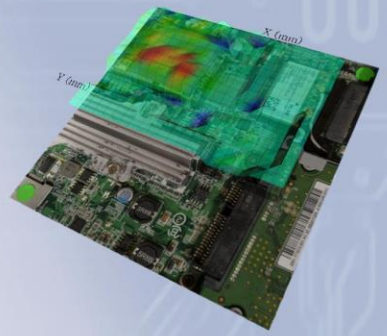

EM-ISight-AMS 5G
Antenna Measurement System

Introduction

- EM-ISight-AMS developed to support 5G antenna and system evaluation
- Created to support the development of a new generation of 5G and 6G devices, including the new IEC JWG 12: IEC/IEEE Joint Working Group "Measurement methods to assess the power density in close proximity to the head and body" standards
- Frequency support for transceivers operating above 10GHz, in line with the next generation of wireless standards ITU-R IMT-202
- Features a set of analytical tools for accurate evaluation of device performance for frequencies up to 110 GHz

What is 5G

- **Super Data Layer Key Bands**
  - **24.25 – 29.5GHz* / 37 – 43.5GHz**
- C-Band Coverage and Capacity Layer 3300-4200MHz & 4400-5000MHz (APREL will not focus on this band)
- ITU-R IMT-202
  - **3 Communication Scenarios**

1) eMBB Enhanced Mobile Broadband (key for >6GHz)
2) mMTC Massive Machine Type Communications
3) URLLC Ultra Reliable & Low Latency Communications

***Pioneer Band 26GHz is the accepted way forward**

What is 5G

Current Status

- 5G management and spectrum assignment under 3GPP 5GNR expected release June 2018
- Key players
  - Europe, China, Japan, South Korea and USA

***Pioneer Band**

- 24.25-27.5GHz Europe
- 27.5-29.5GHz USA & Japan

***APREL have the solution for this band and higher frequencies up to 110GHz**

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What is 5G

Group 30 GHz	Group 40 GHz	Group 50 GHz	Group 70/80 GHz
24.25-27.5 31.8-33.4	37-40.5 40.5-42.5 42.5-43.5	45.5-47 47-47.2 47.2-50.2 50.4-52.6	66-71 71-76 81-86

Proposed Global Band 37-43.5GHz

United Kingdom Licensed Bands (Europe?)
24.25-27.5GHz
37-43.5GHz (40.5-43.5GHz)
66-71GHz
Unlicensed Band
57-65GHz
Fixed Link (backhaul)
70/80GHz

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Global Status

Europe

2018-2019 Trial
- 3.4 -3.8 GHz
- eMBB, IoT

USA

2017-2018 Trial
- 28 and 39 GHz
- Fixed Wireless Access, eMBB

China

2017 Trial, 2019 Commercial
- 3.4-3.6 and 4.8-5 GHz; uplink sharing with sub-2 GHz
- eMBB, NB-IoT

Korea

2017 Trial，2019 commercial
- 28 GHz, 3.4-3.7 GHz
- eMBB

Japan

2017 Trial, 2020 Commercial
- 3.6-4.2 and 4.4-4.9 GHz, and 28 GHz
- eMBB

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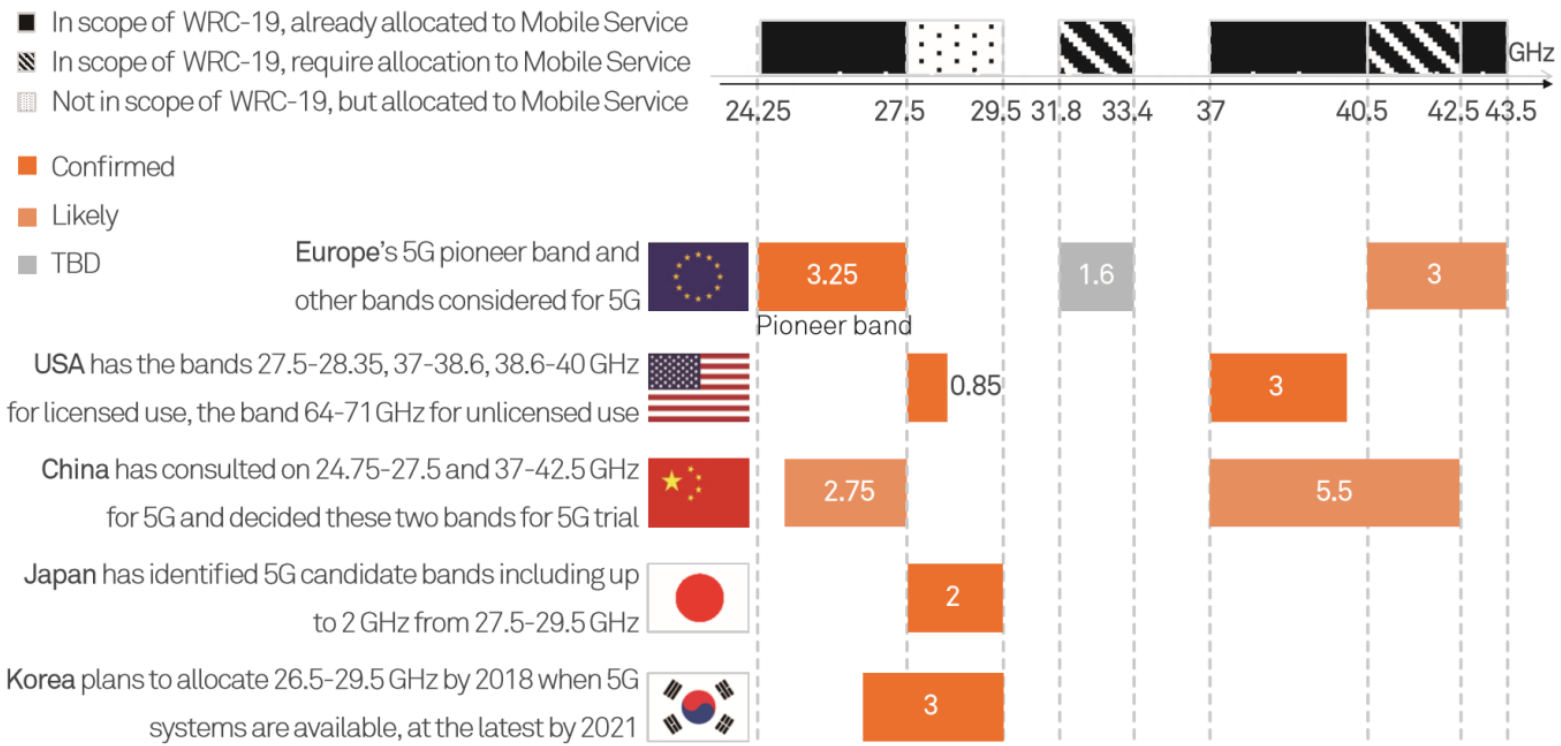
Global Status



Key Players

Band n79 (4400-5000 MHz) **NTT DOCOMO, KDDI, Softbank Mobile, China Mobile, China Unicom, China Telecom**
Band n257 (26.5-29.5 GHz) Band n258 (24.25-27.5 GHz) NTT DOCOMO, KDDI, Softbank Mobile, China Mobile, KT, SK Telecom, LG Uplus, Etisalat, Orange, Verizon, T-Mobile, Telecom Italia, British Telecom, Deutsche Telekom, Telstra
Band n260 (37-40 GHz) * AT&T, Verizon, T-Mobile

verizon

Key player in the USA, currently working on the network compatibility requirements

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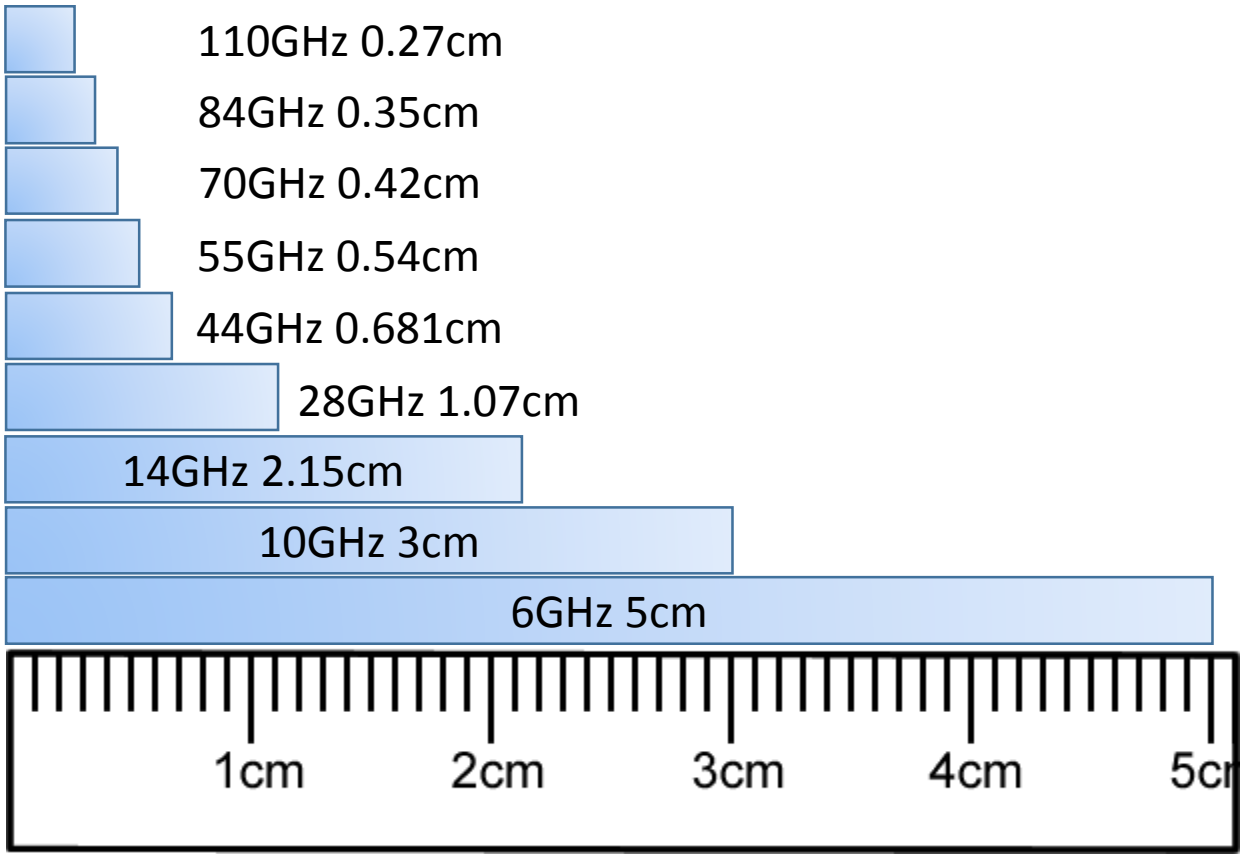
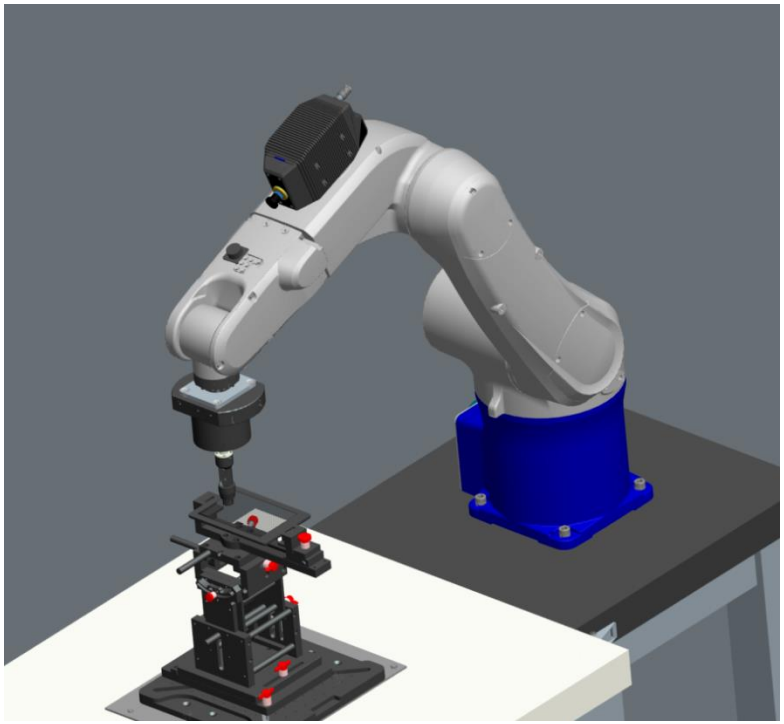
Frequency Wavelength



