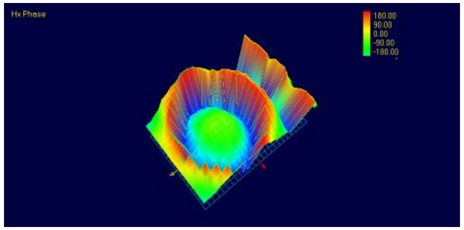
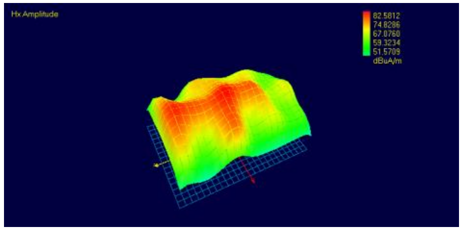
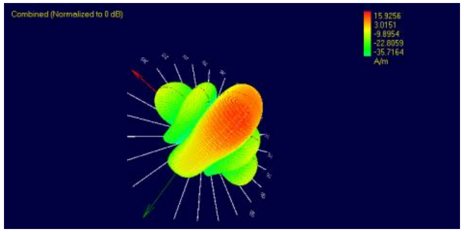
High-Speed, High-Frequency, High-Resolution Scanning Tools

Exploring Antenna Characterisation and Verification Challenges
with
Near Field Scanning Technology







Powerful way to look at your design!

Y.I.C. Technologies LTD

Leading Developer of Near Field, Real Time EMC/EMI and RF Testing and Verification Solutions

Fleet, UK
Main Office - Admin, Sales & Software Development

Calgary, Canada
Manufacturing & Hardware Development

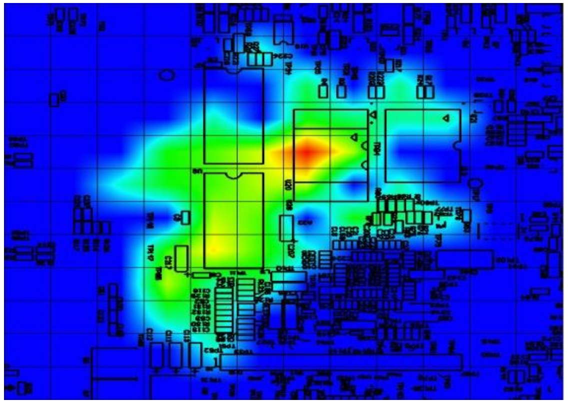
Local Sales & Support
X.Test Vienna, Austria

Chamber on your Desktop

1 Hour in a Chamber or **1 Second** with the Scanner !

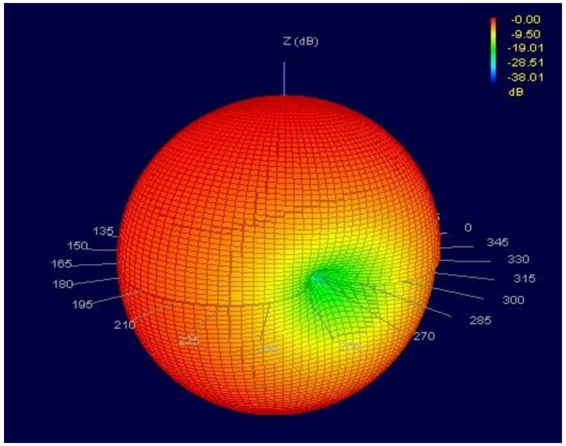
EM Scanning

EMC/EMI diagnostic tool to rapidly diagnose and solve EMC/EMS/EMI problems with real-time PCB emission analysis



RF Scanning

Enable to quickly characterize and evaluate Antenna performance and optimize designs in real-time, Near Field Scanning techniques



YIC TECHNOLOGIES
Results in Realtime

Near Field Antenna Testing
The Fundamentals

YIC TECHNOLOGIES
Results in Realtime

Antenna Testing
Fundamentals

What is an Antenna

An antenna is a device designed to convert electric alternate current into electromagnetic waves or vice versa and used to transmit and receive electromagnetic waves, including radio waves, microwaves, etc.

Antenna parameters and performance metrics

Radiation Properties

- Pattern
- Directivity
- Gain
- Beamwidth
- Polarization

Impedance Properties

- Return Loss
- Bandwidth
- S11
- Efficiency
- VSWR

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Antenna Performance Parameters
Basic Terms

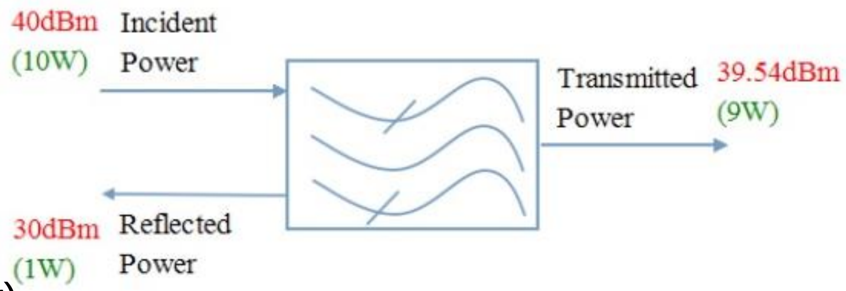
Impedance Properties

Indicate the matching characteristics of an antenna

S11, Return Loss & VSWR

S11 - The Reflection Coefficient

S11 provides information about the reflection coefficient, which includes both magnitude and phase :

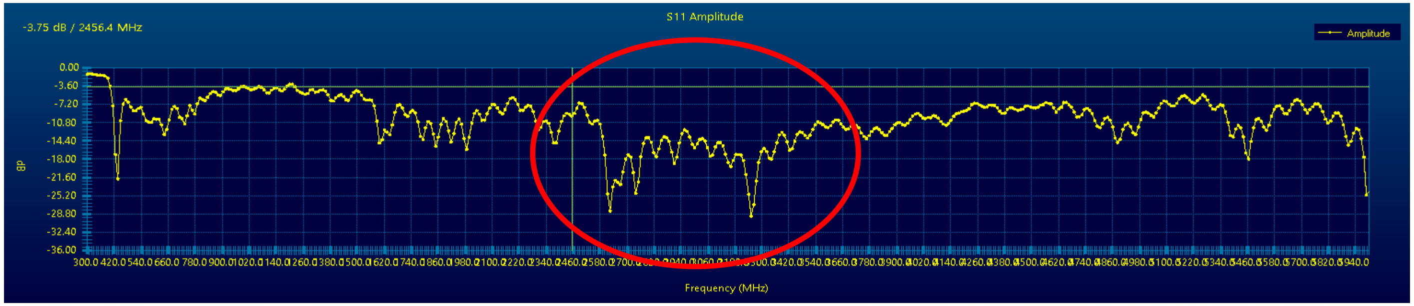


S11 = (Vr / Vi) * e^(-jθ)

where:

- S11 is the reflection coefficient (complex number)
- Vr is the amplitude of the reflected voltage wave
- Vi is the amplitude of the incident voltage wave
- θ is the phase shift between the waves

Recommended Range < -10db



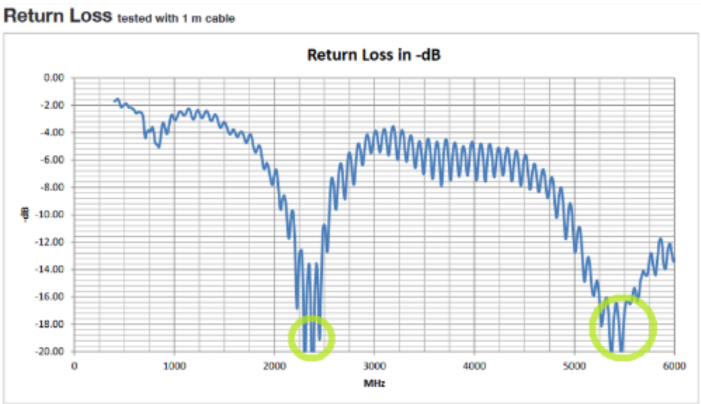
Antenna Performance Parameters
Basic Terms

Return Loss

Return Loss gives a quantitative measure of the power reflection from the antenna in dB, indicating the efficiency of power transfer and the level of impedance mismatch.

Return Loss (dB) = 10 * log10(|Pi/Pr|)

Higher Return Loss = Better Impedance Matching



Return Loss related to S11 by : **Return Loss (dB) = -20 * log10(|S11|)**

VSWR

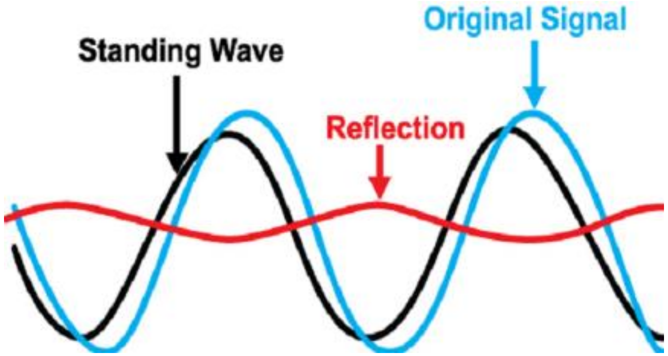
VSWR (Voltage Standing Wave Ratio) is a dimensionless parameter closely related to Return Loss and provides similar information but is expressed in a different format. VSWR represents the ratio of the maximum voltage(or current) amplitude to the minimum voltage(or current) amplitude along a transmission line. It quantifies the magnitude of voltage or current standing waves resulting from impedance mismatches.

VSWR defined as :

VSWR = (Vfwd_max / Vrefl_max)

VSWR related to S11 by :

VSWR = (1 + |S11|) / (1 - |S11|)



Radiation Properties

Refer to the characteristics that describe how an antenna radiates electromagnetic energy into space.

Radiation Pattern, Directivity, Gain, Beamwidth, Polarization, Efficiency, Radiated Power

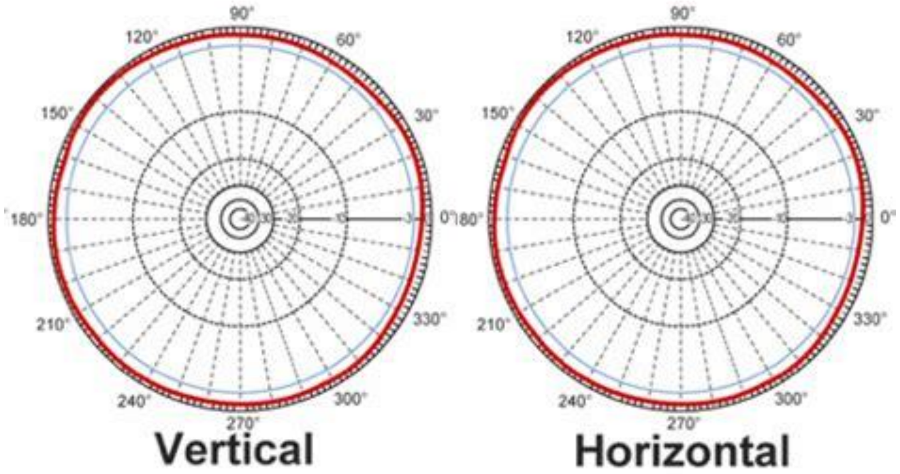
Antenna Performance Parameters

Basic Terms

Isotropic Antenna

An idealized theoretical antenna that radiates or receives electromagnetic energy equally in all directions with equal intensity.

It serves as a reference antenna for comparison purposes and simplifies calculations and analysis in antenna engineering.

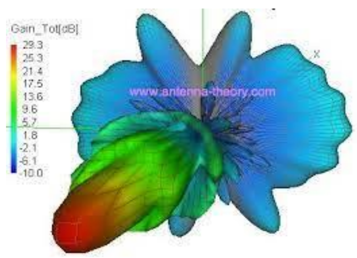


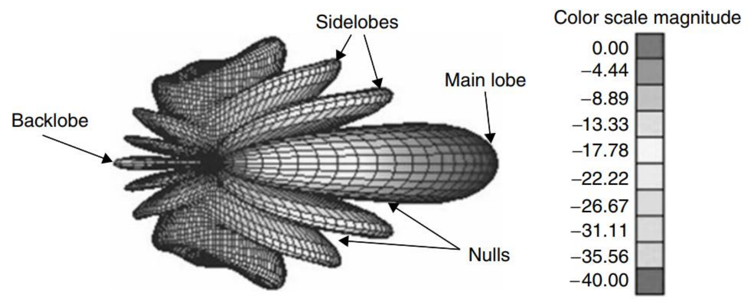
Antenna Performance Parameters

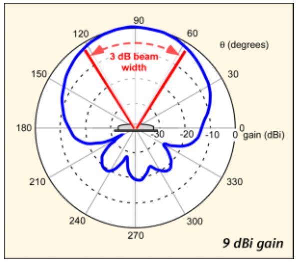
Basic Terms

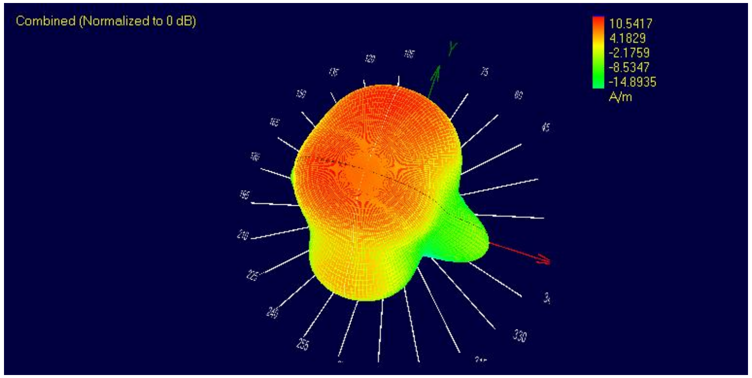
Radiation Pattern

Radiation Patterns is the graphical representations of the electromagnetic power distribution in free space.









RFScaner Radiation Pattern prediction

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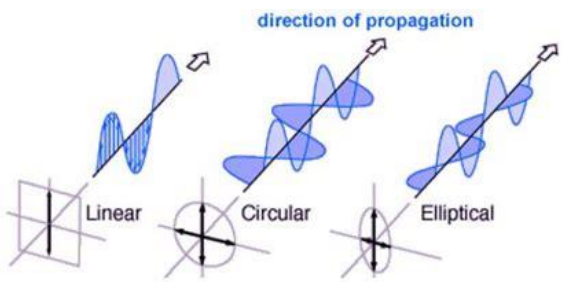
Antenna Performance Parameters

Basic Terms

Polarization

Antenna Polarization is defined as the orientation of the electric field vector of the radiated electromagnetic.



