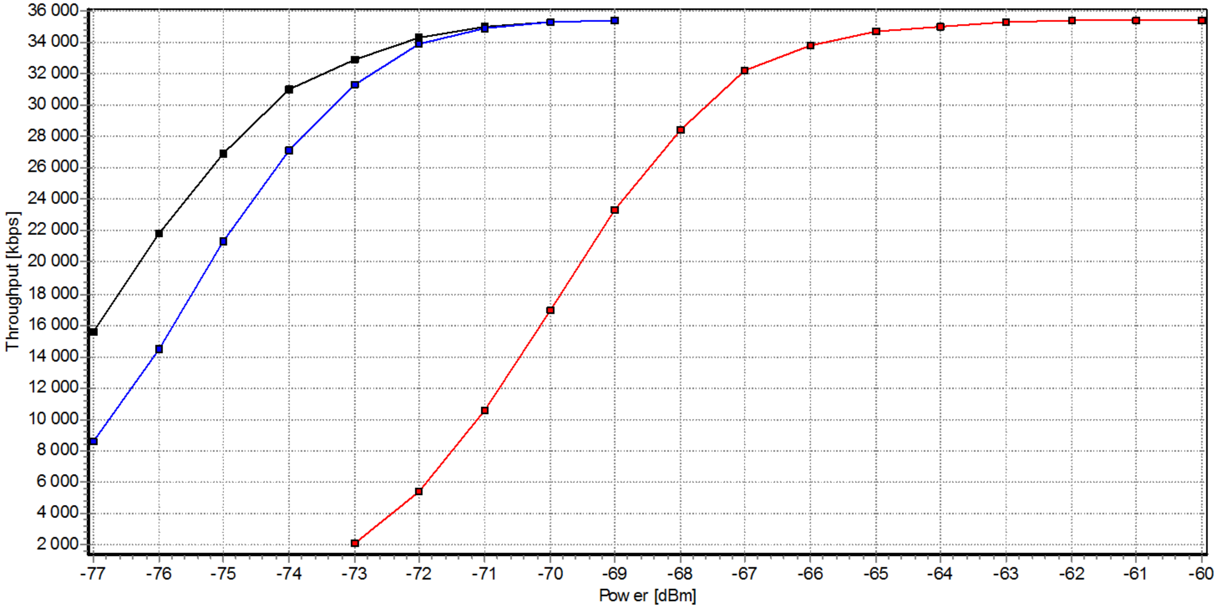
Measurement Setup



Example Results

- TPUT for a phone in
  - NIST (Black)
  - UMi-IS (Blue)
  - UMa-IS (Red)

- More difficult conditions mainly in UMa-IS
  - Higher correlation between MIMO channels

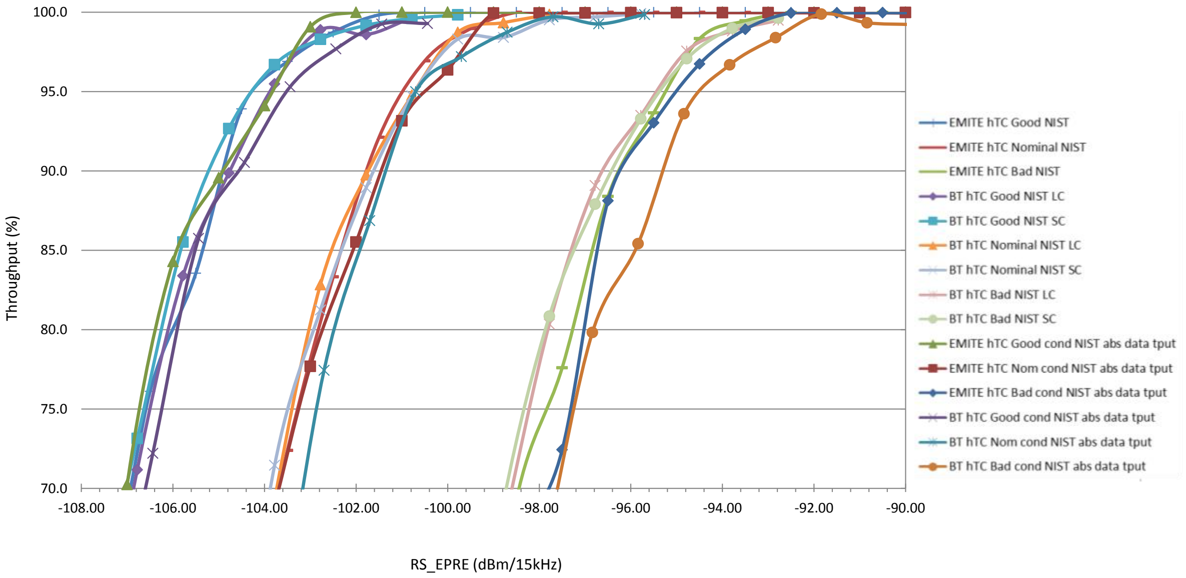


C: IL/IT Results Consistency

- Goal:
  - Inter-lab repeatability within CTIA SISO uncertainty (+/- 2.3 dB)
  - Align results to conducted reference within CTIA SISO uncertainty (+/- 2.3 dB)

