Introductory Microwave Antenna Measurement Methodology

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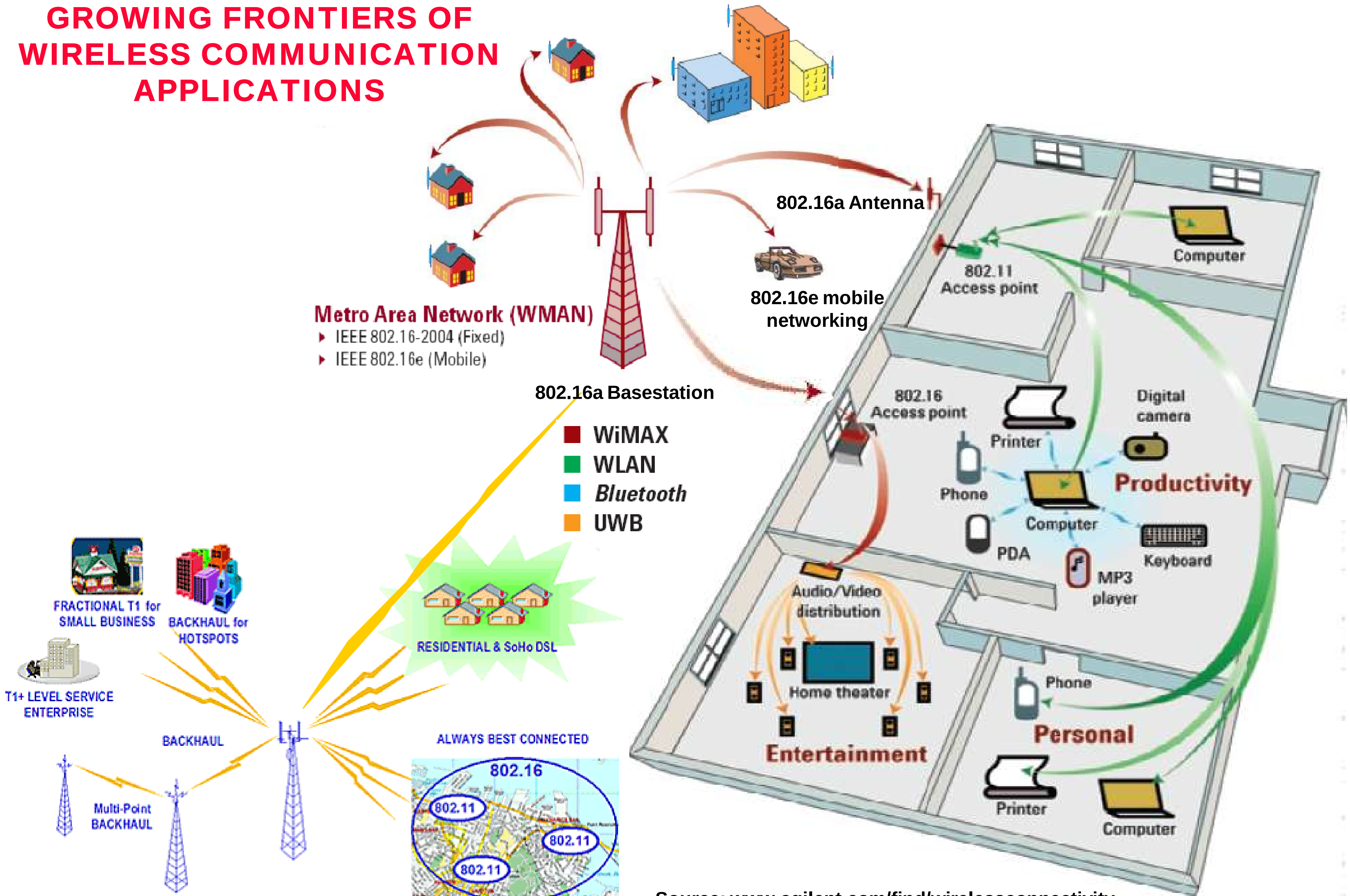
GROWING FRONTIERS OF WIRELESS COMMUNICATION APPLICATIONS



Metro Area Networks 802.16a and 802.16e used for broadband wireless access and 802.11 backhaul.
Source: www.wimaxforum.org