Helix Antennas

Linear Polarization is often used in: Television Broadcasting, Point-to-Point Communication & Wireless Communication

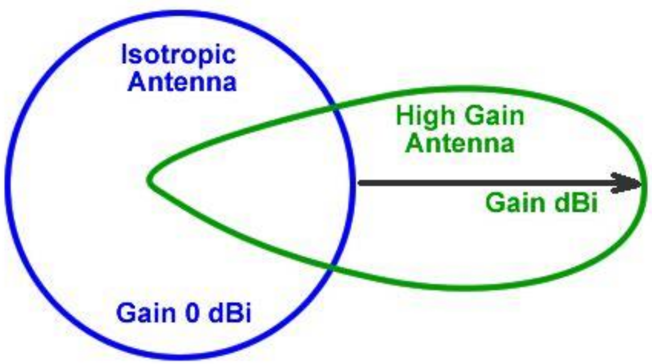
Circular Polarization is often used in: Satellite Communication, RFID Systems, Aerospace and Aviation, Remote Sensing & Wireless Virtual Reality (VR)

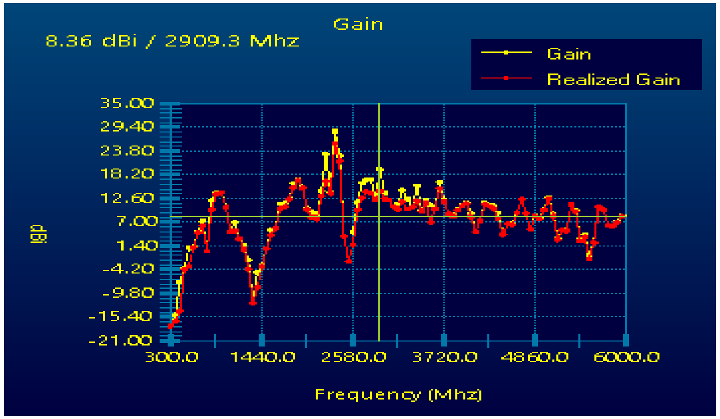
Antenna Performance Parameters

Basic Terms

Gain and Directivity

Gain : Calculated by comparing the power radiated by the antenna in a specific direction to that of an **isotropic radiator** or a reference antenna.





RFScaner Measured Gain

Directivity : Calculated by considering the power radiated by the antenna in a particular direction compared to the **average power radiated** over all directions.

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Antenna Performance Parameters
Basic Terms

Efficiency

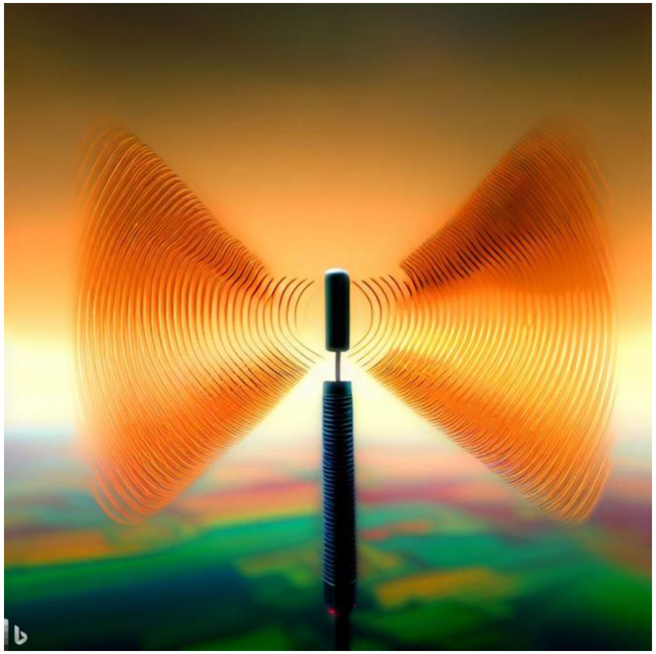
A measure of how effectively an antenna converts the supplied electrical power into radiated power

Efficiency = (Prad / Pi) * 100%

Radiated efficiency
Radiated efficiency specifically measures the portion of the input power that is successfully converted into radiated power.

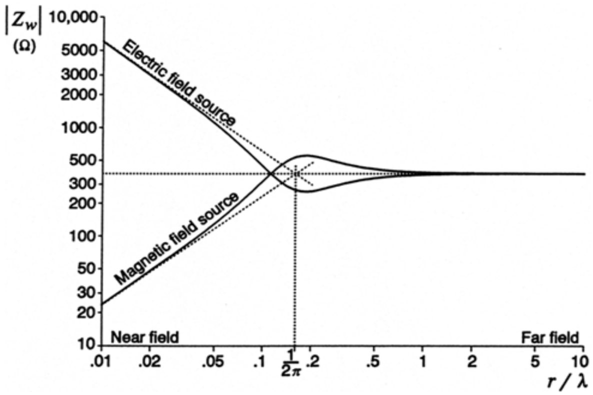
Near Field Antenna Testing

The Near Field



Fundamentals
Near-Field

The region in close proximity to the antenna where the electromagnetic fields are not fully developed into the far field.



Reactive Near Field

This region is closest to the antenna. The electric and magnetic fields behavior cannot be fully described by the simple radiation patterns associated with the far field region.

Radiating Near Field (Fresnel Zone):

This region is a transitional zone between the **reactive near field** and the **far field**.

The **Electric** NF Boundary distance can be calculated by : **MNFB = 0.62 * sqrt(D^3 / λ)**
The **Magnetic** NF Boundary distance can be calculated : **MNFB = 0.8 * sqrt(D^3 / λ)**

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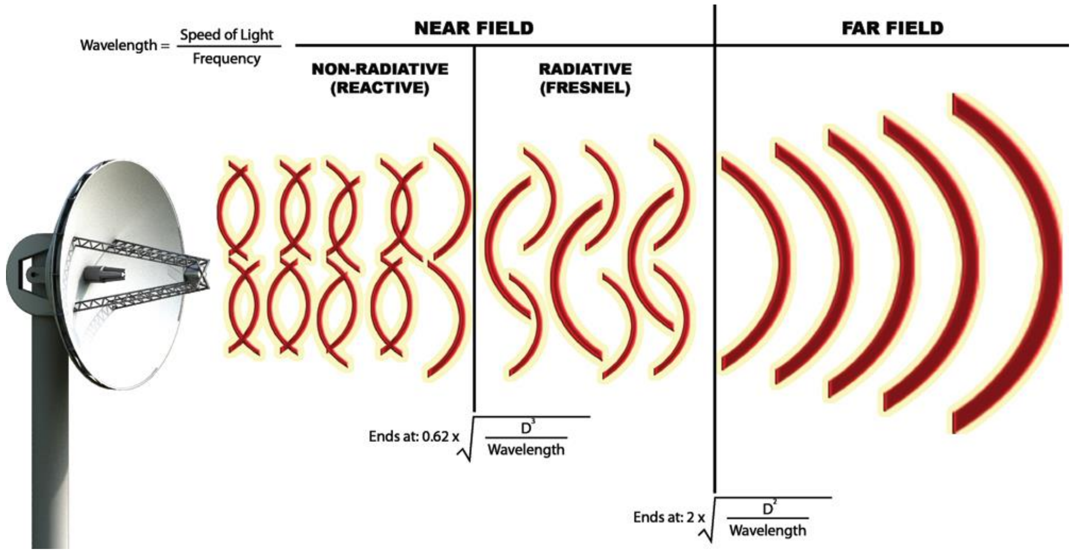
Fundamentals
Near-Field and Far-Field

Far-Field

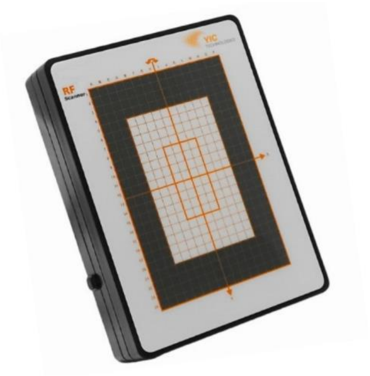
Typically considered to be beyond a distance of about few wavelengths (2λ) from the antenna.

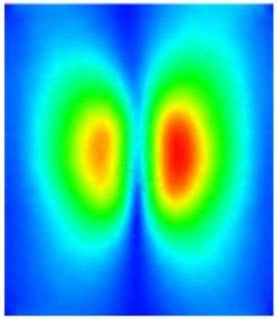
In this region, the electric and magnetic fields are fully coupled and form a well-defined electromagnetic wave that propagates away from the antenna.

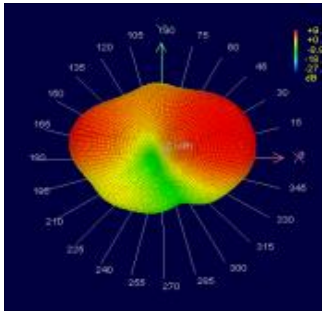


The RFScanner

Paradigm Shift in RF Testing

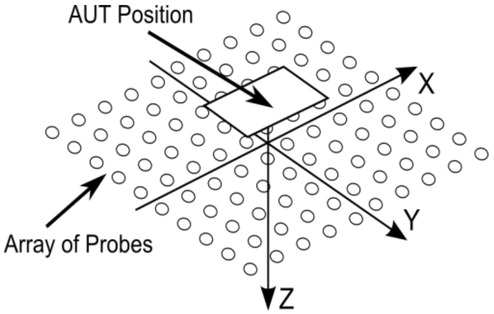






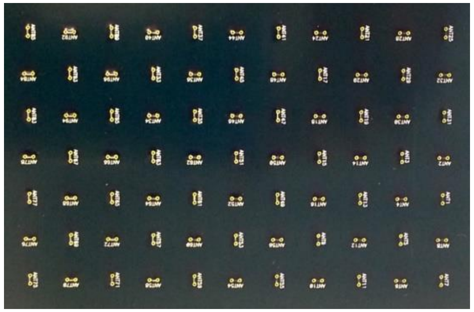
Fundamentals
Principles of near field scanning technology

The principles of near field scanning technology involve placing a scanning probe or an array of probes in the near-field region of the DUT.



Advantages and limitations of near field scanning technology:

- **Detailed characterization:** Detailed characterization and analysis of the near-field properties of the AUT.
- **Simplicity & Flexibility:** Near field scanning can be performed in various configurations, allowing for measurements on different types of antennas and devices. It can accommodate complex geometries and non-standard antennas.
- **Diagnostic capabilities:** Near field scanning helps identify design issues, such as surface currents, undesired radiation, or impedance mismatches.



Limitations of near field scanning technology:

- **Extrapolation to far field:** Transformation to the far-field is based on mathematical algorithms and assumptions.

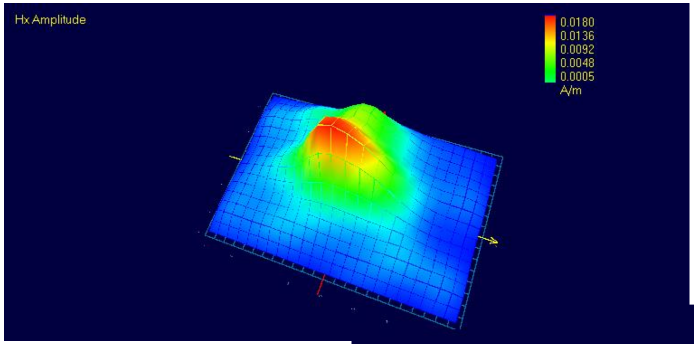
Near-Field Testing

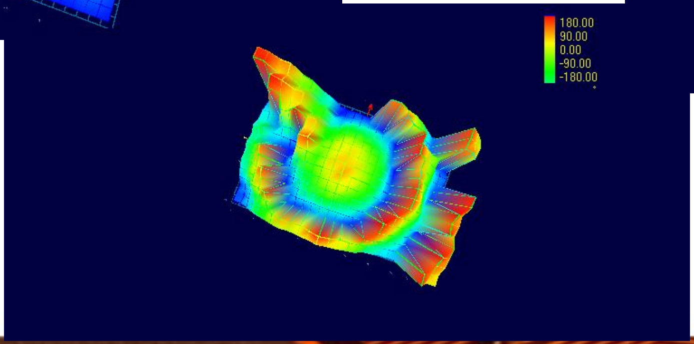
High-density Near Field antenna array

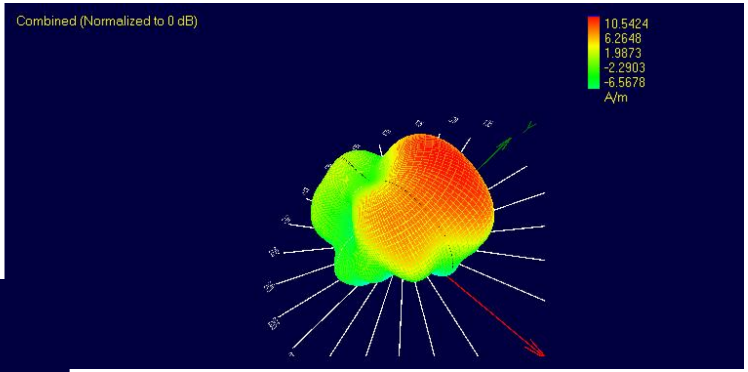
Near Field Testing benefits:

- Ability to see surface currents
- “Real-time” fast measurement
- Repeatable
- “Easy” and Simple to use

Far-Field is not everything







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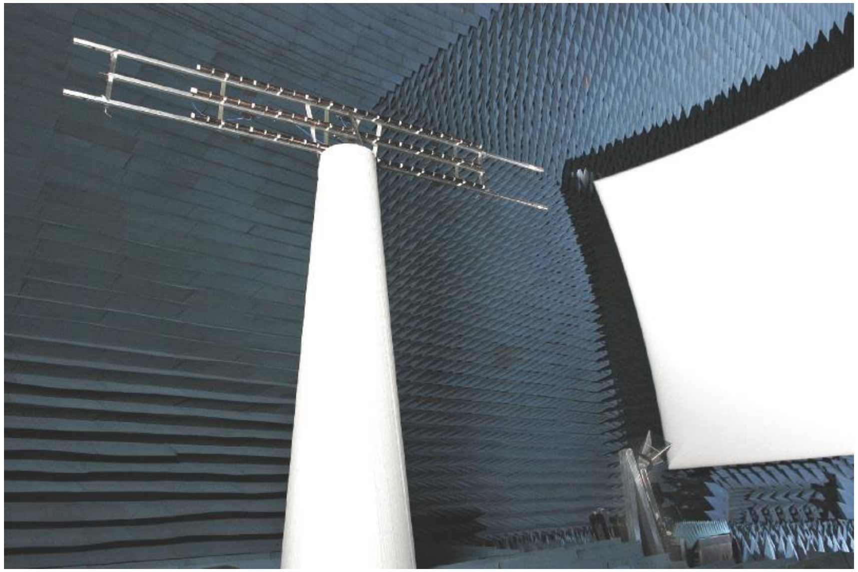
Existing Solutions
Far-Field Measurements