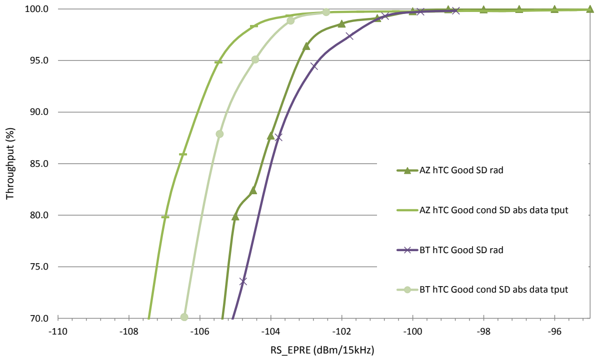
C: IL/IT Results Consistency

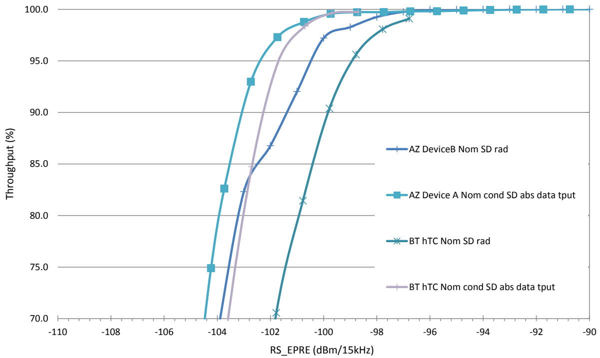
- RC - NIST

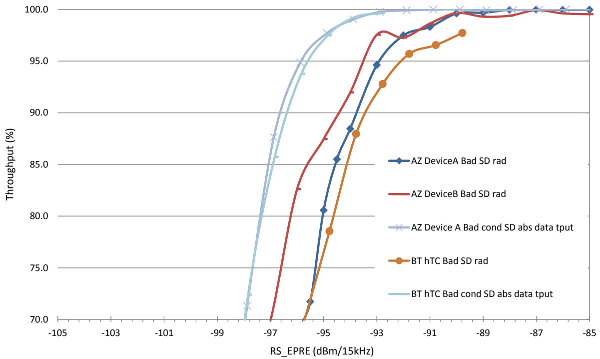


C: IL/IT Results Consistency

- RC – UMi

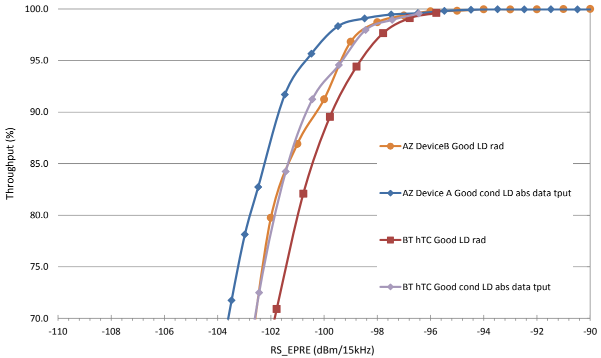


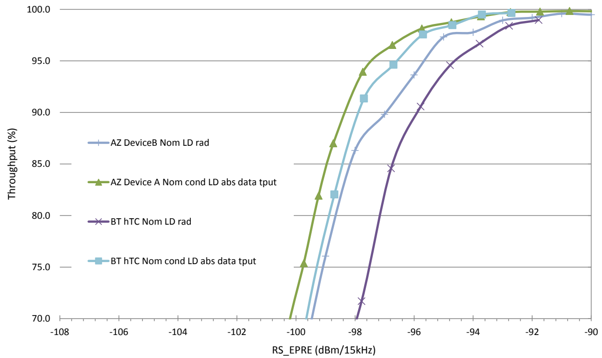


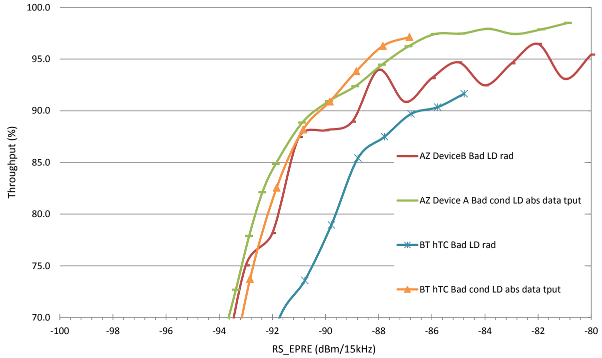


C: IL/IT Results Consistency

- RC –UMa

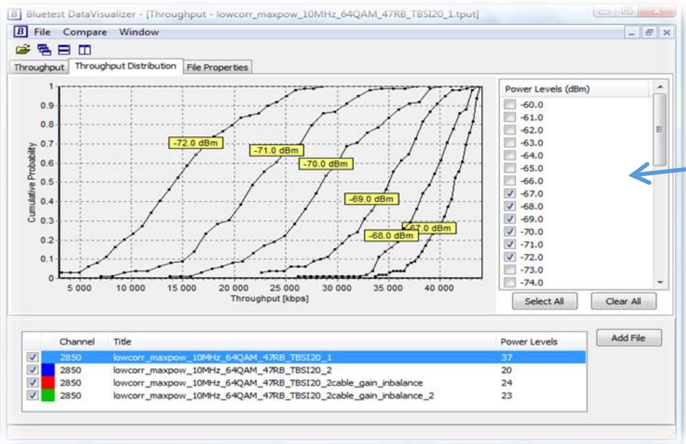






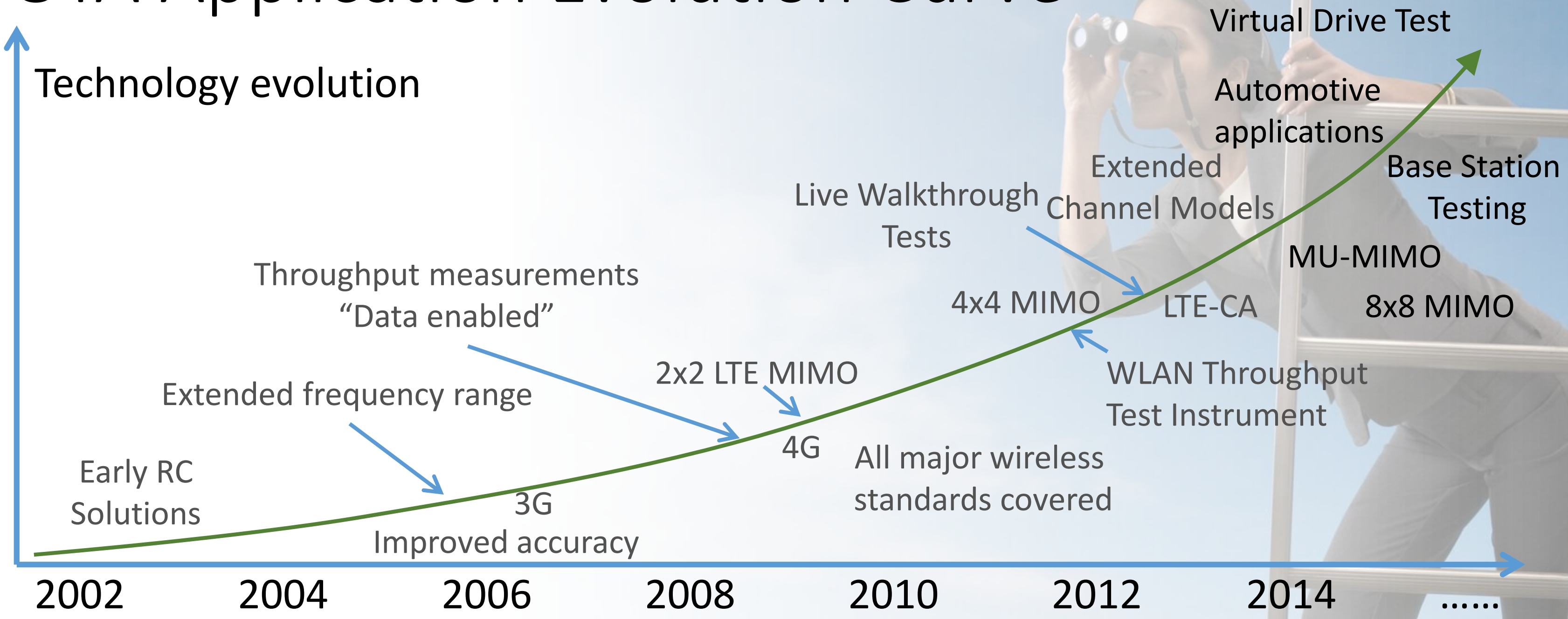
