NASA's Horizontal Planar Near-Field Facility:

A Large-Scale, High-Accuracy System for Spaceborne Antenna Testing

DOMENIC BELGIOVANE, PH.D.[1]

JIM DOWNEY[2], BRYAN SCHOENHOLTZ[2], FELIX MIRANDA[2]

EVAN BEERS[1], JAMES CAPUTO [1]

1. MVG-OATI, 2. NASA GLENN RESEARCH CENTER

MAY 20TH 2025

Near-Field Planar Scanner

Made for Space-Borne Antennas / Vehicle Mounted Antennas

SCANNER DIMENSIONS: 10M X 10M

Technology

- Horizontal Planar Near-field Scanner:
  - Better for deployable to prevent distortions to the parabolic shape.
  - Can drive in large vehicles for insitu-measurements for upper-hemisphere measurements
  - E.g. Lunar Vehicles or UAVs

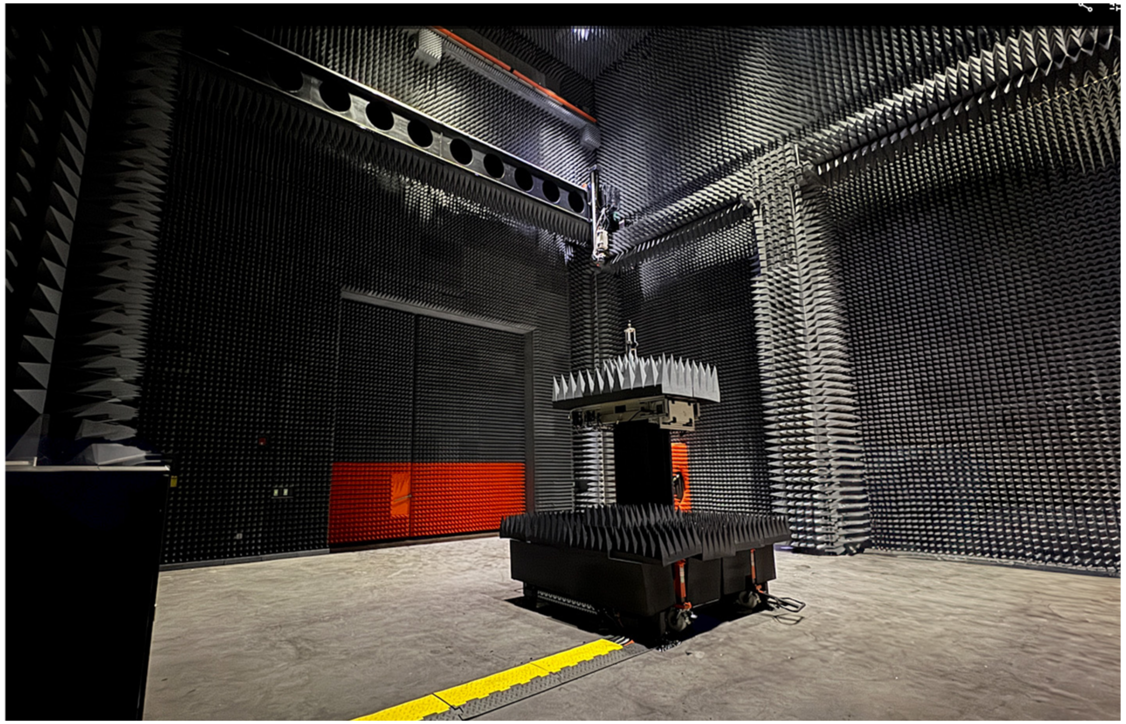
Measurement capabilities

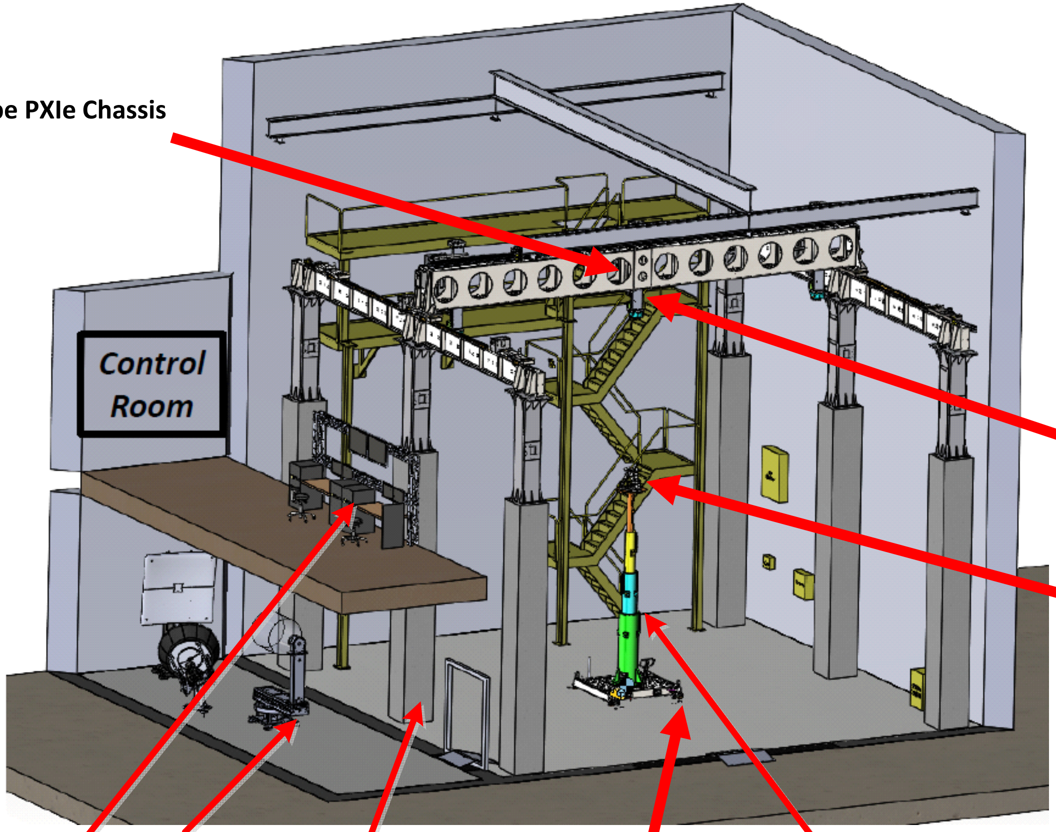
- Gain
- Beamwidth
- Sidelobe levels
- Radiation pattern in any polarizations - (linear)
- Multi beam antenna measurement and calibration
- Directivity
- 3D radiation patterns
- Beam pointing properties
- Full payload testing
- EIRP, G/T, IMD,
- Pulsed Measurements
- Gain Compression

Frequency bands	1 to 110 GHz (and beyond?)

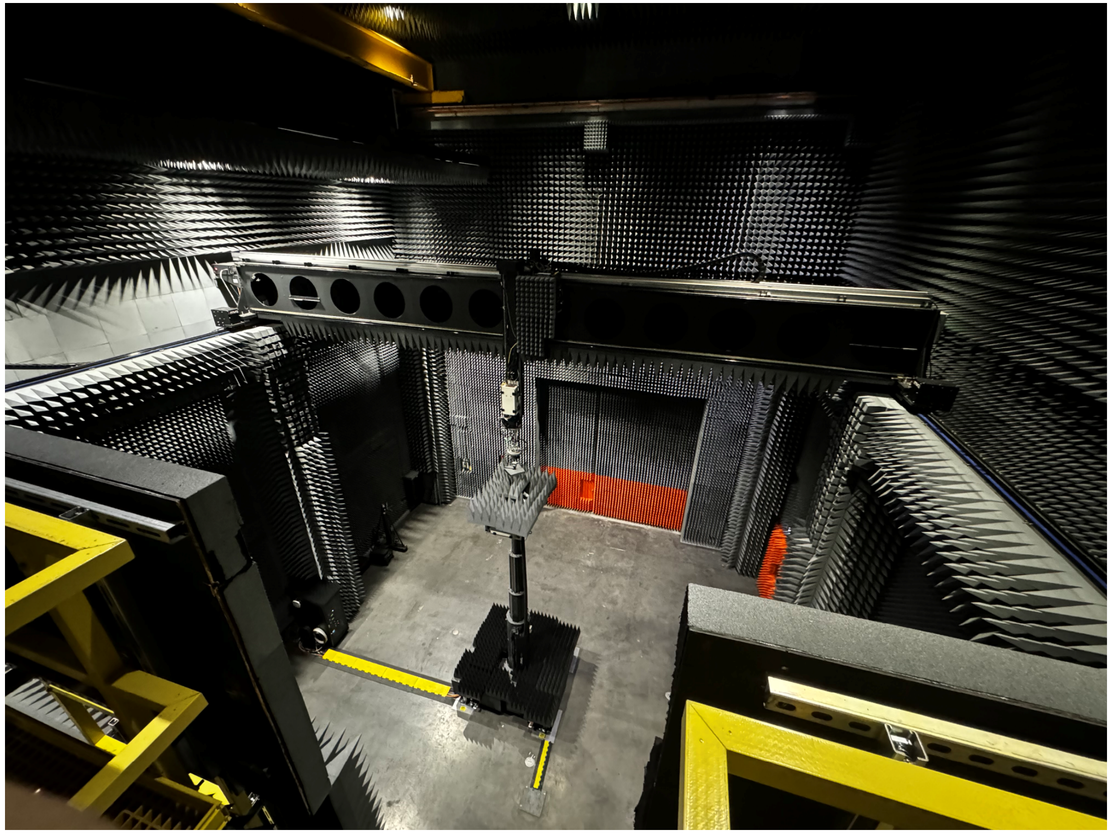
Large DUT, system-level testing, wide frequency bands

System Overview

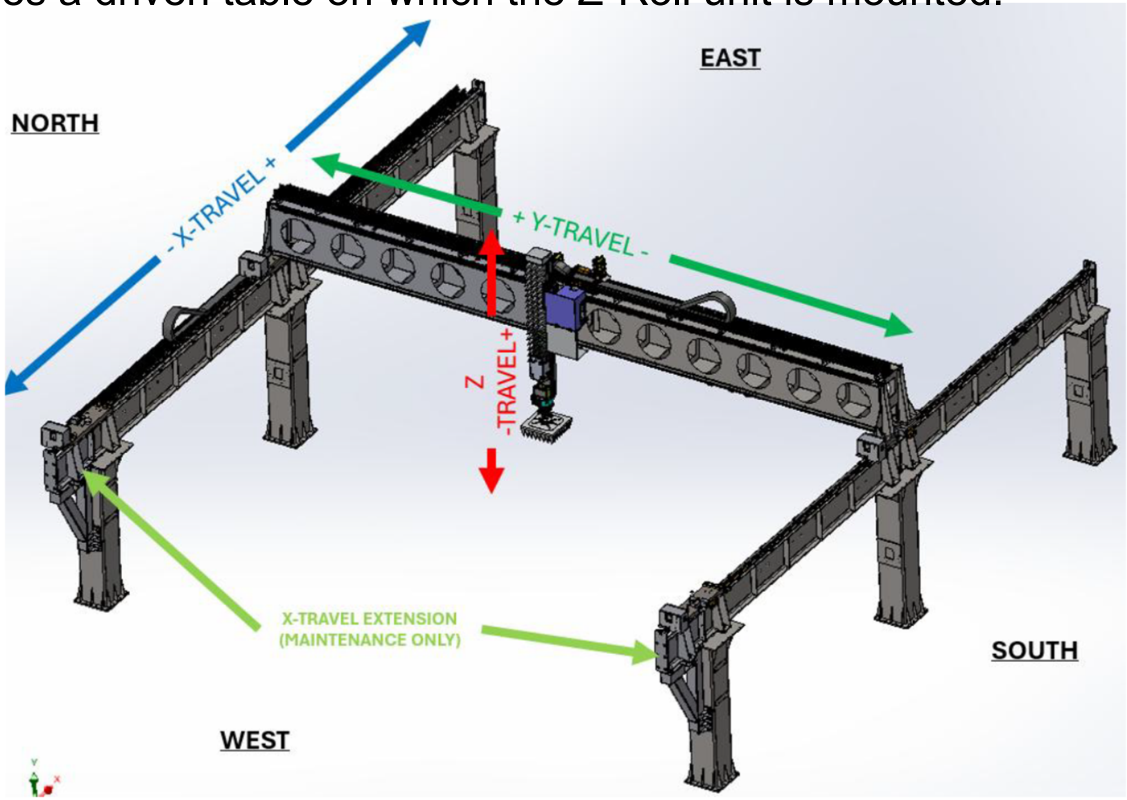




Pictures of the HPNF Facility

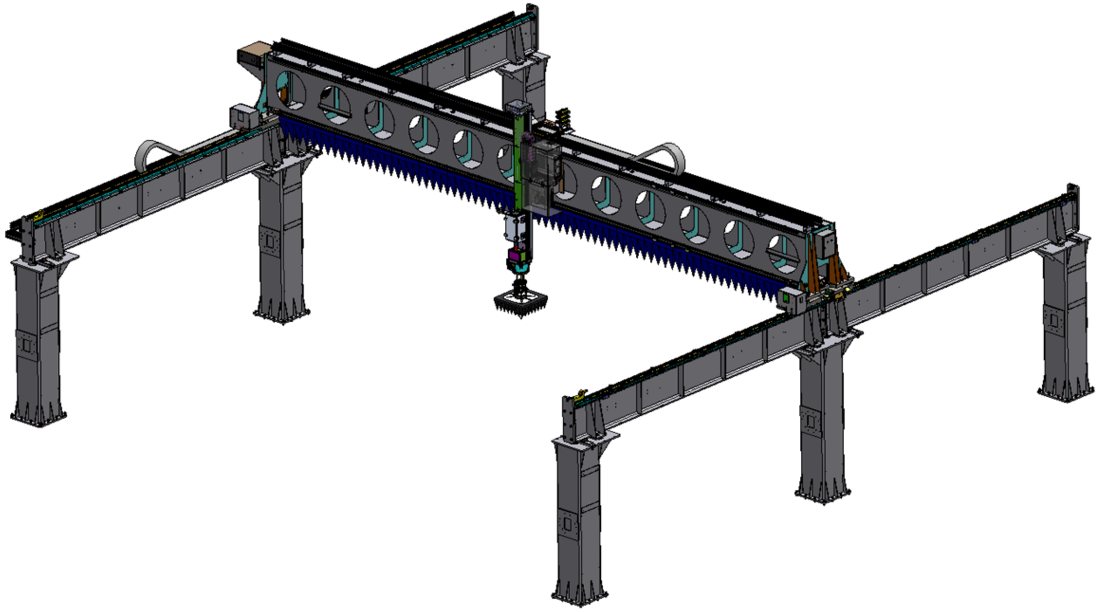


- The scanner is built from two X-axis linear slides and a Y-axis beam moving in the horizontal plane.
- The X-axis linear slide is constructed of two modular sections, which are securely mounted on six supporting masts fixed to the floor and are leveled to it as one integral unit.
- The Y-axis linear slide is mounted on top of the X-axis linear slides and moves along them. The Y-axis carries a driven table on which the Z-Roll unit is mounted.



