mmWave AiP Validation Test with Lower Measurement Uncertainty and Higher Speed

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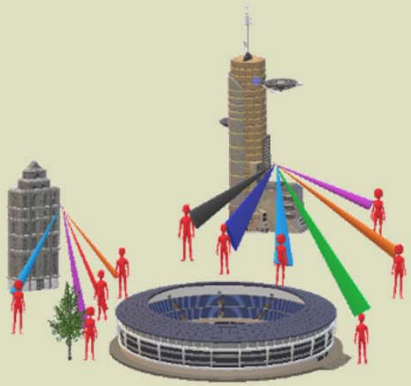
National Instruments

Virtual Event • May 11-13, 2020

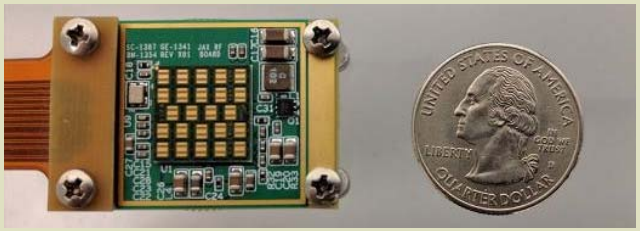
5G mmWave Requires In-Depth Over-the-Air (OTA) Test Knowledge

From 2G to 5G

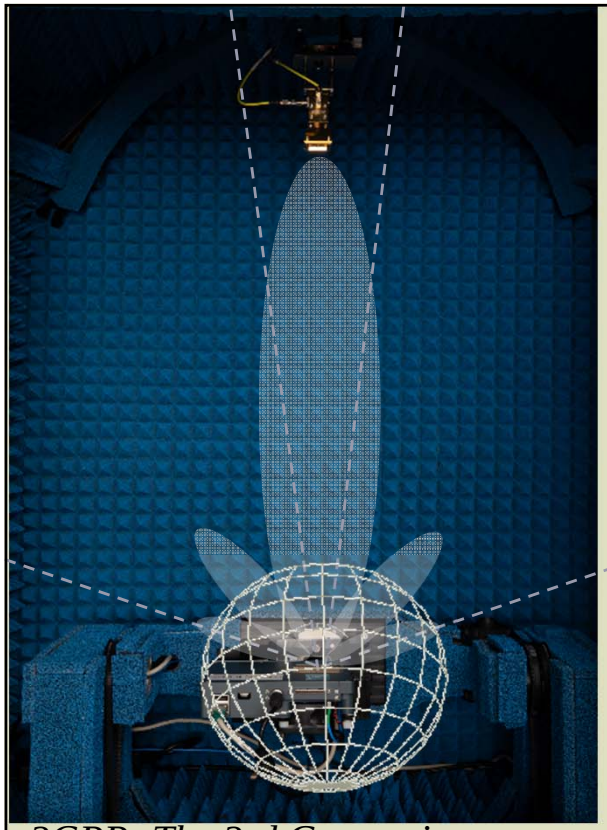
2G to 4G



5G



Performance of multiple antennas must be tested OTA



3GPP: The 3rd Generation Partnership Project

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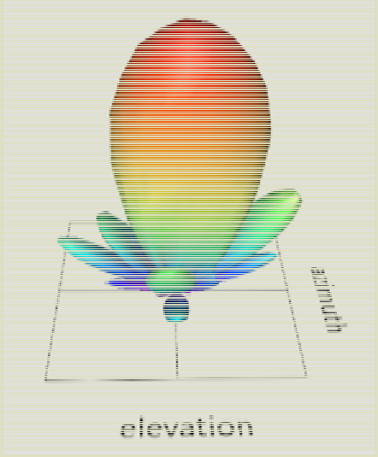
Job to-be-done: Measure the Far-Field Radiation Patterns of 5G Beamforming RFICs

Detailed 3D Scanning to find:

- Power versus position
- Other measurements versus position (3GPP New Radio (NR) standard)
  - Modulation Accuracy
  - Emissions
  - Distortion
  - Sensitivity

3GPP A GLOBAL INITIATIVE



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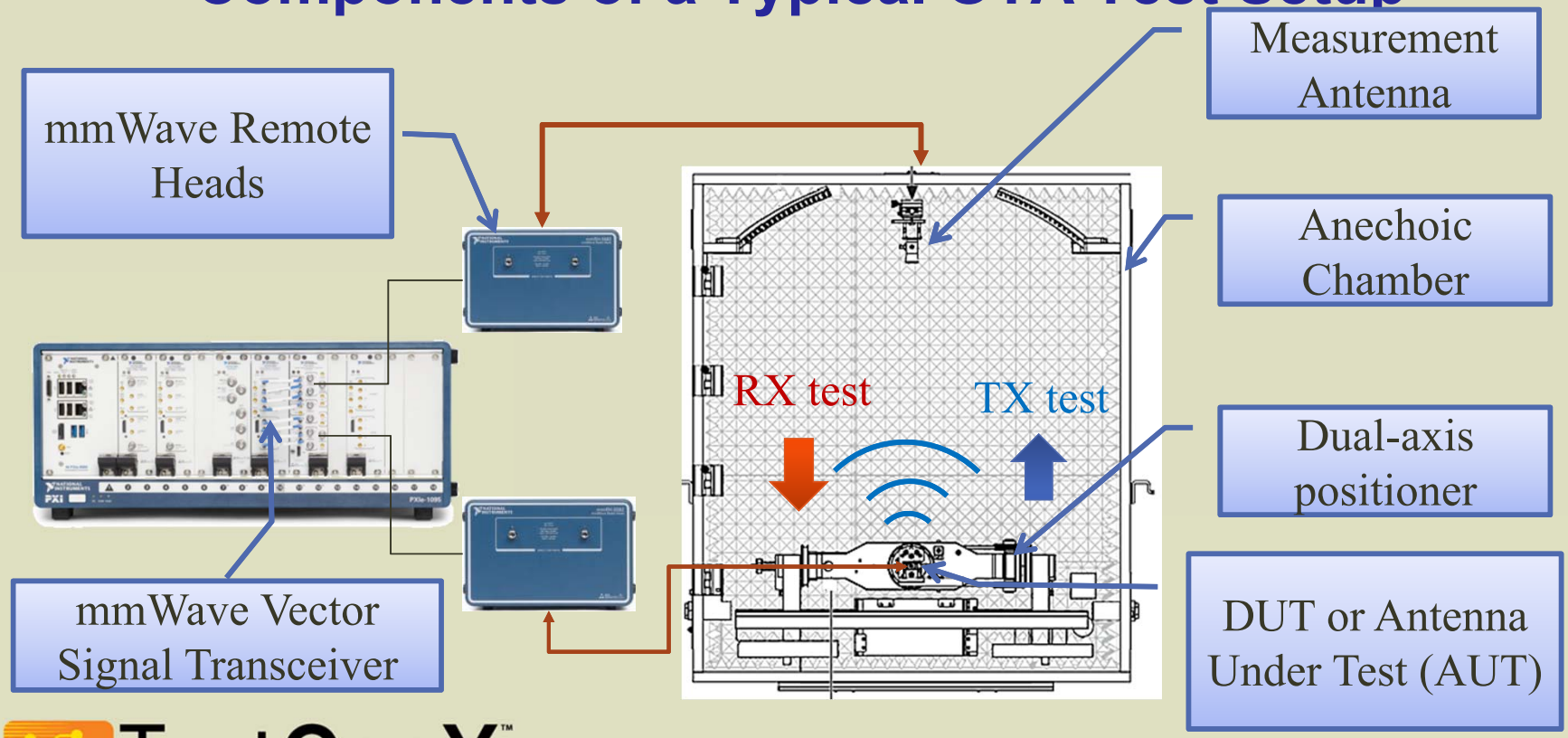
Components of a Typical OTA Test Setup