Integration and Extension

- System efficiency
- Diversity & MIMO gain



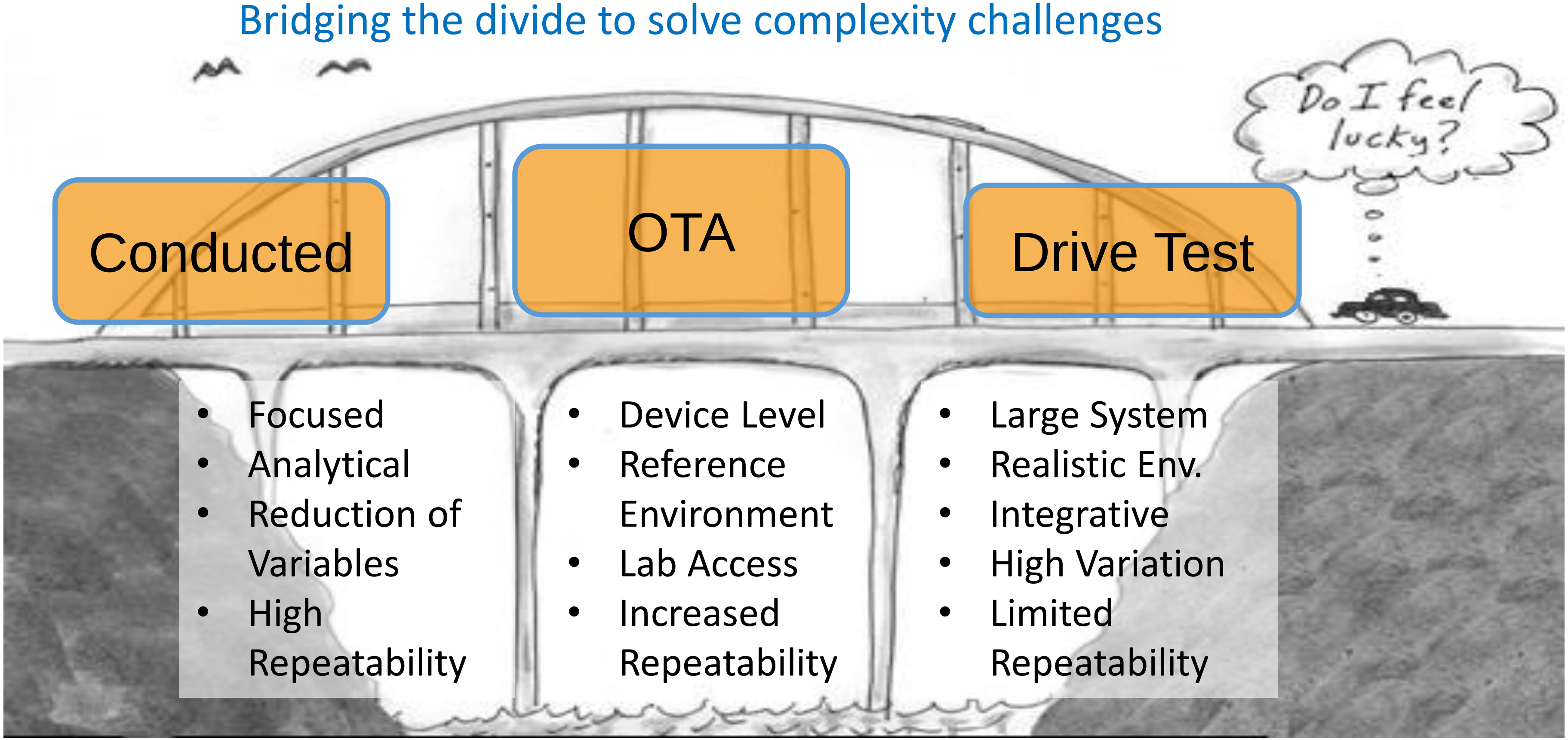
- **Existing: TRP** Total Radiated Power
  - How well does my transmitter and transmitter antenna design work?
- **Existing: TIS** – Total Isotropic Sensitivity
  - How well does my receiver and receiver antenna work?
- **Available: Throughput**
  - Data throughput vs signal level, on IP and/or MAC layer
  - Multi-format, Carrier-Aggregation
- **Extension: Coordinated Solutions**
  - Conducted Tests
  - Drive Test Systems

OTA Application Evolution Curve



The Promise of OTA

Bridging the divide to solve complexity challenges



Conducted

- Focused
- Analytical
- Reduction of Variables
- High Repeatability

OTA

- Device Level
- Reference Environment
- Lab Access
- Increased Repeatability

Drive Test

- Large System
- Realistic Env.
- Integrative
- High Variation
- Limited Repeatability

Questions?