Source: www.agilent.com/find/wirelessconnectivity

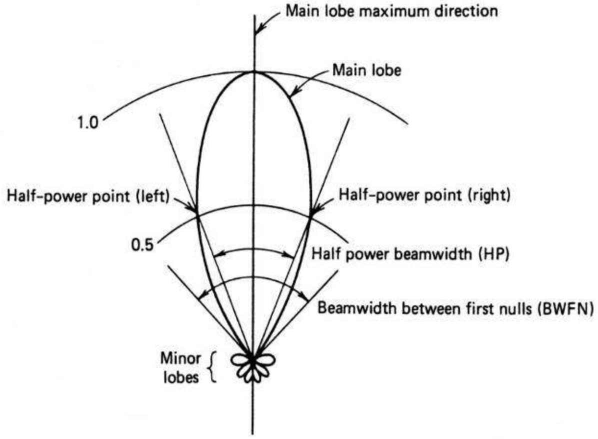
POPULAR WIRELESS COMMUNICATION STANDARDS AND APPLICABLE ANTENNA FEATURE

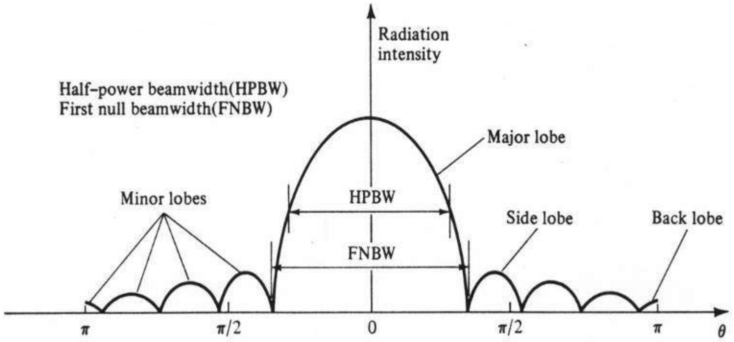
Wireless Technology	CELLULAR COMMUNICATION: GSM/GPRS/EGPRS/UMTS/HSDPA/etc	Bluetooth® 1.2 and Bluetooth EDR IEEE 802.15.1, 1a	IEEE 802.11a/b/g/h/j/n (MIMO)	Ultra-Wideband (previously IEEE 802.15.3a) *Bluetooth* Future	IEEE 802.16-2004 and 802.16e (WiMAX)
Networking Description	High-mobility cellular comm. for voice, SMS, and/or circuit and packet switched data	Medium-Speed Wireless PAN EDR: Enhanced Data Rate	Wireless Local Area Network (LAN)	High Speed Ultra Wide Band Wireless PAN	Wireless Metropolitan Area Network (MAN)
Geography	Worldwide; some protocols are territory dependent	Worldwide	Worldwide	Worldwide	Worldwide
Primary Service	High-mobility cellular: Voice, SMS, circuit switched data and/or packet switched data	Low mobility data and voice	Low mobility data	Low-mobility streaming video/data Certified Wireless USB Next generation *Bluetooth*	"Last mile", backhaul, and mobile broadband wireless access
First Commercial Deployment And Frequency Range	GSM: 1992 GPRS: 2002 EGPRS:2003 CDMA:~1995 CDMA2000(1XRTT):2001 W-CDMA:2004; HSDPA:2006 Most popular GSM Bands: GSM850: 824~894MHz E-GSM900: 880~960MHz DCS1800: 1.71~1.88GHz PCS1900: 1.85~1.99GHz UMTS Bands (I~VI): 824~2170 MHz CDMA Bands (Typical) 824~1990 MHz 2110~2170 MHz	Bluetooth: 2000 Bluetooth EDR: 2005 ISM band: 2.4 ~ 2.4835 GHz	b: 1999 a/g: 2002 to 2003 h: 2003 to 2004 j: 2004 n: 2007 b/g: 2.4 to 2.4835 GHz (ISM) a/h/j: 4.9 to 5 GHz (Japan) 5.03 to 5.091 GHz (Japan) 5.15 to 5.35 GHz (UNII) 5.47 to 5.725 GHz 5.725 to 5.825 GHz (ISM, UNII) n: 2.4 to 2.4835 GHz (ISM) 5.15 to 5.35 GHz (UNII) 5.725 to 5.825 GHz (ISM, UNII)	Radios registered: Q3 2006 Consumer products: Q4 2006/2007 3.17 to 10.56 GHz (North America) 6.34 to 8.98 GHz, 4.22 to 4.75 GHz (DDA–Detect and Avoid – after 2010), 3.17 to 4.22 GHz (DAA) (Europe) 7.39 to 10.03 GHz, 4.22 to 4.75 GHz (DDA after 2010), 3.70 to 4.22 GHz (DAA) (Japan)	Fixed access: 2006 Mobile access: 2007 Licensed/unlicensed bands, 2-11 GHz (Typical: 2.3, 2.5, 3.5, 4.9, 5.8 GHz)
Maximum Data Rate	GSM: ≦14.4 kbps EGPRS: ≦ 473.6 kbps UMTS: 384 kbps HSDPA: ≦13.976 Mbps(DL)	1 Mbps raw (EDR: 2~3 Mbps)	b: 11 Mbps a/g/h/j: 54 Mbps n: > 100 Mbps	480 Mbps	Fixed: 75 Mbps Mobile: 30 Mbps
Service Range	Cell Deployment Dependent	Up to 30 ft	Up to 300 ft	Up to 30 ft	1 ~ 20 miles
Typical Over-The-Air Pattern Requirement	Wider angular coverage, omni-directional preferably; polarization diversity may be applied for better coverage	Wider angular coverage, omni-directional preferably; polarization diversity may be applied for better coverage	Omni-directional/fan-beam for AP; preferably directional for distance booster; better coverage with antenna diversity	Ultra wide bandwidth; preferably wider angular coverage for easier device to device alignment	Narrow beam coverage for long distance point-to-point communications; fan-beam coverage for last-mile base station broadcasting or A.P.
Applicable Antenna Types	Monopol/dipole; low profile/ planar antennas: PIFA micro-strip antenna, chip antenna, PCB (SMT) antenna, etc.	Low profile/planar antenna: PIFA microstrip antenna, chip antenna, PCB antenna (SMT), etc.	Monopole/dipole for A.P.; multi-element array for booster; client devices with planar type antennas	Low profile, dipole array; spiral antenna; ceramic chip antenna	Clusters of multi-element panel antennas for different band coverage; LP dipole array antennas; smart antennas
Remarks	Source: www.3gpp.org www.3gpp2.org	*Source:* www.bluetooth.org *Bluetooth* is a trademark owned by Bluetooth SIG, Inc., U.S.A.	Source: www.wi-fi.org www.ieee802.org/11	Source: www.ieee802.org/15 www.uwbforum.org www.wimedia.org www.usb.org	Source: www.wimaxforum.org www.wirelessman.org