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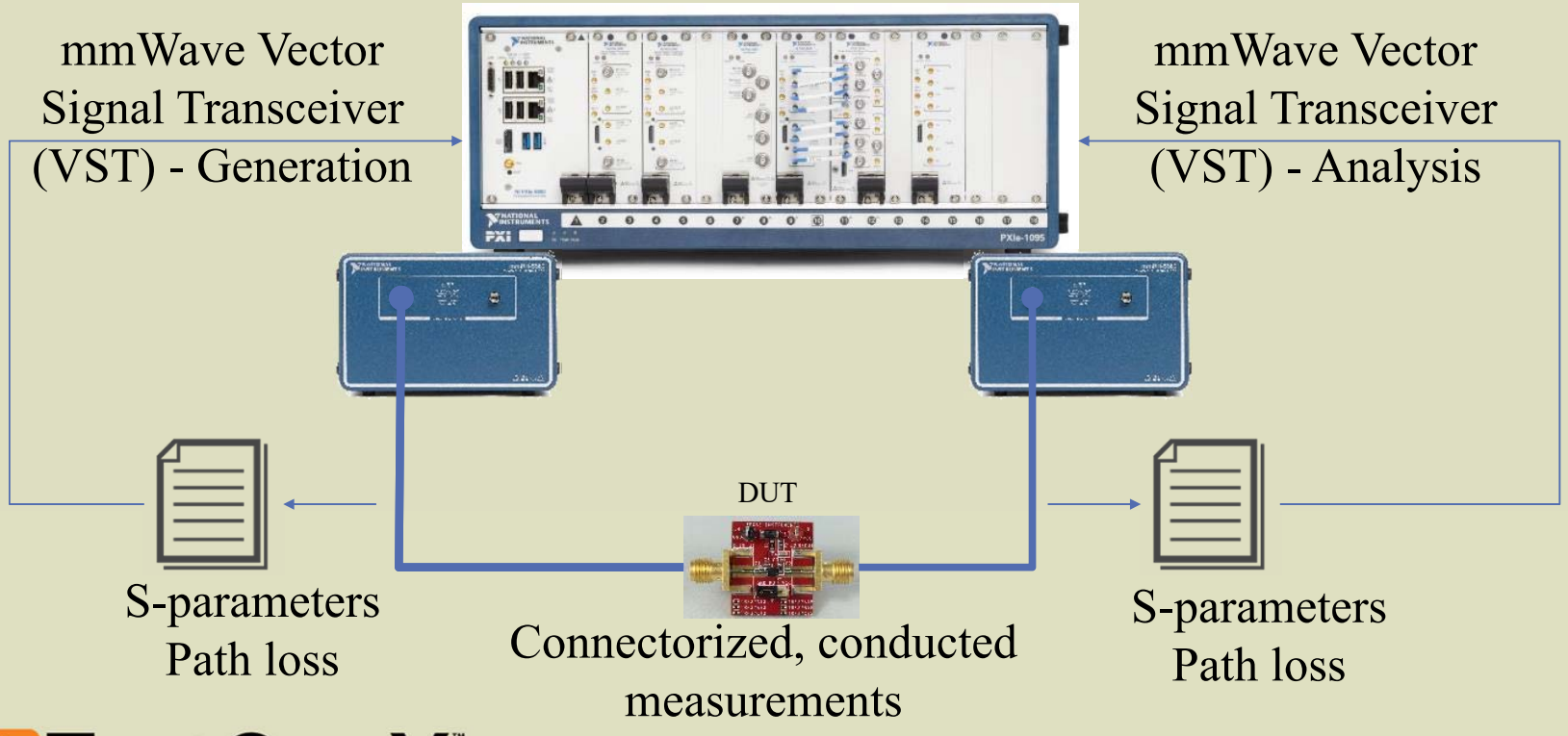
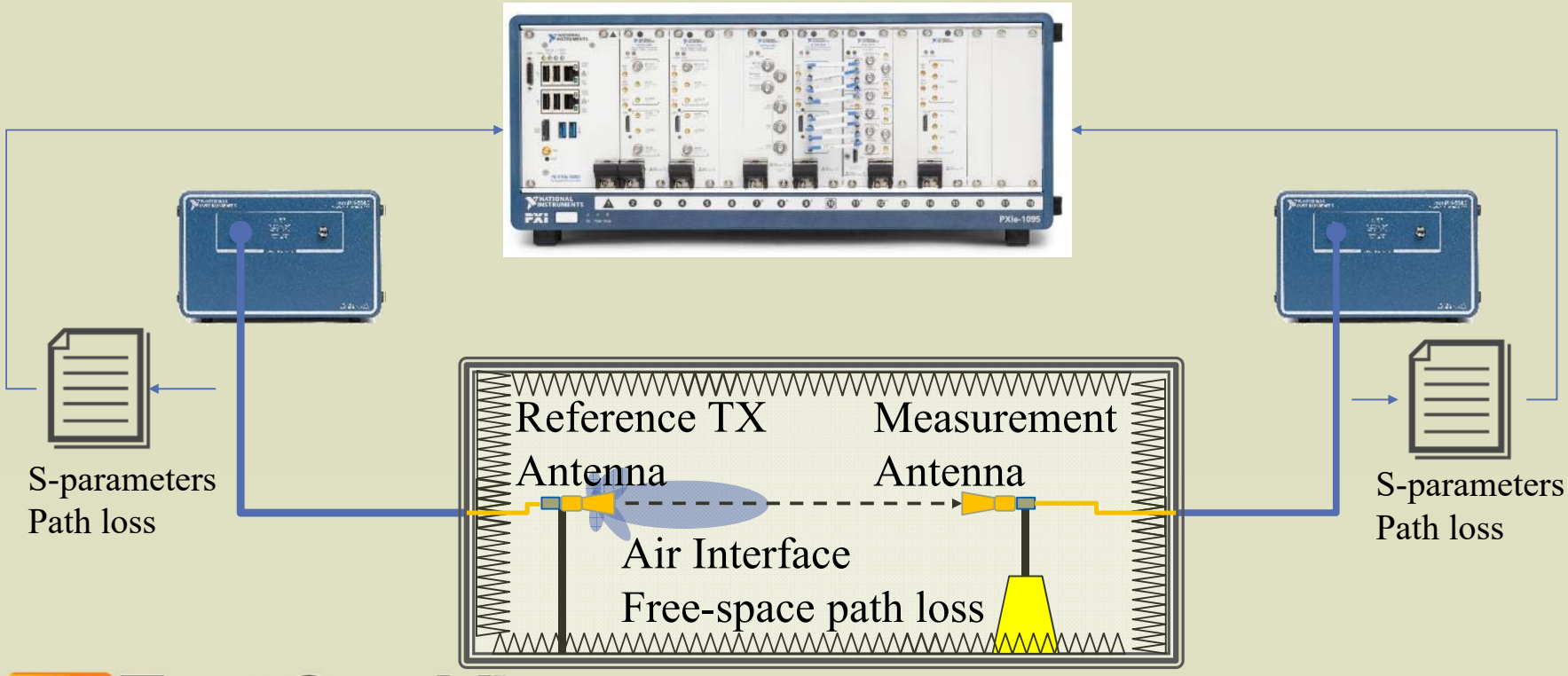
Calibrating Out a Traditional, Conducted Test Setup