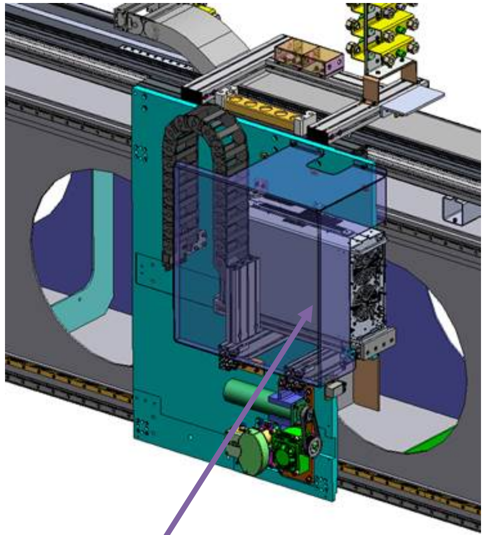
Horizontal Scanner – General

- Scanning Area & Motion
  - Scan area of 10m x 10m x 1.5m (X / Y / Z).
  - Probe mounting location has roll / polarization alignment.
  - Probe aperture can be located at a height of ~9.1m – ~7.6m.
  - Overall Dimensions: 13.64m x 13.25m x 12m

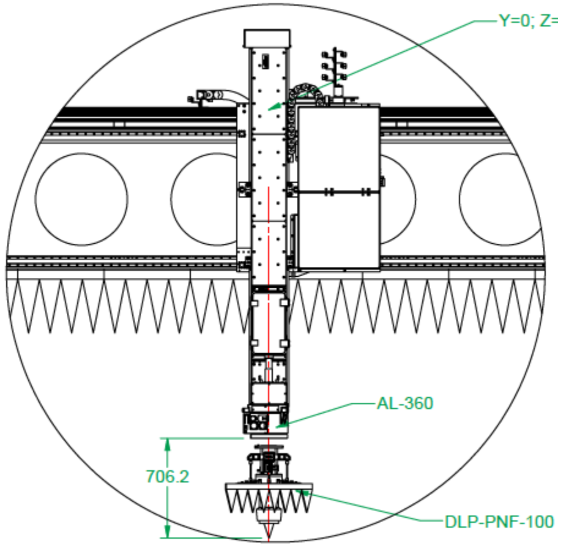


Parameter	X-axis	Y-axis	Z-axis	Polarization AXIS
Travel range	10000mm	10000mm	1500 mm	360 deg
Scan speed	250 mm/sec.	500 mm/sec.	10 mm/sec.	1rpm
Load	N/A	N/A	80 Kg	N/A
Resolution	0.001 mm	0.001 mm	0.003 mm	0.001 deg
Accuracy (corrected)	+/- 0.06 mm	+/- 0.06 mm	+/- 0.06 mm	+/- 0.02 deg
Planarity	0.035 RMS mm corrected			

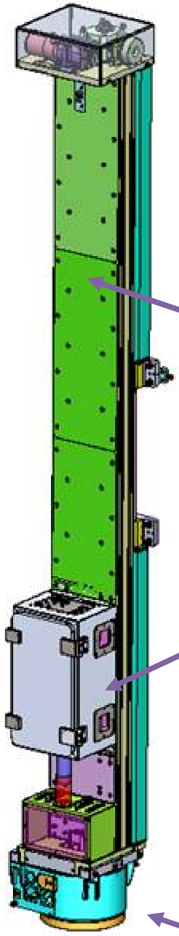
RF Unit Locations on Z-Axis



PXIe unit



DETAIL D
SCALE 1 : 25

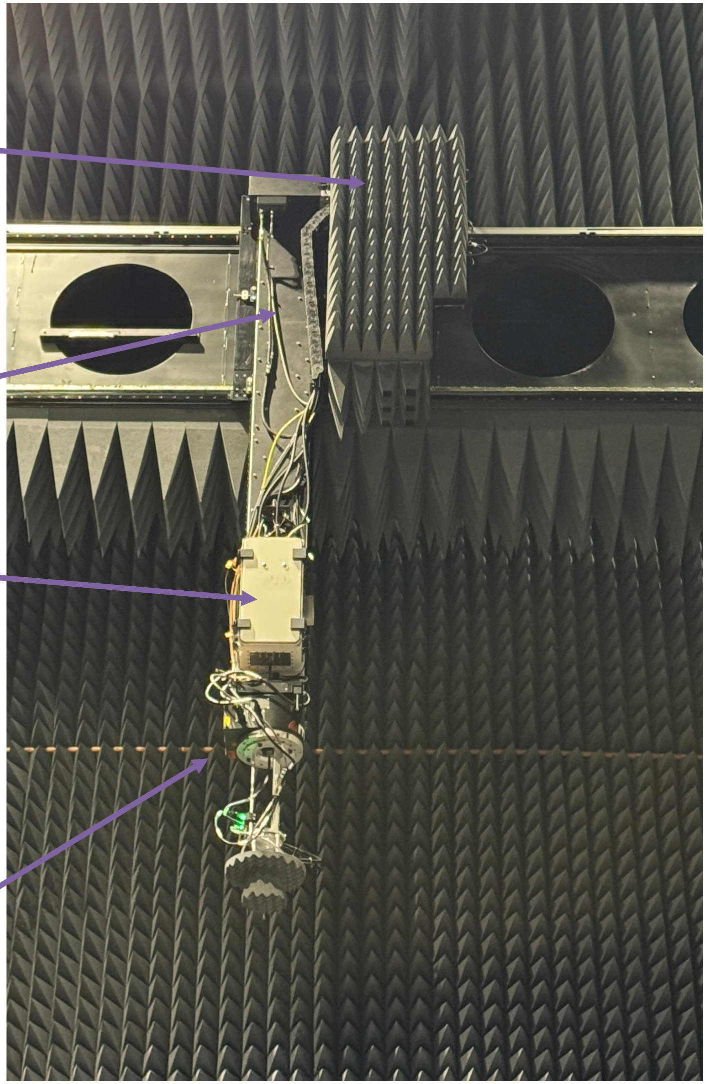


PXIe unit

Z-Axis Positioner

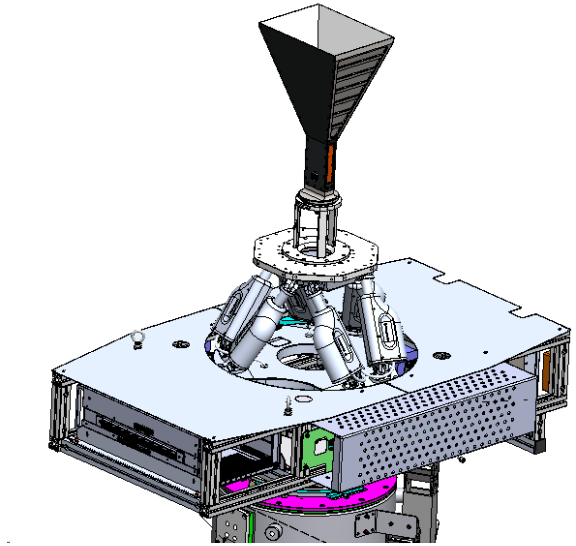
RF shielded enclosure

Roll Positioner



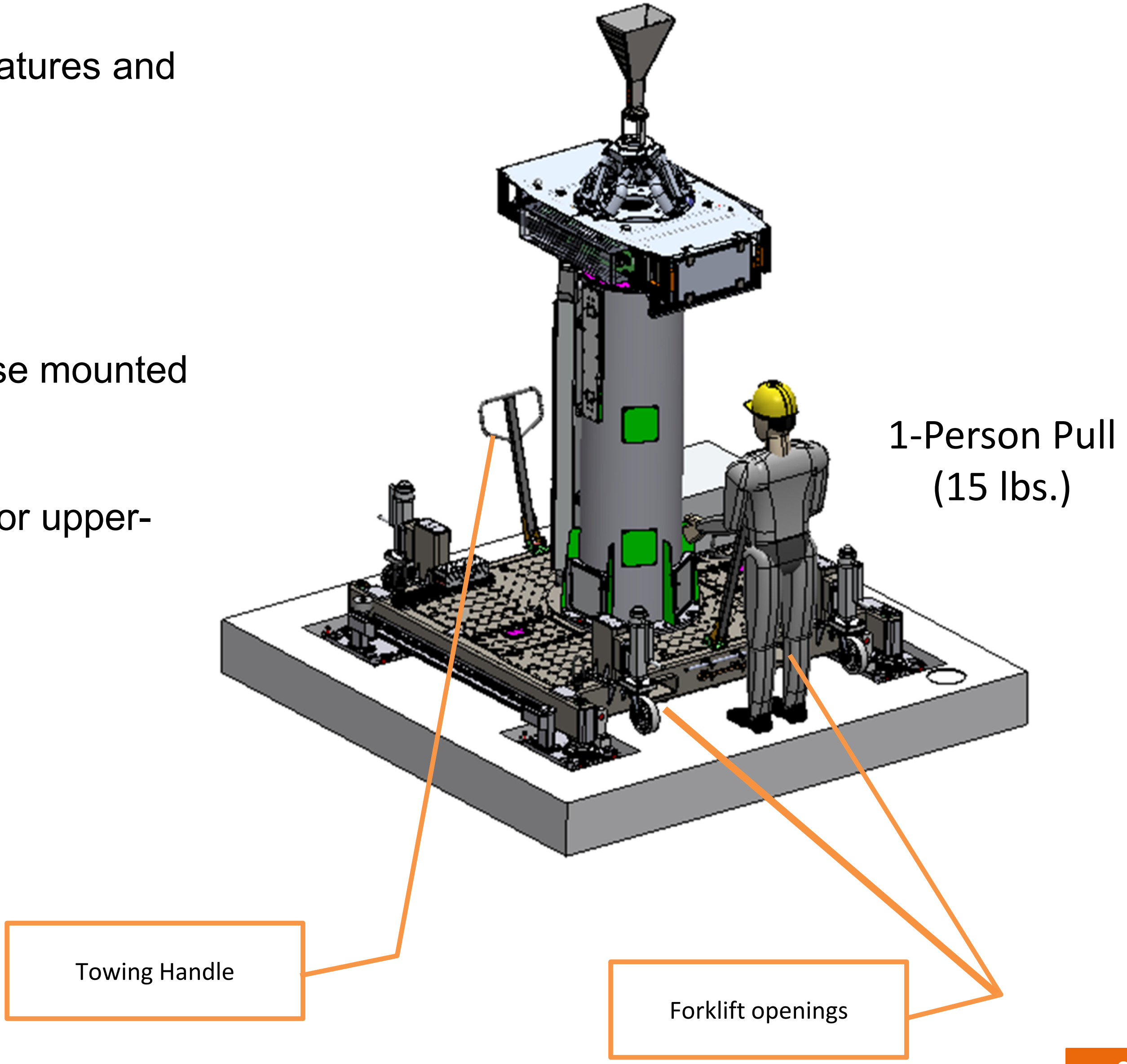
DUT Positioner– General

- DUT Mast has telescoping height from 3m to 6m
- Cart dimensions: 2m x 2m
- Top of the DUT Cart is a Symmetrie BREVA Hexapod used for precision DUT alignment
  - Sized to be able to support a group 3 drones (55 – 1320 lbs)
  - Precision alignment for mm-Wave measurements
- DUT mounting face/sides includes holes for SMR targets for DUT alignment



Moveable DUT Platform

- Positioner cart is pushed by hand over tapered locating features and lowered into testing position with jack wheels
- Allows for it to be moved in and out of the chamber
  - Repeatability: ~.02mm
- Allows for rolling in large antennas that cannot be otherwise mounted
  - Can drive in large vehicles for insitu-measurements for upper-hemisphere measurements
  - E.g. Lunar Vehicles or UAVs



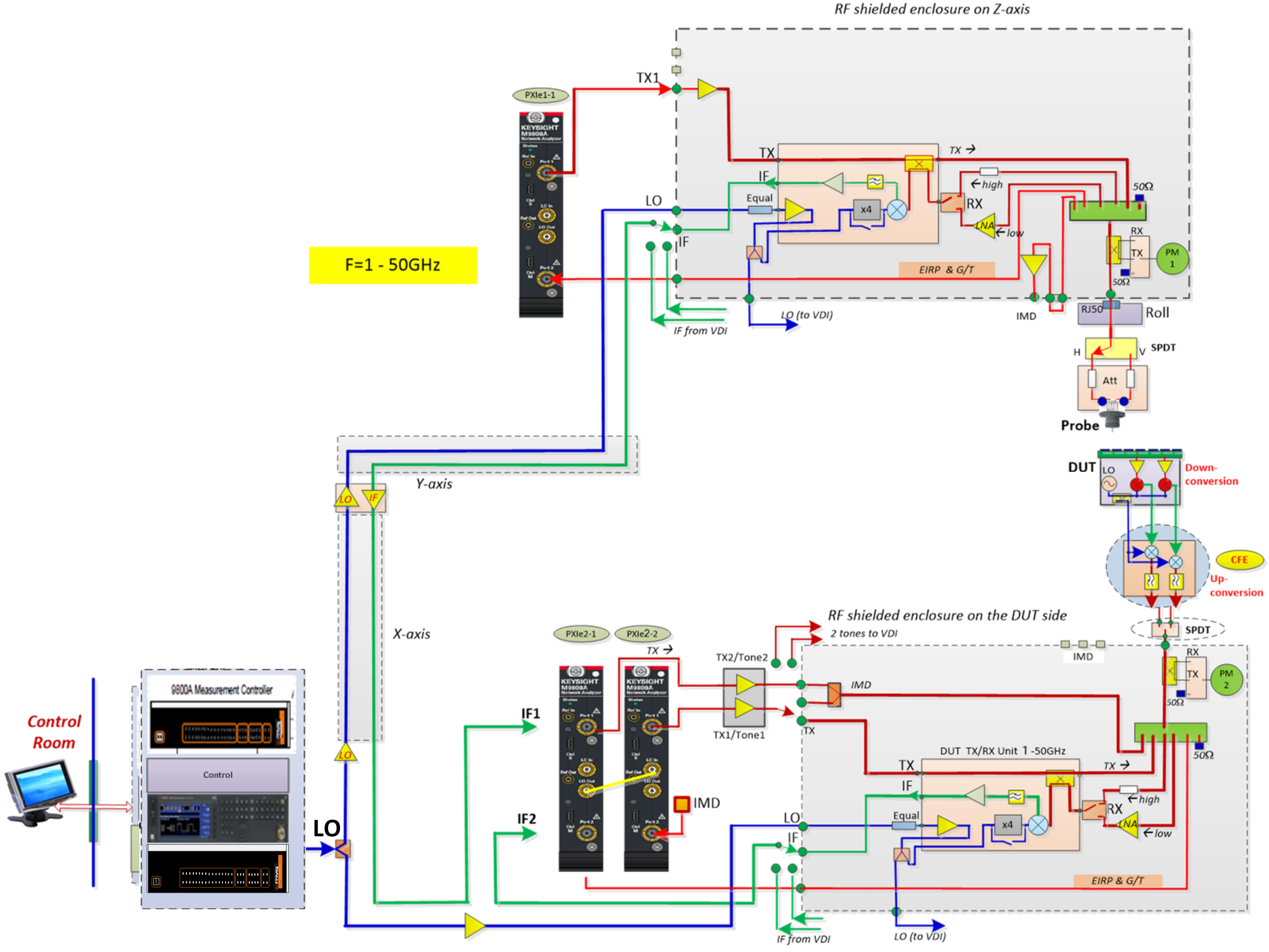
Integration and Utilization of Laser tracker

- A Laser tracker was used for initial alignment and positioner corrections (MV-Cor)
  - HNF scanner
    - Corrected X- Axis as a function (X,Y)
    - Corrected Y-Axis as a function (X,Y)
    - Correction of Z Planarity as a function (X,Y)
    - Roll Pointing aligned to scan plane
  - DUT Mounting
    - X,Y, Z rotation errors and translation
- Long term goal is to also allow for
  - Surface metrology aligned to the near-field data
    - For back projection of the data to Ideally correlate the defects
  - Characterization of parabolic surfaces
    - Directly mounting a laser scanner on the probe positioner mounts

RF Subsystem

RF System Configuration (1-50GHz)

- Features a Dual PXI Architecture
  - 1 PXIe at the DUT and one on the Scanner
  - Direct RF 1-50 GHz
- Phase Coherency through an MXG located in a rack on the ground
- Shielded RF Enclosures
  - Down-convert test and reference signals to an IF
  - Multiplier is used for down-conversion above 20 GHz
- LO runs up from the rack through Scanner and DUT tower