Standard System Setup



- True near-field antenna/DUT scanning system with real E and H data output
- Six axis robotic solution
- Single setup for measurements, removes the need for multiple waveguide formats
- Precision positioning over DUT
- Planer and Spherical and great arc analysis
- Vision system positioning along with laser marking for accuracy to 20um
- Beam-forming antenna analysis with values for peak, average gain including circular and rectangular methods
- MPE/Power density analysis in line with IEC standards for governmental compliance
- Fully characterised along with calibration references
- Broadband E/H near-field probes
  - 9kHz to 45GHz
  - 50GHz to 110GH

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Functionality (antenna/compliance)

5G MPE Assessment

- Power density
- Emitted power
- E and H field peak cross-detection
- Poynting vector

5G Antenna design

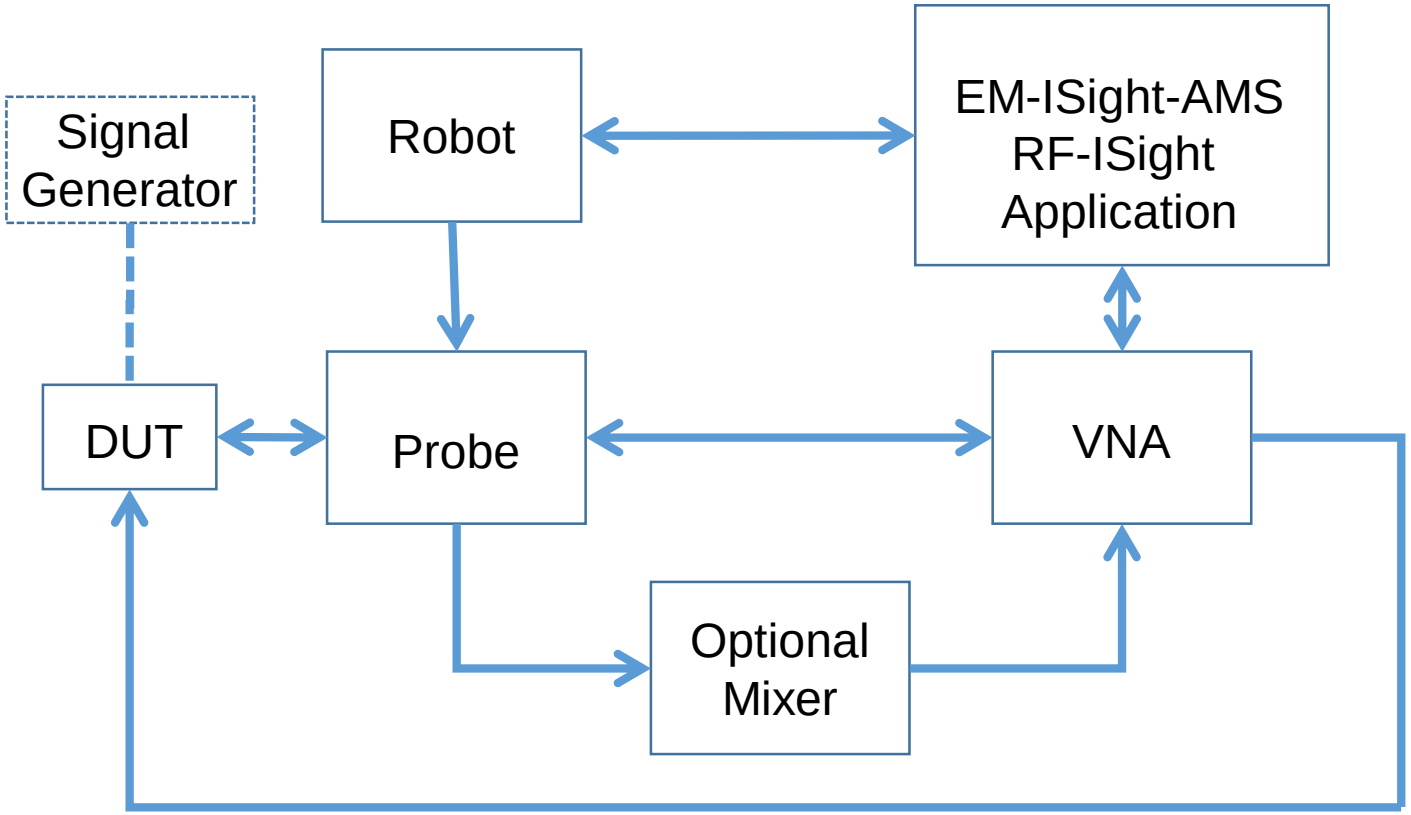
- Directivity/gain
- Efficiency
- E/H phase shift
- Beam forming/orientation
- Reverse energy

Functionality (design)

EMI/SI/PI Diagnostics

- Stochastic waves
- Parasitic resonances
- Predominant field sources
- Standing waves
- Backscattering