MICROWAVE ANTENNA AND ANTENNA RADIATION PATTERN

Antenna Basic Features

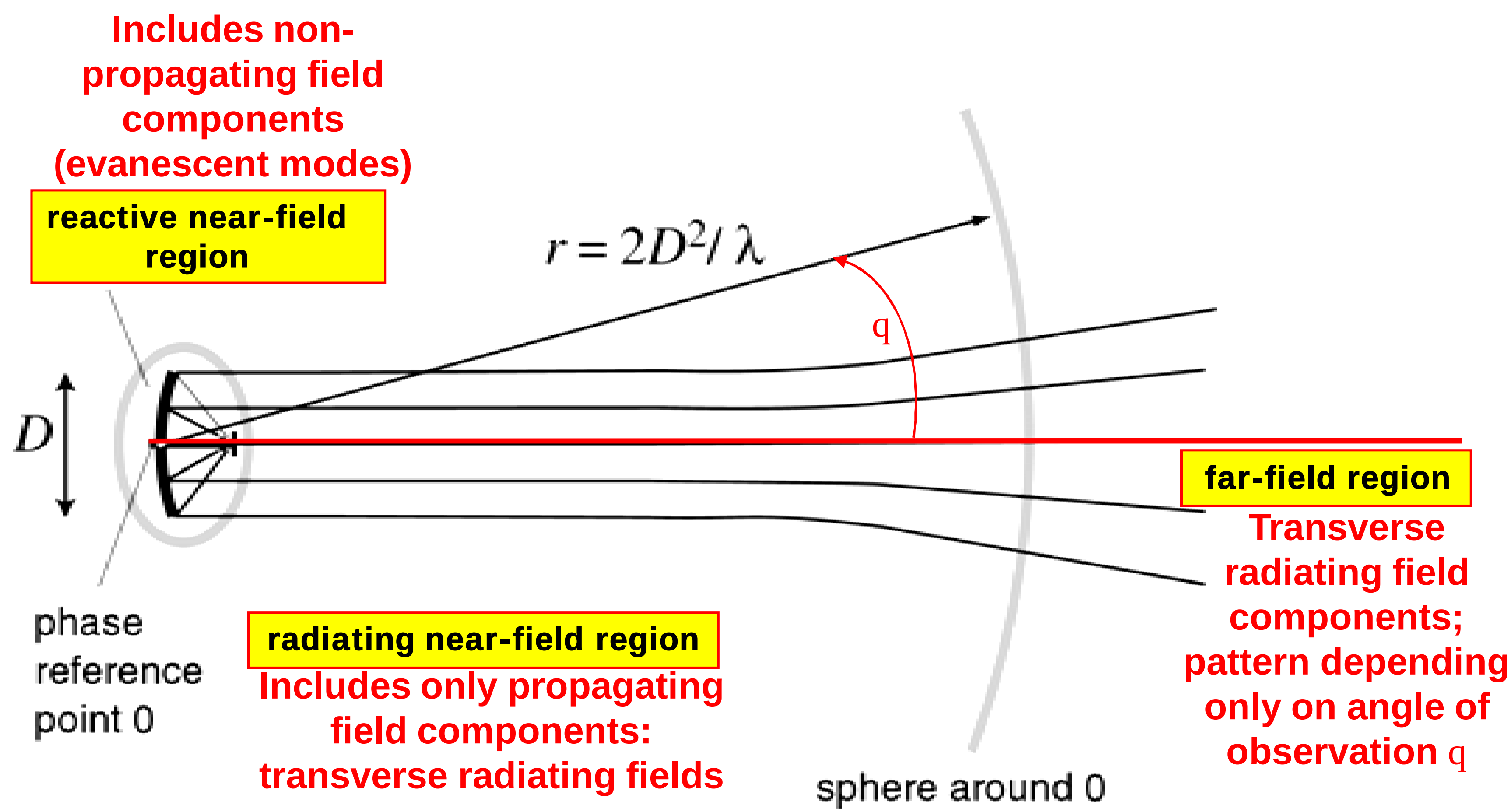
- ***An antenna provides a means of accepting energy from a transmission line and radiating this energy with minimum loss.***