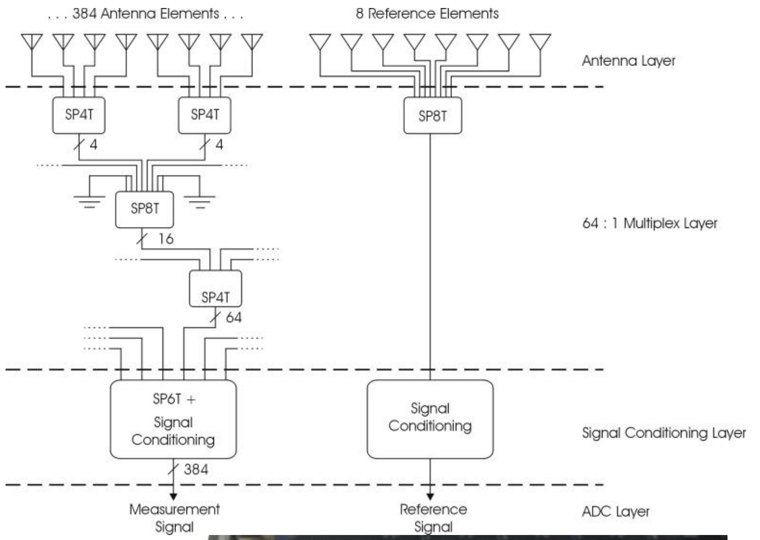
- **Far-field site far and demanding a large area**
- **Open-air-test-site (OATS) avoids reflections**
  - Almost impossible in an urban environment
- **Anechoic Chambers**

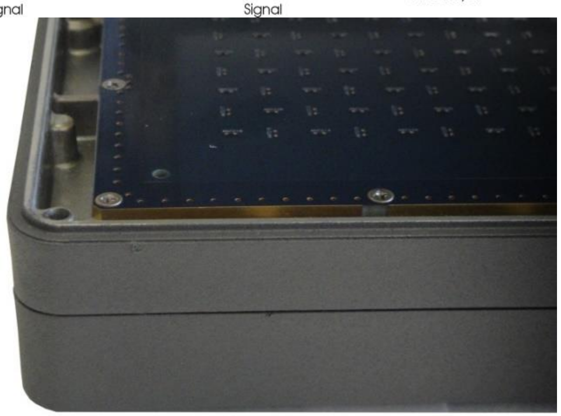


Near-Field Implementation

Easier Said than Done

- Array of probes
- Addressable array of probes makes near-field sampling very fast and repeatable
- Small probes not sensitive but very broadband, with good isolation and polarization specifications
- Reference channel - phase measurement is needed

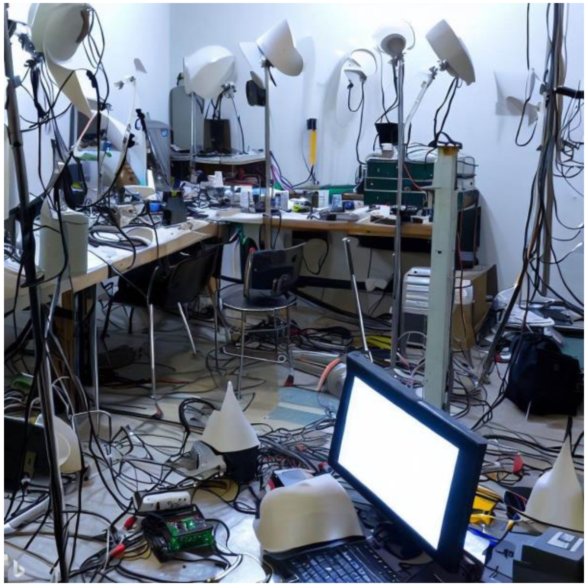




Even more challenges

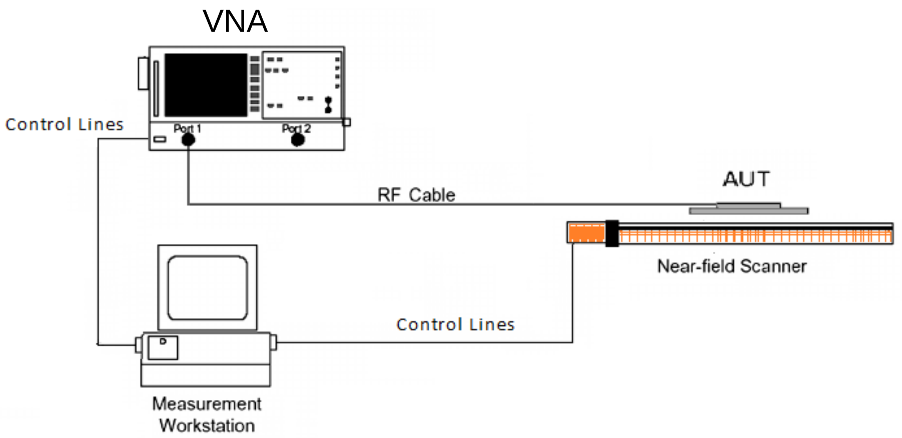
- Accurate positioning for repeatable results
- Probe-to-antenna distance – too far less accurate and lower resolution, too close results in measurement in antenna to probe coupling
- Environmental factors effect measurement accuracy

Near Field Antenna Testing
Setup & Lab Environment

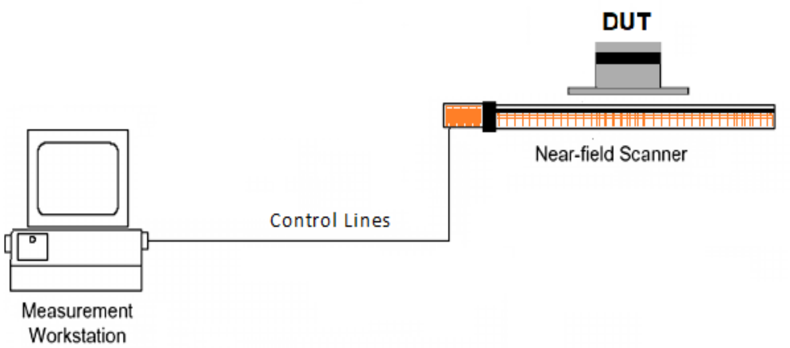


Setup

Principles of near field scanning technology



Set for Sweep Mode - Antenna

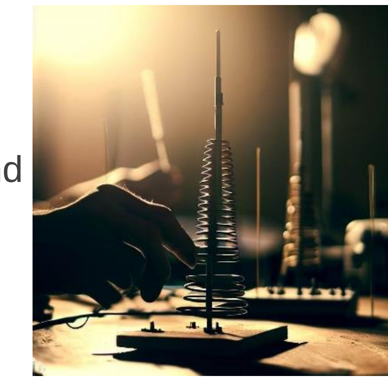


Set for Fixed Frequency Mode - Device

General Guidelines

The Base Platform

- Wooden desk is the best possible platform. Metal desks may affect the repeatability of the test results.
- Anti-static mats are conductive and may affect the test results.



Objects around AUT

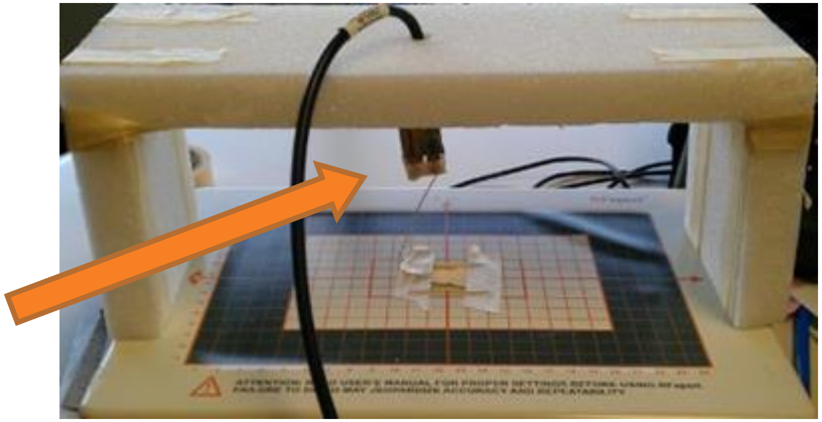
- Leave a minimum 60-100 cm distance between RFScanner and the objects around
- Use wood / styrofoam to prop up the antenna or wireless device on RFScanner.
- **Do not use metal.**
- Keep a distance from walls, there may be metal studs in walls.
- Desk frame can be made of metal. Keep distance from any metal frame.
- Cables & Connectors should not be placed on the scanning area. **Use ferrite beads.**

Objects above the AUT

- Make sure you don’t place RFScanner under metal shelves. Large metal reflectors above RFScanner may affect the repeatability.
- Light Fixtures - Try to avoid fluorescent lights are often hung in large metal boxes. Be cautious about placing RFScanner under these light fixtures.

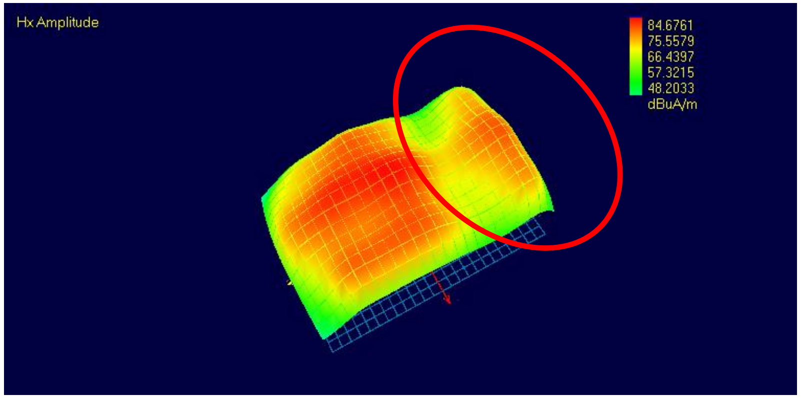
Cables & connectors!

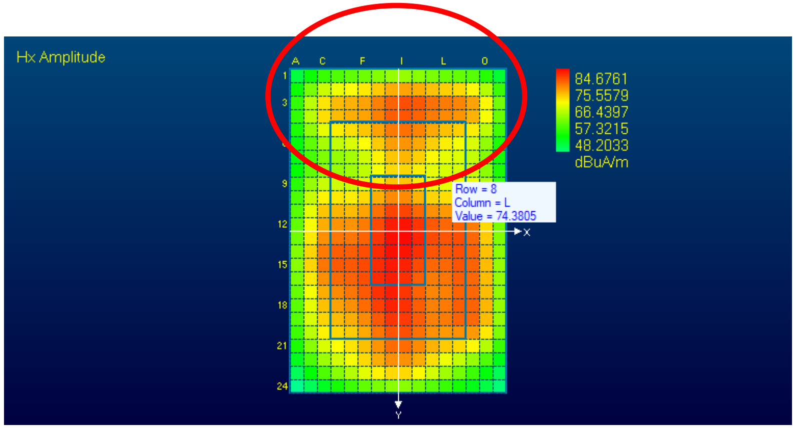
The easiest way to minimize the effects from cables currents is to have the cable normal to the surface of the scanner



Better Positioning

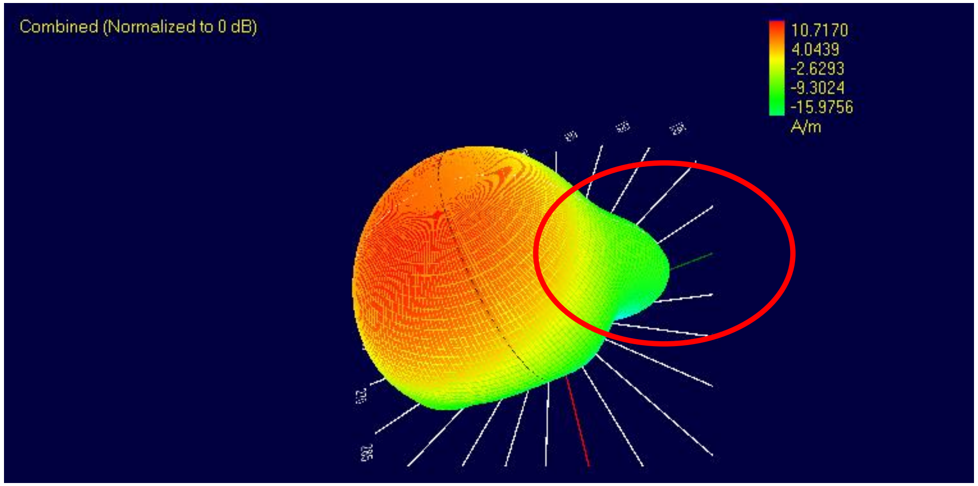
Effect of a bad Connector

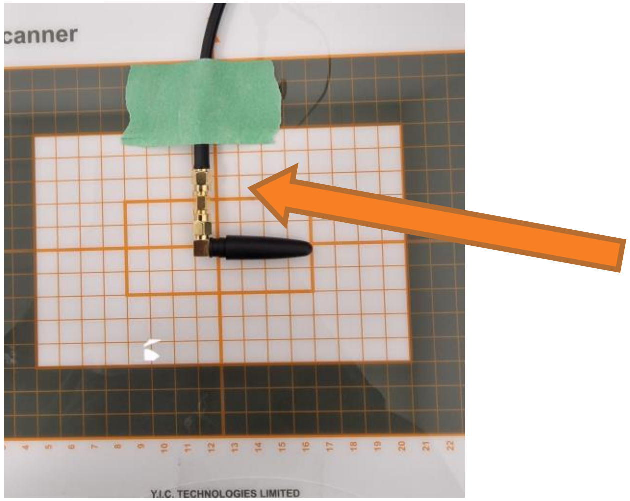


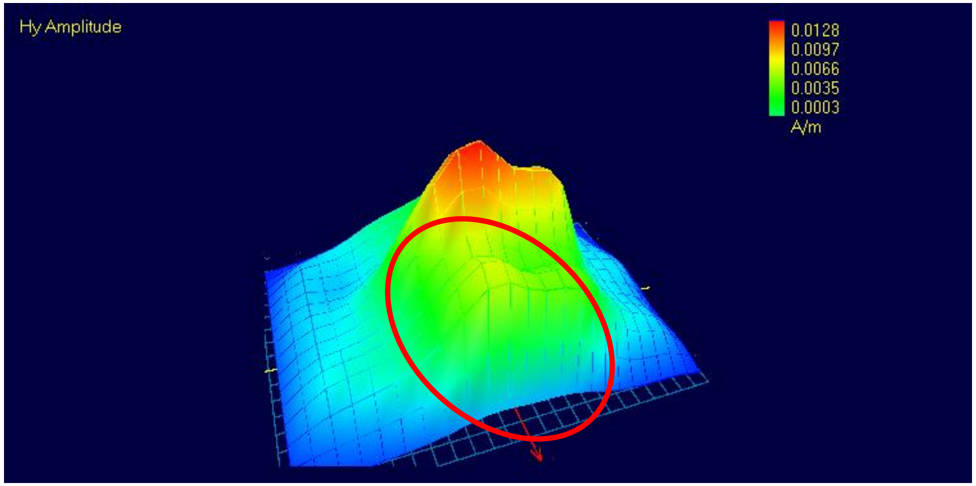


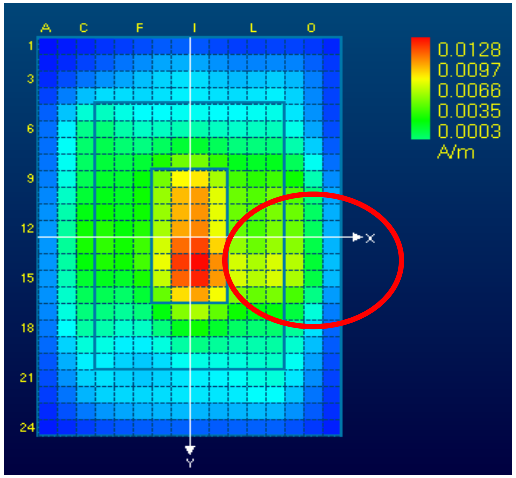
Cables & connectors!