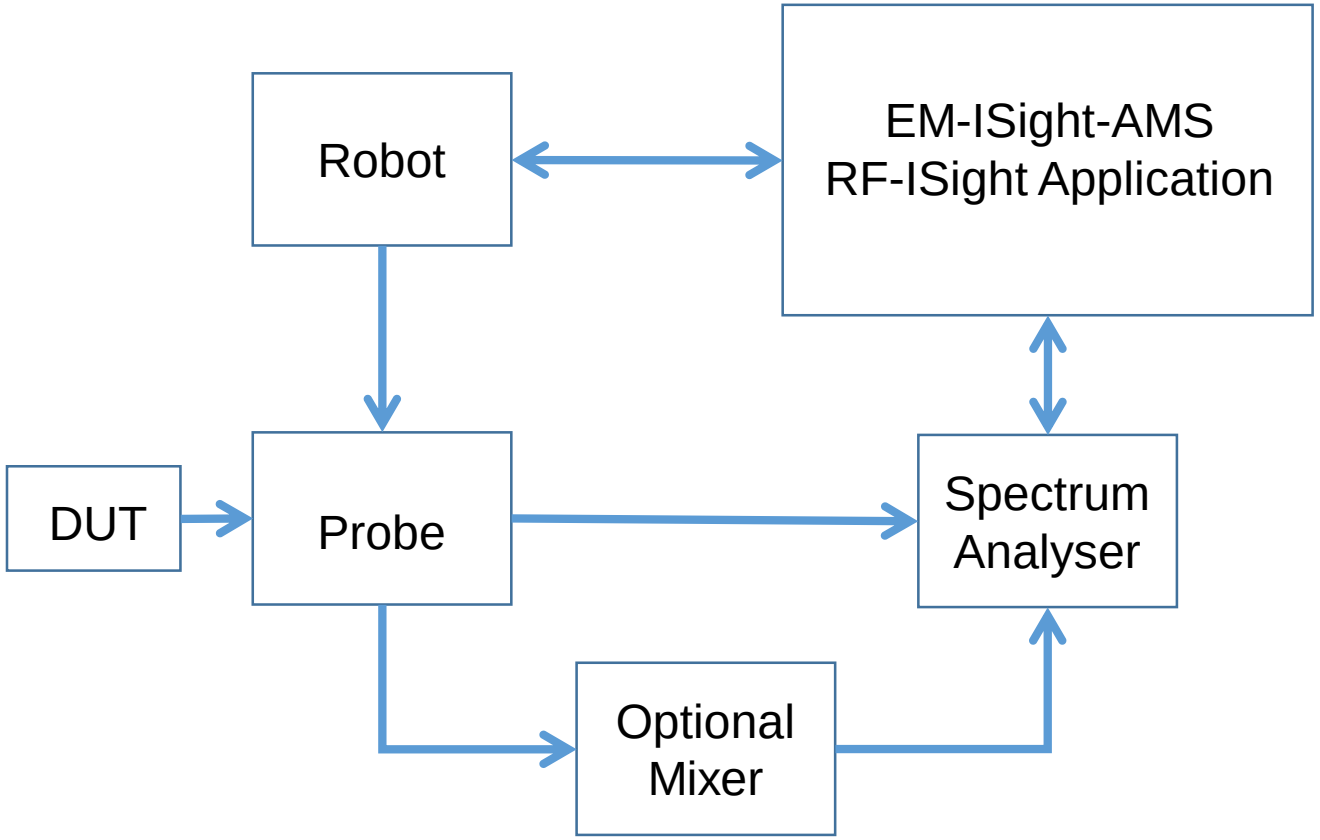
System options Antenna Performance



Measure in the near-field (less than 1 lambda)
Do not reconstruct from far-field

APREL

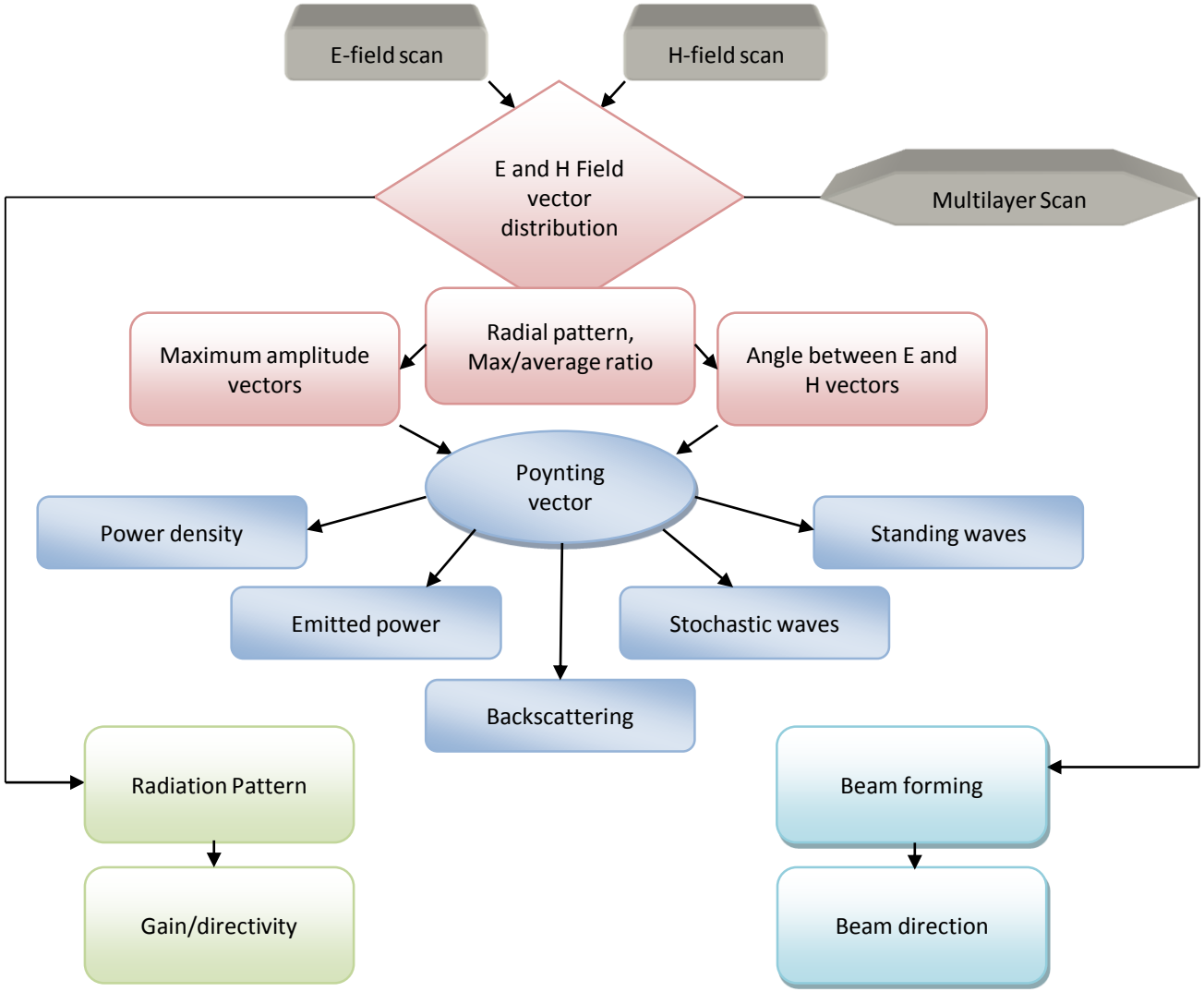
System Options MPE/Power Density



Measure in the near-field (less than 1 lambda)
Do not reconstruct from far-field

APREL

Functionality



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APREL 5G Test Solution

MPE/Power Density Solution <50GHz

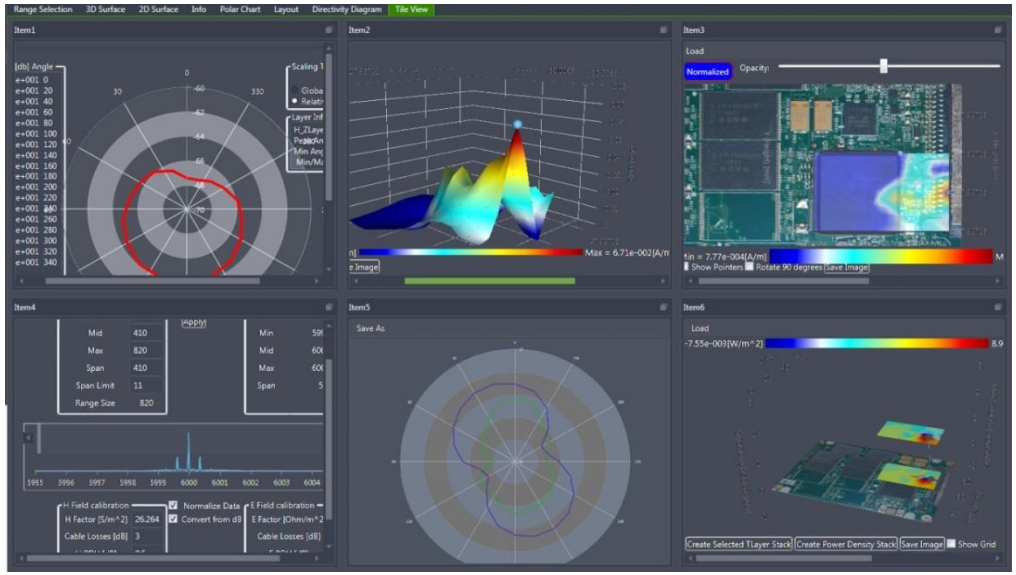
MPE Power Density Standard

This requirement will replace SAR

- IEC TC106 AHG10
- Frequency span 10GHz to 300GHz
- Technical report stage, initial publication of Technical Report Q2 2018
- Final requirements have still to be established
  - Directional/Planer
  - Averaging area 1/4/20 cm^2
  - Spherical or rectangular
  - Still more work to be done…….

EM-ISight-AMS Application Concept

- RF-ISight is an analytical instrument for EM-ISight measurement system
- Created to support the development of a new generation of 5G and 6G devices
- Features a set of analytical tools for accurate evaluation of device performances at frequencies up to 110 GHz



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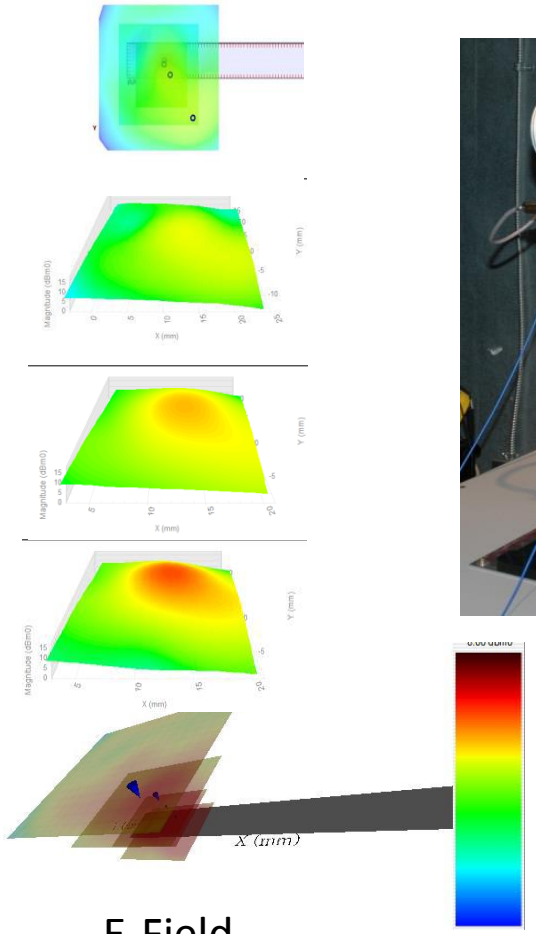
Beam Formation 28GHz

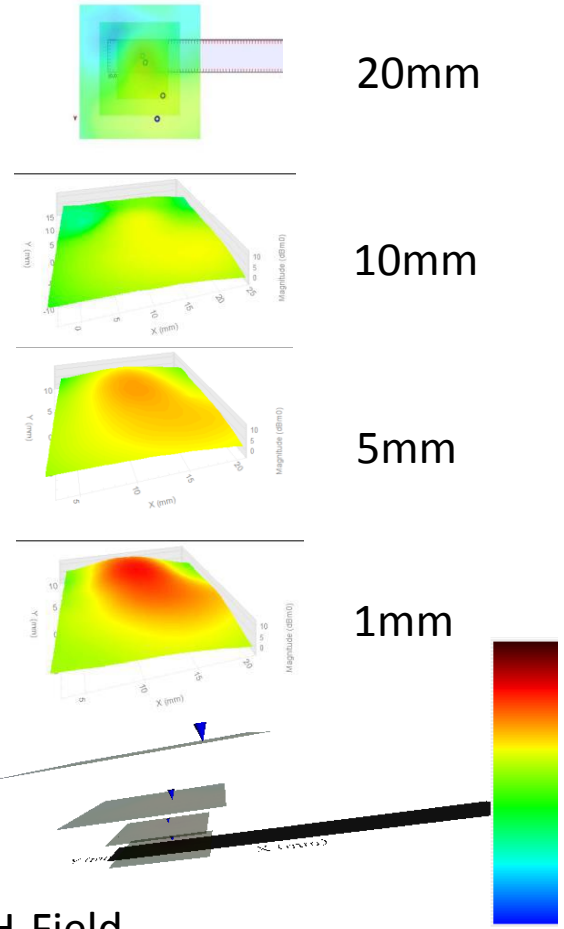
20mm

10mm

5mm

1mm





20mm

10mm

5mm

1mm

E-Field

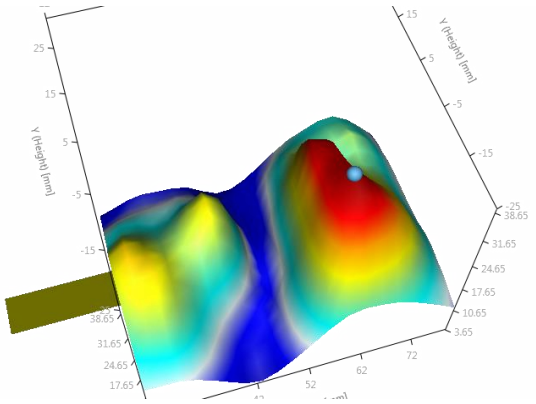
H-Field

APREL

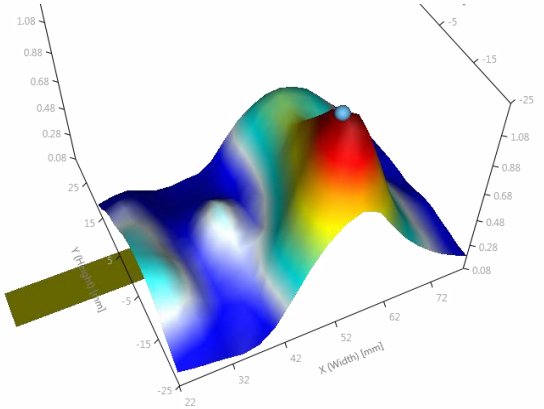
Beam Forming

- Close near-field behaviour for different phase shifts between elements of antenna
- Direction of the beam propagation for different phase shift parameters between antenna elements