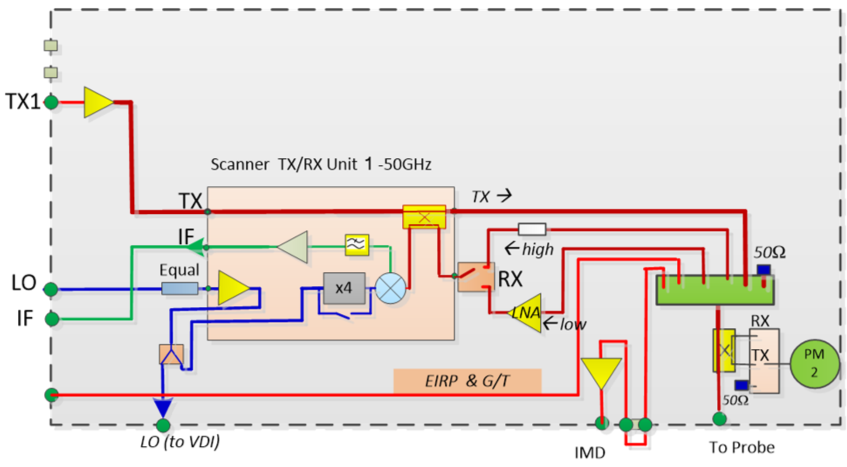


PXIe Chassis

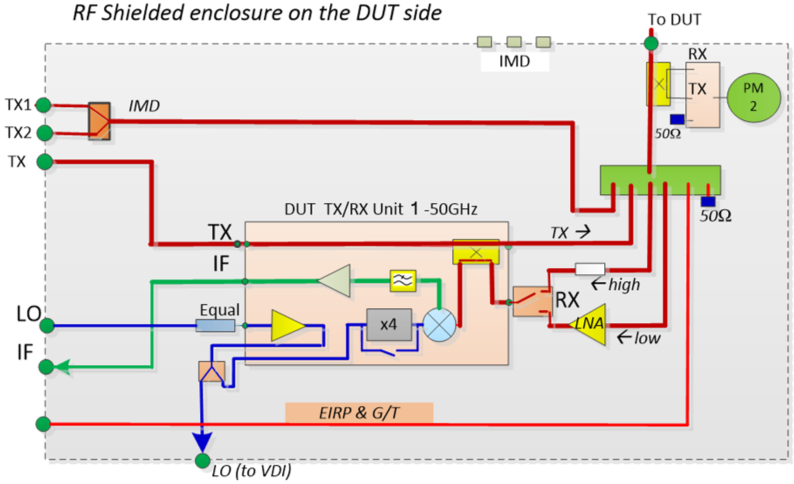
- 2x M9010A 10-Sot PXIe Chassis
  - Keysight M9808A-200 100 kHz to 53 GHz PXIe Vector Network Analyzer
- System will include (2) Chassis
  - DUT Chassis, configured with (2) M9808A modules
  - Probe Chassis, configured with (1) M9808A module
    - Spectrum Analyzer Hardware/Software
    - Intermodulation Distortion (IMD) Software
    - Pulse Modulation Hardware and Software

RF Shielded Enclosures

RF Shielded enclosure on Z-axis

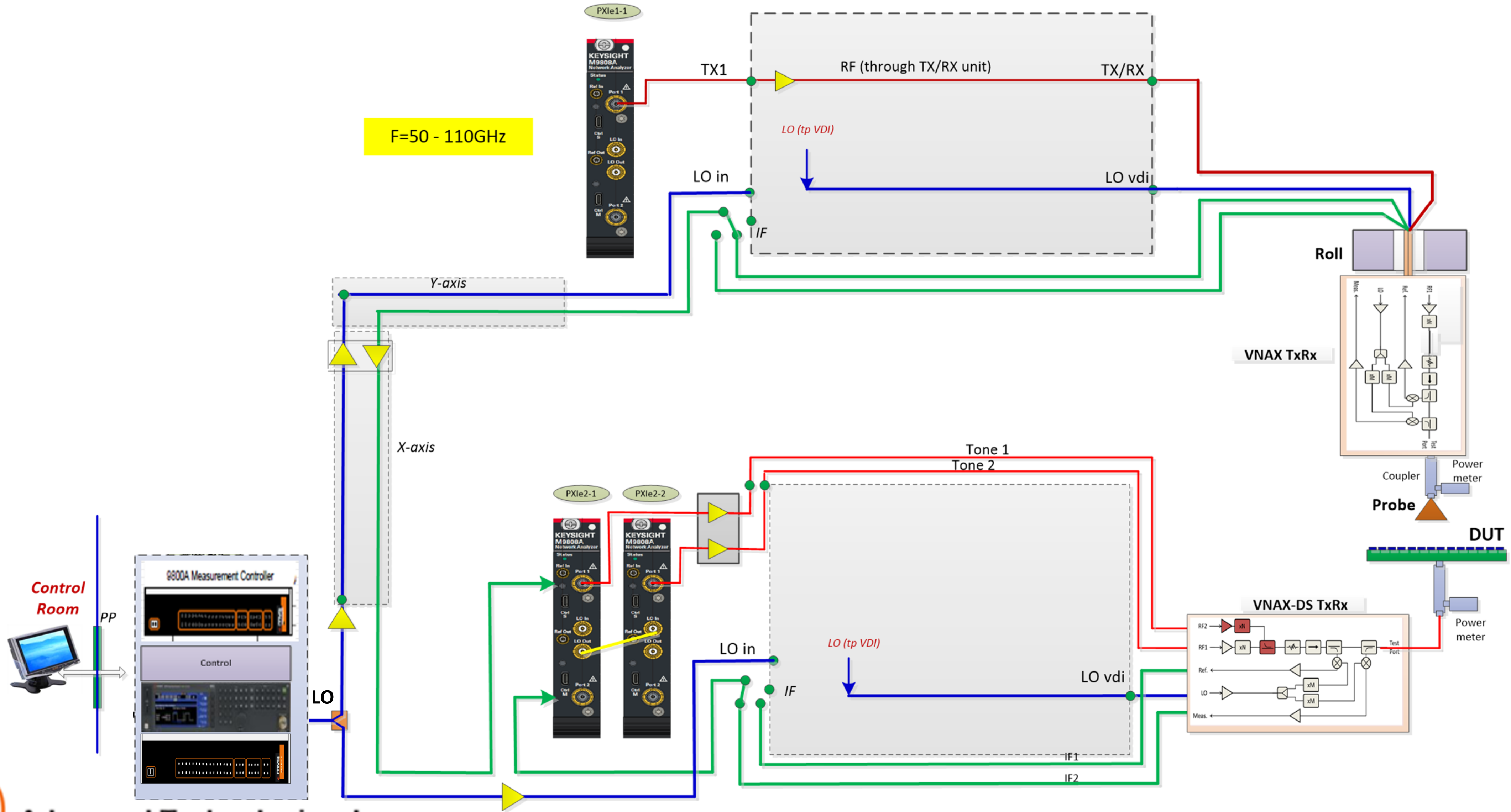


RF Shielded enclosure on the DUT side



Shielded enclosure Specification	
Frequency Range	0.5-50 GHz
Shielding effectiveness	-80dB @ 1-10 GHz -65dB @ 10-50 GHz
Dimensions	500/250/200 mm
Input power	24V DC

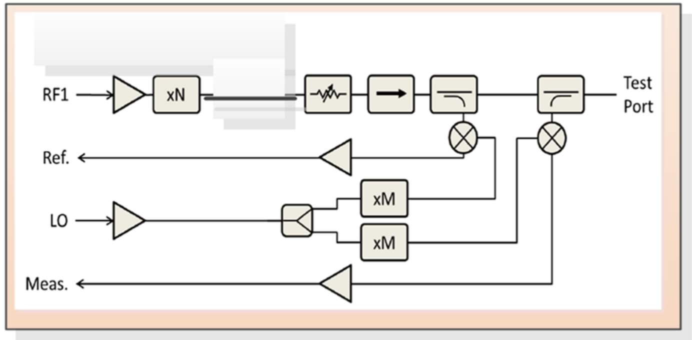
RF System Configuration (50-110GHz)

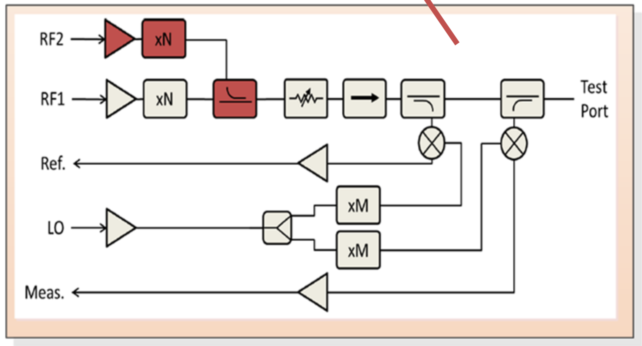


Advanced Technologies, Inc.

VDI Frequency Extender Modules

#	Freq Band	Probe Side	DUT Side	Required in Addition	Comments
1	V (50-75GHz) WR15	TxRx WR15VNATxRxM	TxRx-DS WR15VNATxRxM-DS	V281CS WR15 to 1mm(F) adaptor	TxRx-DS with attenuator
2	E (60-90GHz) WR12	TxRx WR12VNATxRxM	TxRx-DS WR12VNATxRxM-DS	E281CS WR12 to 1mm(F) adaptor	
3	W (75-110GHz) WR10	TxRx WR10VNATxRxM	TxRx-DS WR10VNATxRxM-DS	W281CS WR10 to 1mm(F) adaptor	





Power Sensors

- Integrated power sensors for RF and mmWave Modes
  - Utilized for EIRP and G/T measurement modes.

- Alternatively, the PXI can be used in Spectrum Analyzer mode if more sensitivity is needed, but required a manual setup.

	Unit	P/N	Probe side	DUT side	Description	Comments	
2	Power sensor 10MHz-54GHz	U2056XA	1	1	Average power -70...+20dBm	U2056XA-100 Connector 1.85mm Accuracy: +/-0.24dB @50GHz	
1	Power sensor DC-120GHz	U8489A	1	-----	Thermocouple, -35...+20dBm	U8489A-200 Connector 1.0mm Accuracy: 7.6% @110GHz	

HNF Nearfield Probes

- Each probe assembly includes:
  - Mechanical drawing
  - AEP Absorber Collar
  - Standoff cage and mounting plate
  - Probe pattern correction coefficients (CST generated)
  - Gain calibration at UPM
  - Simulated Probe Correction Files

P/N	Freq (GHz)	Freq. Band	Polarization	Connector	
DLP-PNF-100	0.8 - 2.0	L	Dual Linear	3.5mm (f)	
DLP-PNF-200	2.0 - 4.5	S	Dual Linear	3.5mm (f)	
DLP-PNF-400	4.0 - 8.0	C	Dual Linear	3.5mm (f)	
DLP-PNF-800	8.0 - 18.0	Ku	Dual Linear	3.5mm (f)	
DLP-PNF-1800	18.0 - 40.0	Ka	Dual Linear	2.92mm (f)	
DLP-PNF-3300	33.0 - 55.0	Q	Dual Linear	2.4mm (f)	
OEW5000	50.0 - 75.0	WR15	Single Linear	w/g	
OEW6000	60.0 – 90.0	WR12	Single Linear	w/g	
OEW7500	75.0 - 110.0	WR10	Single Linear	w/g	

Measurements Below 50 GHz are dual Polarized

mmWave Bands must rotate the roll axis of the probe

HNF Reference Antennas

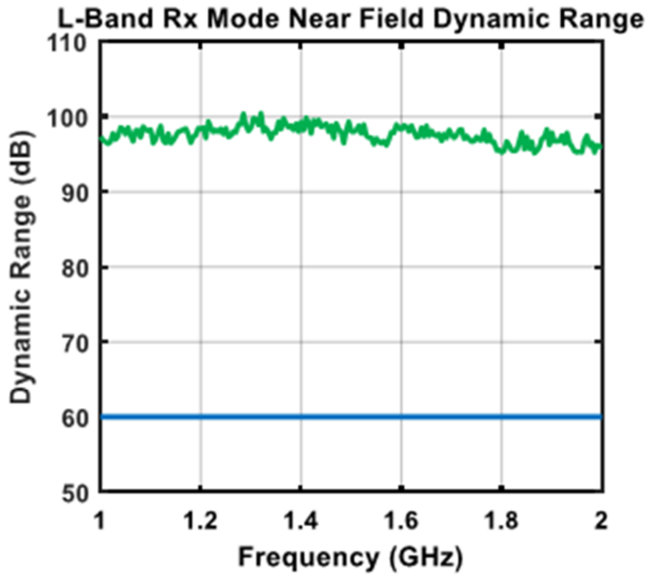
- Each SGH assembly includes:
  - Mechanical drawing
  - AEP Absorber Collar
  - Standoff cage and mounting plate
  - On-axis gain calibration performed at NPL

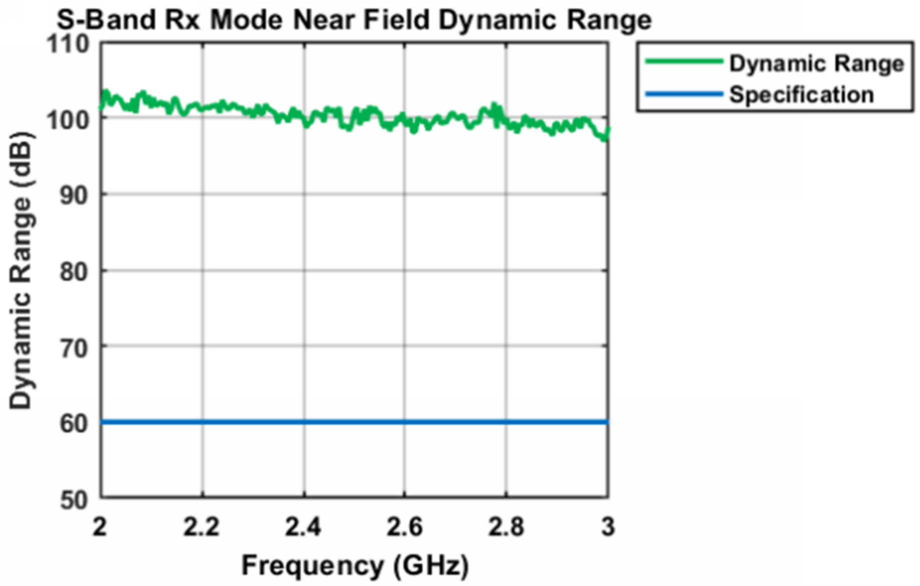
P/N	Freq (GHz)	WG Band	Connector
SGH112	1.12 – 1.7	WR650	N (f)
SGH170-A	1.7 – 2.6	WR430	N (f)
SGH260	2.6 – 3.95	WR284	N (f)
SGH395	3.95 – 5.85	WR187	N (f)
SGH585	5.85 – 8.2	WR137	N (f)
SGH820	8.2 – 12.4	WR90	N (f)
SGH1000	10.0 – 15.0	WR75	SMA (f)
SGH1240	12.4 – 18.0	WR62	N (f)
SGH1800	18.0 – 26.5	WR42	SMA (f)
SGH2200	22.0 – 33.0	WR34	2.9mm (f)
SGH2650	26.5 – 40.0	WR28	2.9mm (f)
SGH3300	33.0 – 55.0	WR22	w/g
SGH5000	50.0 – 75.0	WR15	w/g
SGH6000	60.0 – 90.0	WR12	w/g
SGH7500	75.0 – 110.0	WR10	w/g