Cable







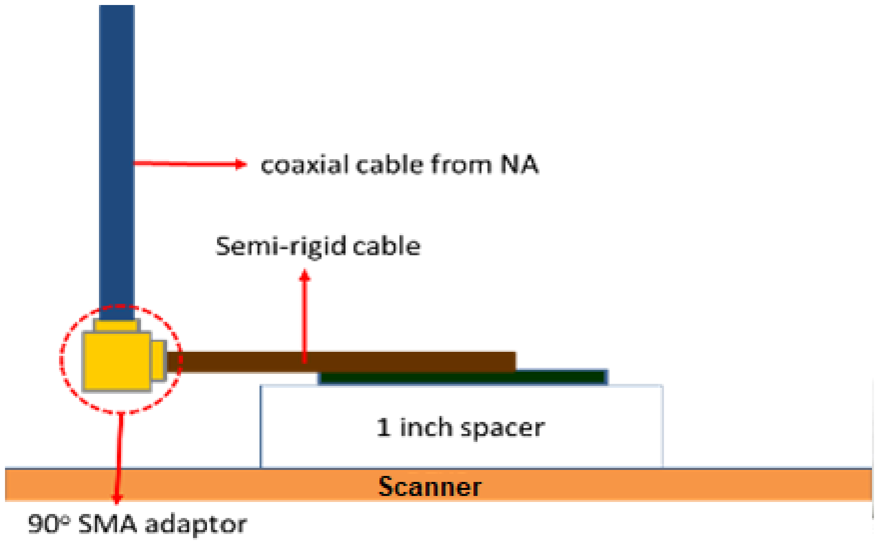


Extra Foam Spacing

2.5 cm spacing accommodated by the software

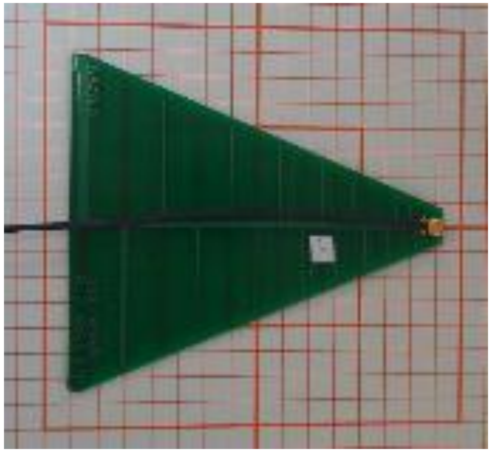
- Below 1 GHz, coupling between scanner and AUT reduced with extra separation
- Efficiency measurements at all frequencies

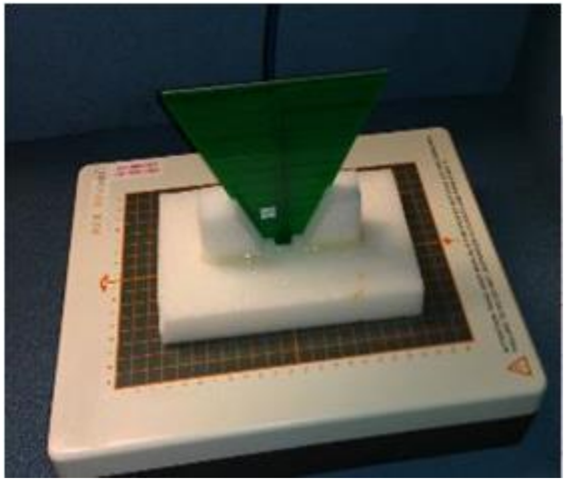
- **Best test is to look at free space S11. Be below – 10 dB**



Orientation of the Antenna

- The main beam should be directed towards the scanner for optimum pattern accuracy
- Orient the antenna in any direction to find the main beam direction



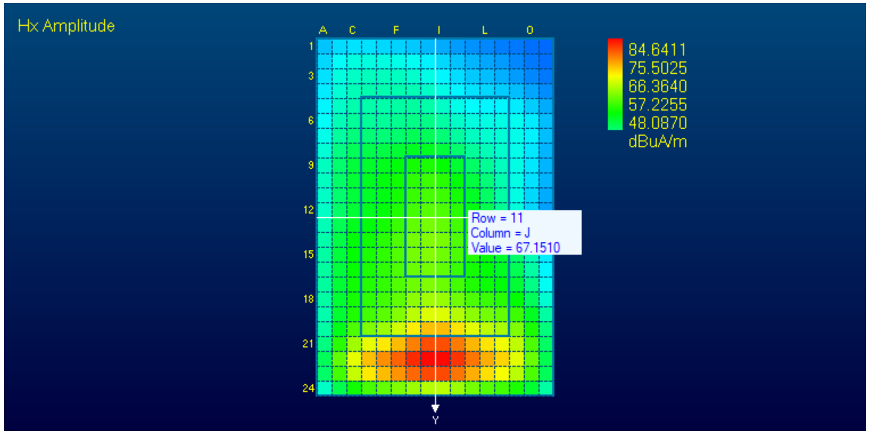


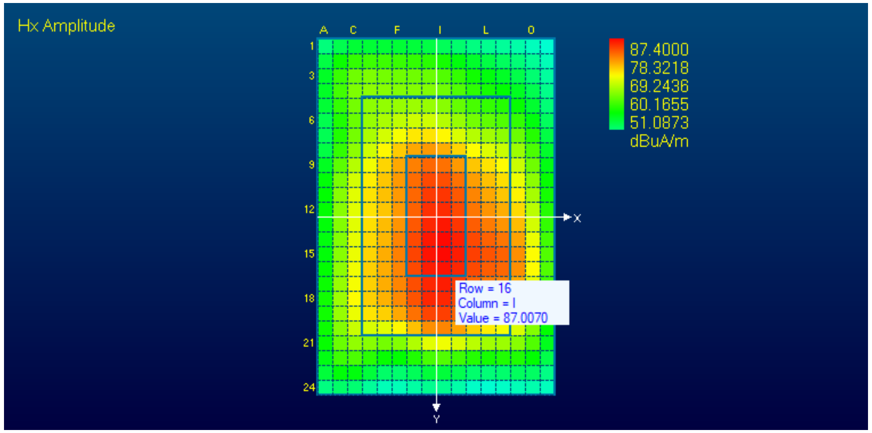
- Place the antenna horizontally, measure the distance of the radiation source to the RFScanner lid
- Enter the distance as separation

Positioning the Antenna

The physical center of the device is not always the radiation center
The easiest way to check this is to run a scan and look at the near-field results

- No sufficient information for accurate results
- Inaccurate PRAD, Efficiency and Far field results

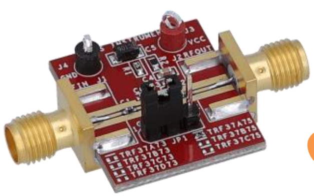




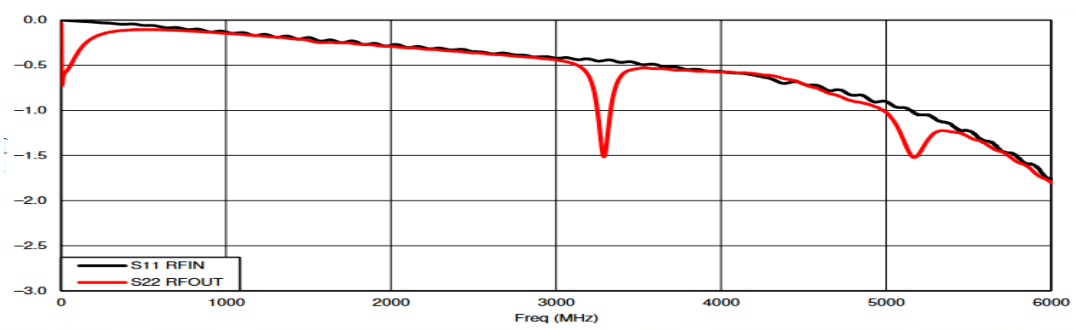
Amplifying the Signal

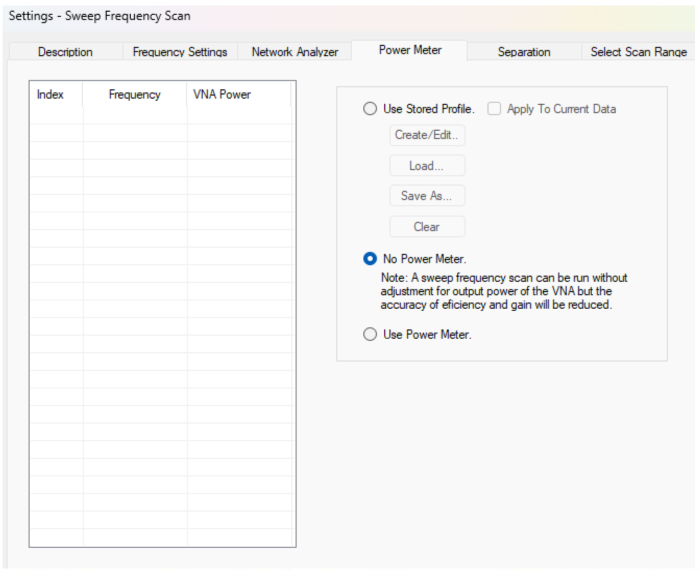
- Placing the amplifier **near the RF source** can help minimize the noise added by the RF source and improve the linearity and SNR of the system, reduce distortion and interference from other sources. Inaccurate PRAD, Efficiency and Far field results.
- The overall system and amplifier Response should be measured and compensated for.
- Power meter should be used next to the antenna

TRF37A75EVM



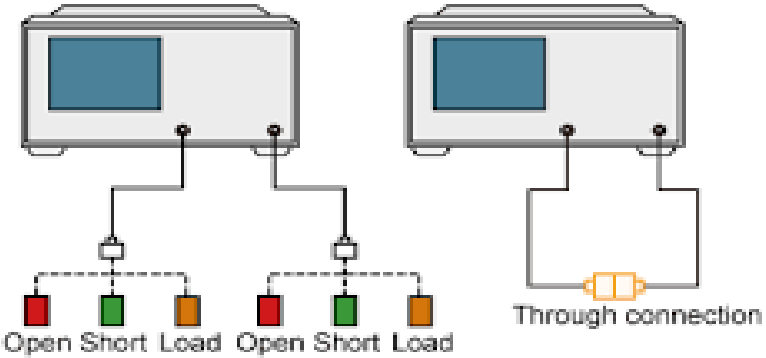
Calibration Plan !!!