Synchronized 2 active antenna elements @28GHz

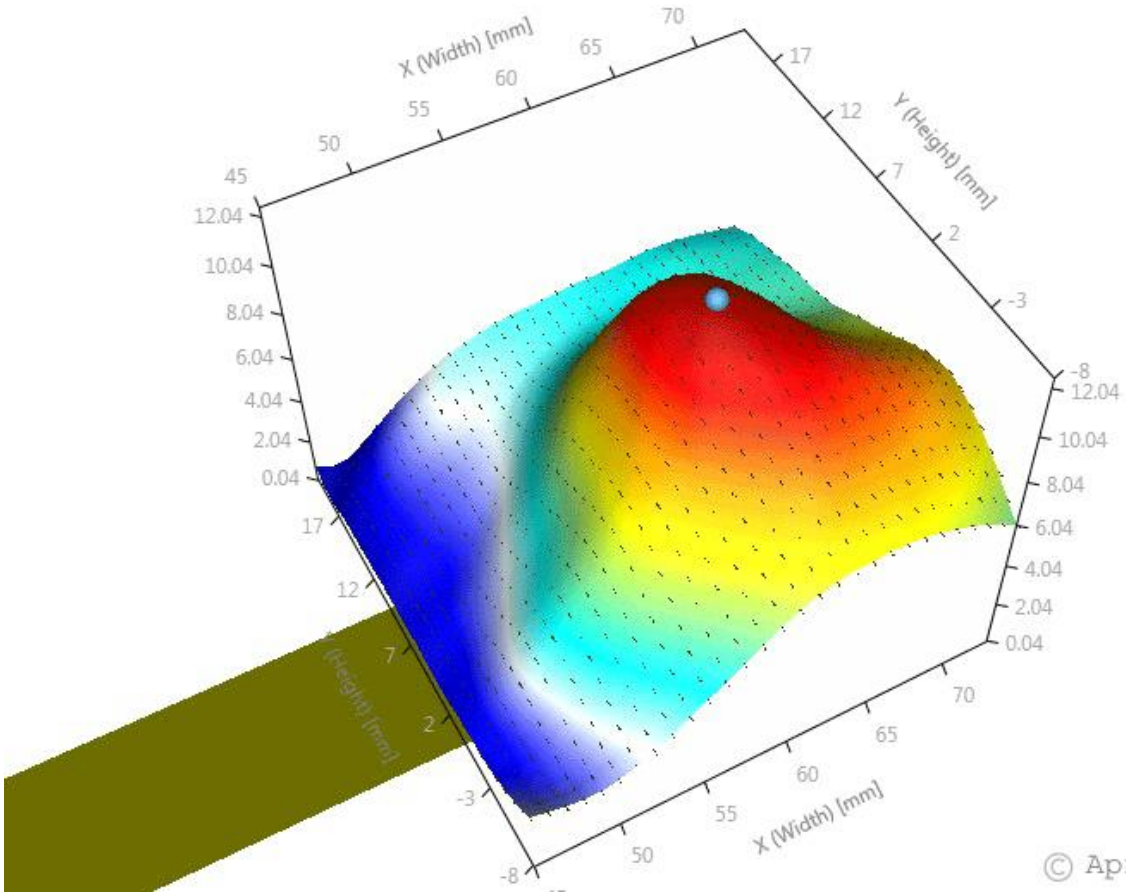


90 degree phase between 2 active antenna elements @28GHz



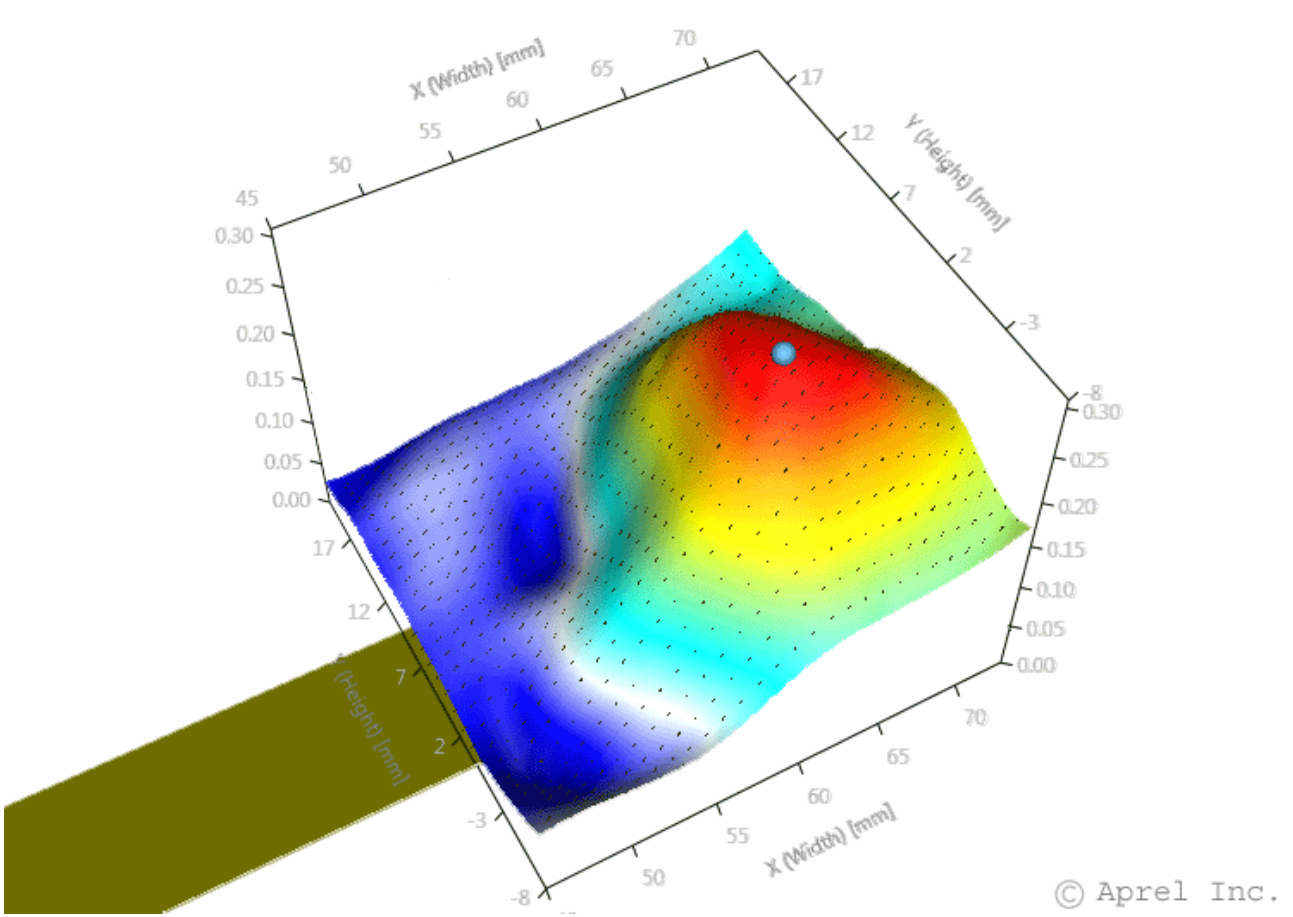
APREL

Beam Forming Zero Phase Shift



APREL

Beam Forming 90 Degree Phase Shift



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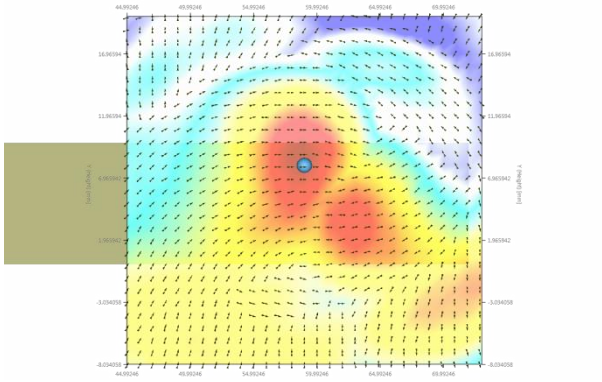
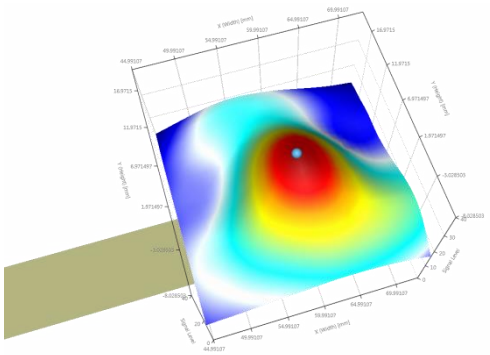
Field Vectors

- E and H field vectors measured in the reactive near-field zone presented in 2D and 3D formats
- E and H field maxima quantification
- Phase shift between E and H fields assessment
- Power density evaluation using the Poynting vector theorem
- Emitted power estimation



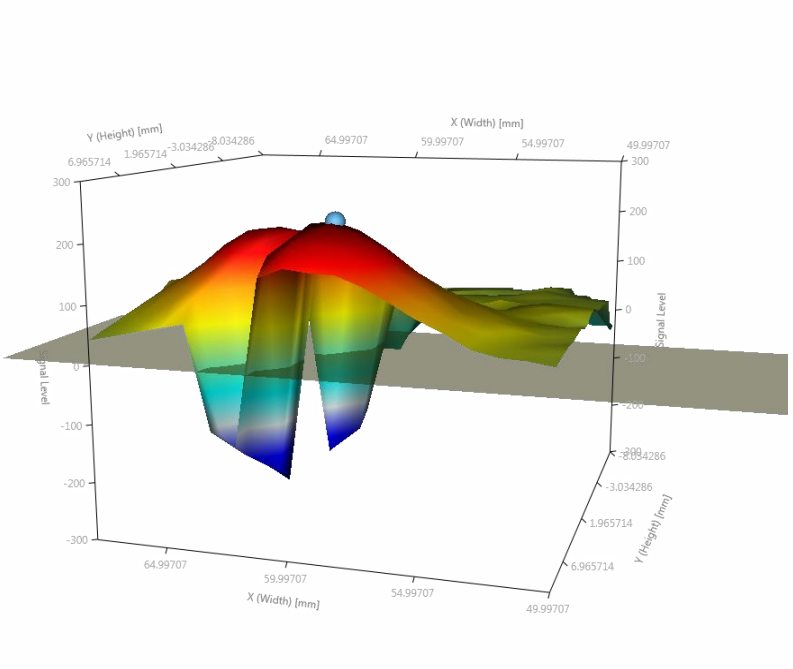
H Field for array antenna @ 28 GHz



E Field for array antenna @ 28 GHz

5G MPE

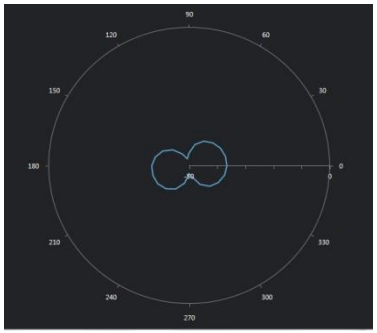
- Power density (W/m2)
  - Directional and Isotropic
  - Averaged over areas of 1cm^2, 4cm^2, and 20cm^2
- Emitted power
- Reverse energy
- Standing wave ratio



Polar Charts for Radial Field Distribution Analysis

- Field radial patterns for every measured point of a test grid
- Comparison of E and H field components
- Main lobe spatial evolution in respect to a distance from a signal source
- Gain data Peak and Average

E Field

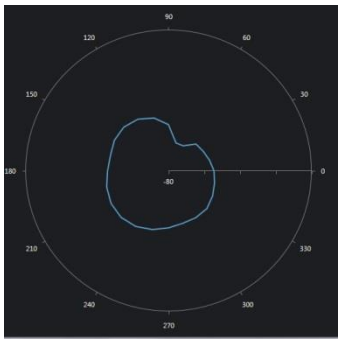


@5mm

@20mm

H Field

@5mm

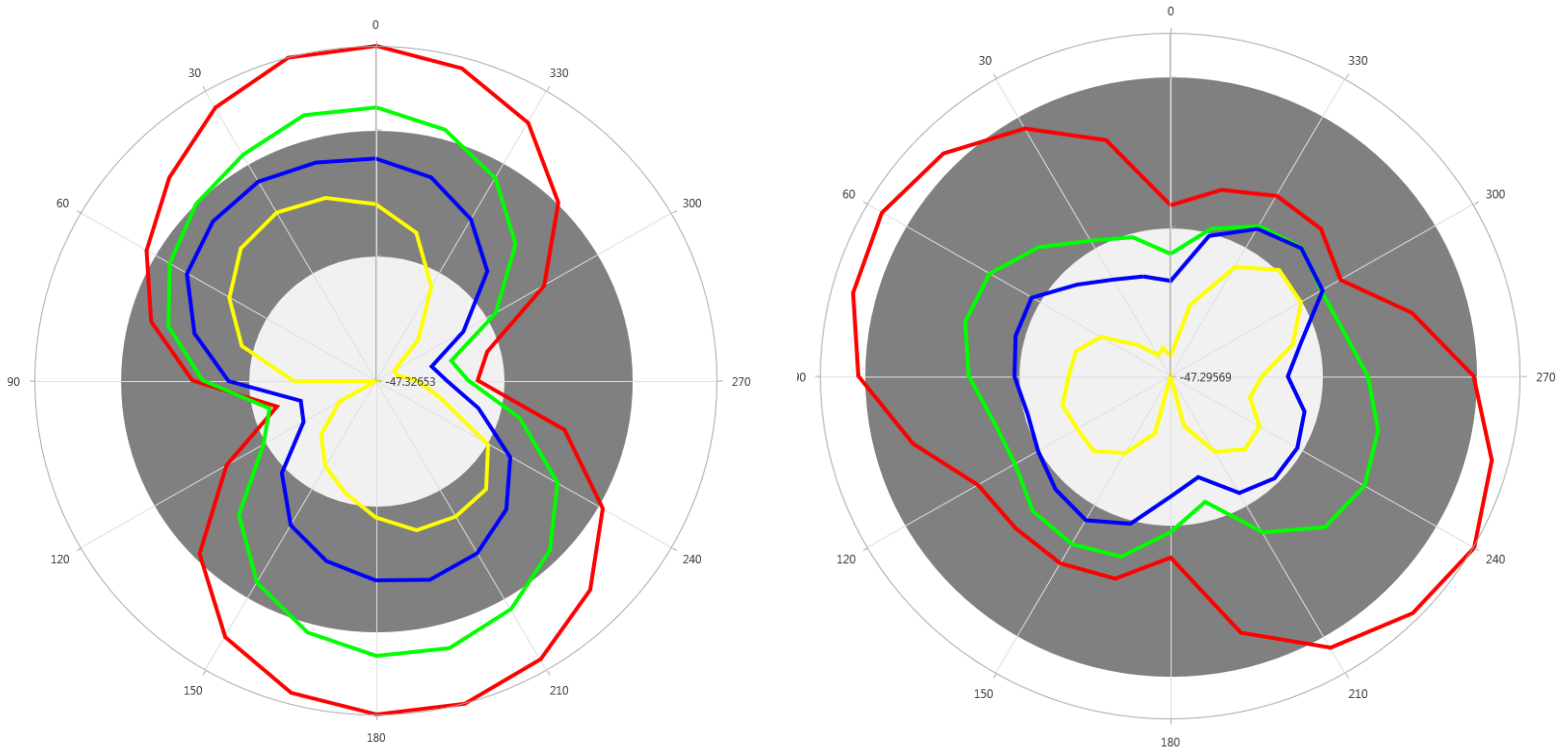


@20mm

APREL

Signal Gain/Directivity Diagram

- Represents maximum measured amplitude for the energy emitted in different directions

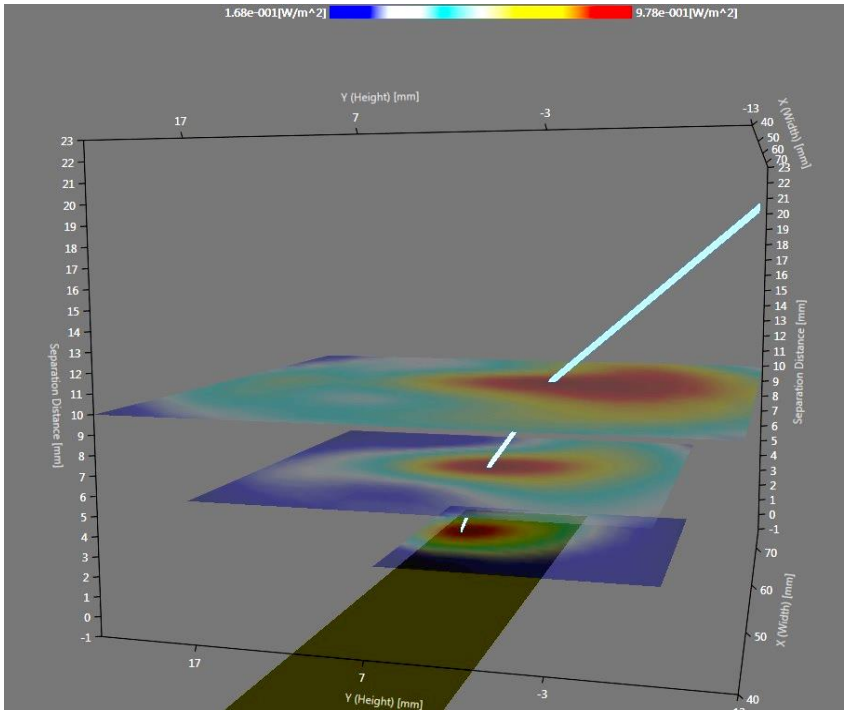


E field (left) and H field gradual evolution for λ/4, λ/2, λ, and 2λ progression

APREL

Signal Propagation

- Multi-layer test data presented in the 3D plot
- Calculated Peak Point drift angle indicates orientation of wave propagation in regards to the device surface