OTA Measurements - Calibrating Out the Test Setup



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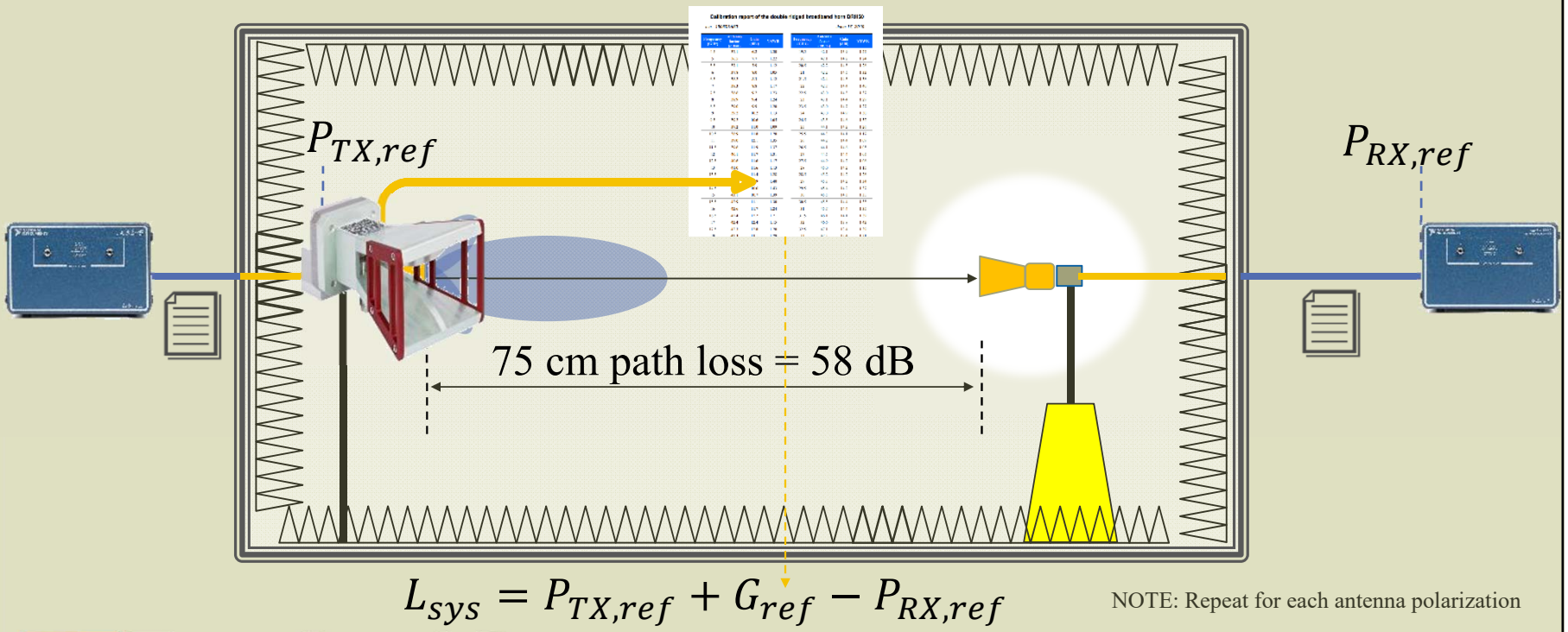
OTA Frequency Response Measurement