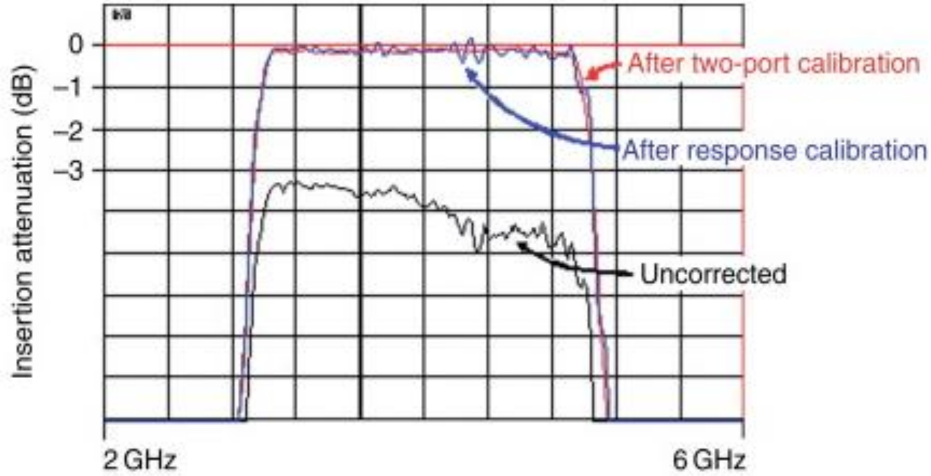




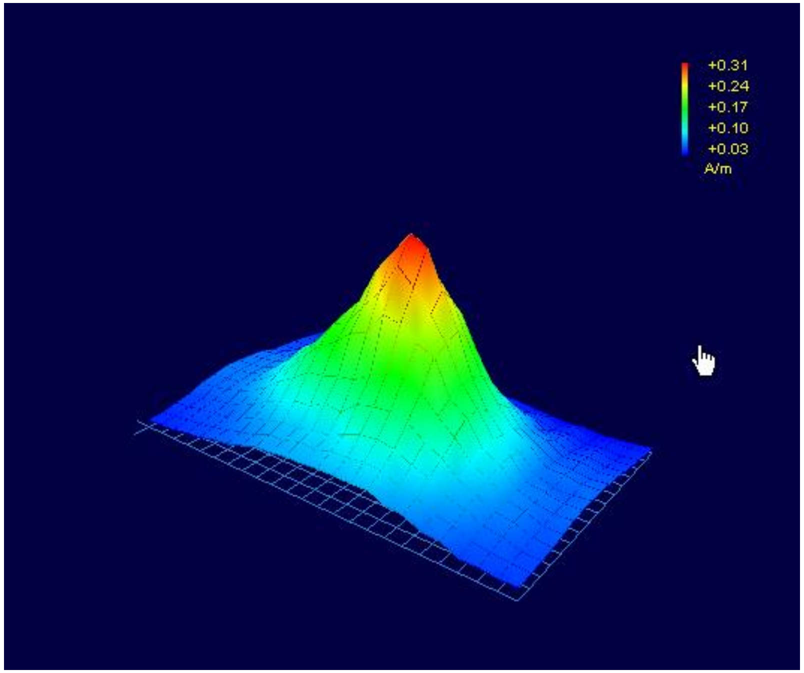
Calibration

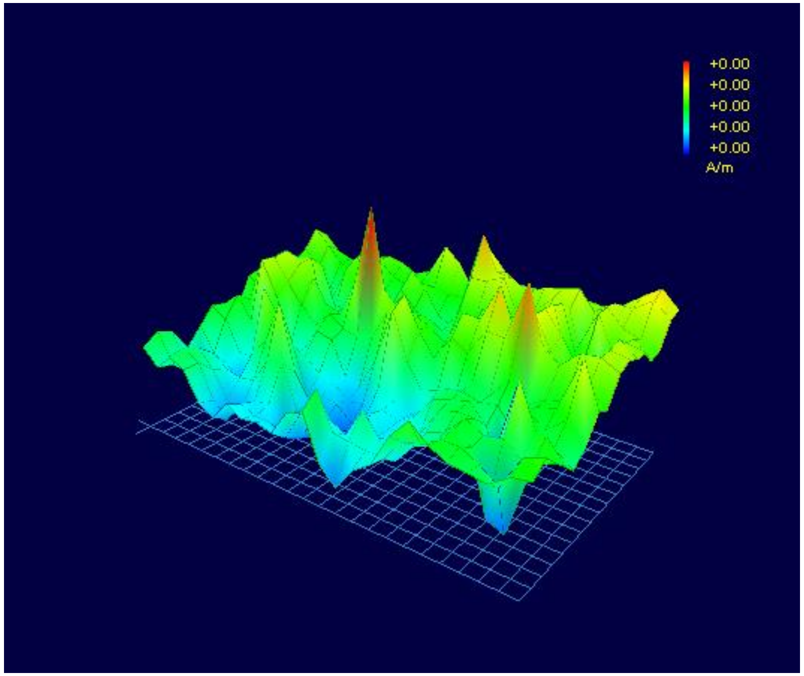
VNA Calibration





Validate the Results



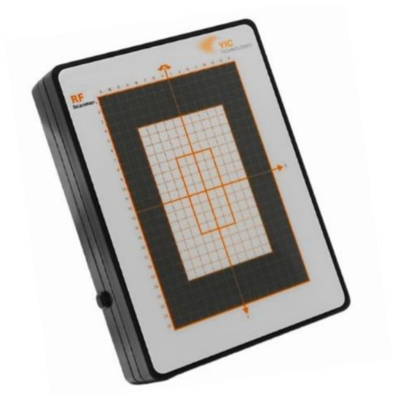


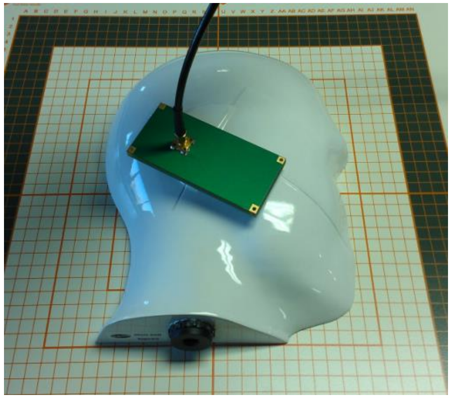
Results with a typical antenna should always look smooth with a peak near where the antenna is place.

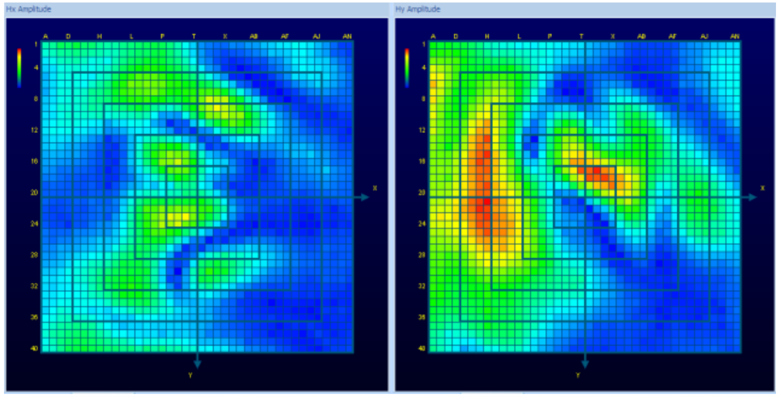
Amplitude value > 0.01 A/m

Results that look like noise mean power not on, wrong frequency selected or antenna not working or connected properly.

Modes of Operation







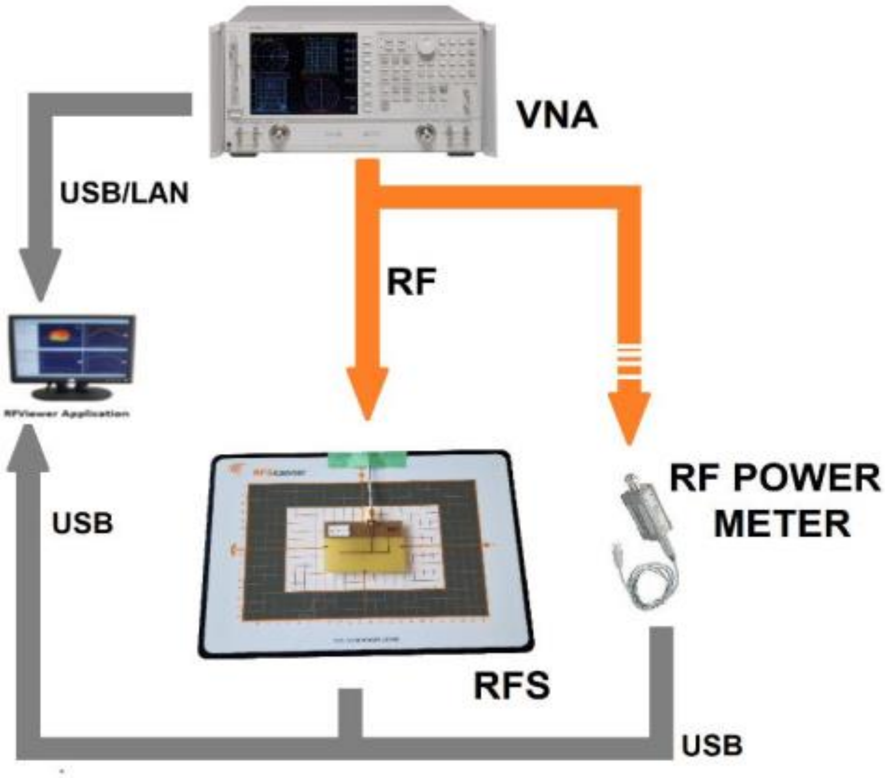
Self-Emitting Mode

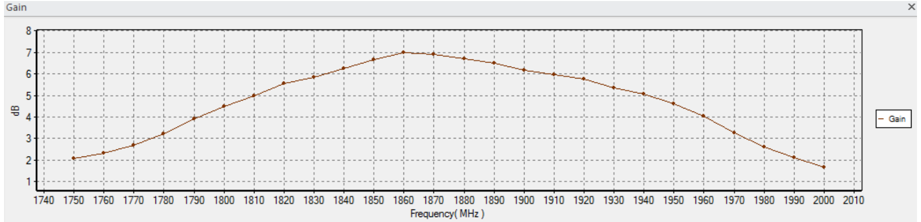
- **An Active DUT**
  - A radiating Antenna, an active device or a passive device connected to RF source
- **Measurements**
  - TRP and EIRP
  - Radiation pattern
  - Pattern correlation
  - Far-field polarizations
    - Linear and circular
- **With user supplied data**
  - Gain and efficiency
  - Error in user data creates errors in calculated values

The simplest setup

Sweep Mode

- **This setup only works with passive devices and supported VNA models**
- **Power meter required to normalize VNA output power!**
- **Measurements**
  - TRP and EIRP
  - Radiation pattern
  - Pattern correlation
  - Far-field polarizations
    - Linear and circular
  - Gain and efficiency





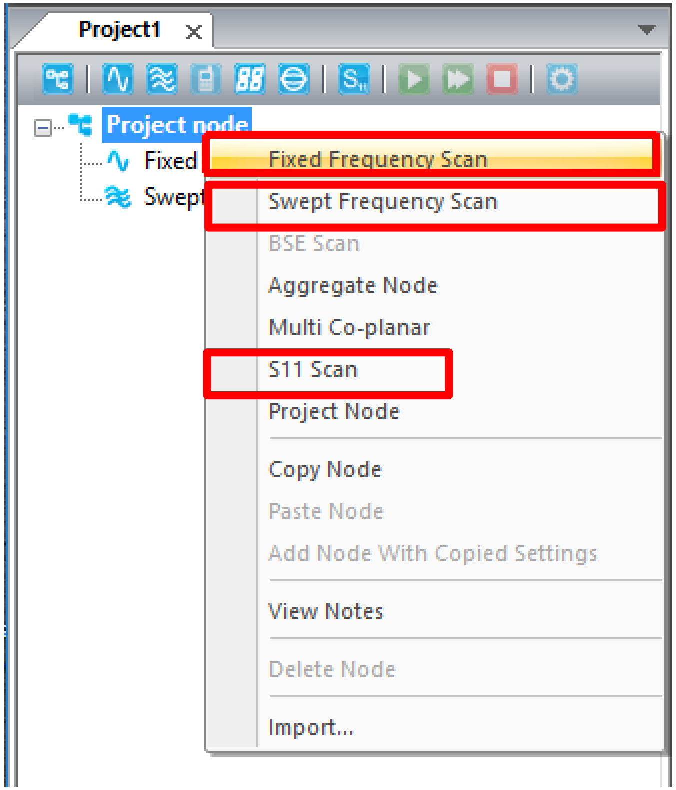
Scan Types

- **Self-Emitting Mode**

  Place the Device on the scanner and click scan
  - Best for active devices and simple setup.
  - No synchronisation possible
  - Run continually
- **Sweep Mode**

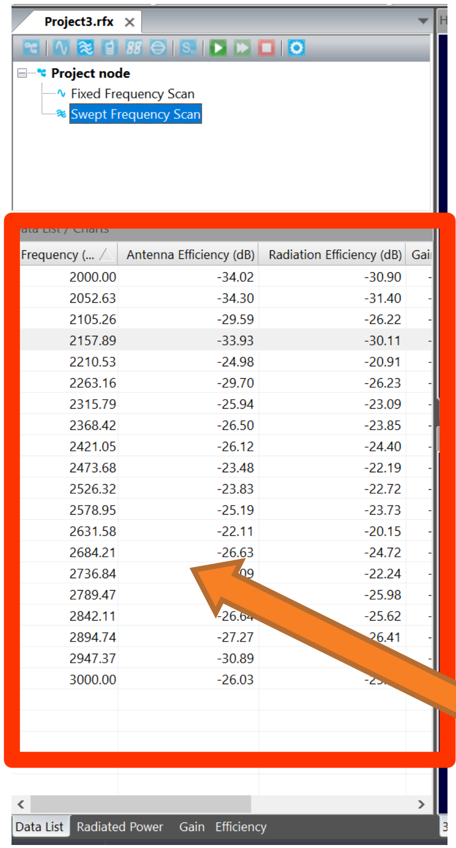
  Requires more complex setup with supported VNA
  - Full DUT/AUT characterization
  - Mostly few Antenna testing and antennas evaluation
- **S11 Scan**

  Requires Supported VNA
  - Precise characterization of the antenna impedance matching and energy transfer

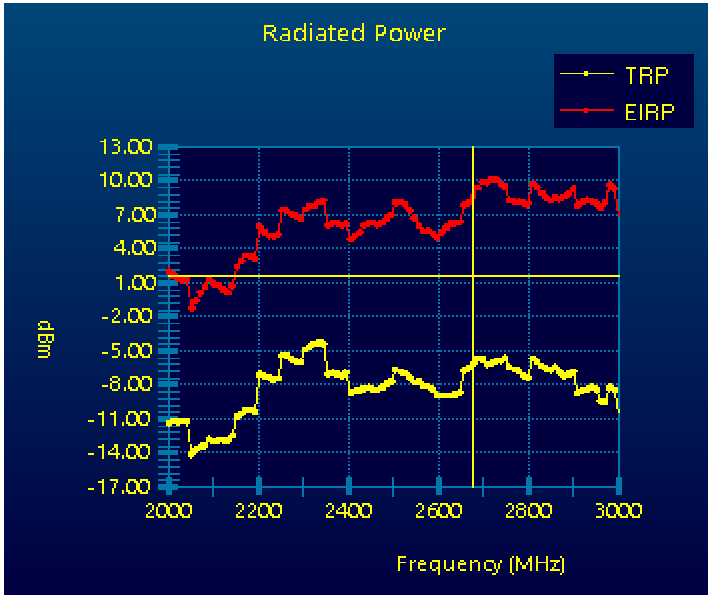


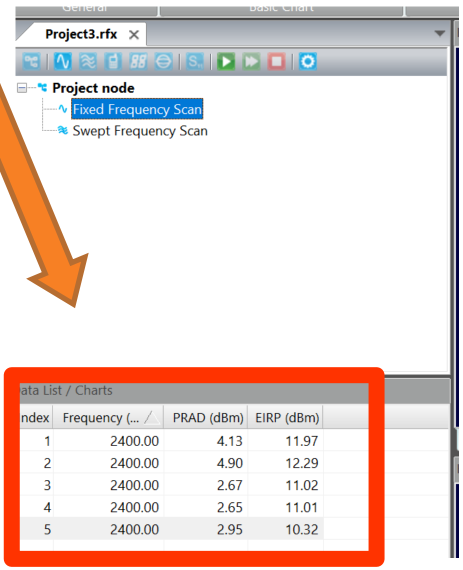
Self-Emitting Mode vs Sweep Frequency Scan