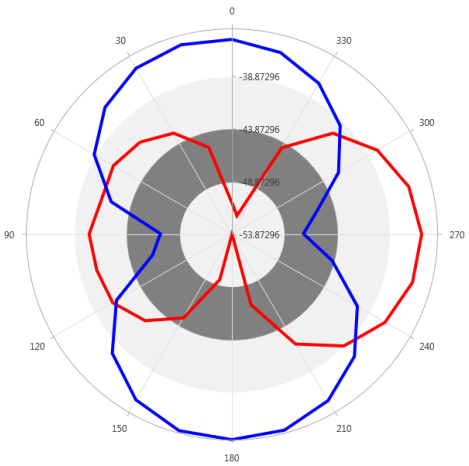


Theoretical Approach

- Assessment of the E and H field vector distribution
  - Measurement of E field radial patterns at each point of the scan grid
  - Measurement of H field radial patterns for the same scan grid
  - Quantification of the maximum amplitude vector and its orientation
- Computation of the Poynting vector as cross-product of maximum amplitude E_{max} and H_{max} vectors for each point of the grid

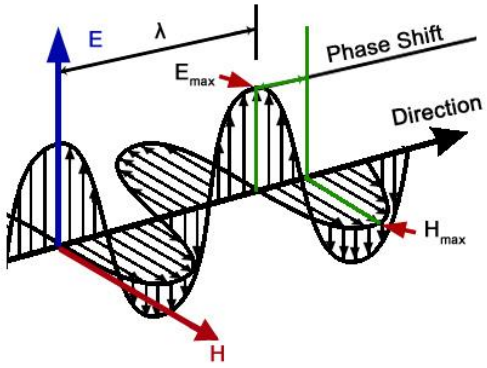
  - $\vec{S} = E_{max} H_{max} \sin\theta \, \hat{n}$, where

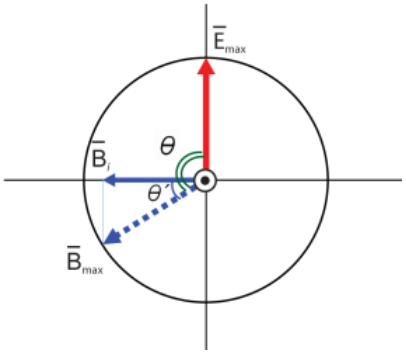
  - $\vec{S}$ - Poynting vector
  - θ - an angle between E_{max} and H_{max}
  - $\hat{n}$ - the unit vector normal to both electric and magnetic vectors

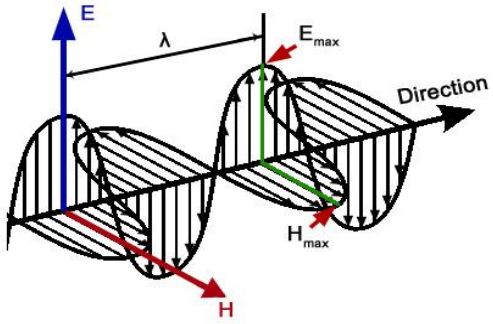


Theoretical Approach

- In close proximity to a resonating elements of antenna the E and H waves are not in phase
- In the far field zone the electric and magnetic oscillations are synchronized and the signal is propagating
- The single point diagram represents the phase shift concept







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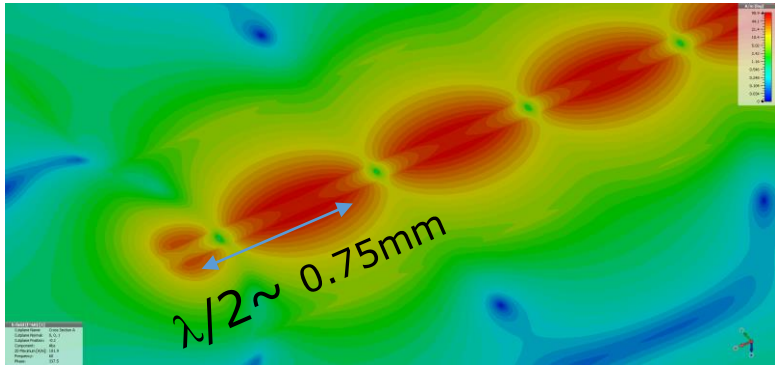
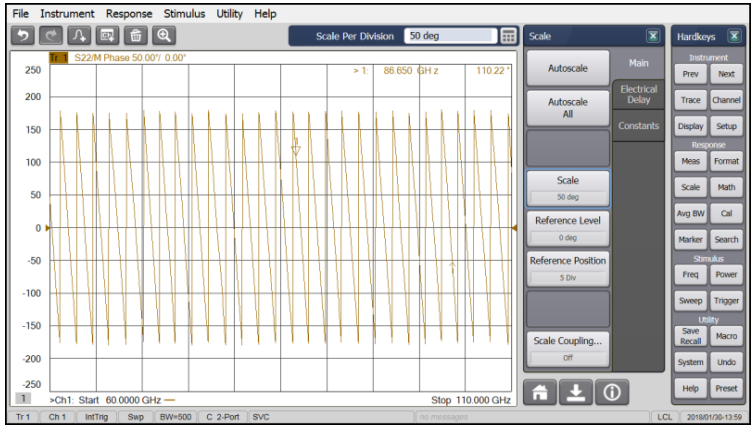
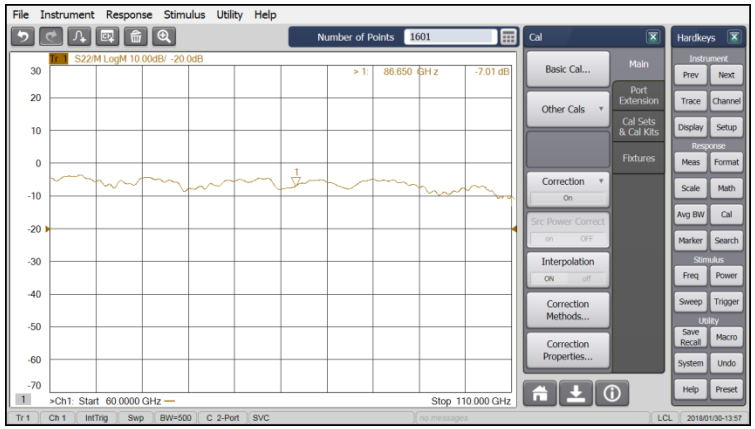
Electric and Magnetic Field Probes

- Fully characterized and assessed from 6 GHz up to 110 GHz for
  - sensitivity in air
  - S parameters
  - Directivity/gain
  - Near-field coupling loss

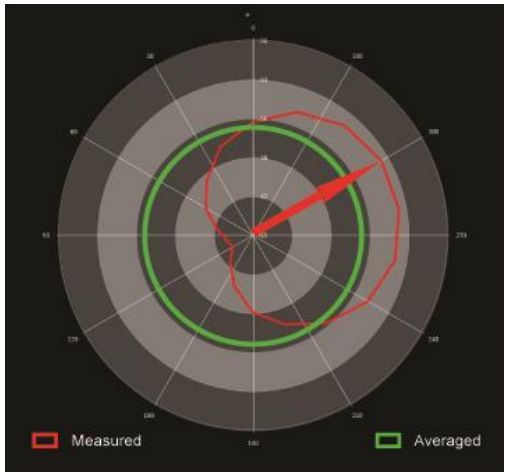
Probe characterization is based on numerical simulations (HFSS and CST) and experimental analysis.

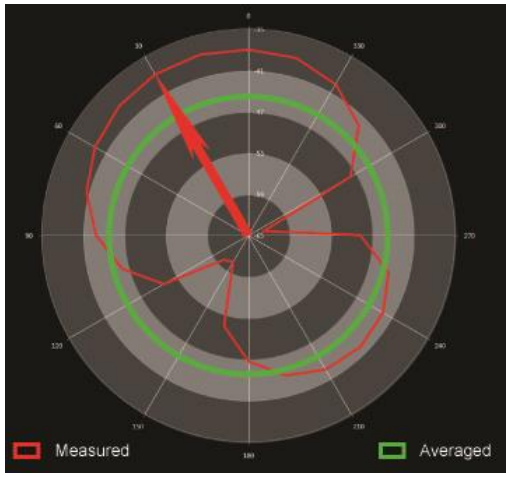






Directional and Isotropic Field Patterns





Field distribution as a function of radial orientation is analysed for the measured field maxima (red vector) and averaged values (green circle). Gain can be presented in dBi for Circular or Rectangular average

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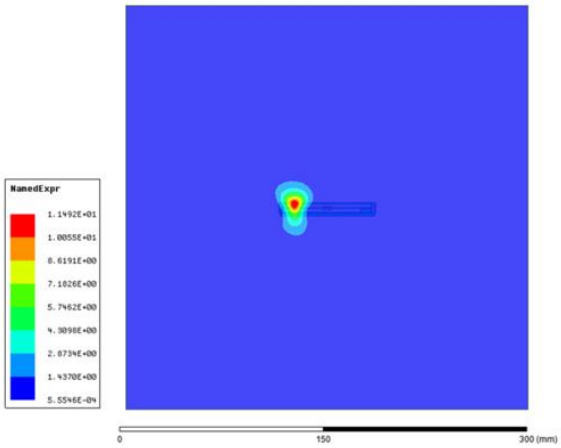
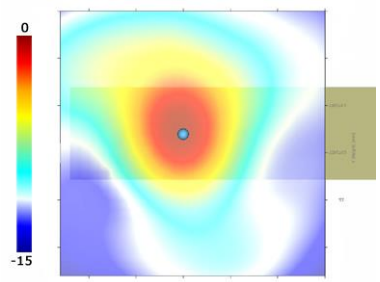
Power Density (PD)

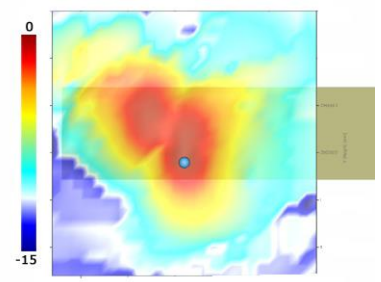
Validation of the system is conducted using experimental and simulation data for the Power Density.

HFSS simulated (left) Power Density distribution is in good correlation with the Isotropic PD measured (centre)

Additional analysis of Directional PD distribution is shows two peaks

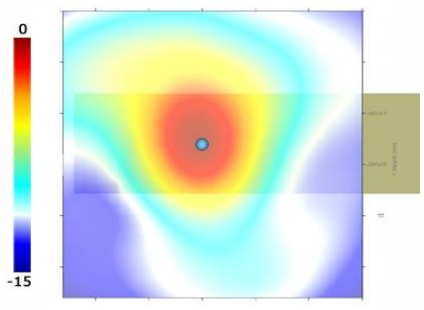




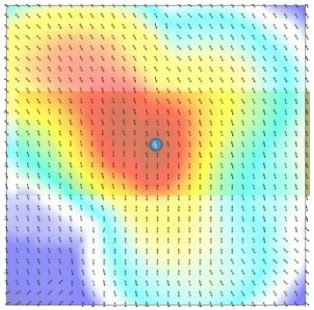


Data Analysis

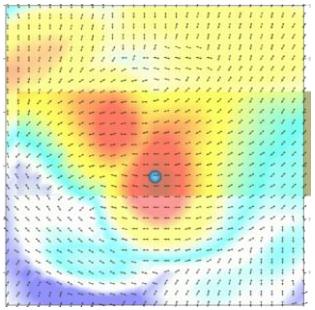
- Isotropic PD distribution is in correlation with the E field plot