Gain Transfer Method

Overall loss measured with reference antennas

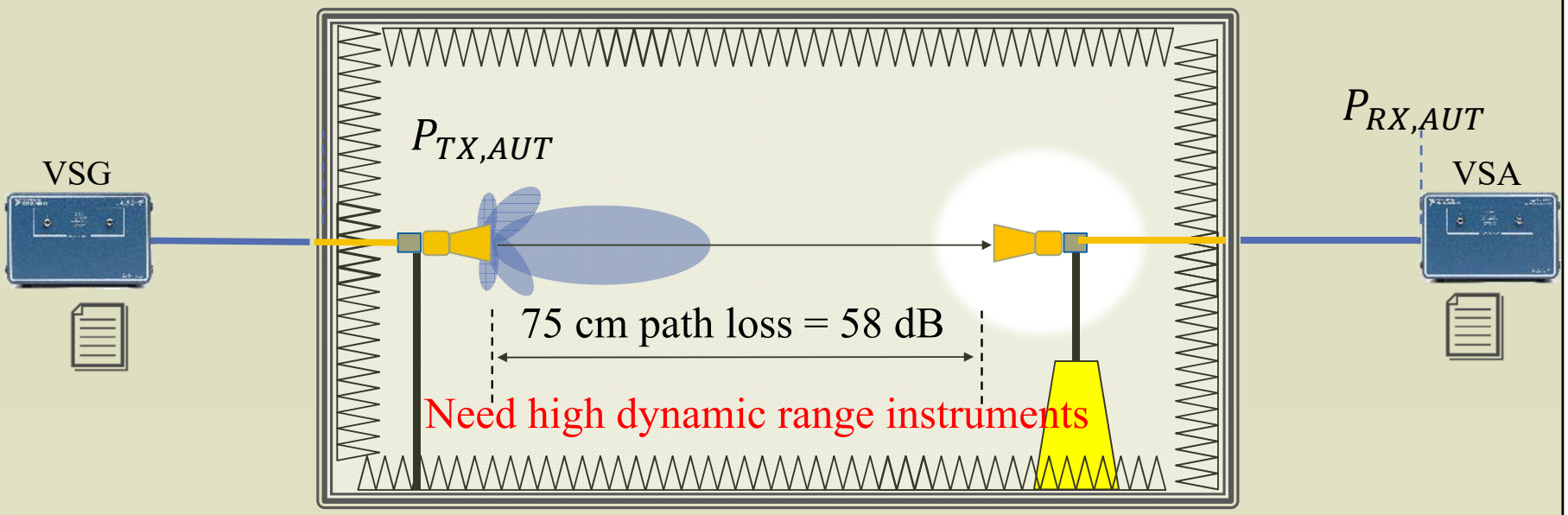


$$L_{sys} = P_{TX,ref} + G_{ref} - P_{RX,ref}$$

NOTE: Repeat for each antenna polarization

OTA Frequency Response Measurement

Gain Transfer Method

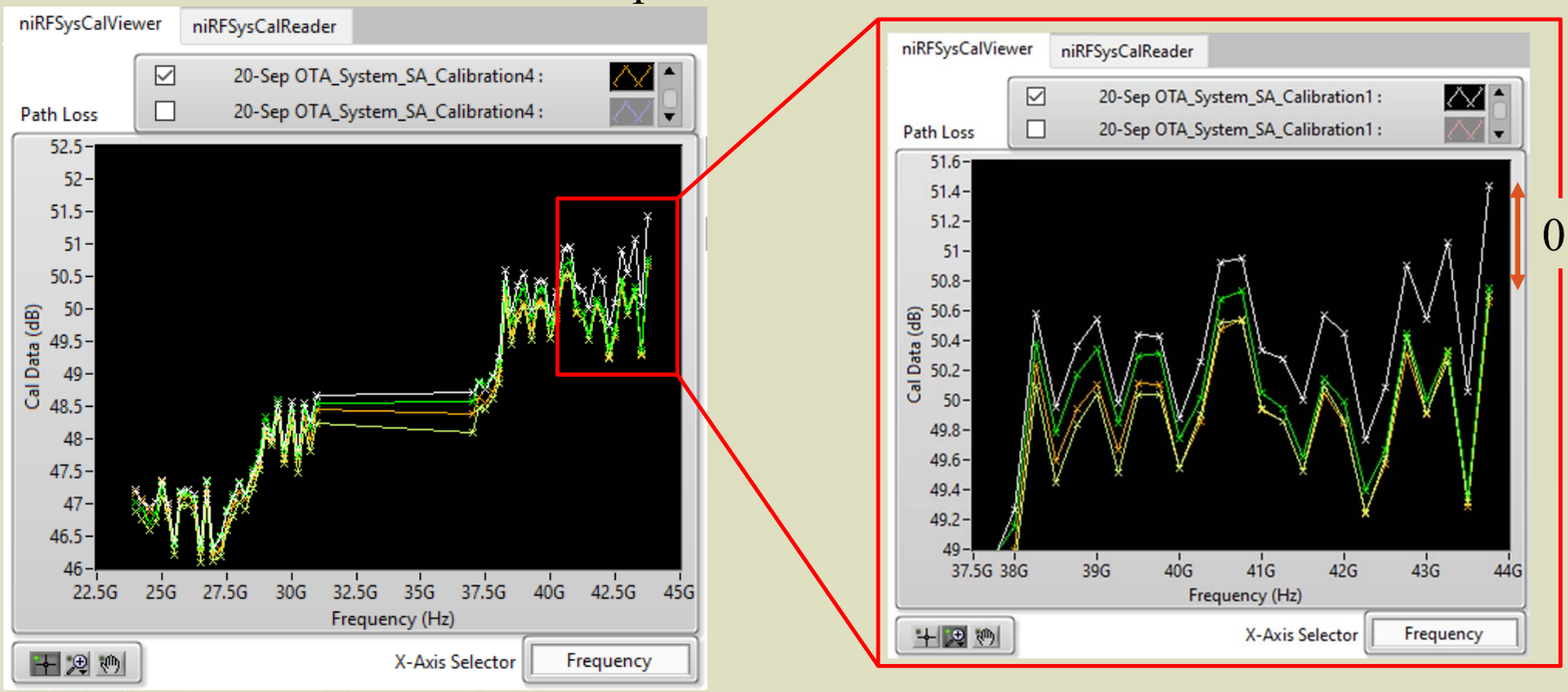


$$G_{AUT} = P_{RX,AUT} + L_{sys} - P_{TX,AUT} \quad \text{OR} \quad G_{AUT} = G_{ref} + P_{RX,AUT} - P_{RX,ref}$$