- ***Antennas shape beams and thus control the distribution of energy in space.***
  - ***To produce a maximum amount of energy in selected directions.***
  - ***To reject signals (or noise) from undesired directions.***

Field Regions of An Antenna



Time-Harmonic Radiation Field And Radiation Field Function In Far-Field Region

General form:

$$\boldsymbol{E}(r, \theta, \varphi) = \frac{1}{r} e^{-jkr} \boldsymbol{G}(\theta, \varphi)$$

Divergence factor ($\frac{1}{r}$)

Phase factor (e^{-jkr})

Complex radiation Field functio ($\boldsymbol{G}(\theta, \varphi)$)

$$\boldsymbol{H}(r, \theta, \varphi) = \frac{1}{\eta} \hat{\mathbf{r}} \times \boldsymbol{E}(r, \theta, \varphi) \qquad \eta = \sqrt{\frac{\mu}{\varepsilon}}$$

When $r = \sqrt{x^2 + y^2 + z^2}$, the phase reference point of $\mathbf{G}(\theta, \varphi)$ is origin (0,0,0)

Radiation Field Function: The Radiation Pattern

$$\mathbf{E}(\mathbf{r}) = \frac{1}{r}e^{-jkr}\,\boldsymbol{G}(\hat{\mathbf{r}}) \qquad \boldsymbol{E}(r, \theta, \varphi) = \frac{1}{r}e^{-jkr}\boldsymbol{G}'(\theta, \varphi)$$

$$\mathbf{r} = x\hat{\mathbf{x}} + y\hat{\mathbf{y}} + z\hat{\mathbf{z}} = \hat{\mathbf{r}}r$$

$$\mathbf{r} = r\sin\theta\cos\varphi\,\hat{\mathbf{x}} + r\sin\theta\sin\varphi\,\hat{\mathbf{y}} + r\cos\theta\,\hat{\mathbf{z}}$$

$$\boldsymbol{G}'(\theta, \varphi) = \boldsymbol{G}(\hat{\mathbf{r}})$$

direction $\hat{\mathbf{r}}$

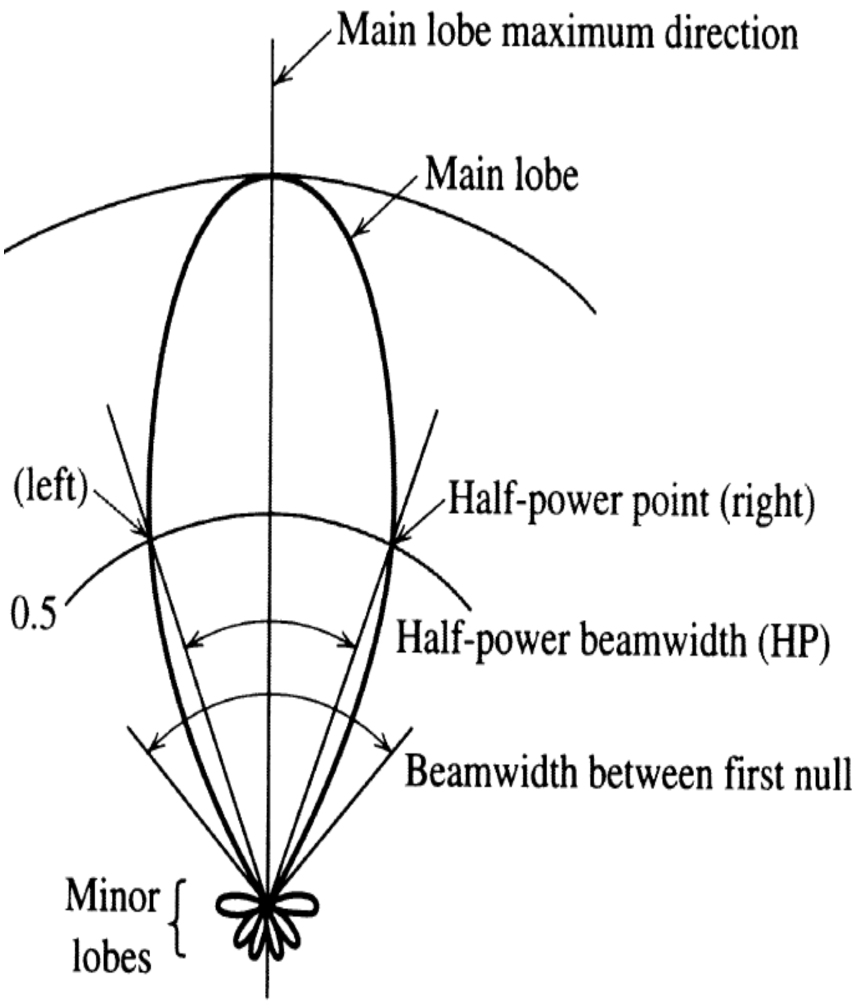
Co- and cross-polar radiation field functions:

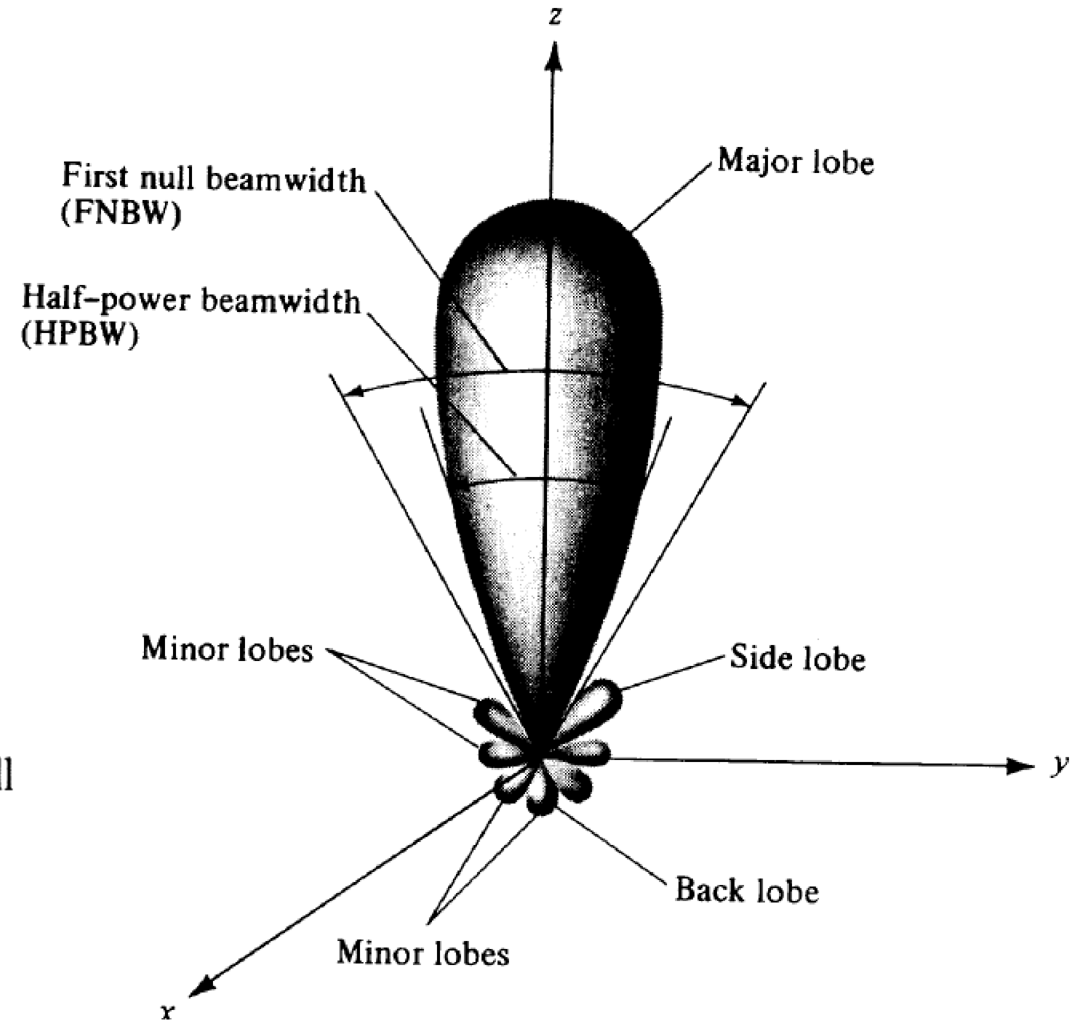
$$G_{co}(\theta, \varphi) = \boldsymbol{G}(\theta, \varphi) \cdot \hat{\boldsymbol{co}}^*(\theta, \varphi)$$

$$G_{xp}(\theta, \varphi) = \boldsymbol{G}(\theta, \varphi) \cdot \hat{\boldsymbol{xp}}^*(\theta, \varphi)$$