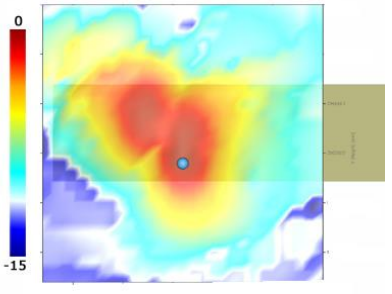
IsoPD



E field



H field



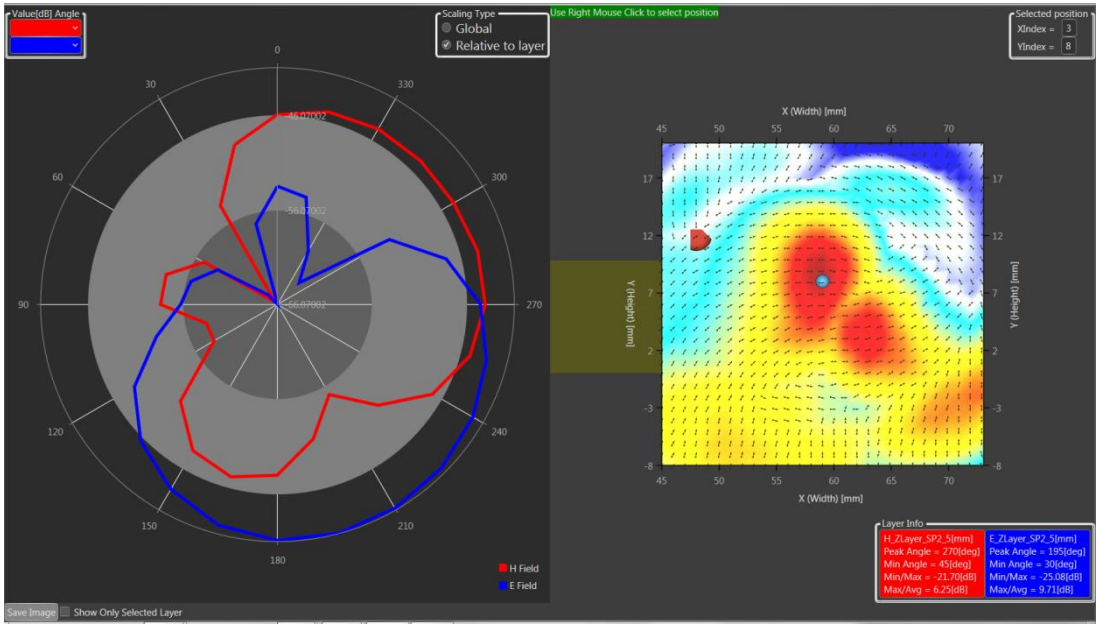
DirPD

- Directional PD distribution is corresponding to the H field

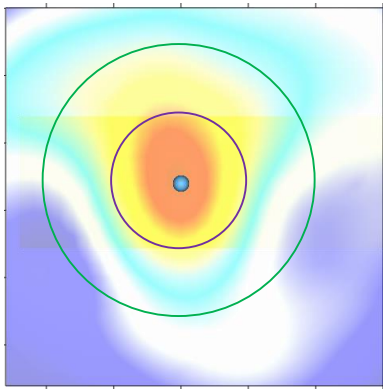
E and H Field Patterns (distribution)

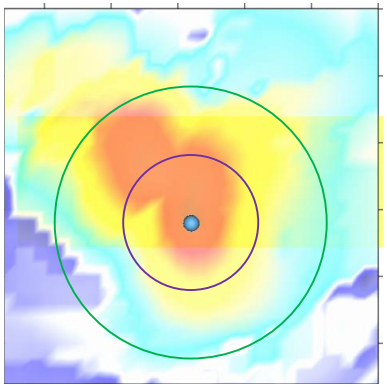
In the polar plot the field patterns, red for H field and blue for E field, are shown for maximum identified location based on the planer 2D plot.

Neither the H nor E field vectors are symmetrical in the near field as shown in the 2D planer plot.

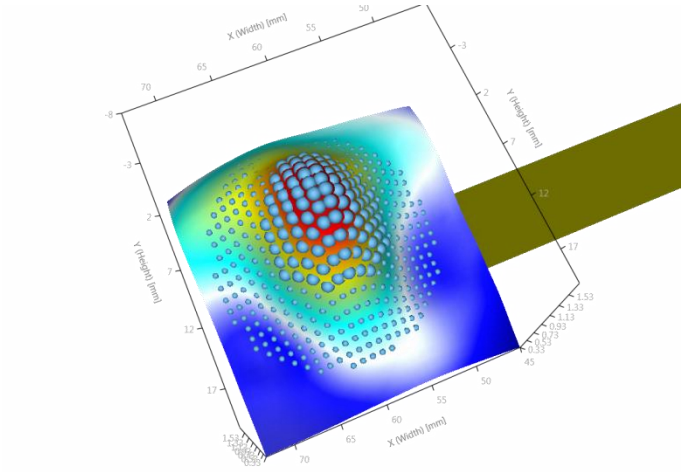


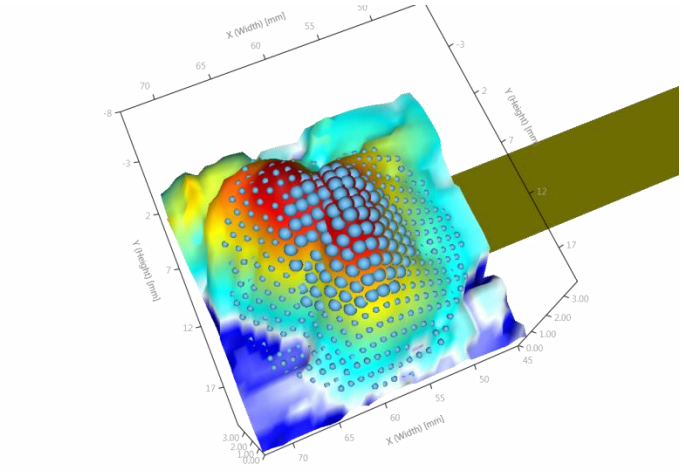
1 cm^2 and 4 cm^2 Averaging Areas





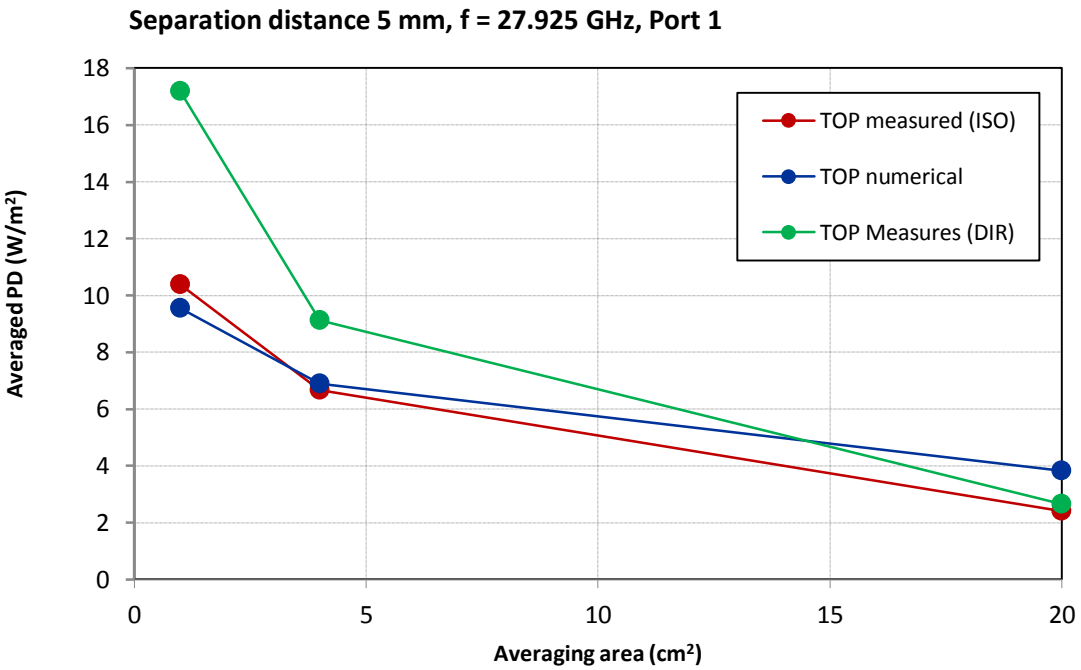
For the 28GHz signal the ratio between maximum and minimum values of the area of 1 cm^2 is around 3dB and for 4 cm^2 area – around 6dB.