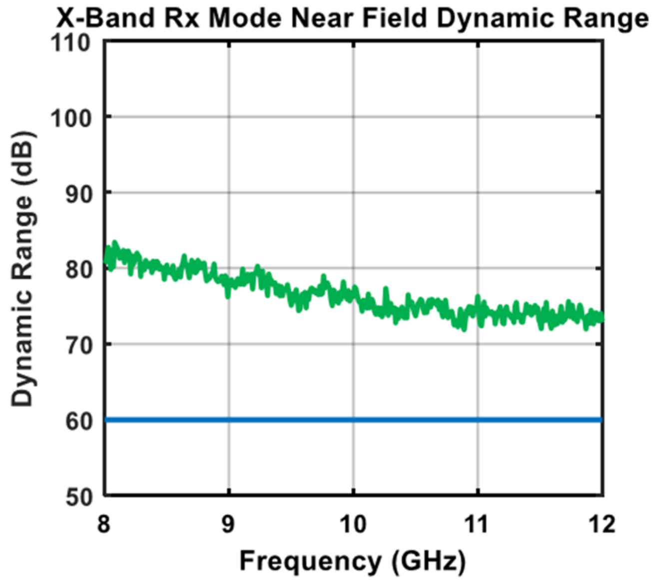
System Performance

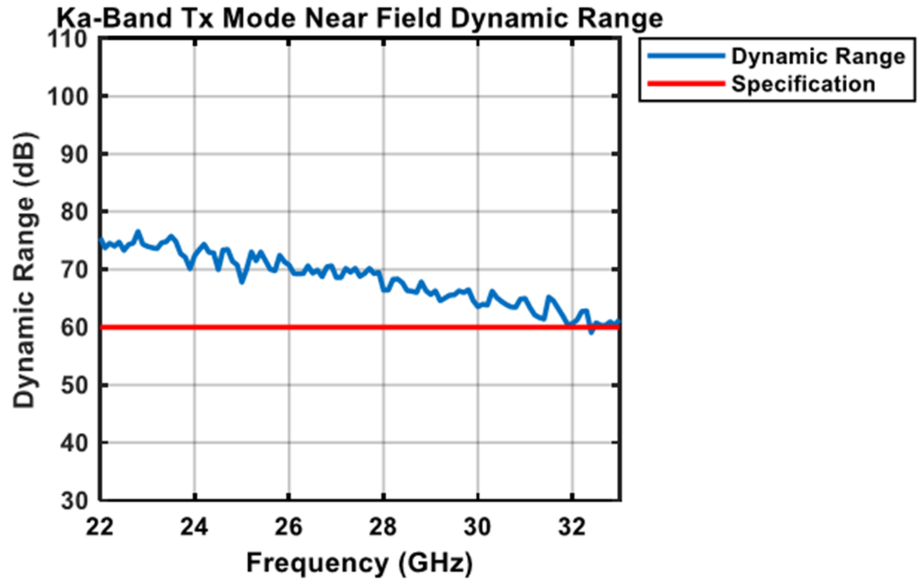
RF Mode Dynamic Range Measurements

- Sample Dynamic Range Measurements taken Over the Air
  - Data taken at boresight coordinates X=0,Y=0
  - 50 Frequency sweeps performed
  - RMS of Signal and Noise computed.
  - 1 KHz IFBW
- With DLP Probes and SGHs
  - L-Band
  - S-Band
  - X-Band
  - Ka-Band
- System Requirements for nearfield dynamic range were >60 dB.
  - Stepped attenuator used to prove system is linear.



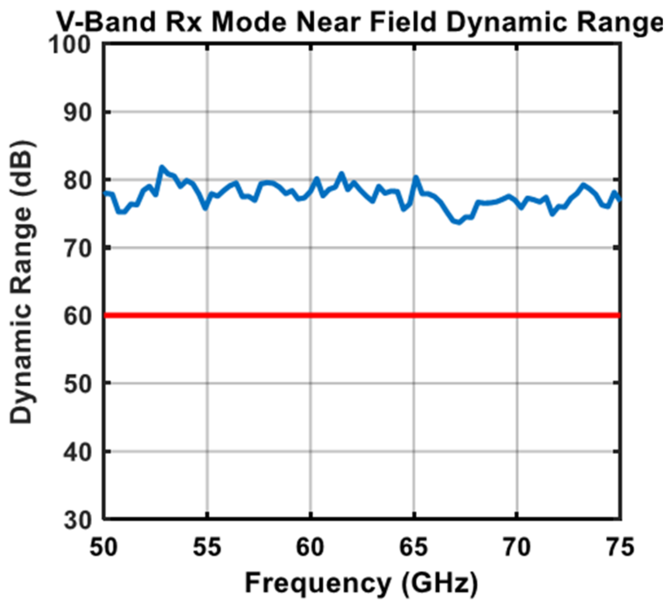


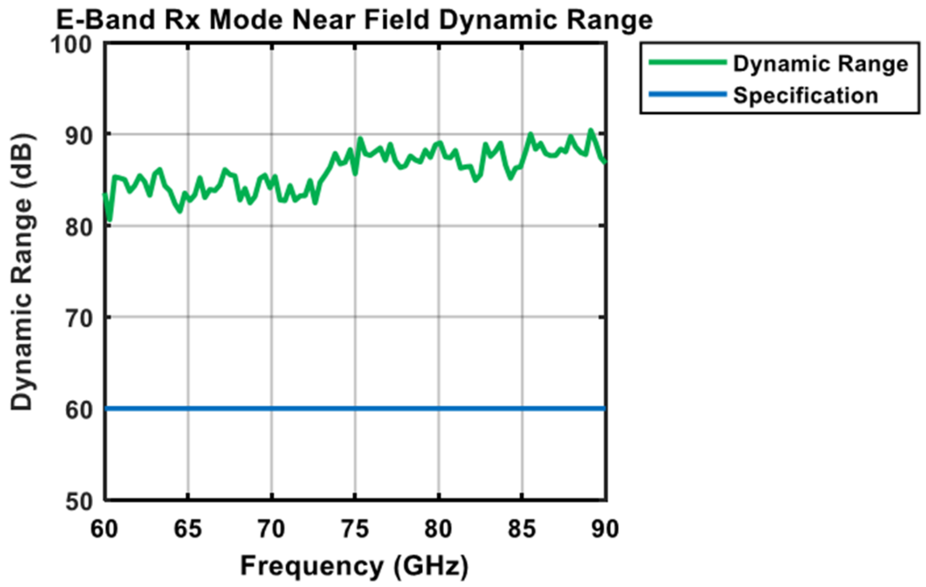


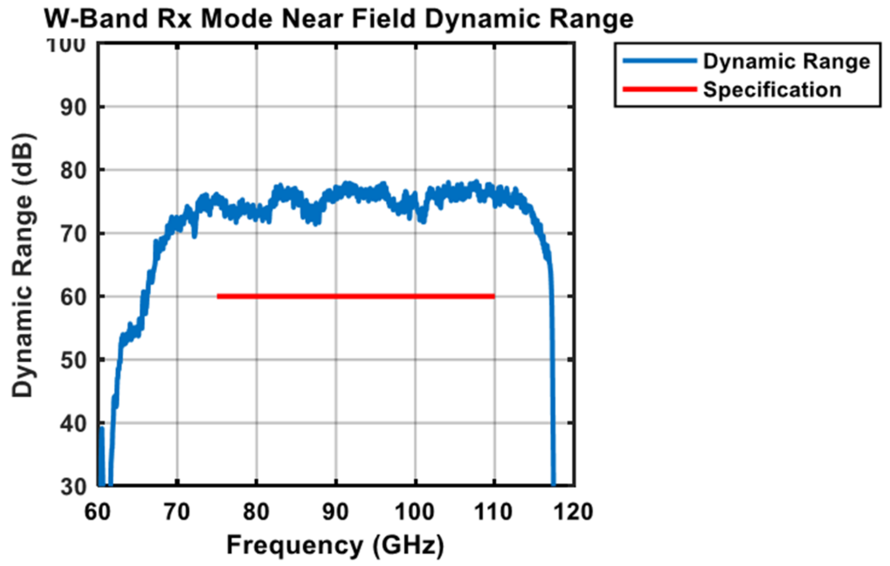


RF Mode Dynamic Range Measurements

- Sample Dynamic Range Measurements taken Over the Air
  - Data taken at boresight coordinates X=0,Y=0
  - 50 Frequency sweeps performed
  - RMS of Signal and Noise computed.
  - 1 KHz IFBW
- With OEW Probes and SGHs
  - V-Band
  - E-Band
  - W-Band
- System Requirements for nearfield dynamic range were >60 dB.







ORBiT Advanced Technologies, Inc.

Special Test Modes

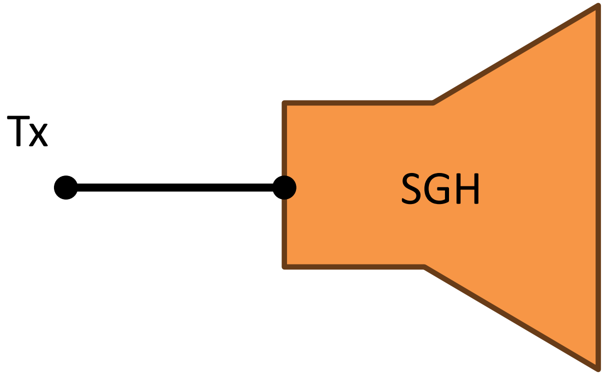
Special Test Modes

- EIRP
- G/T
- Gain Compression Testing
- IMD
- Pulsed RF
- Park & Probe

Active DUT measurements

- The following tests will be performed:
  - Active Antenna patterns for G/T, and IMD
    - Note: Pulsed RF, EIRP and Gain Compression do not require the Amplifier
  - Separable Antenna (SGH and Amplifier required)
  - Ka-Band SGH2200 (22 – 33 GHz)

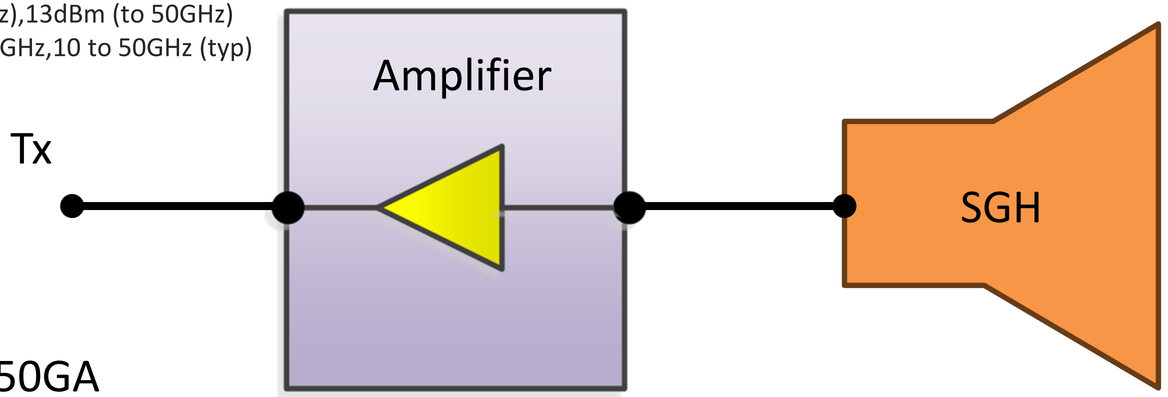
Case 1: Gain Reference Baseline



- Gain of more than 21dB
- P1dB of more than 15dBm (to 40GHz),13dBm (to 50GHz)
- Noise figure of less than 6dB to 26.5GHz,10 to 50GHz (typ)

RF-Lambda RAMP00M50GA

Case 2: Active DUT

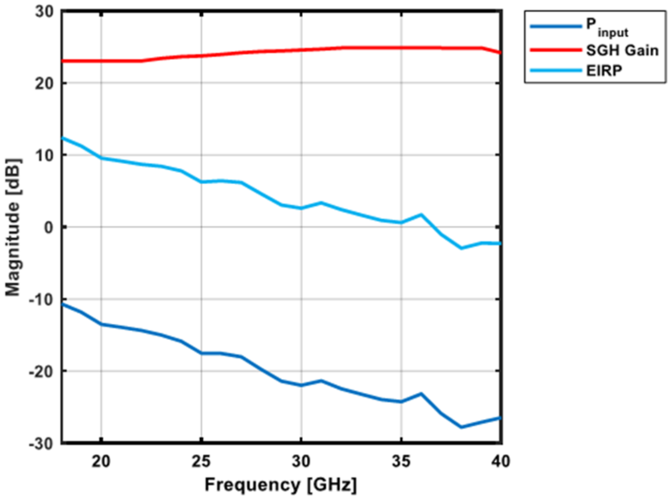


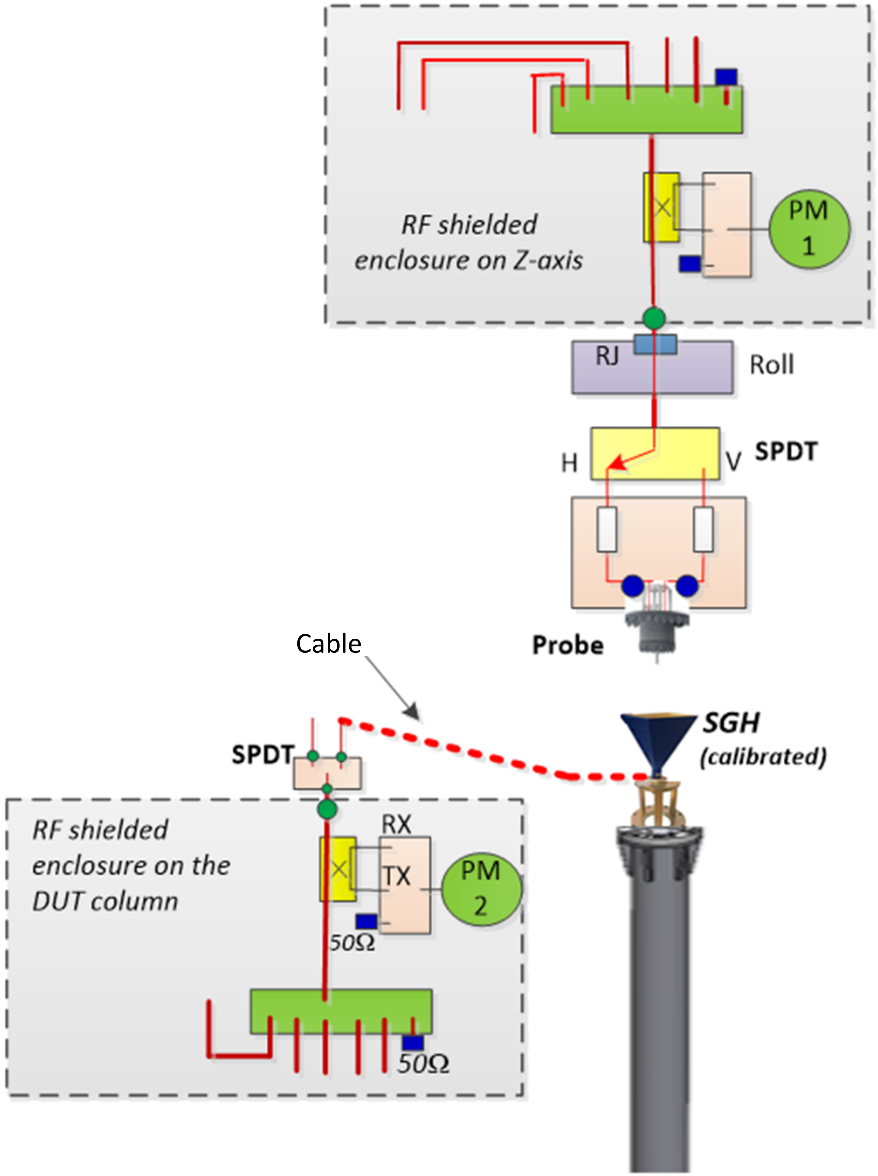
EIRP

- EIRP measurements
  - NF to FF far-field transform is used to determine the DUT Gain
  - Input power is computed by either:
    - Direct Connection of the Cable with PXI in SA mode
      - Required cable to calibrated out
    - Power Meter measurement at PM2
      - Requires calibration path through the coupler.
- EIRP is computed as:

$$EIRP = G_{DUT}\ P_{in}$$

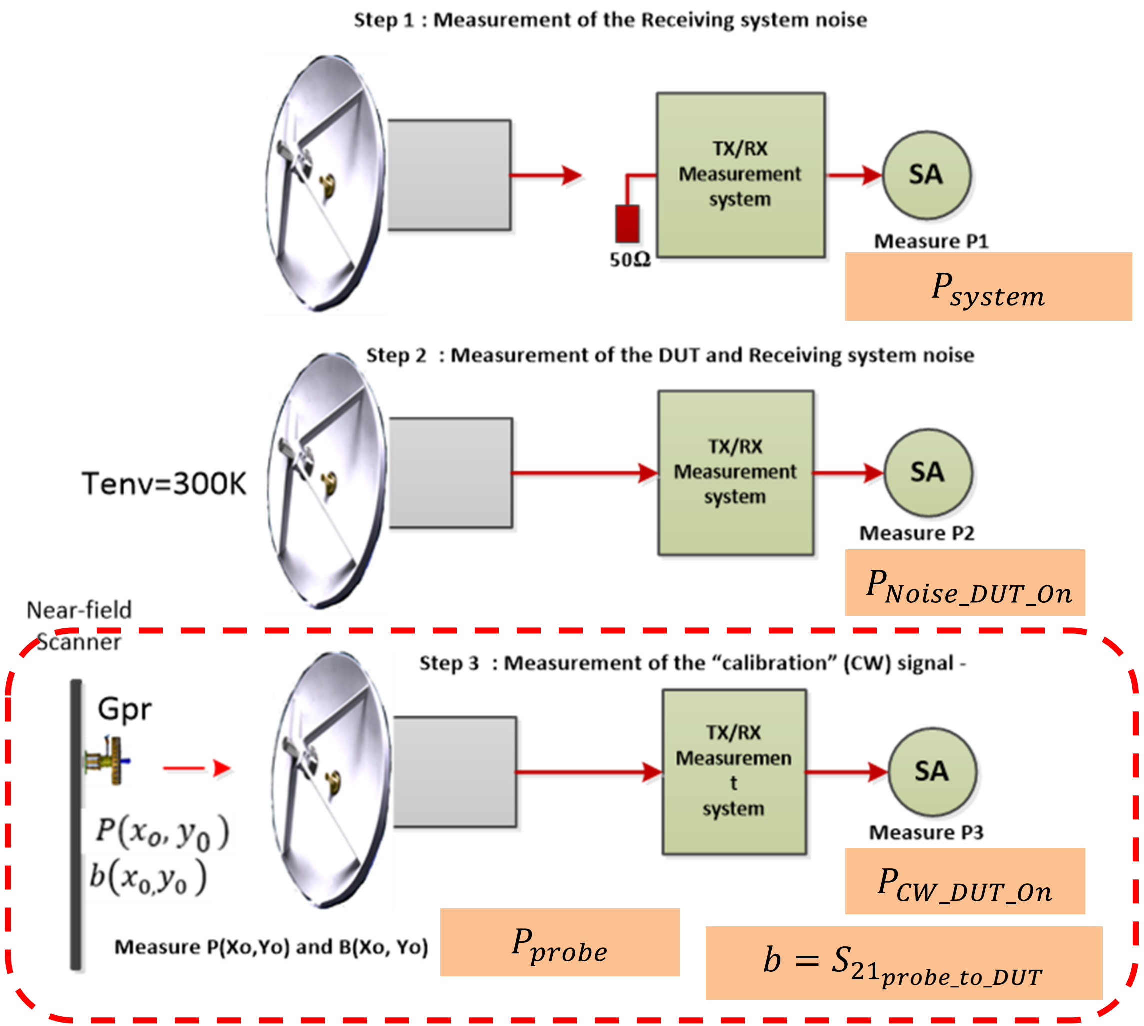
Example EIRP Measurement at Ka-Band using an SGH 2200





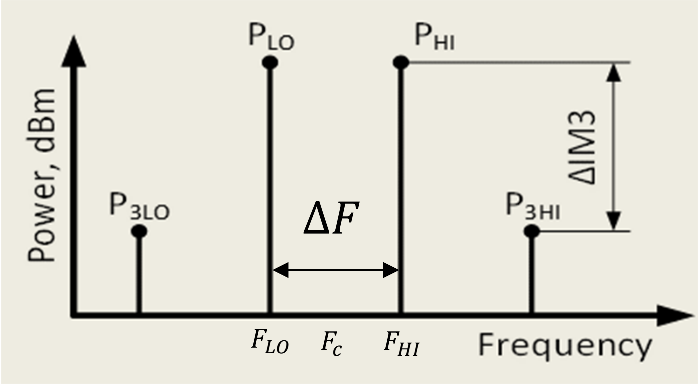
- Perform NF Acquisition
  - Perform NF-to-FF Transform: ***FF(K)***
- Use b_o finder to get peak-near field x_0,y_0
  - Store ***$b(x_0,y_0)$*** value from near-field data
- Move Probe into (x_0,y_0) position, collect Probe Side Power Meter Measurement (***$P_{pr}(x_0,y_0)$***) **(RF Source is ON)**
  - Power meter measurement assumes it is calibrated through the coupler path properly with a correction table.
  - Transmit amp should have low harmonic content.
- Collect Measured DUT received power with Spectrum Analyzer (***P3***) **(RF Source is ON)**
- **Turn RF source off**, collect DUT (and test equipment) noise power with Spectrum Analyzer (***P2***)
- **Turn DUT power off** (or connect a load to the SA input), collect noise power of test equipment with Spectrum analyzer (***P1***).
- Compute G/T metric
  - ***B*** = 1 Hz, ***k*** = 1.380649 × 10−23 joule per kelvin
  - ***$M_{G/T}$*** = 1 (or can be measured, optionally)

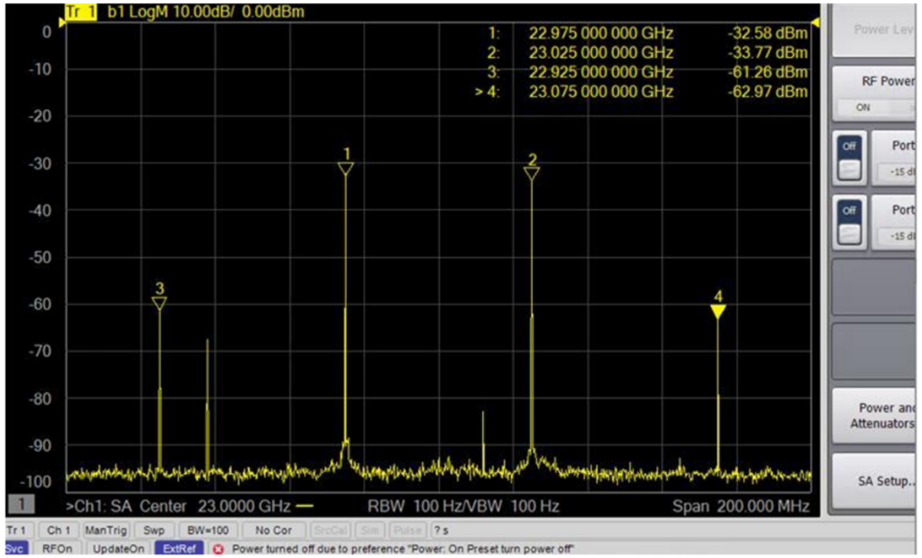
$$G/T = \frac{kB}{M_{G/T} \cdot P_{pr}(x_o, y_0)} \cdot \frac{1}{b^2(x_0, y_0)} \cdot \left(\frac{P_3 - P_2}{P_2 - P_1}\right) \cdot FF(K)$$



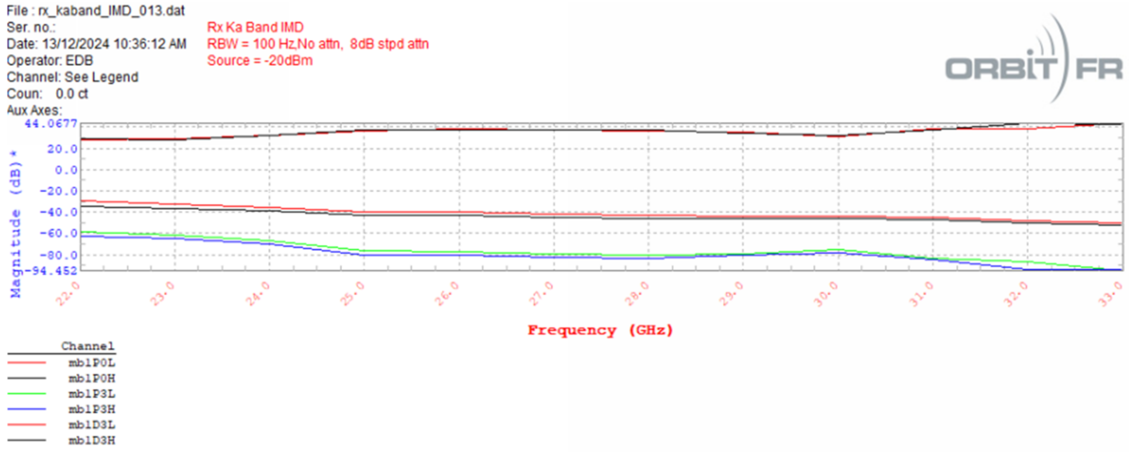
Intermodulation Distortion (IMD) Mode

- ΔIM3 using OTA measurements can be performed using the Dual PXI-Setup
  - DUT PXI using IMD Mode
  - Scanner PXI in SA mode
- These measurement can be performed in two modes:
  - Swept Frequency, Fixed Delta
  - Swept Delta, Fixed Center Frequency



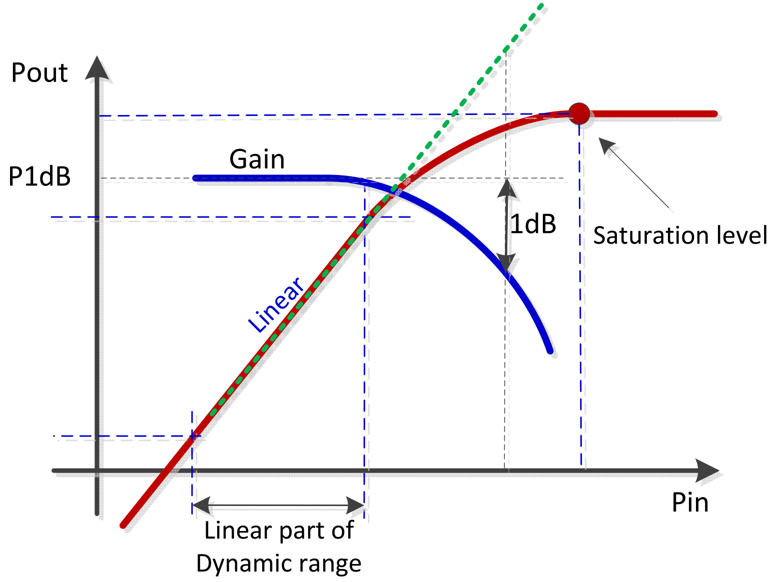


Swept Data Reported in 959 Spectrum

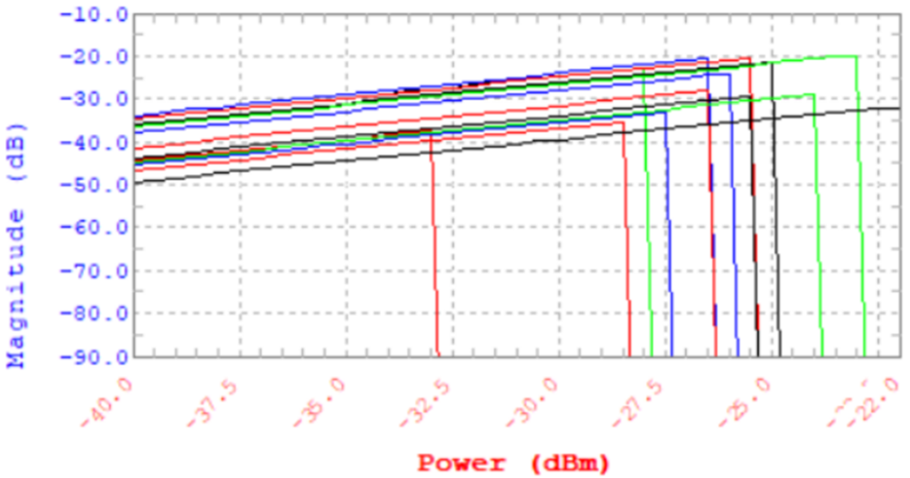


Gain Compression (P1dB) Parameter

- Gain Compression is performed by sweeping the input power of the DUT until a compression point is hit.
  - Power increment and compression point is specified by the user.
- Data collection is automated using 959 Spectrum
  - Power sweeps are conducted to find compression point
  - The Next frequency is measured



Swept Data Reported in 959 Spectrum



Frequency (GHz)	IP1dB
21	-26.5
22	-28
23	-26.5
24	-25.5
25	-25
26	-23
27	-26
28	-26.5
29	-25.5
30	-24
31	-27.5
32	-28.5

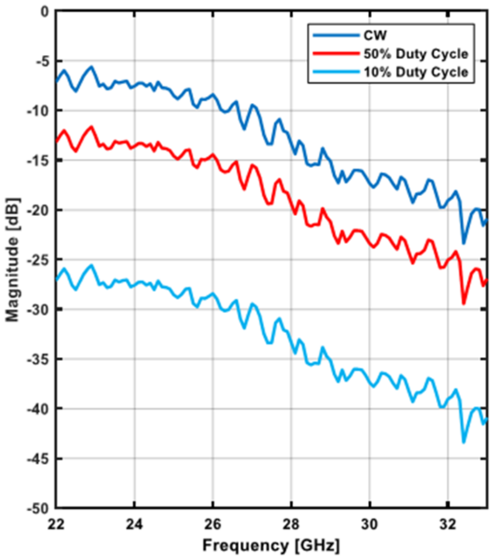
ORBIT Advanced Technologies, Inc.

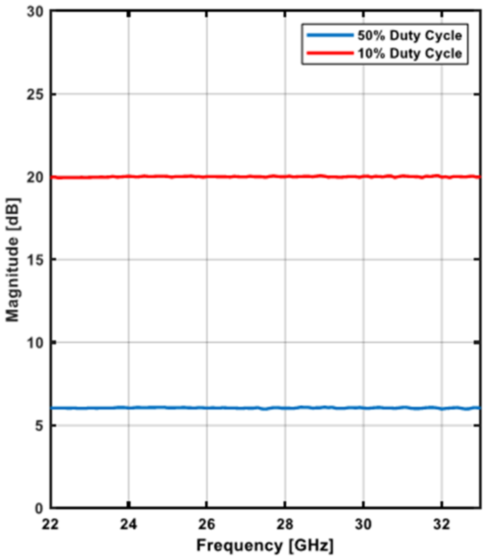
Pulsed RF Mode

- Pulsed RF can be performed in two ways
  - With PXI internal pulsing Hardware
    - Test and Reference Paths are both pulsed
      - Due to down conversion hardware.
  - External Pulsing Switch with PXI as pulse modulator
    - Test Path Pulse, Reference Path is not.