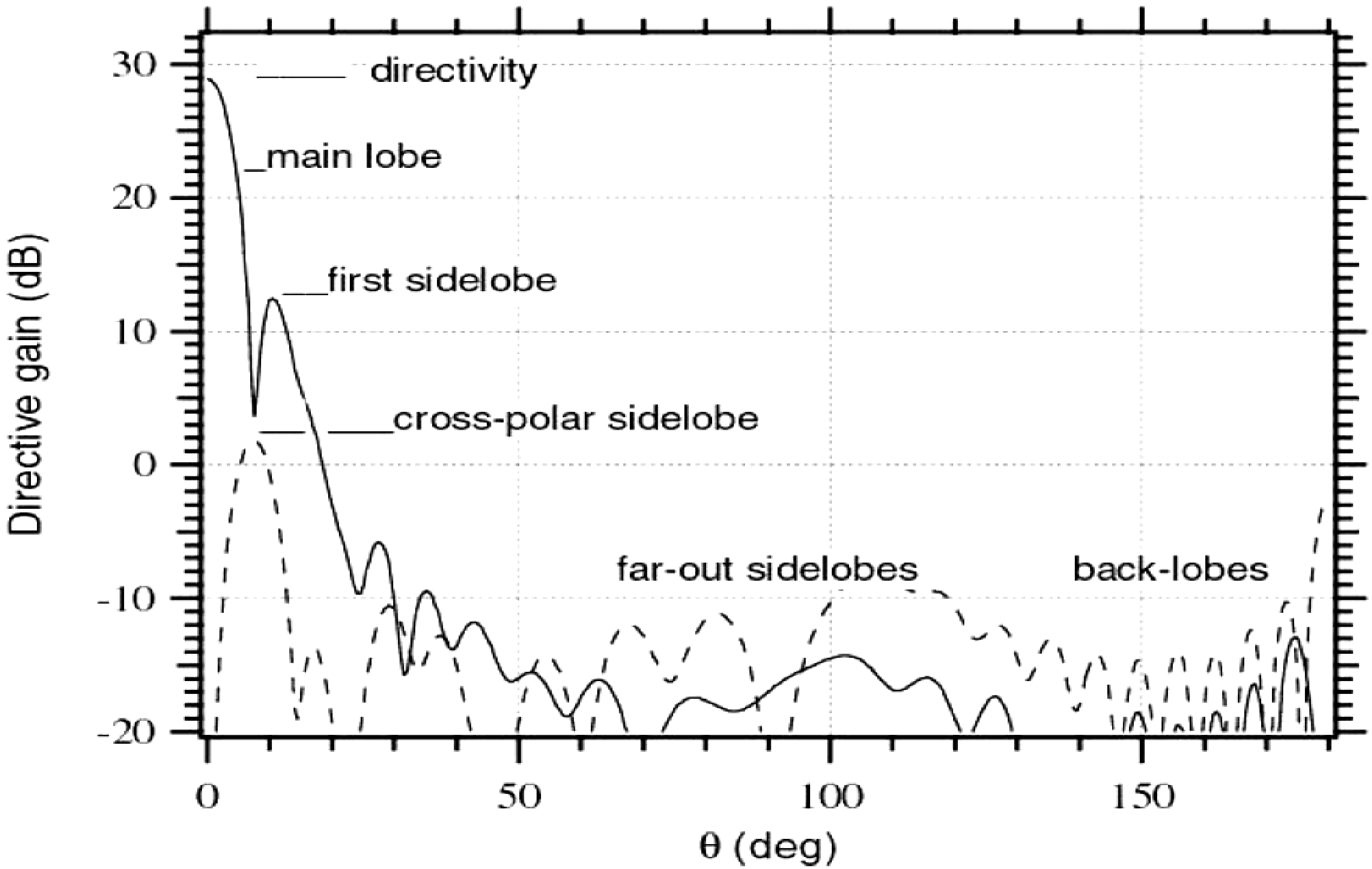
We must require $\hat{\mathbf{co}} \perp \hat{\mathbf{r}}$ and $\hat{\mathbf{xp}} \perp \hat{\mathbf{r}}$