Self-Emitting Device usually operates in a specific frequency



Frequency (...	Antenna Efficiency (dB)	Radiation Efficiency (dB)	Gai
2000.00	-34.02	-30.90	-
2052.63	-34.30	-31.40	-
2105.26	-29.59	-26.22	-
2157.89	-33.93	-30.11	-
2210.53	-24.98	-20.91	-
2263.16	-29.70	-26.23	-
2315.79	-25.94	-23.09	-
2368.42	-26.50	-23.85	-
2421.05	-26.12	-24.40	-
2473.68	-23.48	-22.19	-
2526.32	-23.83	-22.72	-
2578.95	-25.19	-23.73	-
2631.58	-22.11	-20.15	-
2684.21	-26.63	-24.72	-
2736.84	[illegible]	-22.24	-
2789.47	[illegible]	-25.98	-
2842.11	-26.64	-25.62	-
2894.74	-27.27	[illegible]	-
2947.37	-30.89	[illegible]	-
3000.00	-26.03	[illegible]	-





Index	Frequency (...	PRAD (dBm)	EIRP (dBm)
1	2400.00	4.13	11.97
2	2400.00	4.90	12.29
3	2400.00	2.67	11.02
4	2400.00	2.65	11.01
5	2400.00	2.95	10.32

For Antenna Testing use Sweep Mode

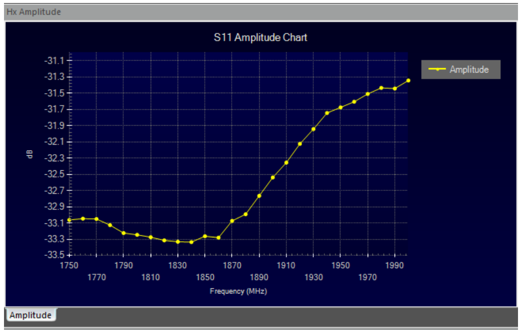
Frequency Sweep

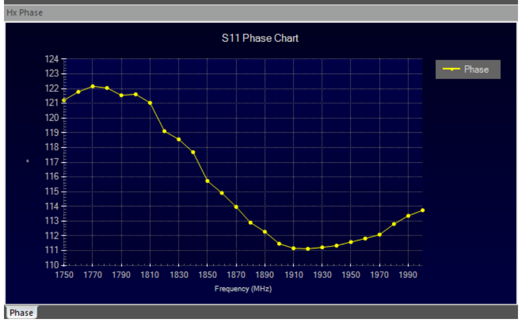
Single Frequency

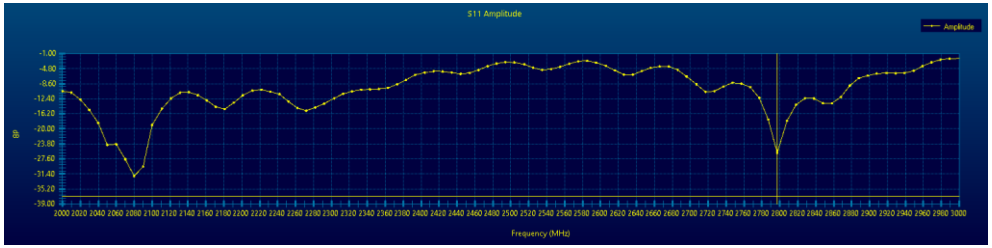
S11 & VSWR Scan

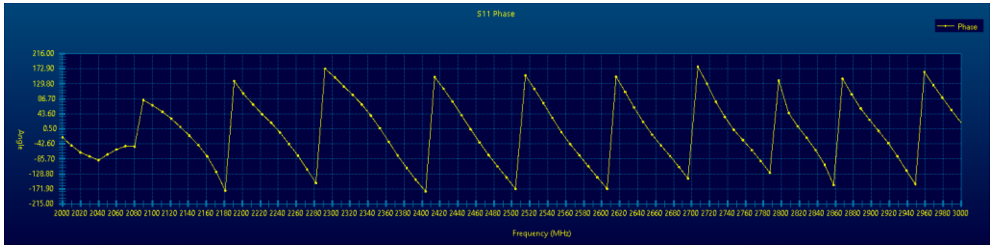
Impedance Matching and Energy Transfer characterization

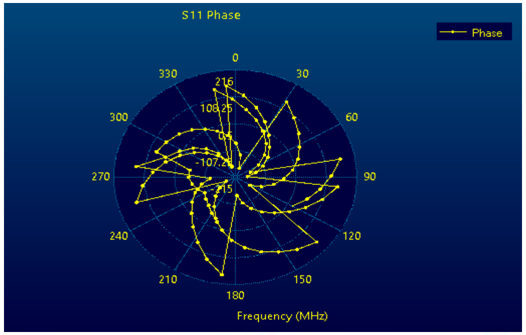
- S11 results extracted from the VNA: Amplitude and Phase
- VNA must be calibrated for accurate results
- Good Results if S11 below -10 dB across the operating region
- Both Cartesian or Polar views







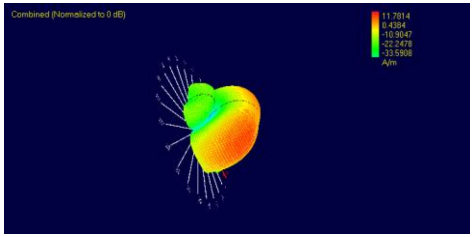




Far-Field Prediction Methods

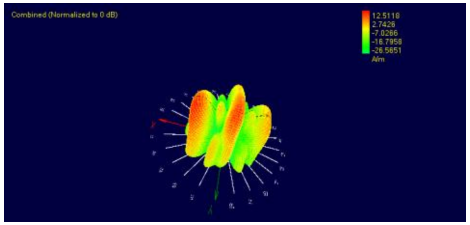
Two Methods are available:

- **Plane Wave Expansion (PWE)** is a method for predicting far-field radiation patterns of an antenna by representing an antenna as a combination of plane waves (infinitely long, uniform waves with a constant amplitude and phase) that are emitted in all directions. The far-field radiation pattern is then obtained by summing the contributions of these plane waves. PWE is a powerful tool for predicting the performance of antennas in various scenarios, and it is widely used in the design and analysis of antennas.



- **Sources Reconstruction Method (SRM)** is a numerical technique based on the principle that the far-field radiation of an antenna can be represented as the superposition of the current distributions on its surface. The far-field pattern is then computed from the reconstructed current distribution using Maxwell's equations.

  SRM is a versatile and powerful tool for predicting the performance of antennas, and it is particularly useful in cases where the current distribution on the antenna is not easily obtainable by other means.



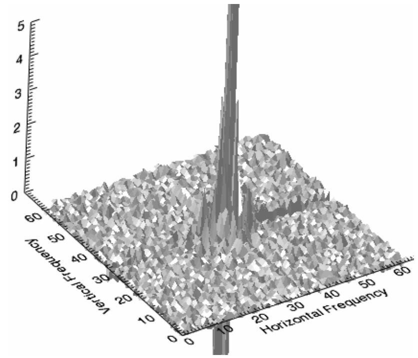
YIC TECHNOLOGIES

Near Field Filtering & Smoothing

2D Fourier Transform

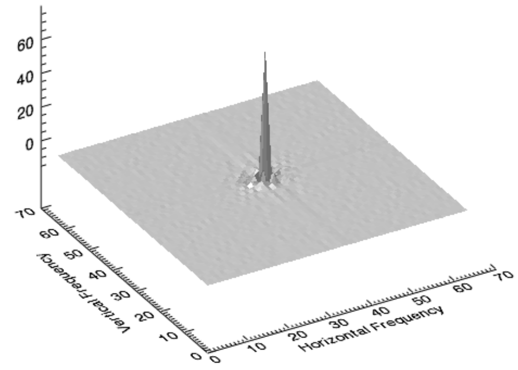
Filtering

2D FFT is been used to remove high frequency noise from the Near Field measurements. The Far-Field Prediction function uses filtered NF results.

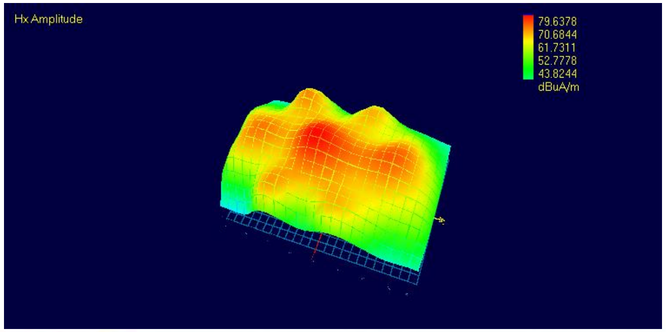


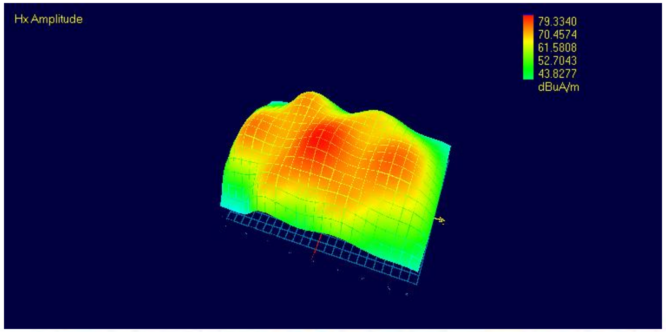
Smoothing

Same 2D FFT function is been used to smooth the results further at user discretion.



Still perfecting the Algorithm, exact Frequency cut-offs will be added to the Datasheet

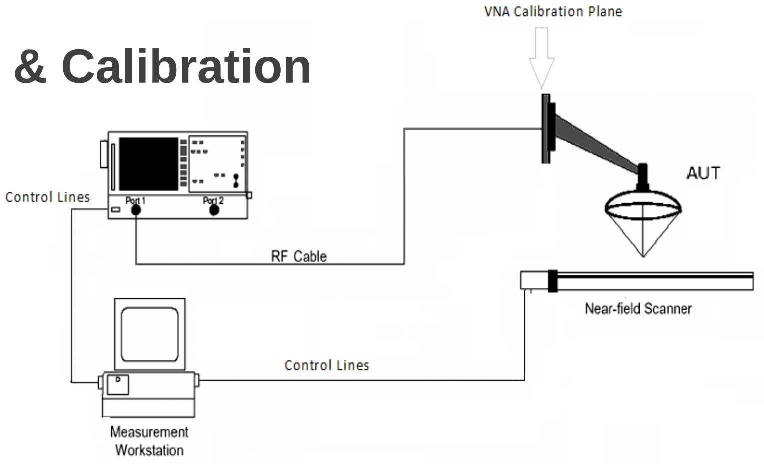




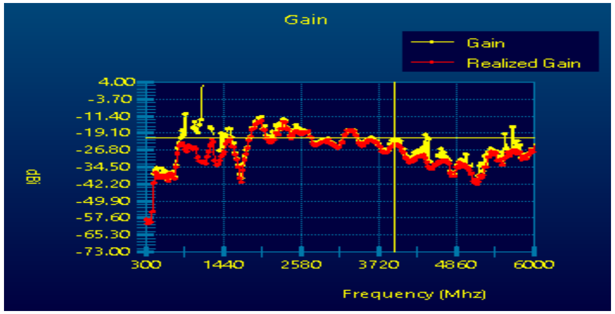
Applications & Use Cases

Antenna Testing - Oscar 20A antenna

1. Setup & Calibration

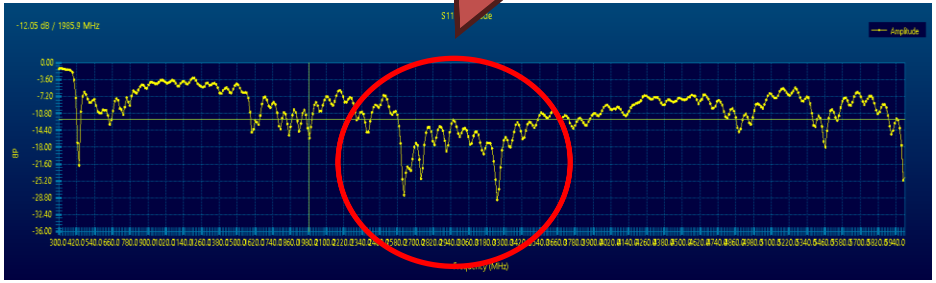


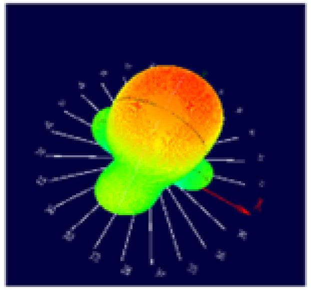
3. Scan

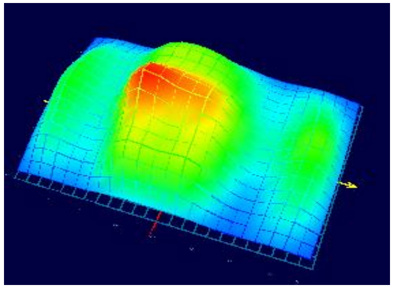


2. Measure S11

Recommended Range of Operation

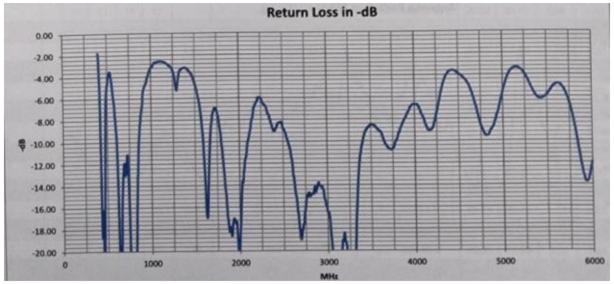




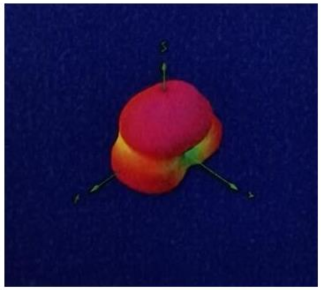


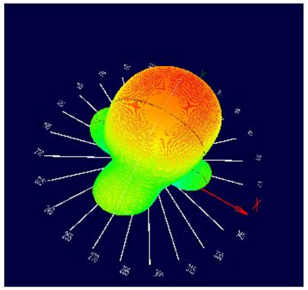
Testing and Characterizing antennas and radiated systems

The Oscar 20A antenna is a high gain, quad band 2G/3G/4G and 5G LTE antenna with extended frequency coverage for connectivity in remote environments where a point to point link is the only effective method of communication between equipment and single cell site.