Unknown antenna realized gain

OTA Pathloss Reproducibility

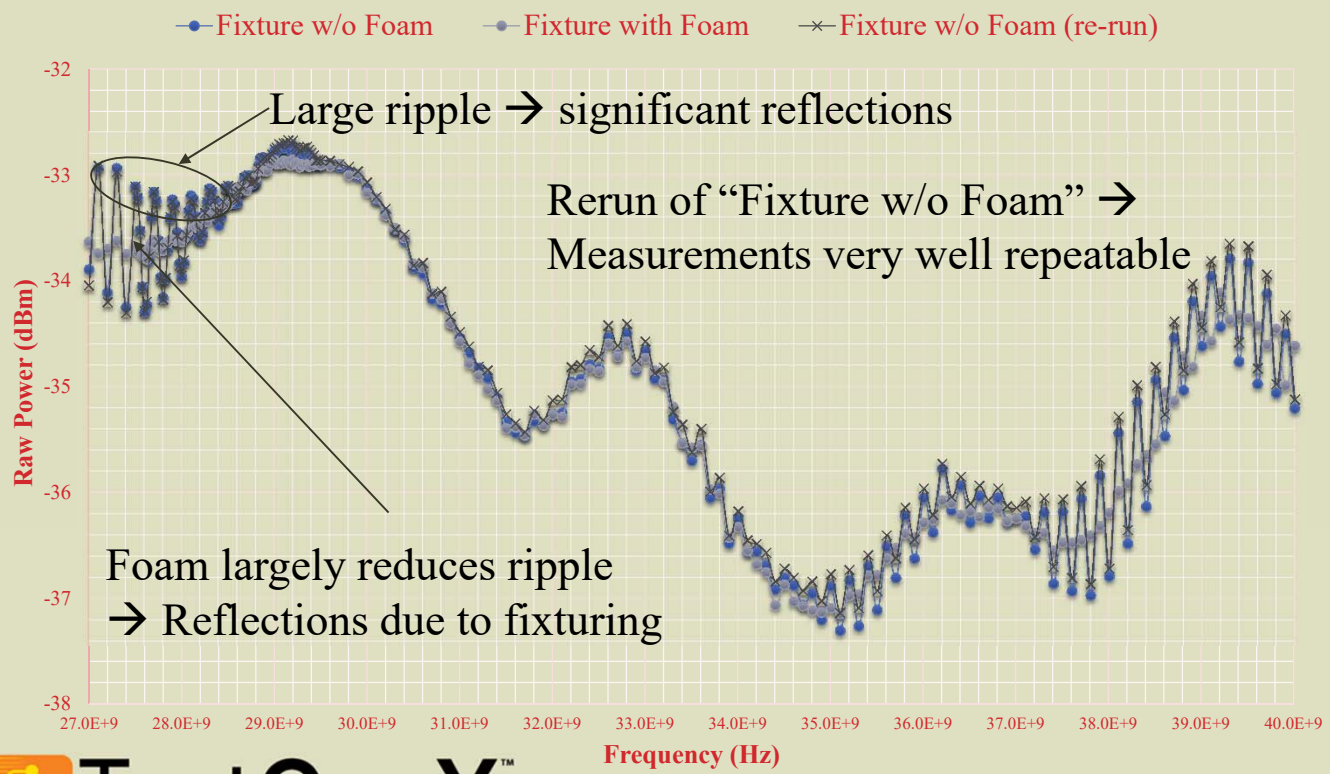
Disconnect/reposition/reconnect and recalibrate OTA

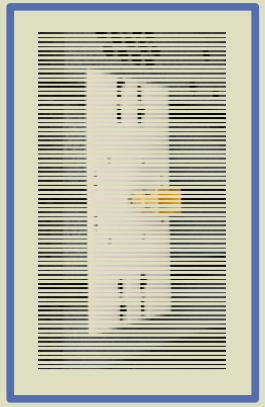


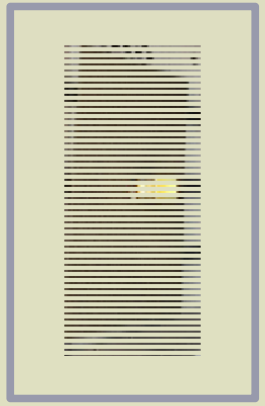
mmWave OTA Measurement Results

Antenna Measurements	3GPP NR Measurements (38.101-2 and 38.104)
• **Effective Isotropic Radiated Power or EIRP** • **Total Radiated Power or TRP** • Half Power Beam Width or HPBW (3dB width) • Beam Peak/Beam Center	• Radiated transmit power (**EIRP**) • OTA base station output power (**TRP**) • OTA power dynamics (**EIRP**) • OTA power ON/OFF power (**TRP**) • OTA transmitter signal quality • OTA unwanted emissions (**TRP**) • OTA transmitter intermodulation (**TRP**) • OTA sensitivity