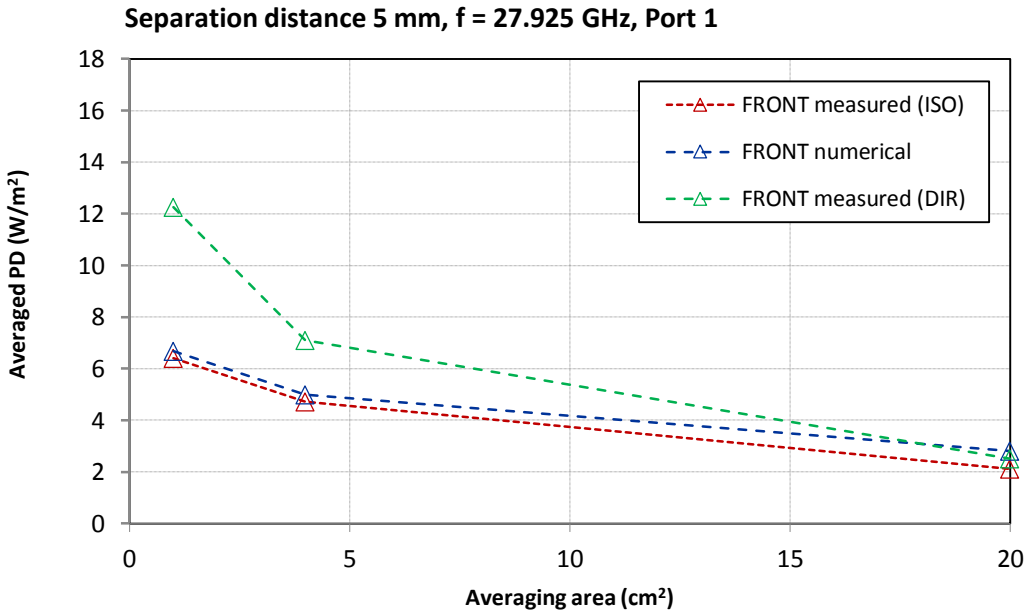


APREL

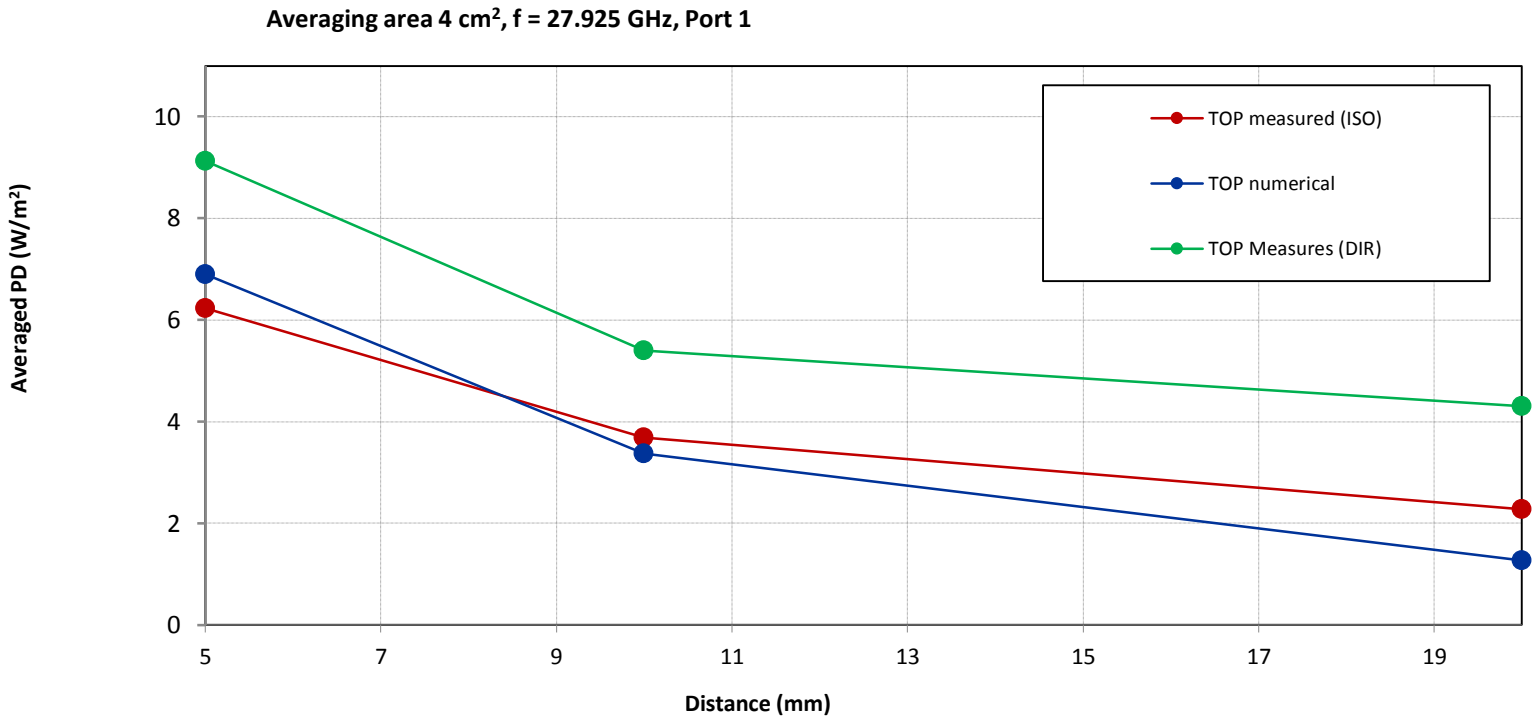
IEC Report Results TOP



IEC Report Results TOP



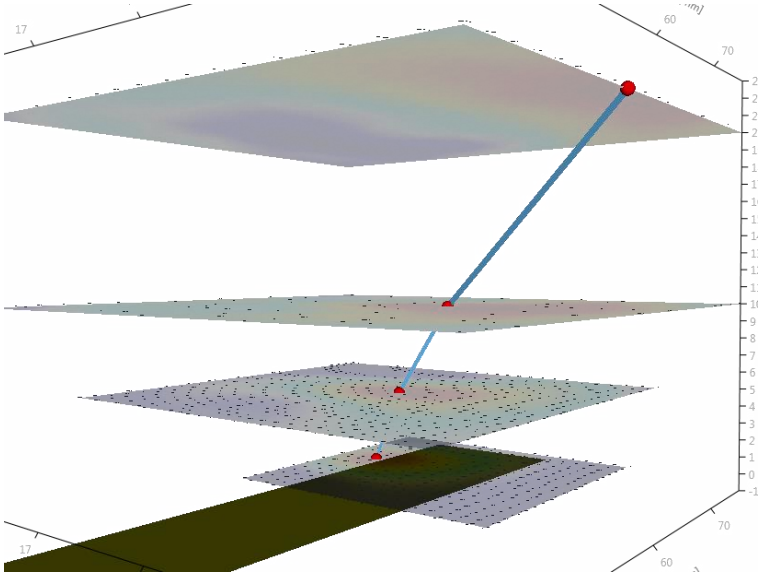
IEC Test Report Distance Results



Averaged power density as a function of distance from source

APREL

Signal Propagation Beamforming

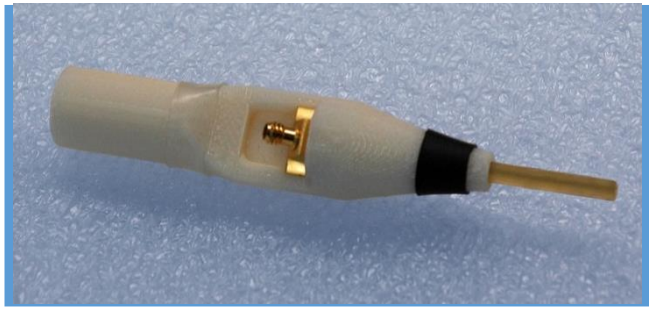


- For the multilayer scan a line intercepting peaks for each layer indicates the direction of beam propagation
- The angle of departure from normal to an evaluation plane represents the orientation of averaged Poynting vector

Considerations for IEC Standard

- 5G E and H probes for robust assessment of the radial pattern of E and H fields
- Consideration for the angle between electric and magnetic vectors
- Multi-layer test setup for the beam direction
- Two methodologies of Power Density evaluation:
  - Directional
  - Isotropic

Broadband Magnetic (H) Probe



High frequency H-Field broadband antenna probe for V/W band analysis with low insertion loss and high dynamic range. Single element antenna mounted onto an advanced substrate using custom 1mm connector. Designed for use with the EM-ISight-mmWave or EM-ISight-AMS solutions phase balanced for use with high frequency Network/Spectrum Analyzers.

Frequency Range	50GHz to 110GHz
Near-Field Sensitivity	< -35dBm
Linearity	+/- 0.1dBm
Plane Wave Field Sensitivity	0.01 W/cm^2
Cross Detection	0.01mm
Key Dimensions	Detector Offset = 0.1mm Sensor Thickness = 0.175mm Sensor Length = 40mm DUT Offset From Sensor = 0.6mm
Connector Type	Custom 1mm Type
Applications	IEC TC106 AHG10 H-Field analysis for 5G wireless transceivers Antenna chip analysis and characterization Maximum Permissible Emissions (MPE) and Power Density (PD) for V and W bands Near/Far Field analysis for automotive
Calibration	Spherical - Gain, Directivity Near-Field - S11, S22 and Coupling Loss

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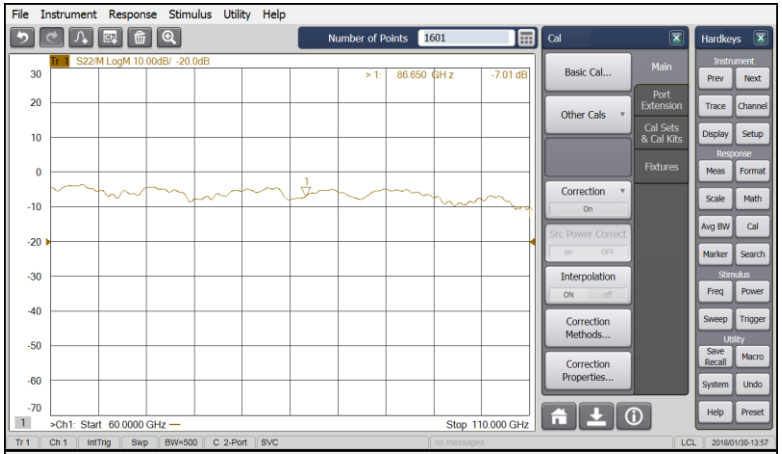
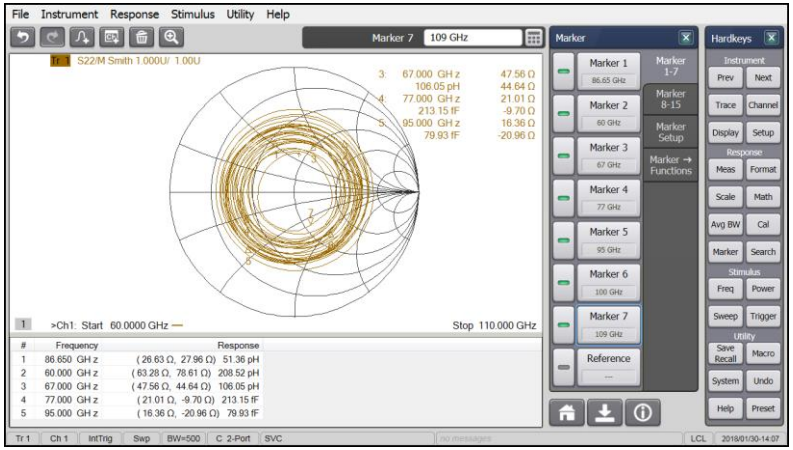
Broadband Magnetic (H) Probe





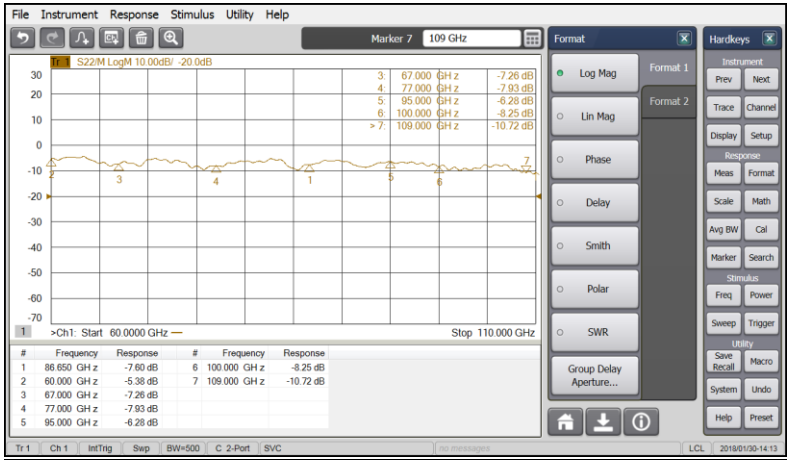
Broadband Electric (E) Probe

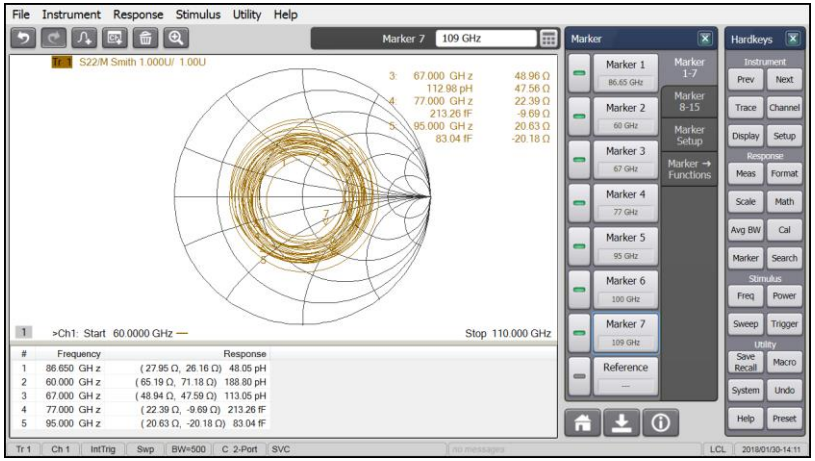
High frequency E-Field broadband antenna probe for V/W band analysis with low insertion loss and high dynamic range. Single element antenna mounted onto an advanced substrate using custom 1mm connector. Designed for use with the EM-ISight-mmWave or EM-ISight-AMS solutions phase balanced for use with high frequency Network/Spectrum Analyzers.

Frequency Range	50GHz to 110GHz
Near-Field Sensitivity	< -35dBm
Linearity	+/- 0.1dBm
Plane Wave Field Sensitivity	0.01 W/cm^2
Cross Detection	0.01mm
Key Dimensions	Detector Offset = 0.1mm Sensor Thickness = 0.175mm Sensor Length = 40mm DUT Offset From Sensor = 0.2mm
Connector Type	Custom 1mm Type
Applications	IEC TC106 AHG10 H-Field analysis for 5G wireless transceivers Antenna chip analysis and characterization Maximum Permissible Emissions (MPE) and Power Density (PD) for V and W bands Near/Far Field analysis for automotive
Calibration	Spherical - Gain, Directivity Near-Field - S11, S22 and Coupling Loss

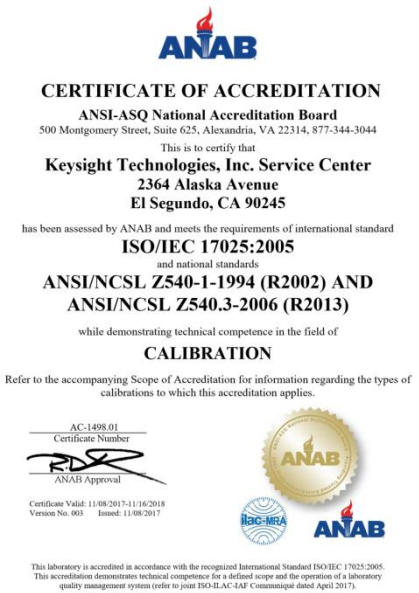
APREL

Broadband Electric (E) Probe





Calibration



ANAB

CERTIFICATE OF ACCREDITATION

ANSI-ASQ National Accreditation Board
500 Montgomery Street, Suite 625, Alexandria, VA 22314, 877-344-3044

This is to certify that

Keysight Technologies, Inc. Service Center
2364 Alaska Avenue
El Segundo, CA 90245

has been assessed by ANAB and meets the requirements of international standard

ISO/IEC 17025:2005

and national standards

ANSI/NCSL Z540-1-1994 (R2002) AND
ANSI/NCSL Z540.3-2006 (R2013)

while demonstrating technical competence in the field of

CALIBRATION

Refer to the accompanying Scope of Accreditation for information regarding the types of calibrations to which this accreditation applies.

AC-1498.01
Certificate Number

ANAB Approval

Certificate Valid: 11/08/2017-11/16/2018
Version No. 003 Issued: 11/08/2017

ANAB

ANAB

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communiqué dated April 2017).