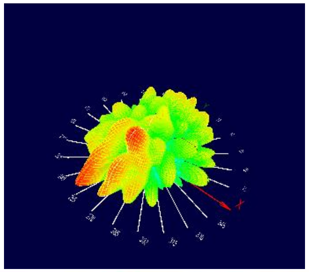


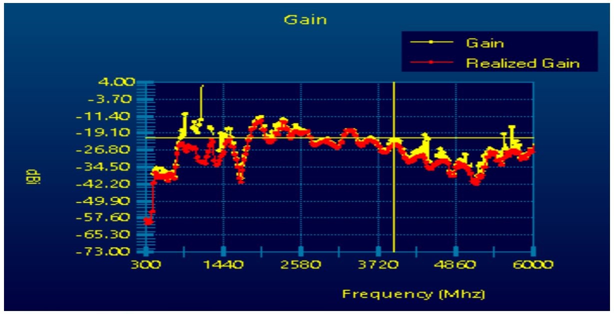
1600MHz

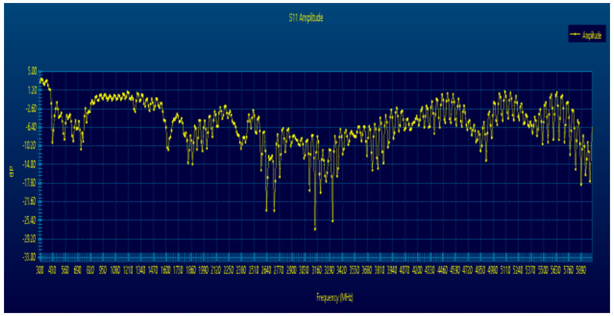




2400MHz

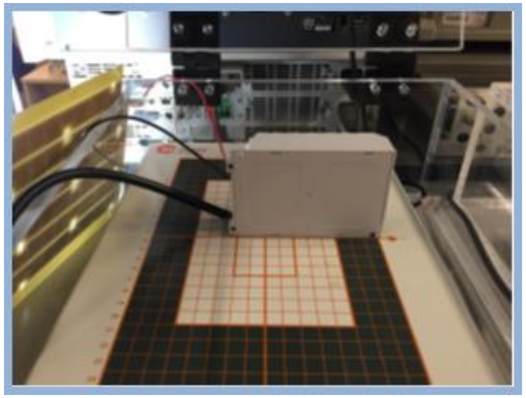


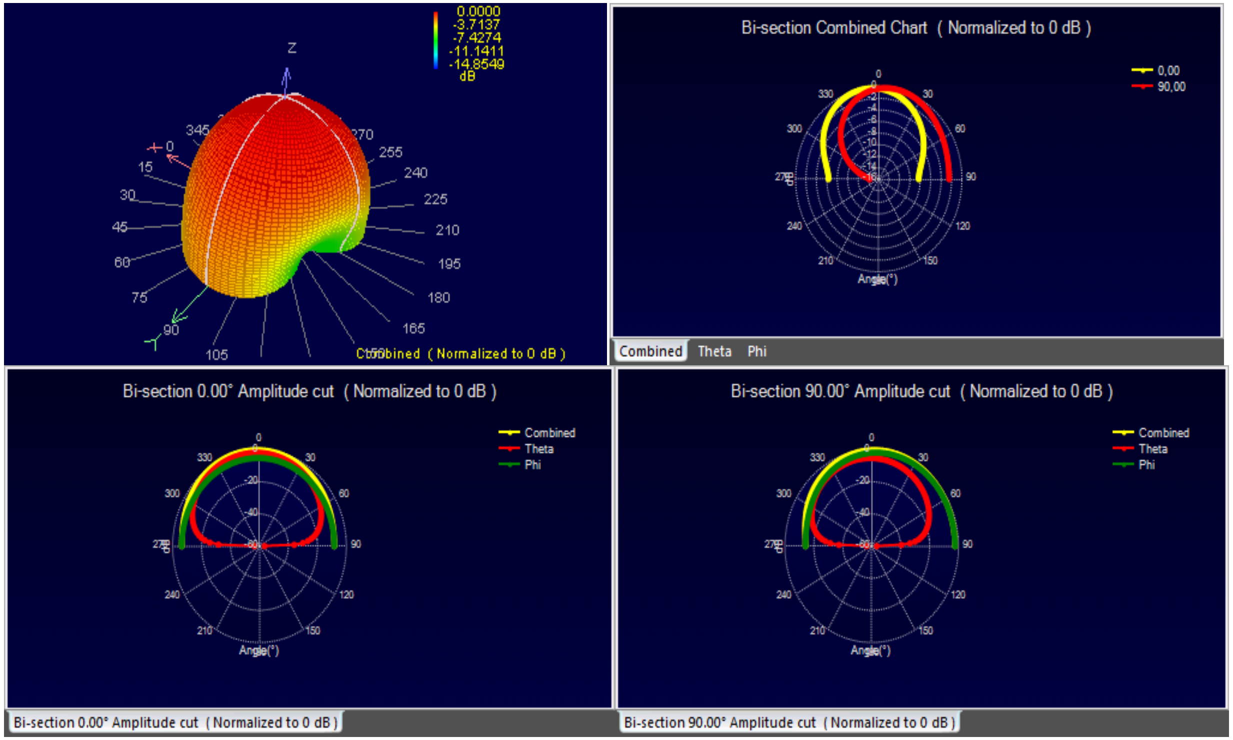




Testing and Characterizing antennas Enclosure

Characterization (radiation pattern and efficiency) as a function of enclosure structure, materials and orientation.

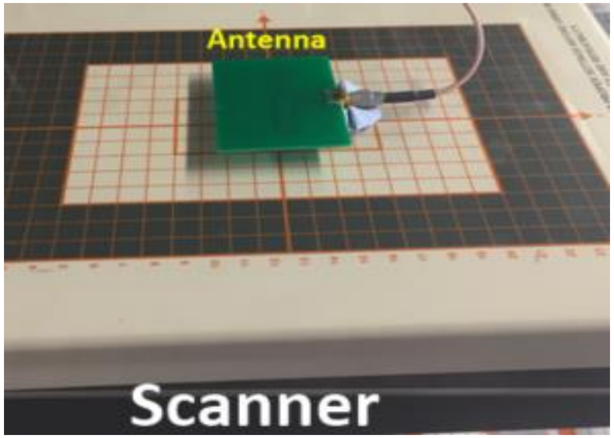


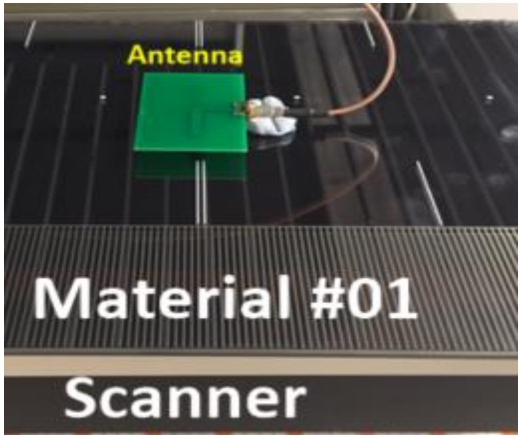


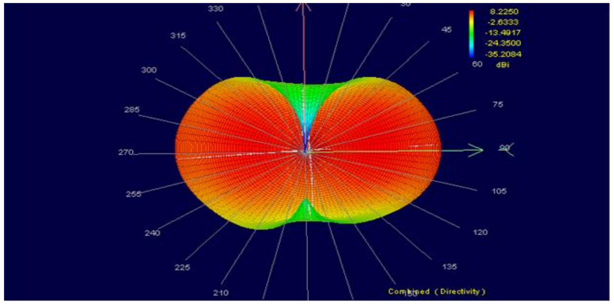
Testing and Characterizing materials response

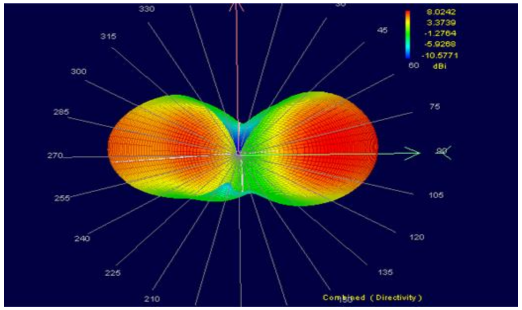
Characterization of materials response

Industrial product testing at 868MHz with PCB antenna



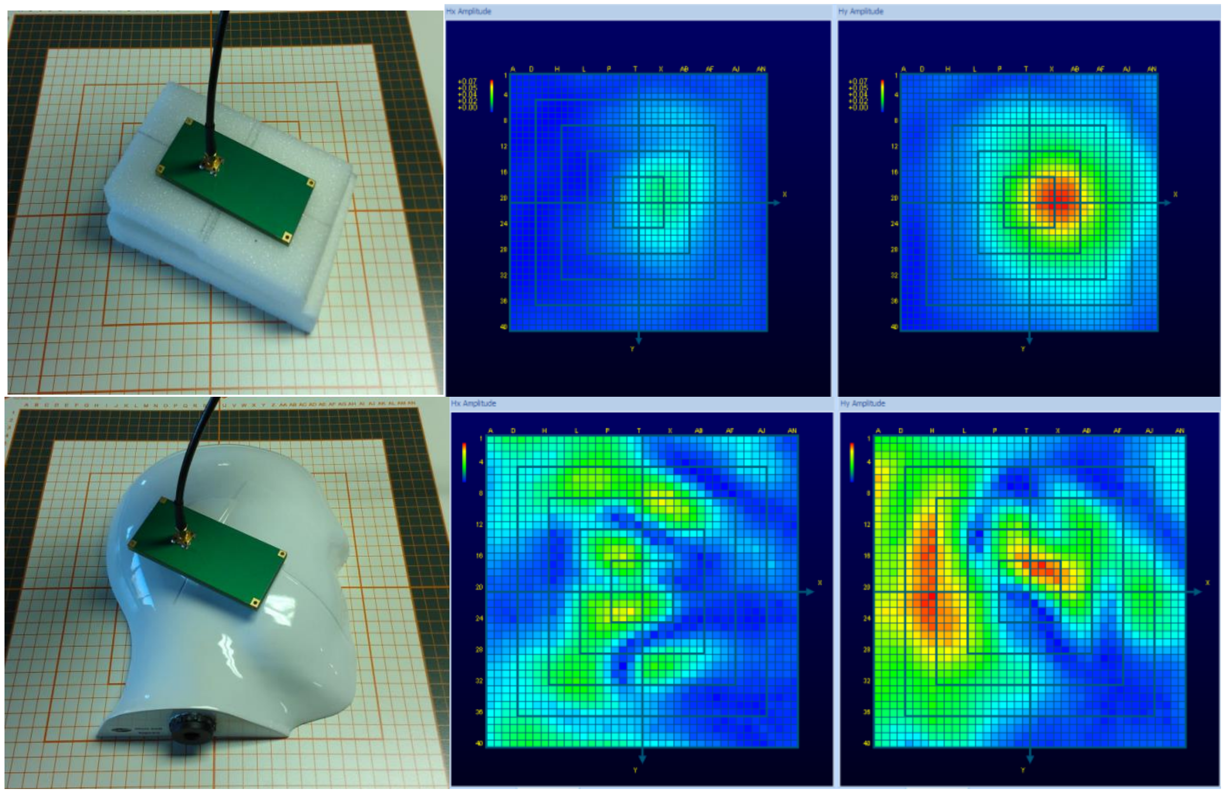






Testing and Characterizing materials response

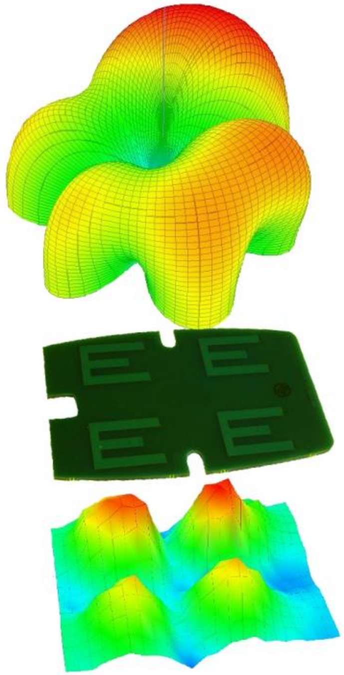
Effects of or on Surrounding Materials and biomass

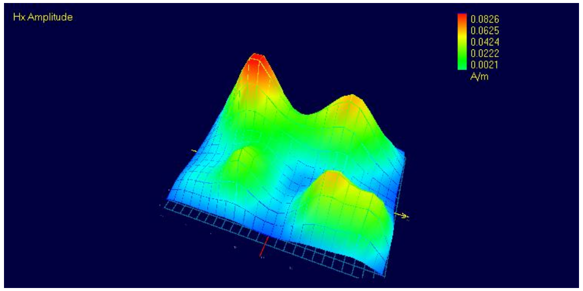


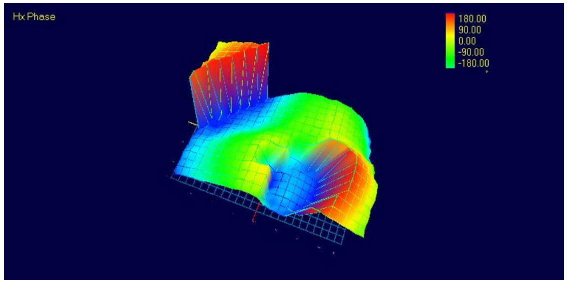
Multiple Element Antennas Testing

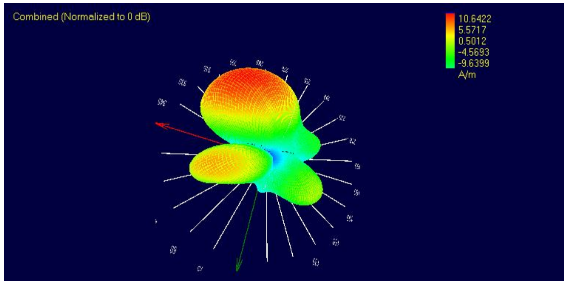
4 Element MIMO Array

- Power Distribution
- Phase Information
- Mutual Coupling
- Far-field for real-time tuning
- Correlation
  - Envelope and pattern correlation