Description	Typical
Minimum pulse width	200 ns
Minimum pulse period	1 µs
Maximum pulse period	10 s

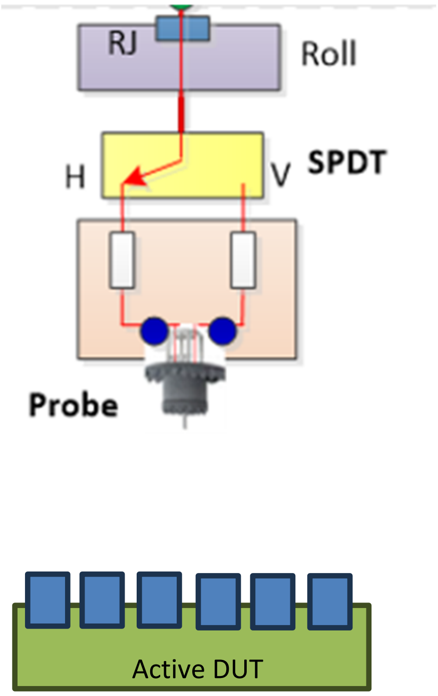
Example Boresight Measurement Showing Duty Cycle Hits Due to Pulsing





Park and Probe Mode

- Primarily for active antenna array calibrations
- Probe moves to designated X,Y Coordinate and performs test
- Each X,Y coordinate has a list of unique DUT coordinates
  - This enables the measurement unique DUT states
  - Probe parks over an active antenna element
    - Cycles through the phase shifter or attenuator states
  - Moves to next element and does an repeats



Uncertainty Analysis

Uncertainty Analysis Overview

- Uncertainty Analysis was Conducted at 8 Different frequency bands at the following frequencies
- Uncertainty based on NIST nearfield18-term error model [3] and IEEE STD 1720
- Values computed inside the valid angle

Band	Frequency Band	OTA Test Frequency	Source Frequency	DUT	Probe	Uncertainty Main Beam (2σ)	Uncertainty -30 dB SLL (2σ)
L	1-2 GHz	1.5 GHz	1.5 GHz	SGH112	DLP-PNF-100	-	-
S	2-4 GHz	3 GHz	2.5 GHz	SGH260	DLP-PNF-200	±0.277	±1.379
C	4-8 GHz	5.5 GHz	5 GHz	SGH395	DLP-PNF-400	±0.230	±0.997
Ku	8-18 GHz	8.5 GHz 15 GHz	8.5 and 15 GHz	SGH820	DLP-PNF-800	±0.444 ±0.410	±1.060 ±0.706
Ka	18-40 GHz	23 GHz 30 GHz	23 and 30 GHz	SGH2650	DLP-PNF-1800	±0.442 ±0.519	±0.855 ±1.562
Q	33-50 GHz	40 GHz	40 GHz	SGH3300	DLP-PNF-3300	-	-
V	50-75 GHz	60 GHz	10 GHz	SGH5000	OEW5000	±0.388	±0.994
W	75-110 GHz	90 GHz	15 GHz	SGH7500	OEW7500	±0.426	±1.315

Uncertainty Analysis Overview (1 – 110 GHz)

- Probe Calibrations (1-4) and DUT calibrations (5,6)
  - Analysis based on UPM calibration data
- Alias (8) and Truncation (9)
  - Processing Errors due sampling and scan size
- Positioner Errors (10,11)
  - Laser tracker data used to perturb ideal data to run through the transform
- Probe-DUT Coupling Room Reflections (12)
  - ¼ wavelength offsets DUT offset from Probe
- Receiver Linearity (13)
  - Boresight Roll Method and Attenuator Checks

#	Uncertainty Term	Method of Evaluating
1	Probe relative pattern	Analysis, Probe Calibration Data
2	Probe polarization ratio	Analysis, Probe Calibration Data
3	Probe gain measurement	Analysis, Probe Calibration Data
4	Probe alignment error	Analysis, Mechanical SAT
5	Normalization constant	Analysis, SGH calibration data
6	Impedance mismatch factor	Analysis
7	DUT alignment error	Analysis, Hexapod Specs
8	Data point spacing (aliasing)	Measurement
9	Measurement area truncation	Measurement
10	Probe x, y-position errors	Analysis, Mechanical SAT
11	Probe z-position errors	Analysis, Mechanical SAT
12	Multiple reflections (probe/DUT)	Measurement
13	Receiver amplitude nonlinearity	Measurement
14	System phase error due to receiver phase errors, flexing cables/rotary joints, and temperature effects	Analysis from RF FAT Drift Measurements
15	Receiver dynamic range	Measurement
16	Room scattering	Measurement
17	Leakage and crosstalk	Measurement
18	Repeatability /Random errors in amplitude/phase	Measurement

Uncertainty Analysis Overview (1 – 110 GHz)

- System Phase Errors (14)
  - Drift testing
- Receiver Dynamic Range (15)
  - Boresight Dynamic range measurements
- Chamber Scattering (16)
  - Fixed DUT offset from Probe with ¼ movement of probe and DUT Mast
- Leakage/Cross Talk (17)
  - Near-Field Scan with terminated cable that attaches to DUT
- Repeatability/Random Errors (18)
  - Back-to-Back measurement taken.

#	Uncertainty Term	Method of Evaluating
1	Probe relative pattern	Analysis, Probe Calibration Data
2	Probe polarization ratio	Analysis, Probe Calibration Data
3	Probe gain measurement	Analysis, Probe Calibration Data
4	Probe alignment error	Analysis, Mechanical SAT
5	Normalization constant	Analysis, SGH calibration data
6	Impedance mismatch factor	Analysis
7	DUT alignment error	Analysis, Hexapod Specs
8	Data point spacing (aliasing)	Measurement
9	Measurement area truncation	Measurement
10	Probe x, y-position errors	Analysis, Mechanical SAT
11	Probe z-position errors	Analysis, Mechanical SAT
12	Multiple reflections (probe/DUT)	Measurement
13	Receiver amplitude nonlinearity	Measurement
14	System phase error due to receiver phase errors, flexing cables/rotary joints, and temperature effects	Analysis from RF FAT Drift Measurements
15	Receiver dynamic range	Measurement
16	Room scattering	Measurement
17	Leakage and crosstalk	Measurement
18	Repeatability /Random errors in amplitude/phase	Measurement

Sample Uncertainty Analysis Results (2σ Results)

Uncertainty Analysis at 5 GHz

Term #	Term Name	Δ Gain [dB]	Main Beam [dB]	Side-lobe@-30 [dB]	Side-lobe@-45 [dB]	Side-lobe ESS [dB]	Source of Data
Frequency/Polarization		5 GHz Eϕ Polarization					
1	Probe Relative Pattern	N/A	N/A	±0.30	±0.45	N/A	Probe Calibration Data
2	Probe Polarization Ratio	NE	N/A	±0.002	±0.196	N/A	Probe Calibration Data
3	Probe Gain Measurement	±0.13	N/A	N/A	N/A	N/A	Probe Calibration Data
4	Probe Alignment Error	N/A	NE	±0.009	±0.012	N/A	Mechanical SAT
5	Normalization Constant	±0.12	N/A	N/A	N/A	N/A	SGH Calibration Data
6	Impedance Mismatch Factor	±0.138	N/A	N/A	N/A	N/A	Analysis
7	DUT Alignment Error	N/A	±0.001	±0.002	±0.012	-102.000	Hexapod Specifications
8	Data Point Spacing (Aliasing)	±0.008	±0.040	±0.190	±1.020	-63.090	Measurement
9	Measurement Area Truncation	±0.002	±0.193	±0.309	±1.608	-58.833	Measurement
10	Probe x,y-position errors	NE	±0.003	±0.027	±0.153	-79.991	Mechanical SAT/Analysis
11	Probe z-position errors	±0.003	±0.004	±0.016	±0.091	-84.533	Mechanical SAT/Analysis
12	Multiple Reflections (Probe/DUT)	±0.040	±0.068	±0.549	±2.713	-53.715	Measurement
13	Receiver Amplitude Nonlinearity	±0.026	N/A	N/A	N/A	N/A	Measurement
14	System Phase Error	NE	NE	±0.003	±0.015	-100.348	Measurement
15	Receiver Dynamic Range	N/A	NE	NE	±0.002	-120.188	Measurement
16	Room Scattering	±0.028	±0.050	±0.595	±2.916	-52.981	Measurement
17	Leakage and Crosstalk	±0.001	±0.001	±0.029	±0.112	N/A	Measurement
18	Random Errors	±0.012	±0.052	±0.420	±2.137	-56.090	Measurement
Total Error		±0.230	±0.220	±0.997	±4.389		

Uncertainty Analysis at 90 GHz

Term #	Term Name	Δ Gain [dB]	Main Beam [dB]	Side-lobe@-30 [dB]	Side-lobe@-45 [dB]	Side-lobe ESS [dB]	Source of Data
Frequency/Polarization		90 GHz Eϕ Polarization					
1	Probe Relative Pattern	N/A	N/A	±0.30	±0.45	N/A	Probe Calibration Data
2	Probe Polarization Ratio	NE	N/A	±0.007	±0.116	N/A	Probe Calibration Data
3	Probe Gain Measurement	±0.31	N/A	N/A	N/A	N/A	Probe Calibration Data
4	Probe Alignment Error	N/A	NE	±0.010	±0.016	N/A	Mechanical SAT
5	Normalization Constant	±0.15	N/A	N/A	N/A	N/A	SGH Calibration Data
6	Impedance Mismatch Factor	±0.129	N/A	N/A	N/A	N/A	Analysis
7	DUT Alignment Error	N/A	±0.001	±0.001	±0.008	-105.688	Hexapod Specifications
8	Data Point Spacing (Aliasing)	±0.013	±0.053	±0.285	±1.493	-59.540	Measurement
9	Measurement Area Truncation	±0.006	±0.066	±0.160	±0.865	-64.596	Measurement
10	Probe x,y-position errors	±0.014	±0.056	±0.389	±1.989	-56.789	Mechanical SAT/Analysis
11	Probe z-position errors	±0.006	±0.016	±0.044	±0.243	-75.957	Mechanical SAT/Analysis
12	Multiple Reflections (Probe/DUT)	±0.216	±0.185	±1.086	±4.854	-47.516	Measurement
13	Receiver Amplitude Nonlinearity	±0.009	N/A	N/A	N/A	N/A	Measurement
14	System Phase Error	±0.013	±0.020	±0.060	±0.335	-73.111	Measurement
15	Receiver Dynamic Range	N/A	NE	±0.003	±0.014	-100.802	Measurement
16	Room Scattering	±0.044	±0.046	±0.311	±1.620	-58.762	Measurement
17	Leakage and Crosstalk	±0.002	±0.093	±0.176	±0.913	N/A	Measurement
18	Random Errors	±0.024	±0.019	±0.413	±2.102	-56.25	Measurement
Total Error (RSS)		±0.426	±0.236	±1.315	±5.569		

ORBIT Advanced Technologies, Inc.

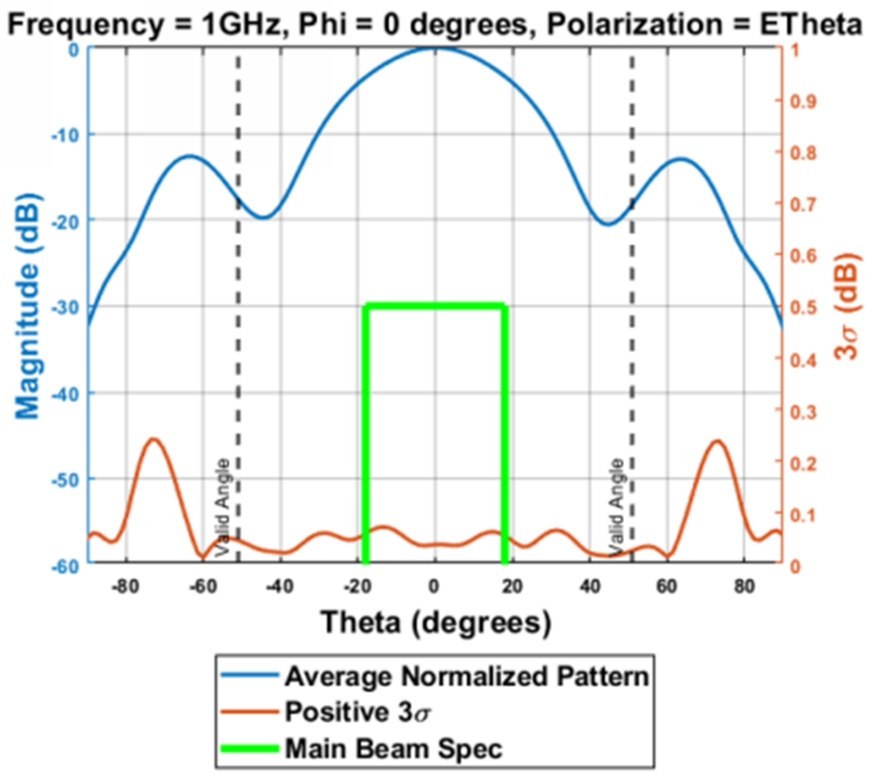
Antenna Gain Measurements

Antenna Gain Measurement Accuracy

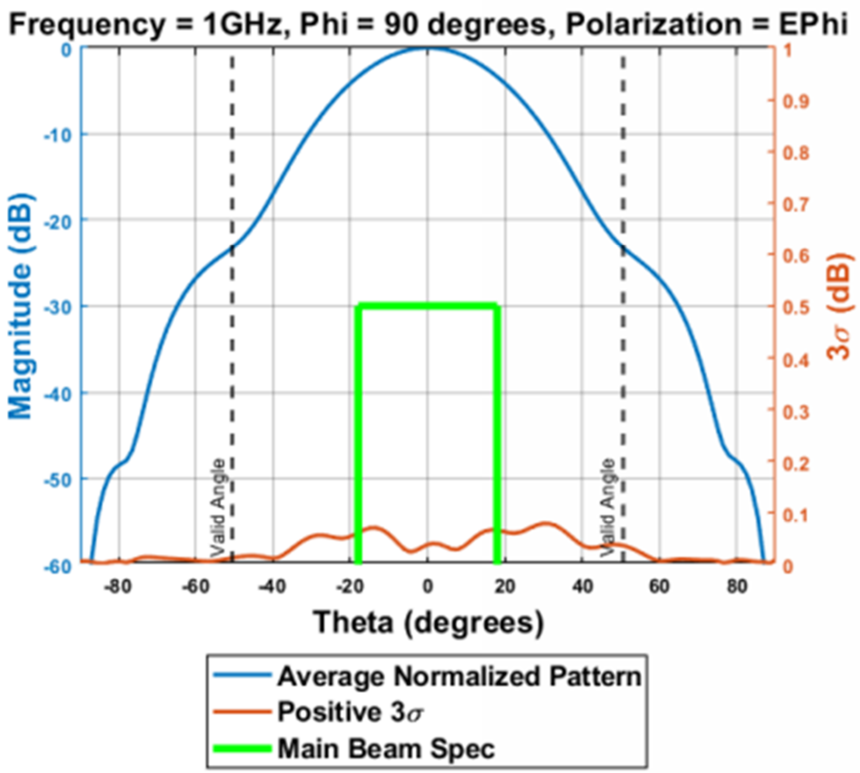
- 5 antenna measurements were taken at 1/8 wavelength Z-axis steps at each band
  - A mean of the 5 patterns was taken to determine the "Truth"
  - 3σ STD taken within the 3dB mean with was taken to determine a main beam metric

- Worst Case values for reported for Theta/Phi polarizations and band overlaps
  - Statement of work had a requirement to measure the 3σ gain accuracy
  - Compared 2σ values from the uncertainty analysis with the 3σ from the gain accuracy measurements
    - 3σ (99.7% confidence) should fall within the 2σ (95.4% confidence) interval