Example of Radiation Pattern



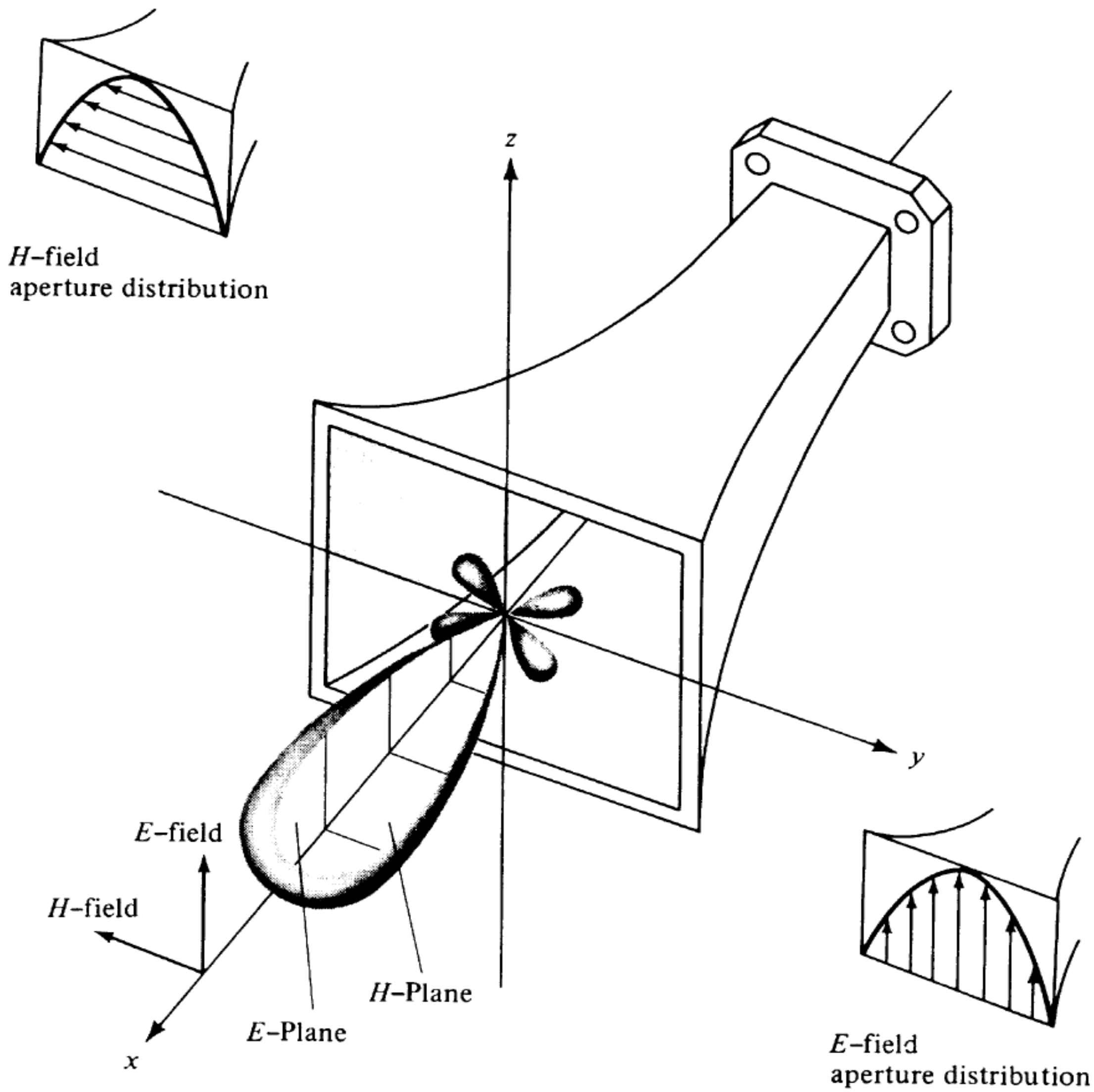


Example of Radiation Pattern, continued



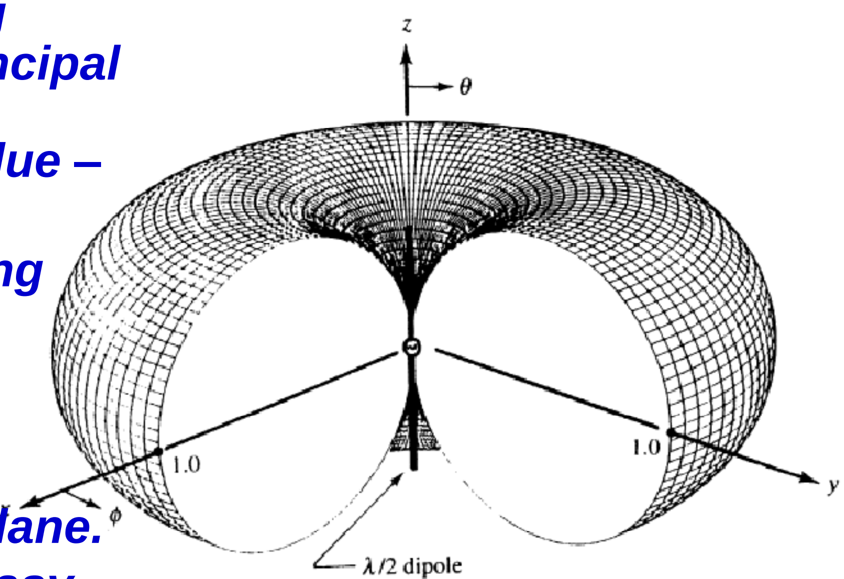
Far-Field Radiation Pattern of A Horn Antenna

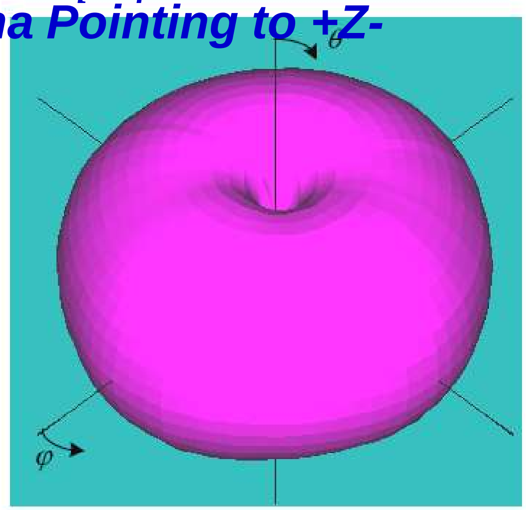
- *Electric (E) Field Component Pointing along Z-axis : Vertically Linear Polarized, Principal E-Plane of the Antenna is X-Z Plane.*
- *Magnetic (H) Field Component Pointing along Y-axis : Principal H-Plane of the Antenna is X-Y Plane.*
- *X-Polarization of the Electric Field Component defined in Y-axis Direction.*
- *Co-Pol vs. X-Pol Features Are Most Easy to Identify in the XYZ Rectangular Coordinate System with the Antenna Pointing to +Z-axis.*