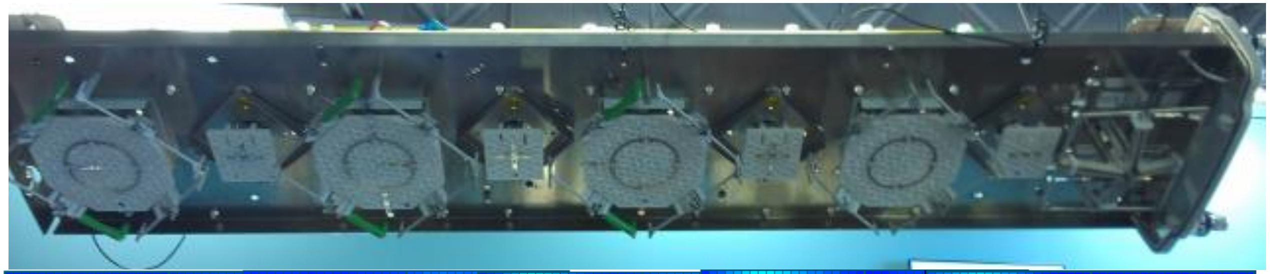


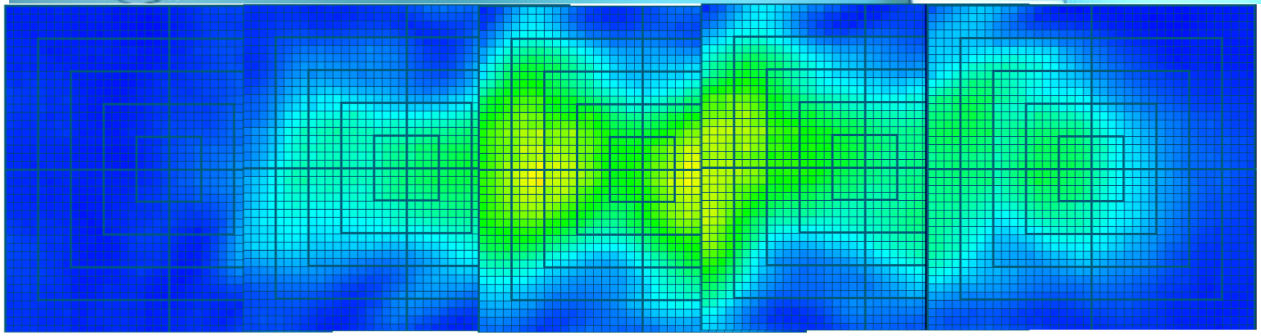


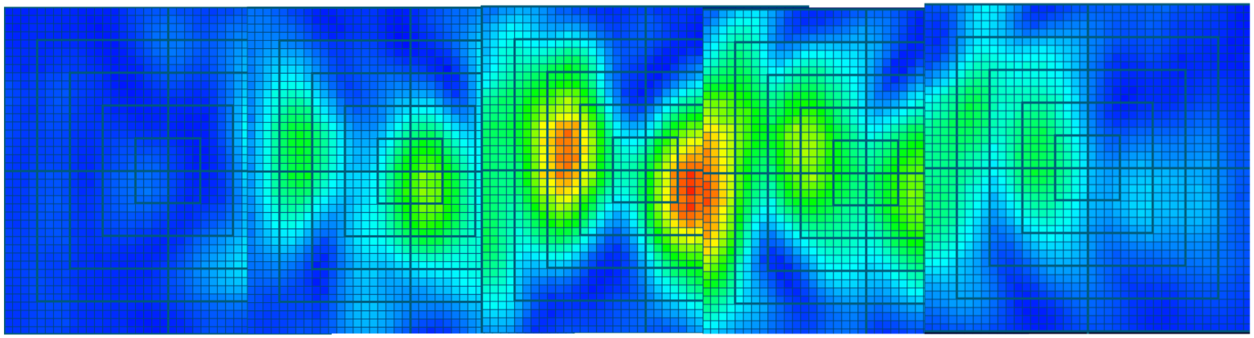




Aggregated Very-Near-Field

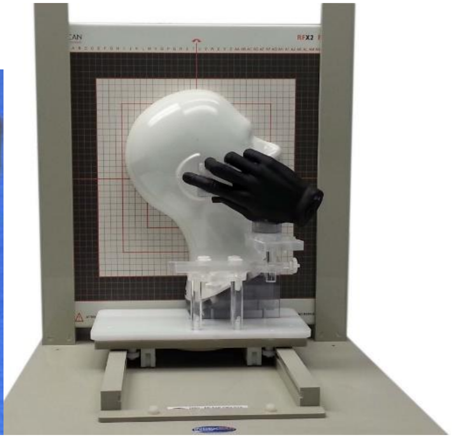






Wireless Instruments

- **Connectivity with**
  - GSM, Mobile
  - WLAN / WiFi
  - ZigBee
  - M-Bus
  - Custom
  - Others …
- **Cellular Phone**
- **Smart Meters**
- GPS Antennas
- **IoT Devices** - Fast p
  certification



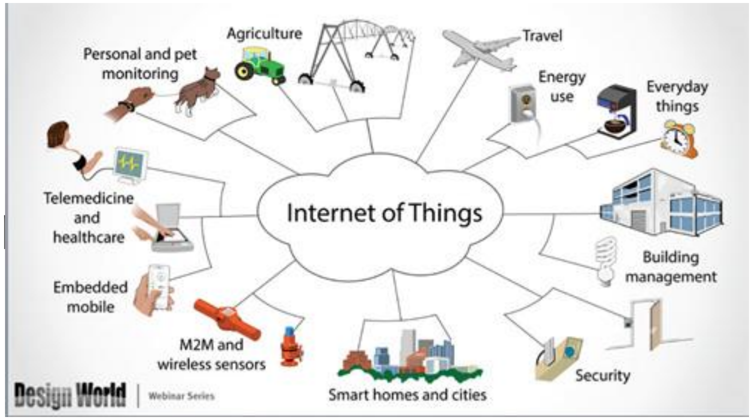
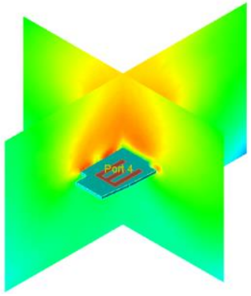


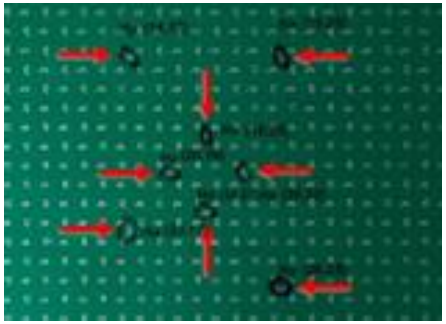
Figure 2-3
Cell relay meter with flexible, dual band (850 MHz and 1900 MHz) antenna affixed to interior surface of the meter cover.

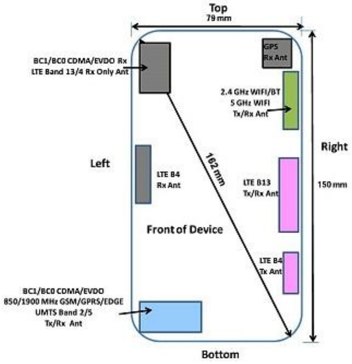
Future Thoughts

Multi-Sides Measurements



OTA (Over The Air) Testing and Calibration and Protocol Awareness





Open Discussion and Live Demos

Coming up – Demonstrations!

1. Self Emitting
    4 Elements MIMO Array Demonstration Tool
2. Sweep Mode

and More…

Live Demonstration - 4 Elements MIMO Array

Self Emitting Mode Demo

The MIMO demo tool has 4 printed patch antennas on the back side. These patches are linearly polarized E-shaped with a PIFA type structure. They are organized in a rectangular grid as shown in the picture.

The MIMO Demo tool is not an actual MIMO device but is simulating the phased array transmission capabilities of a MIMO device to highlight the fast speed and features of the RFScanner.

The tool has a 2x2 array transmitting at 2440 MHz with an ability to cycle through 6 pre-established patterns.

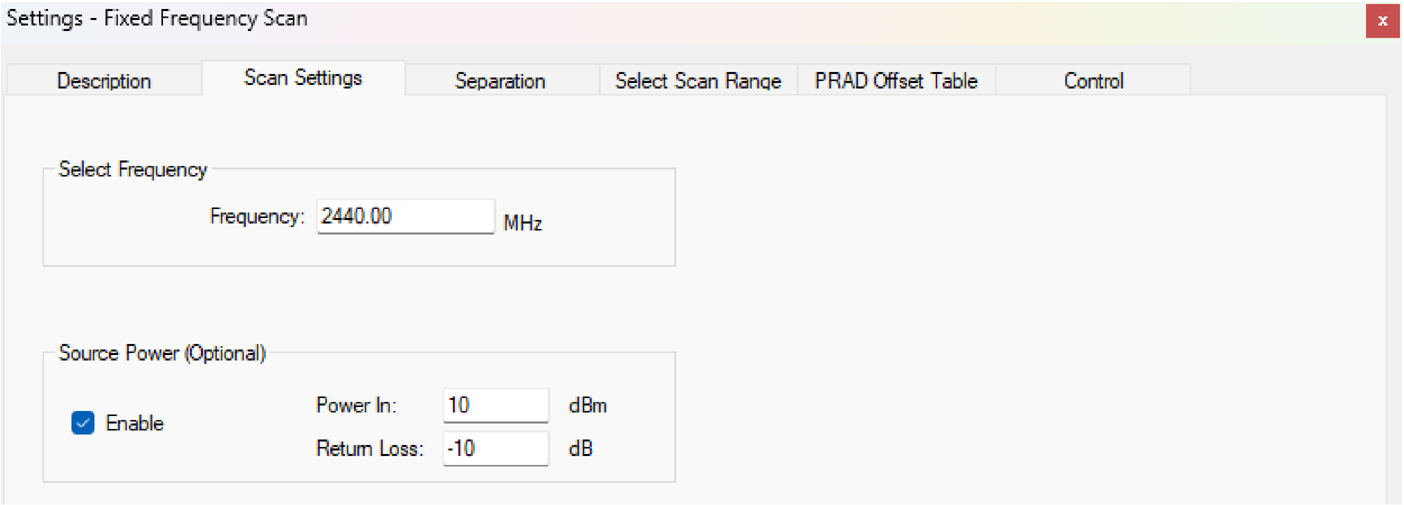
Live Demonstration - 4 Elements MIMO Array

Project Setting

Self Emitting Mode Demo

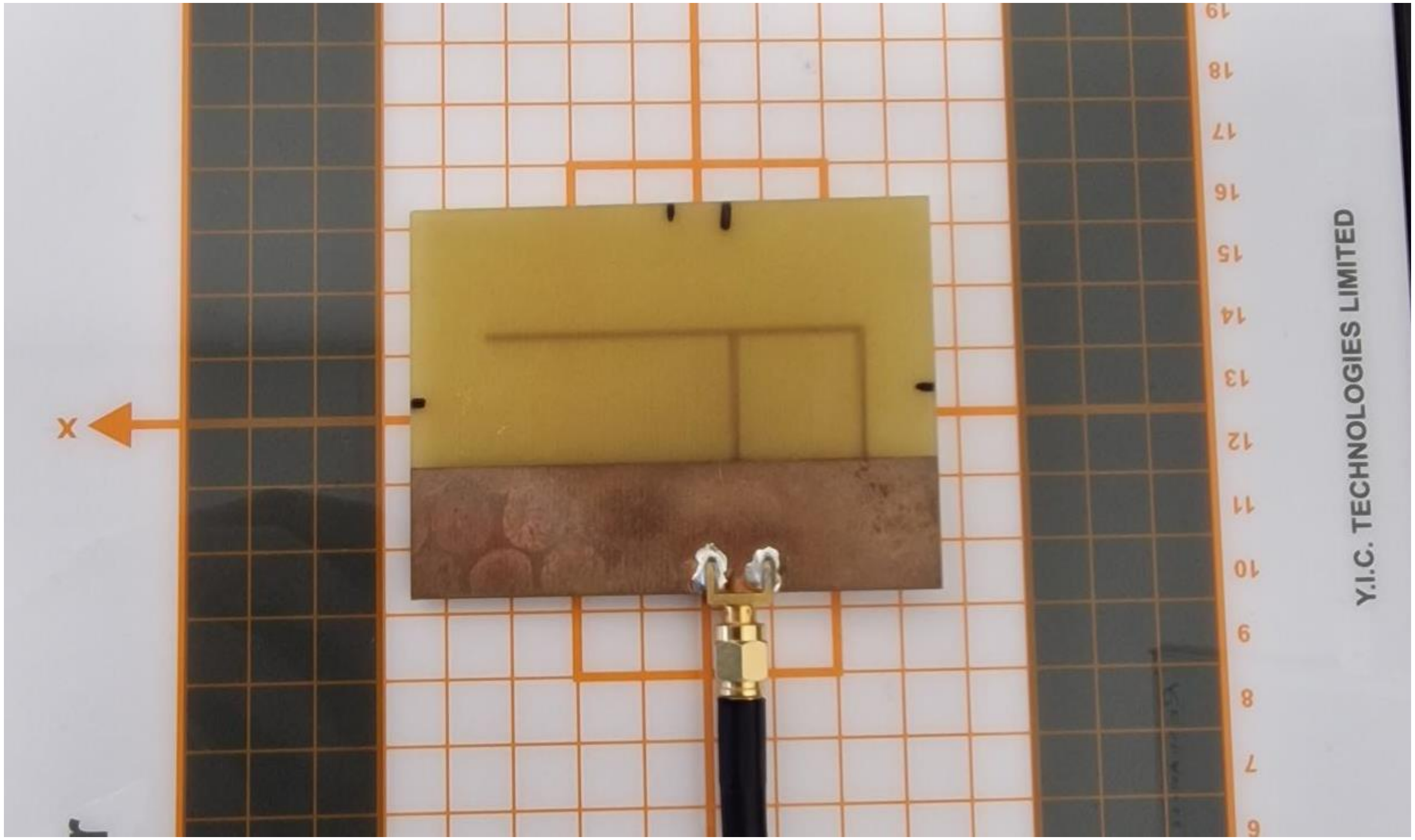
To activate Gain and Efficiency calculation, enter following values in the Source Power and Return Loss settings tab.

- Set the Frequency to 2440 MHz
- Set the Return Loss to -10dB which implies a well matched antenna.
- Set the Source Power value to 10dBm



NOTE : For Demonstration Purposes Only

Live Demonstration - Sweep



Demonstration

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