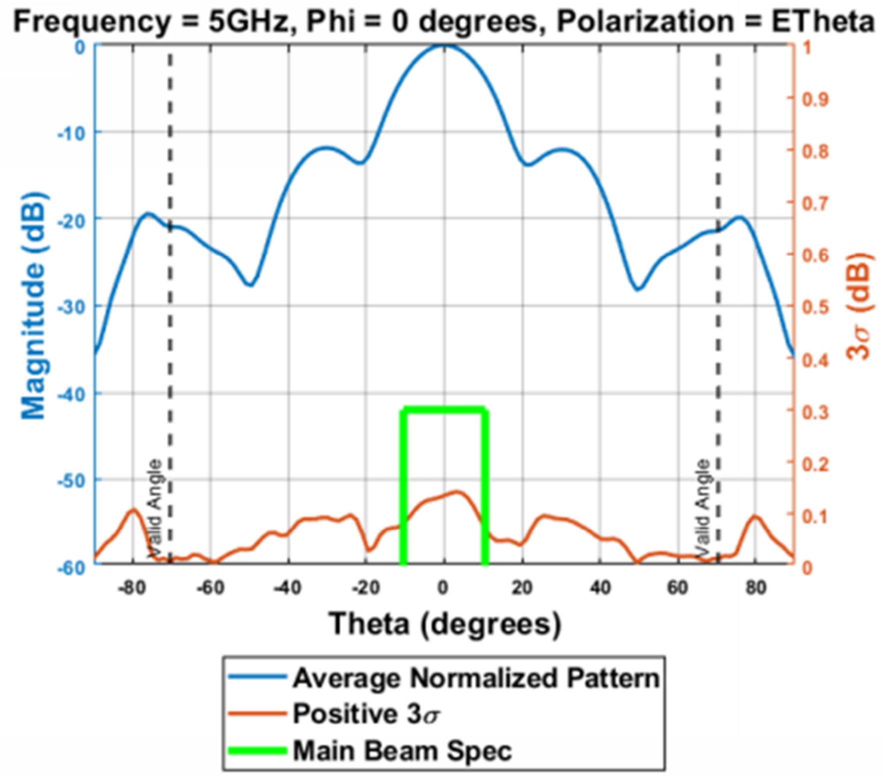
Band	Frequency Band	OTA Test Frequency	Source Frequency	DUT	Probe	Uncertainty Main Beam 2σ [dB]	Main Beam Gain Accuracy 2σ [dB]	Main Beam Gain Accuracy 3σ [dB]
L	1-2 GHz	1.5 GHz	1.5 GHz	SGH112	DLP-PNF-100	-	±0.089	±0.133
S	2-4 GHz	2.5 GHz	2.5 GHz	SGH260	DLP-PNF-200	±0.277	±0.095	±0.142
C	4-8 GHz	5 GHz	5 GHz	SGH395	DLP-PNF-400	±0.230	±0.095	±0.143
X	8-12 GHz	8.5 GHz	8.5 GHz	SGH820	DLP-PNF-800	±0.444	±0.061	±0.092
Ku	12.5-18 GHz	15 GHz	15 GHz	SGH1240	DLP-PNF-800	±0.410	±0.125	±0.187
Ka	18-40 GHz	23 GHz 30 GHz	23 GHz 30 GHz	SGH2650	DLP-PNF-1800	±0.442 ±0.519	±0.110 ±0.029	±0.165 ±0.348
Q	33-50 GHz	40 GHz	40 GHz	SGH3300	DLP-PNF-3300	-	±0.102	±0.153
V	50-75 GHz	60 GHz	10 GHz	SGH5000	OEW5000	±0.388	±0.102	±0.263
W	75-110 GHz	90 GHz	15 GHz	SGH7500	OEW7500	±0.426	±0.178	±0.267



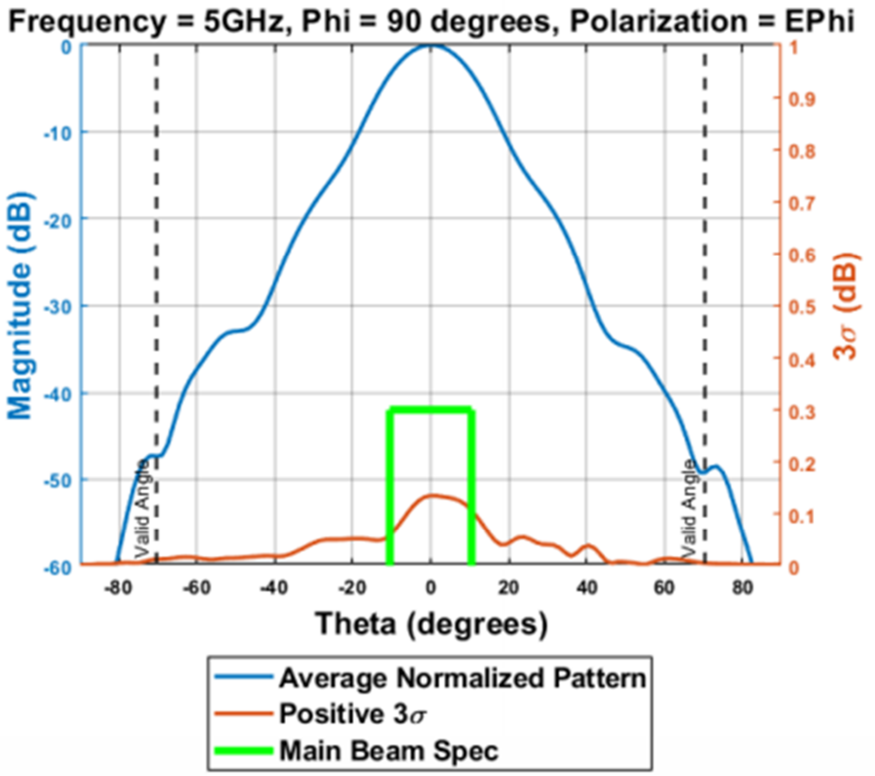
Frequency = 1GHz, Phi = 0 degrees, Polarization = ETheta
Magnitude (dB)
3σ (dB)
Theta (degrees)
Valid Angle
Valid Angle
Average Normalized Pattern
Positive 3σ
Main Beam Spec



Frequency = 1GHz, Phi = 90 degrees, Polarization = EPhi
Magnitude (dB)
3σ (dB)
Theta (degrees)
Valid Angle
Valid Angle
Average Normalized Pattern
Positive 3σ
Main Beam Spec

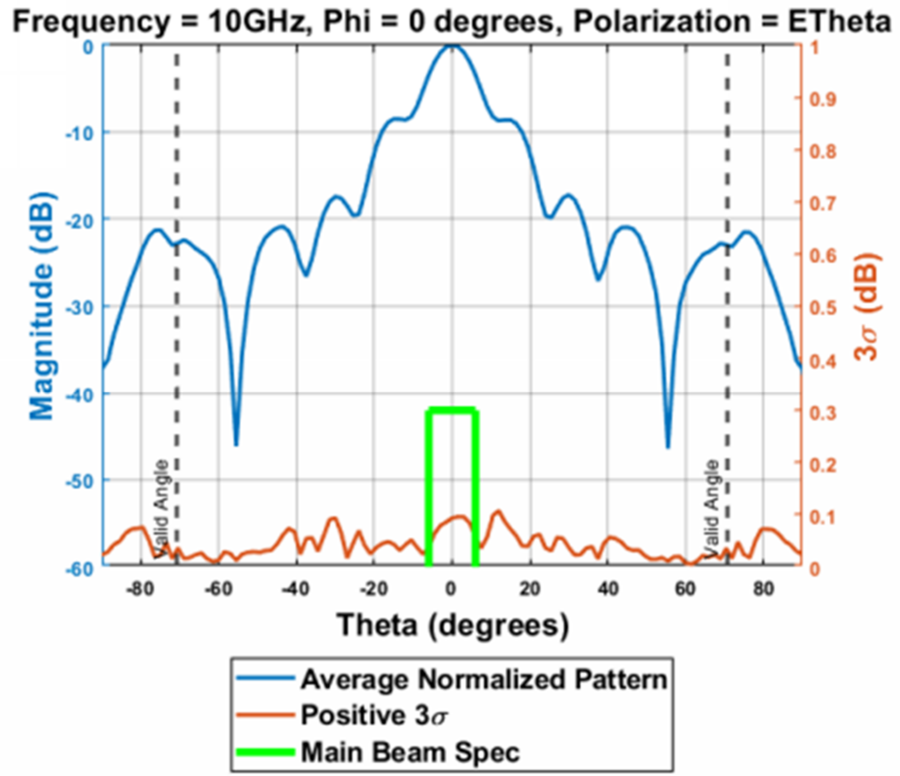


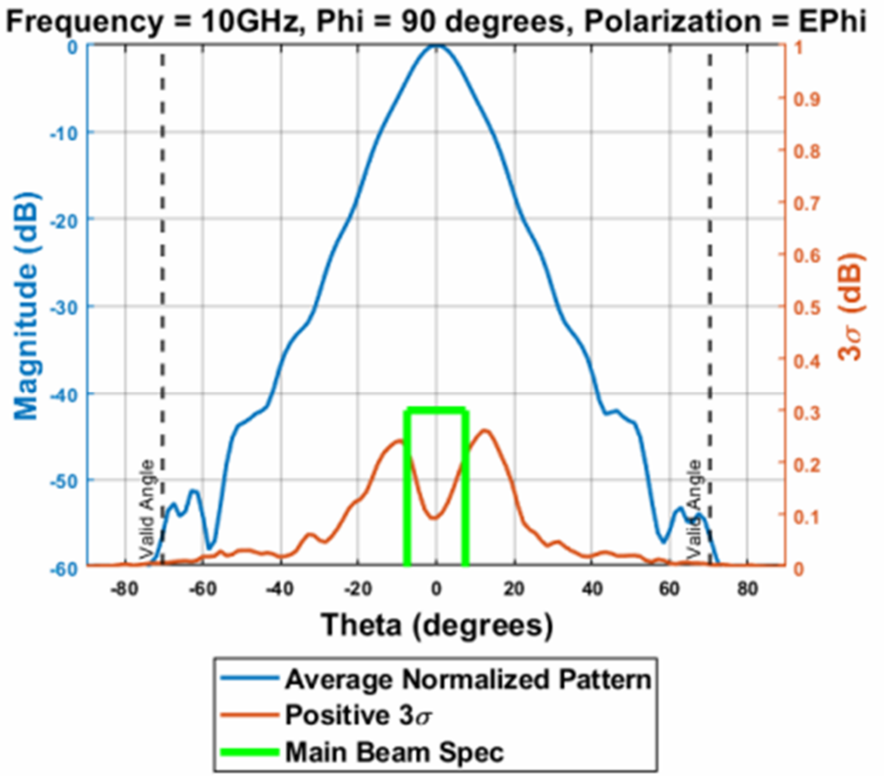
Frequency = 5GHz, Phi = 0 degrees, Polarization = ETheta
Magnitude (dB)
3σ (dB)
Theta (degrees)
Valid Angle
Valid Angle
Average Normalized Pattern
Positive 3σ
Main Beam Spec

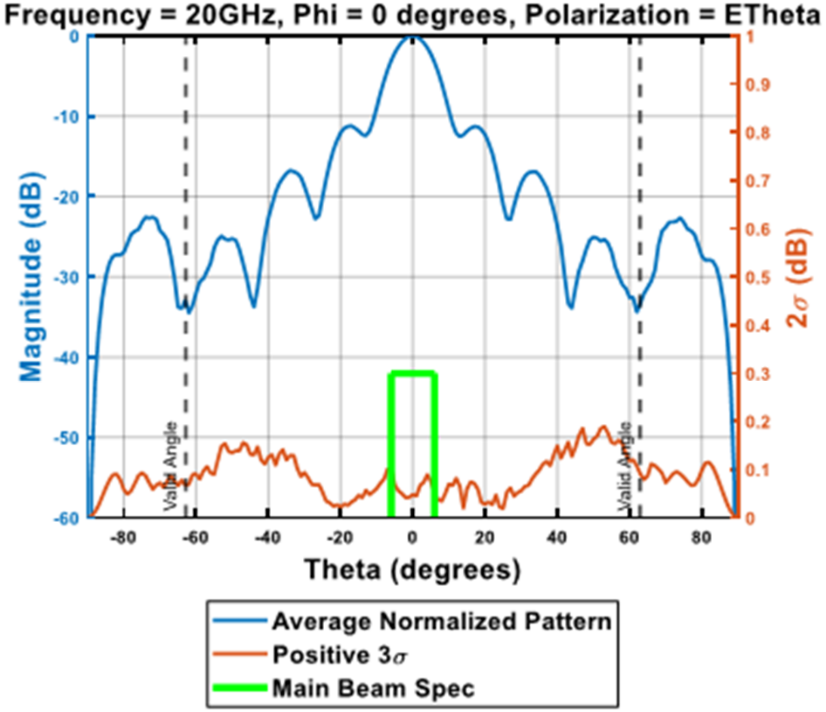


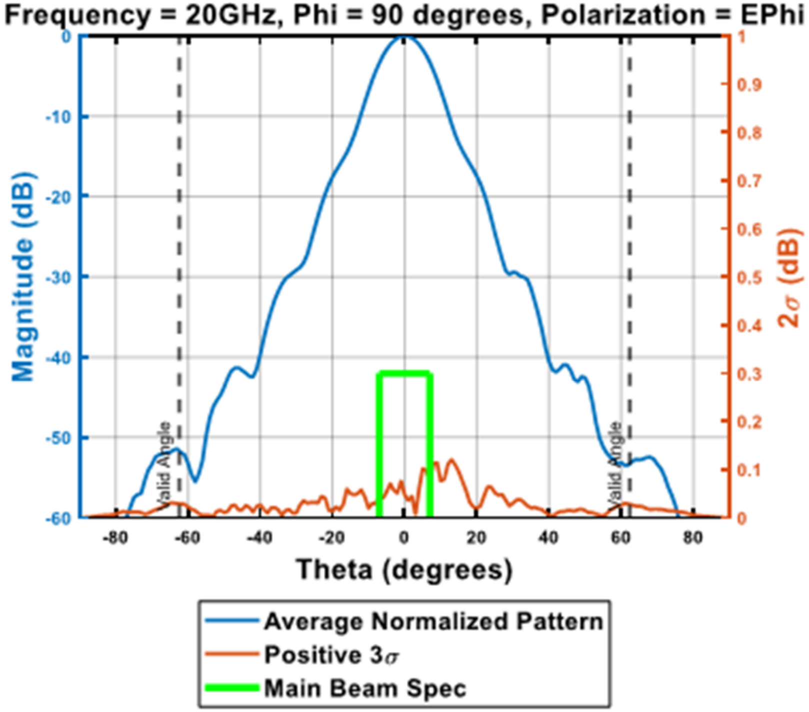
Frequency = 5GHz, Phi = 90 degrees, Polarization = EPhi
Magnitude (dB)
3σ (dB)
Theta (degrees)
Valid Angle
Valid Angle
Average Normalized Pattern
Positive 3σ
Main Beam Spec

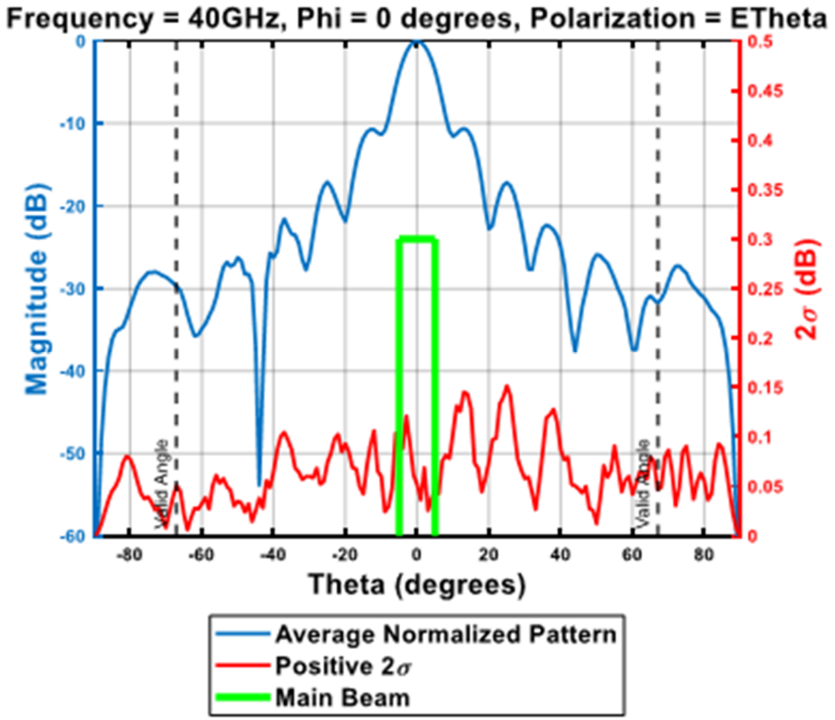
Antenna Gain Measurement Accuracy at 10 GHz