Repeatability, Reflectivity







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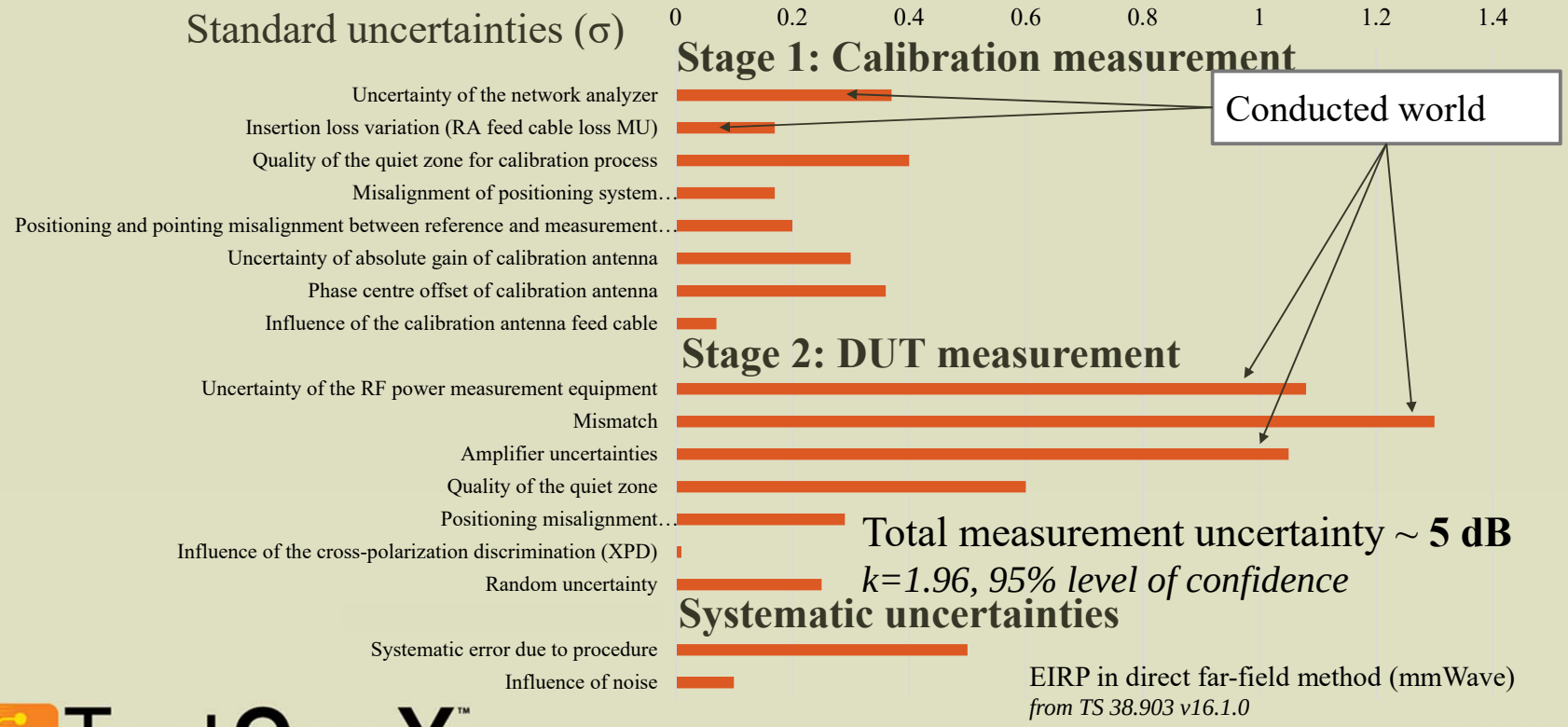
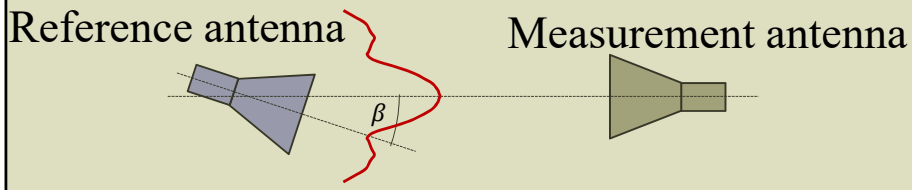
Measurement Uncertainty (MU) Contributors for Max Output Power

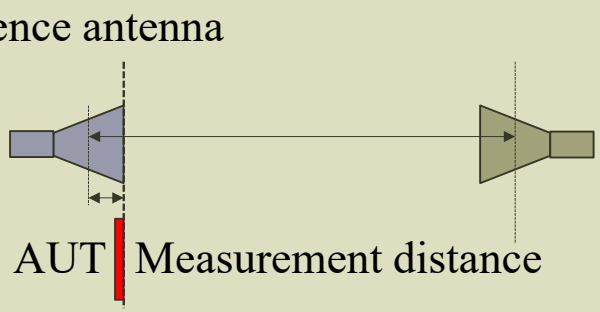


Uncertainty from Positioning and Reference Antenna

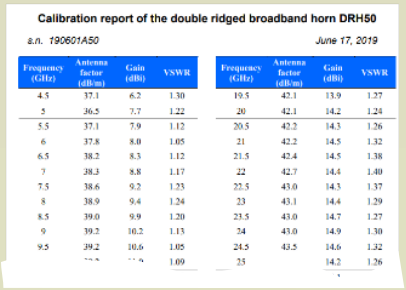
Antenna pointing misalignment



Positional offset reference antenna - AUT



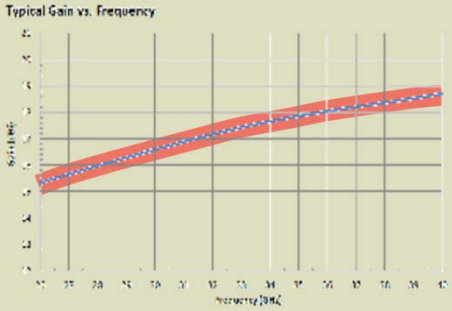
Reference antenna gain uncertainty



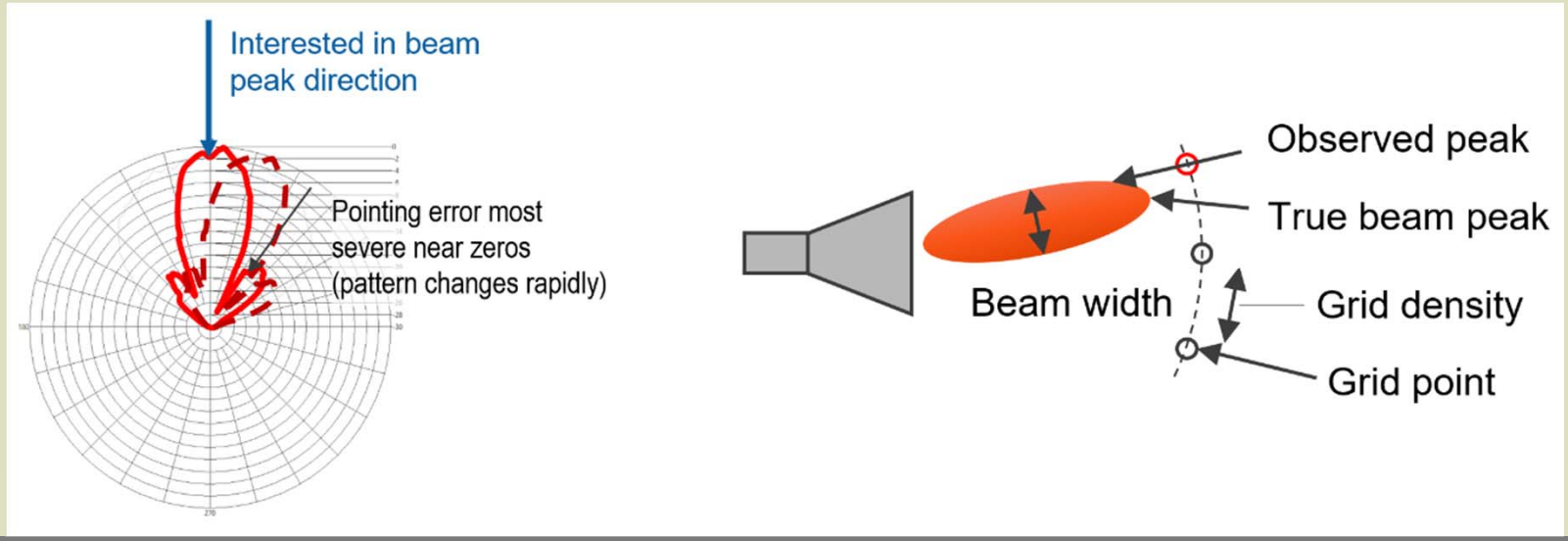
Calibration report of the double ridged broadband horn DRH50