For antenna factor calibrations APREL will be working with NIST and NPL, goal is for APREL to calibrate all antennas for ISO/IEC-17025 Accreditation up to 110GHz

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

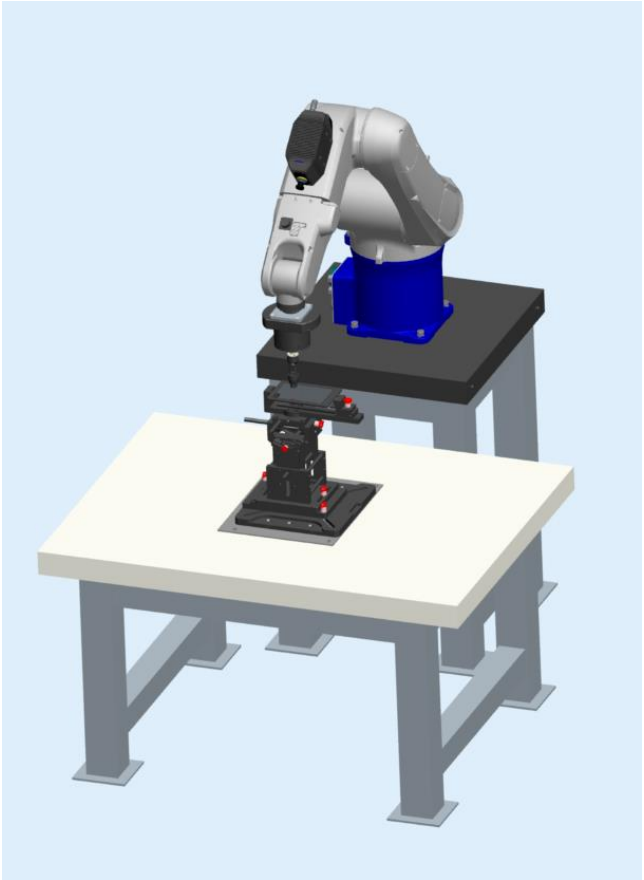
NPL
National Physical Laboratory

Currently APREL will work with Keysight for s11/s21 calibration of references up to 110GHz

APREL

Cost

- Extended Reach platform, workstation, device positioner and PC
- System fully calibrated includes cables for input/output 1mm type (1m length) low frequency option available
- Calibrated broadband Electric and Magnetic field probes
- Validation and self calibration modules **(excludes VNA calibration kit)**
- Vision and laser positioning system for 20um
- Software includes
  - Standard near-field measurement tools
  - MPE/Power density
  - Antenna measurement
  - Data reporting
  - Viewer license
- Support for Keysight PNA/PXA/UXA systems **(customer purchase Keysight hardware direct)**
- Software and hardware warranty for 12 months, includes full software upgrades
- **End User Price $216,000 (includes installation & training)**



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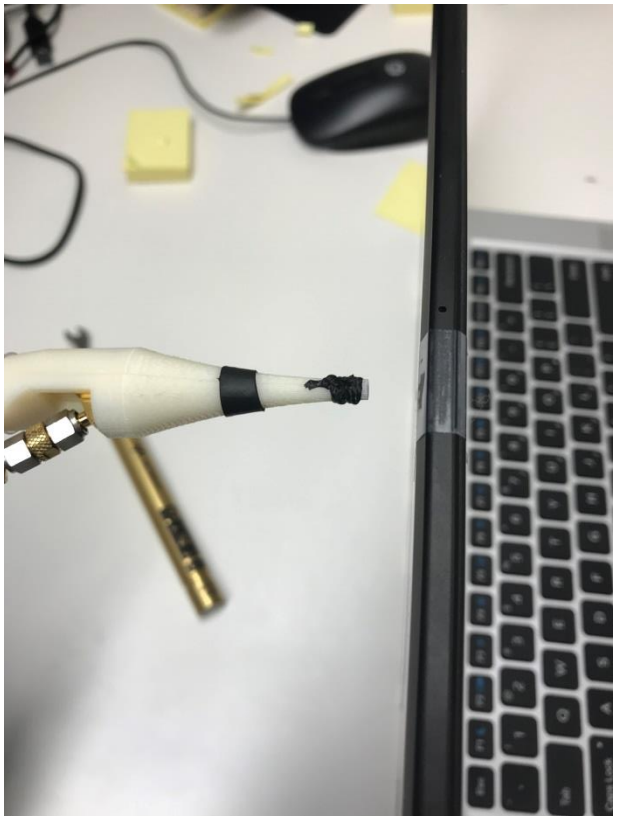
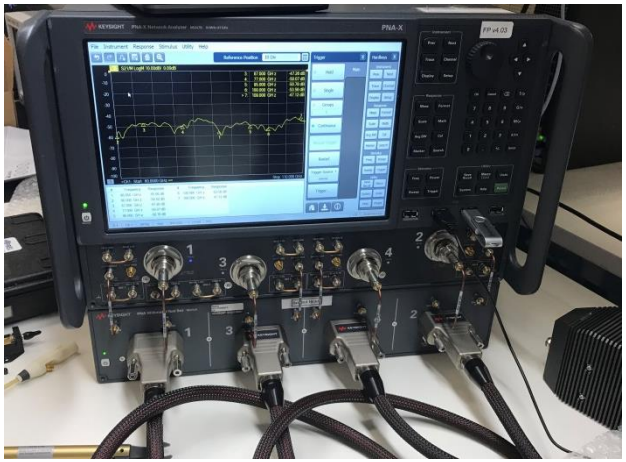
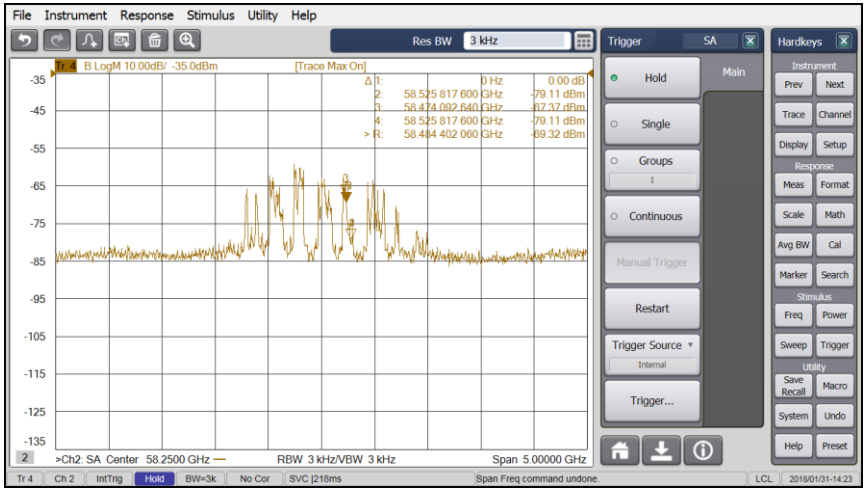
WiGig Setup







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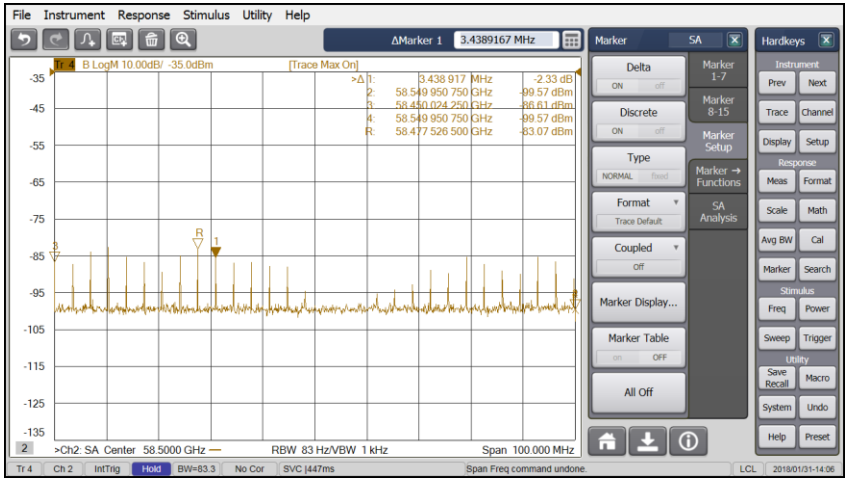
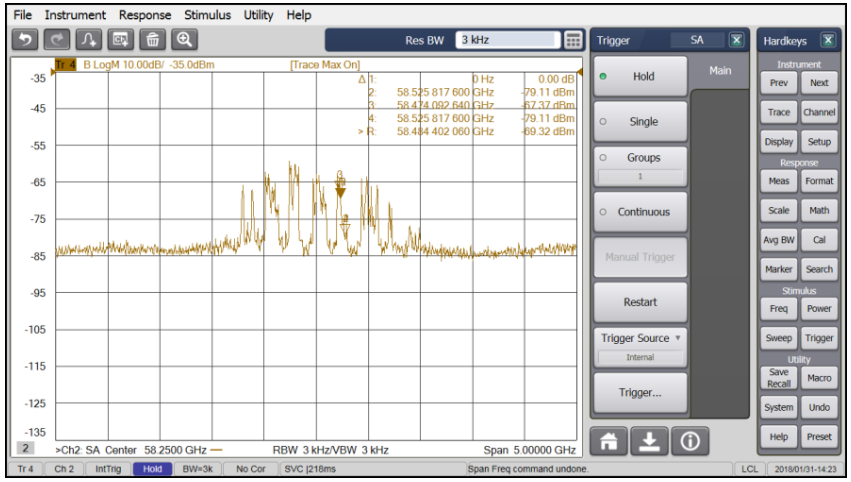
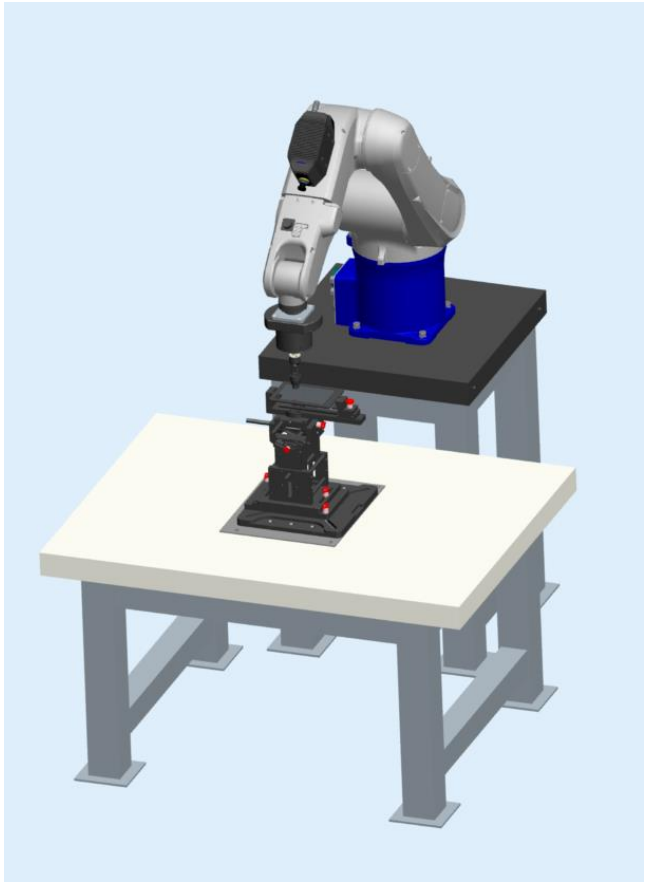
Complex Signals

- How to evaluate power density for the 5G modulated signals?

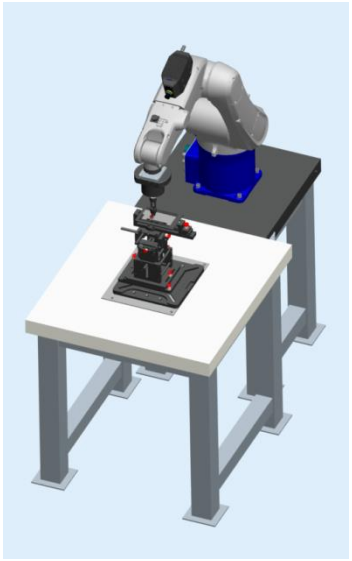


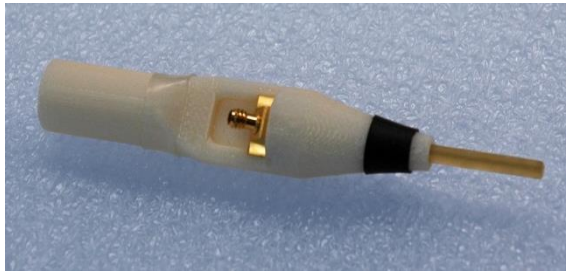


Keysight PNA-X B



Hardware Options





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