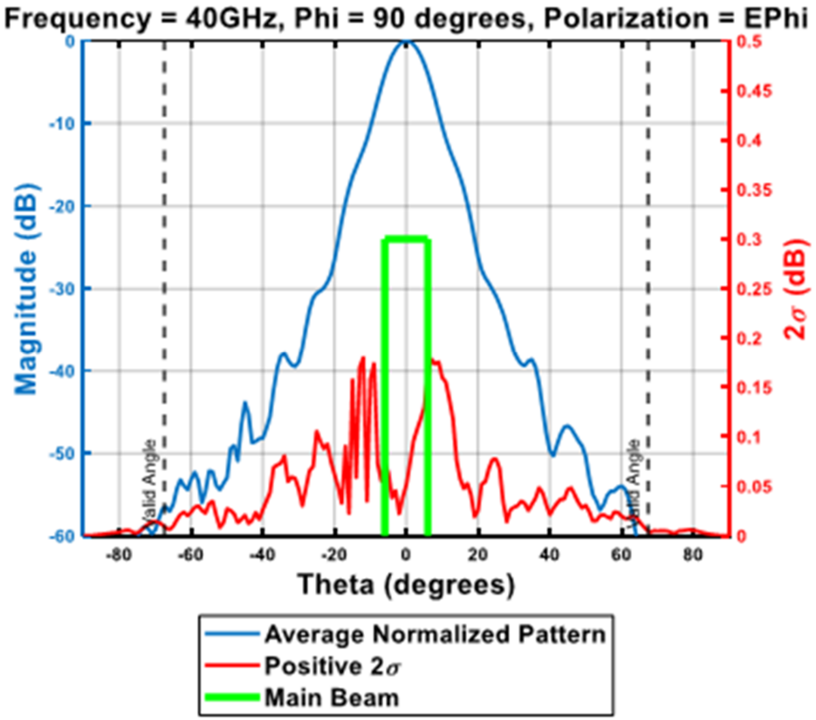



Frequency = 20GHz, Phi = 0 degrees, Polarization = ETheta
Magnitude (dB)
2σ (dB)
Theta (degrees)
Valid Angle
Valid Angle
Average Normalized Pattern
Positive 3σ
Main Beam Spec


Frequency = 20GHz, Phi = 90 degrees, Polarization = EPhi
Magnitude (dB)
2σ (dB)
Theta (degrees)
Valid Angle
Valid Angle
Average Normalized Pattern
Positive 3σ
Main Beam Spec

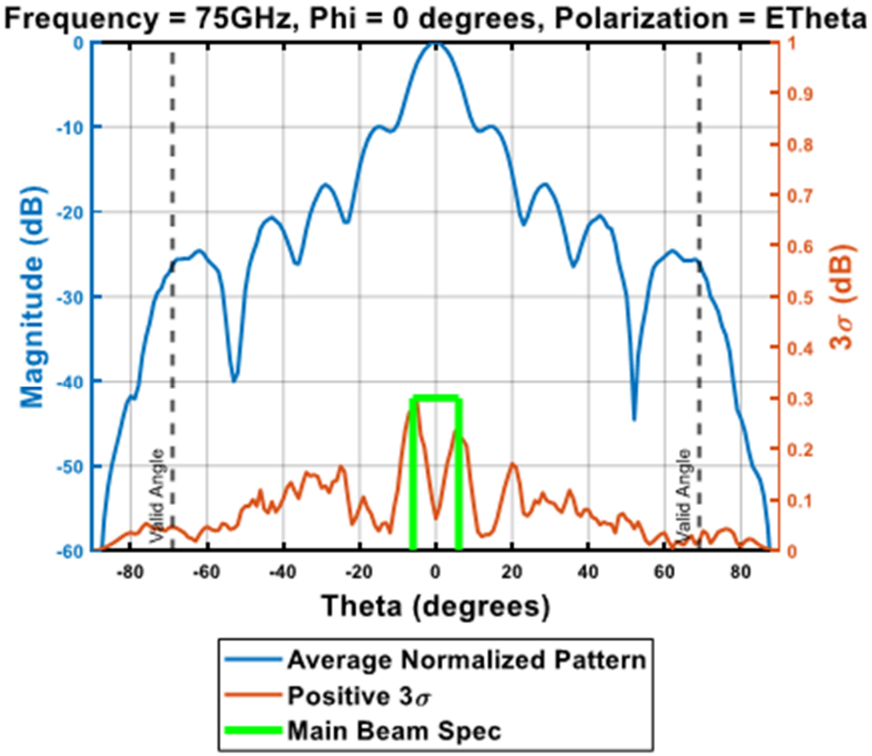


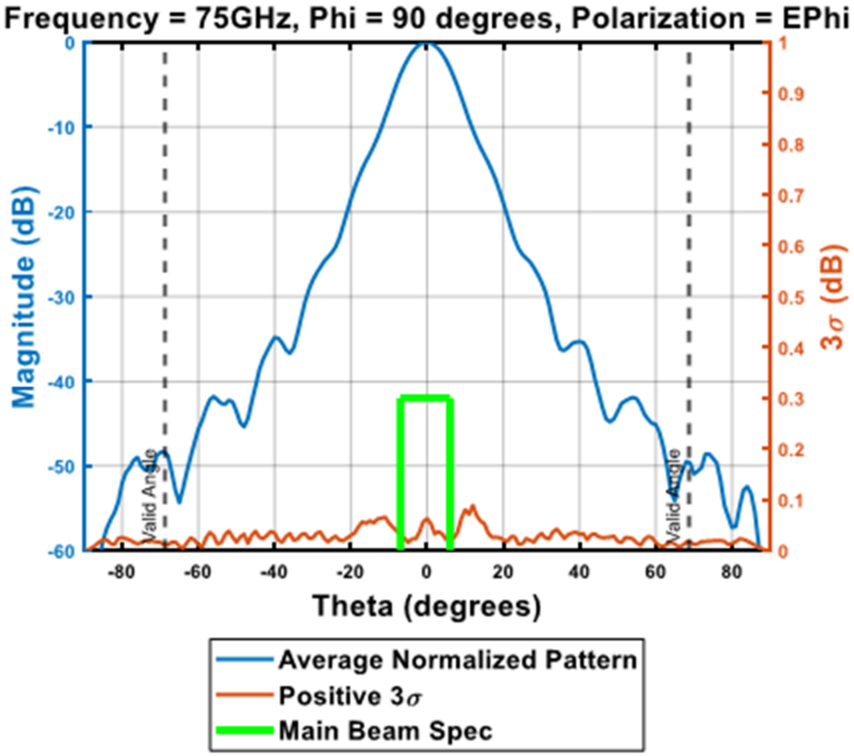
Frequency = 40GHz, Phi = 0 degrees, Polarization = ETheta
Magnitude (dB)
2σ (dB)
Theta (degrees)
Valid Angle
Valid Angle
Average Normalized Pattern
Positive 2σ
Main Beam



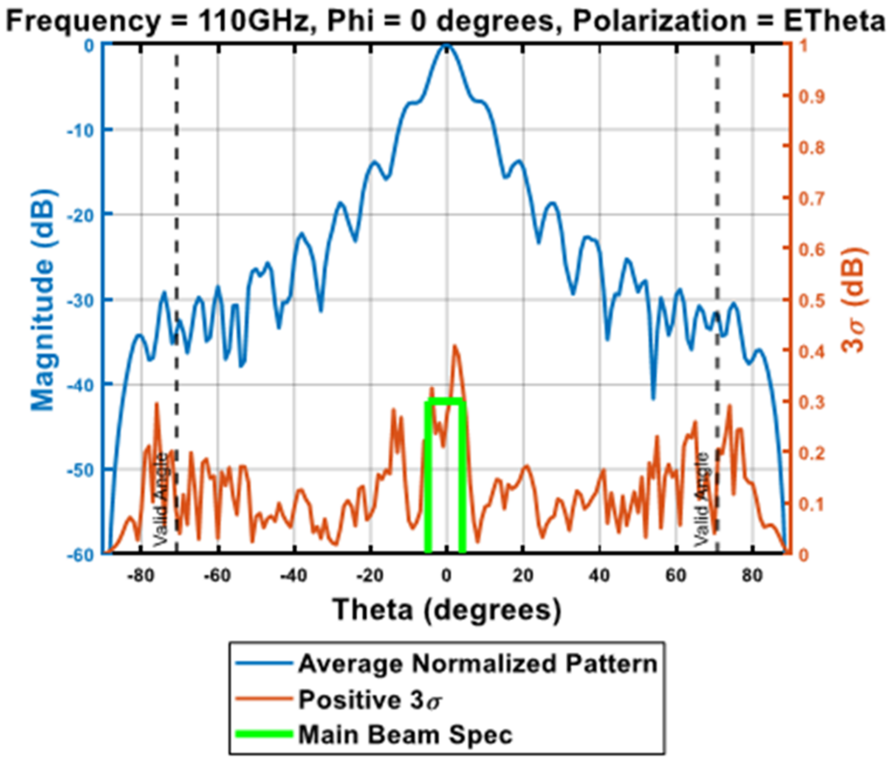
Frequency = 40GHz, Phi = 90 degrees, Polarization = EPhi
Magnitude (dB)
2σ (dB)
Theta (degrees)
Valid Angle
Valid Angle
Average Normalized Pattern
Positive 2σ
Main Beam

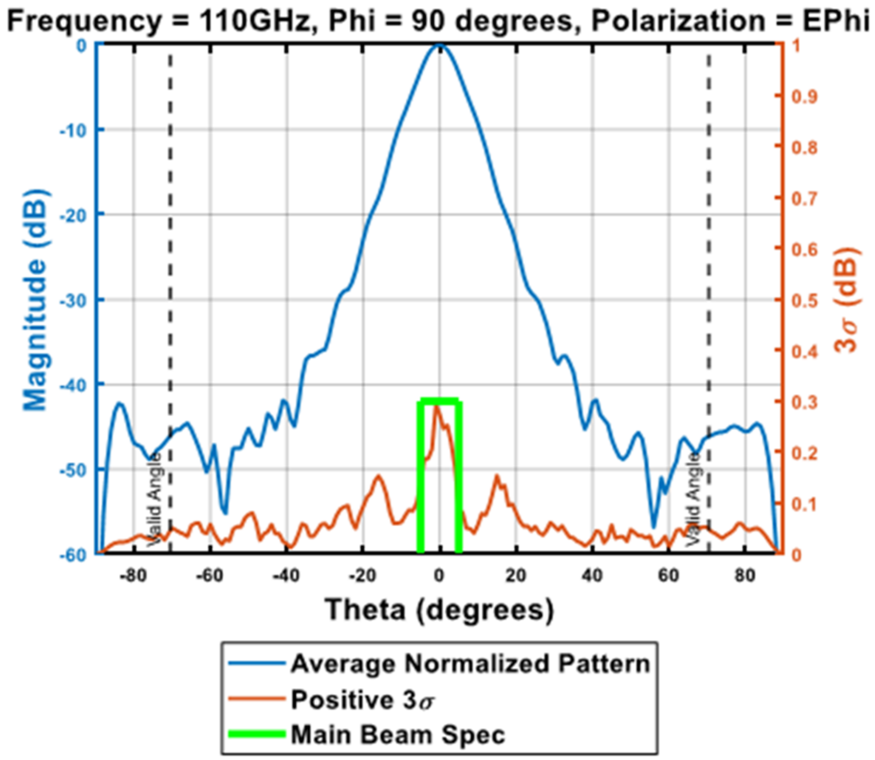
Antenna Gain Measurement Accuracy at 75 GHz





Antenna Gain Measurement Accuracy at 110 GHz





- NASA Commissioned a Large HPNF Measurement Facility
  - 10 m x 10 m Scan plane
  - 1 – 110 GHz
  - Antenna Gain Measurements and Radiation Patterns
  - Special Test modes
    - EIRP, G/T, IMD, Gain Compression, Pulsed Mode, Park and Probe

- Antenna Range is capable of measurement of very large antennas
  - DUT mast can be removed to allow for very heavy payloads on the floor

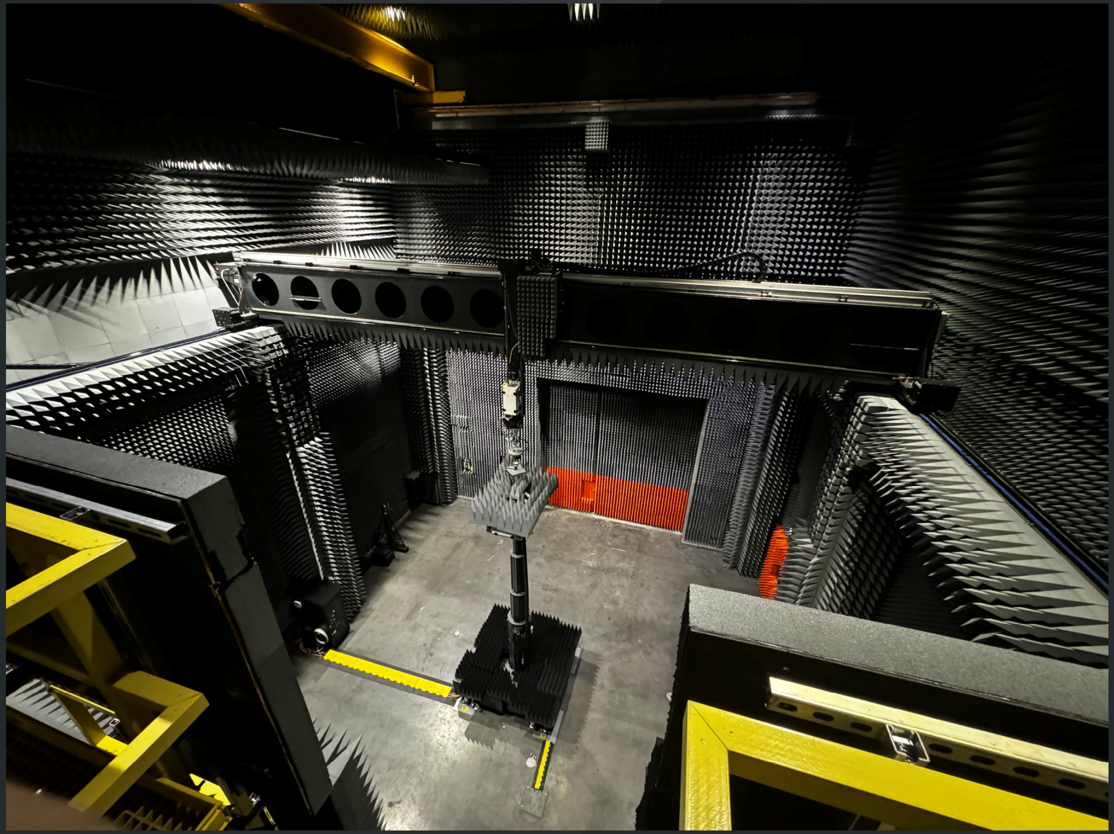
- Higher Frequency VDI units can further extend the maximum frequency range

- Future work can include integration of k-corrections for improvement on the measurement accuracies

References

1. IEEE Std 1720-2012 “Recommended Practice for Near-Field Antenna Measurements”
2. Cutshall, et, al (2022). A New Valid Angle Equation for PNF Measurements. 1-6. 10.23919/AMTA55213.2022.9955005.
3. A. G. Repjar, A. C. Newell, M. H. Francis “Accurate Determination of Planar Near-Field Correction
4. Parameters for Linearly Polarized Probes”, IEEE Transactions on Antennas and Propagation, vol. 36, no. 6,
5. June 1988
6. A. C. Newell, R. D. Ward and E. J. McFarlane “Gain and Power Parameter Using Planar Near-Field Techniques”, IEEE Transactions on Antennas and Propagation, vol. 36, no. 6, June 1988
7. F. Jensen, A. Frandsen, “On the number of modes in spherical wave expansion”, AMTA Symposium, October 2004, Stone Mountain, GA, USA
8. MV-Plane User Manual
9. MV-Holography User Manual
10. MV-Echo User Manual

MVG Microwave Vision Group | ORBIT Advanced Technologies, Inc.



Thank you
Questions ?

ORBIT Advanced Technologies, Inc. — MVG Microwave Vision Group

Domenic Belgiovane, Ph.D.
Principal Systems Engineer | Pre-Sales Support

Orbit Advanced Technologies, Inc.
A Division of Orbit/FR, Inc.

650 Louis Drive, Suite 100
Warminster, PA 18974
Mobile: +1 419 231 3838

domenicb@orbitfr.com
www.mvg-world.com

Backup Slides