s.n. 190601A50 June 17, 2019

Frequency (GHz)	Antenna factor (dB/m)	Gain (dBi)	VSWR	Frequency (GHz)	Antenna factor (dB/m)	Gain (dBi)	VSWR
4.5	37.1	6.2	1.30	19.5	42.1	13.9	1.27
5	36.5	7.7	1.22	20	42.1	14.2	1.24
5.5	37.1	7.9	1.12	20.5	42.2	14.3	1.26
6	37.8	8.0	1.05	21	42.2	14.5	1.32
6.5	38.2	8.3	1.12	21.5	42.4	14.5	1.38
7	38.3	8.8	1.17	22	42.7	14.4	1.40
7.5	38.6	9.2	1.23	22.5	43.0	14.3	1.37
8	38.9	9.4	1.24	23	43.1	14.4	1.29
8.5	39.0	9.9	1.20	23.5	43.0	14.7	1.27
9	39.2	10.2	1.13	24	43.0	14.9	1.30
9.5	39.2	10.6	1.05	24.5	43.5	14.6	1.32
			1.09	25		14.2	1.26

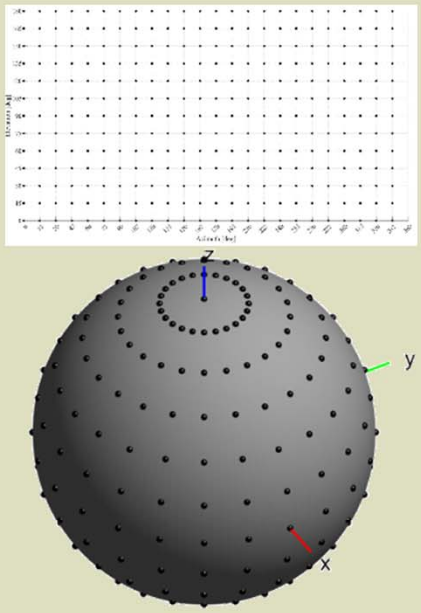


OTA Test – Sources of Measurement Uncertainty

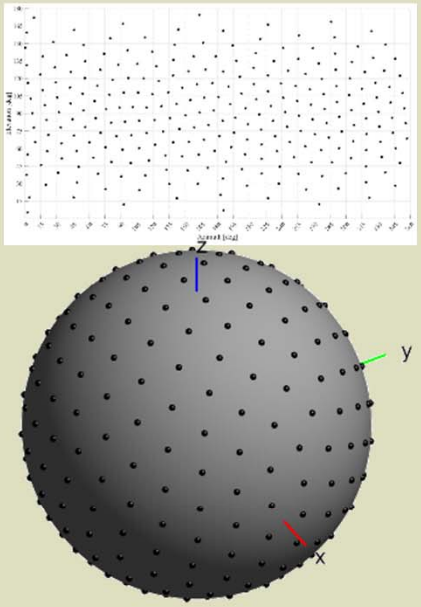


Grid Size

Spatial Scanning Grids

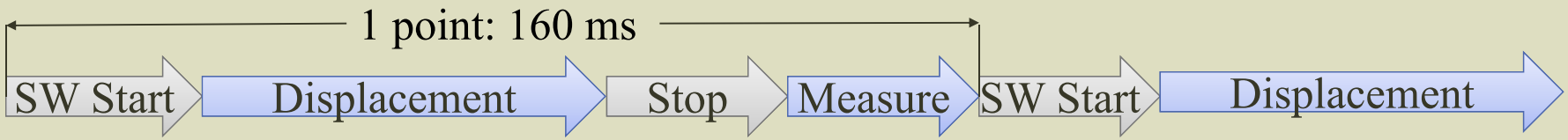


constant step size grid with $\Delta\theta=\Delta\phi=15^{o}$ - 266 pts



Constant density grid with 266 pts

Challenge: Long Test Times



No. of grid points (constant step size)	Test time (s)	Test Time for 3 Powers 10 Codes	TXP EIRP Mean error (dB)
7082 (3°)	1180 s (20 min)	10 Hours	0.02
762 (9°)	127 s	1 Hour	0.2
266 (15°)	45 s	22 minutes	0.7

More test points: lower measurement uncertainty, but higher test time

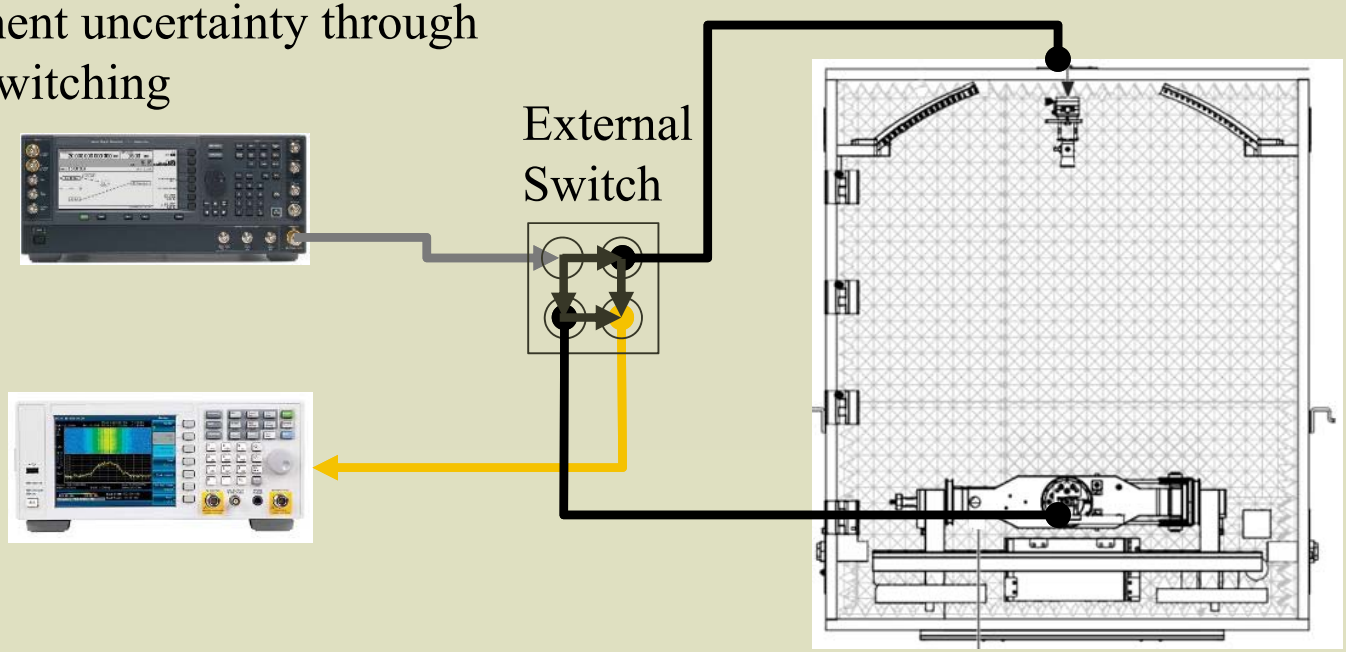
Challenge: Cost

Using general-purpose instrumentation and components results in expensive test benches

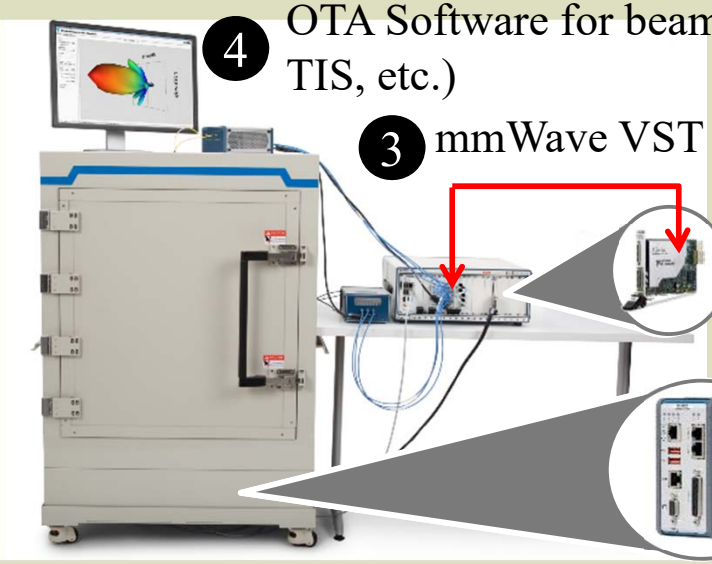
VNA | VSG + VSA | Large Anechoic Chamber

Challenge: Signal Switching

Increased path losses and measurement uncertainty through external switching



Reducing OTA Test Time with Autonomous Sweep



4 OTA Software for beam measurements and visualization (3D, polar, TRP, EIRP, TIS, etc.)

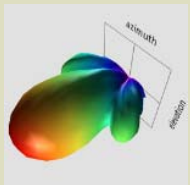
3 mmWave VST acquires IQ samples for every trigger → [(ϕ,θ), IQ] list

2 PXI Digital I/O module synchronizes with positioner and triggers RF acquisition every X degrees

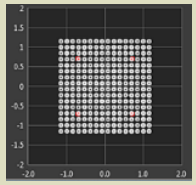
1 User sets a continuous sweep path on Motion Controller

No. of grid points	SW based	HW-based
4000 Every 4° azimuth and elevation	640 s (~10 min)	84 s

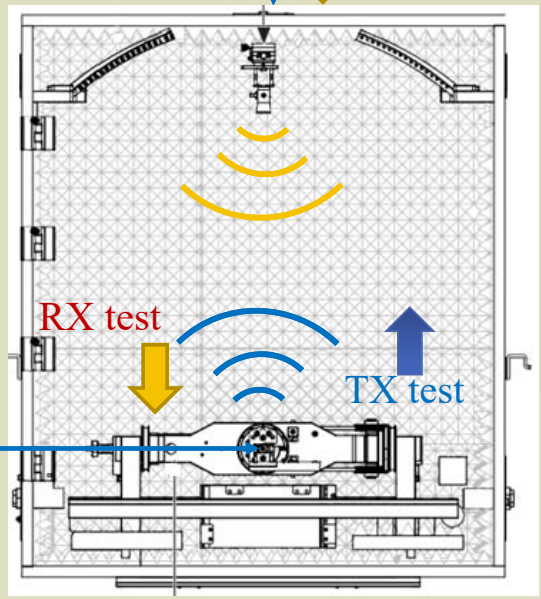
Reducing Uncertainty with an Integrated Setup



CW



Modulated



The bi-directional design of the mmWave VST's ports allows for testing a DUT in transmit and receive modes.

Competing solutions using a VSA (Vector Signal Analyzer) and a VSG (Vector Signal Generator) need to switch the signal externally, introducing uncertainty

Conclusions

- Integration of instrumentation (Signal Analyzer, Generator and Switches) reduces total system uncertainty
- Integrated system calibration routines reduce measurement uncertainty
- Integration of movement and instrumentation for faster OTA
- Denser grids reduce systematic uncertainty
- Still need innovation to reduce total uncertainty

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