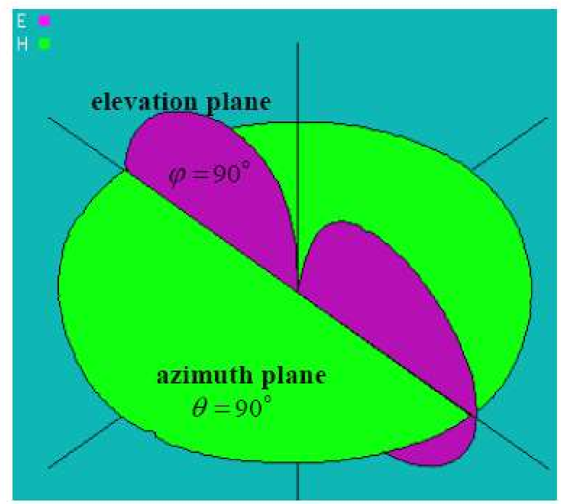


Far-Field Radiation Pattern of A Dipole Antenna

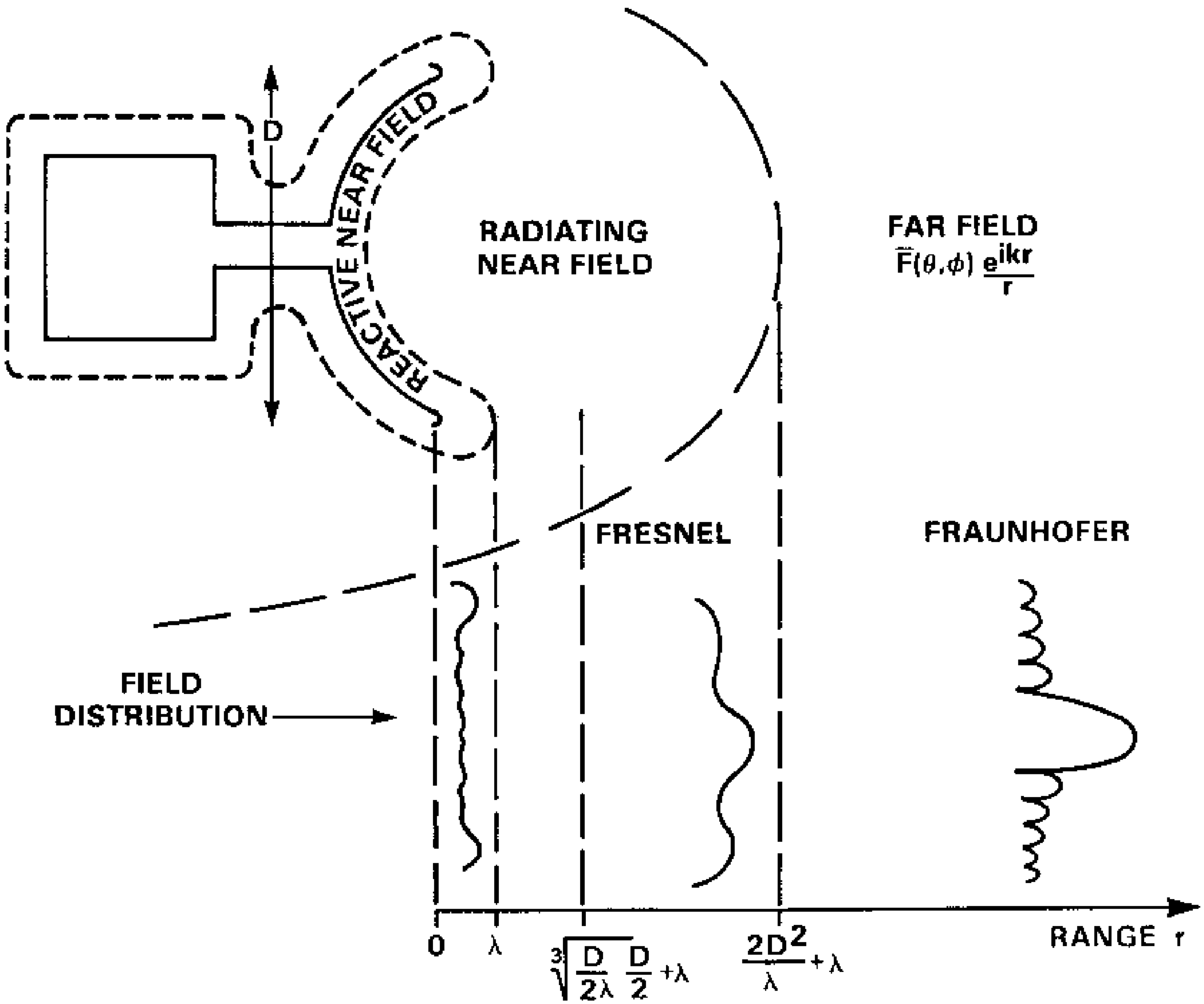
- *Electric (E) Field Component Pointing along q -dir : Vertically Polarized; Principal E-Plane of the Antenna Can Be Any Vertical Plane-cut with Constant ƒ Value – Omni-directional in ƒ -dir.*
- *Magnetic (H) Field Component Pointing along ƒ -dir : Principal H-Plane of the Antenna is defined by q =90 deg, X-Y Plane.*
- *X-Polarization of the Electric Field Component defined in ƒ -dir on X-Y Plane.*
- *Co-Pol vs. X-Pol Features Are Most Easy to Identify in the Spherical q –ƒ Coordinate System with the Antenna Pointing to +Z-axis.*



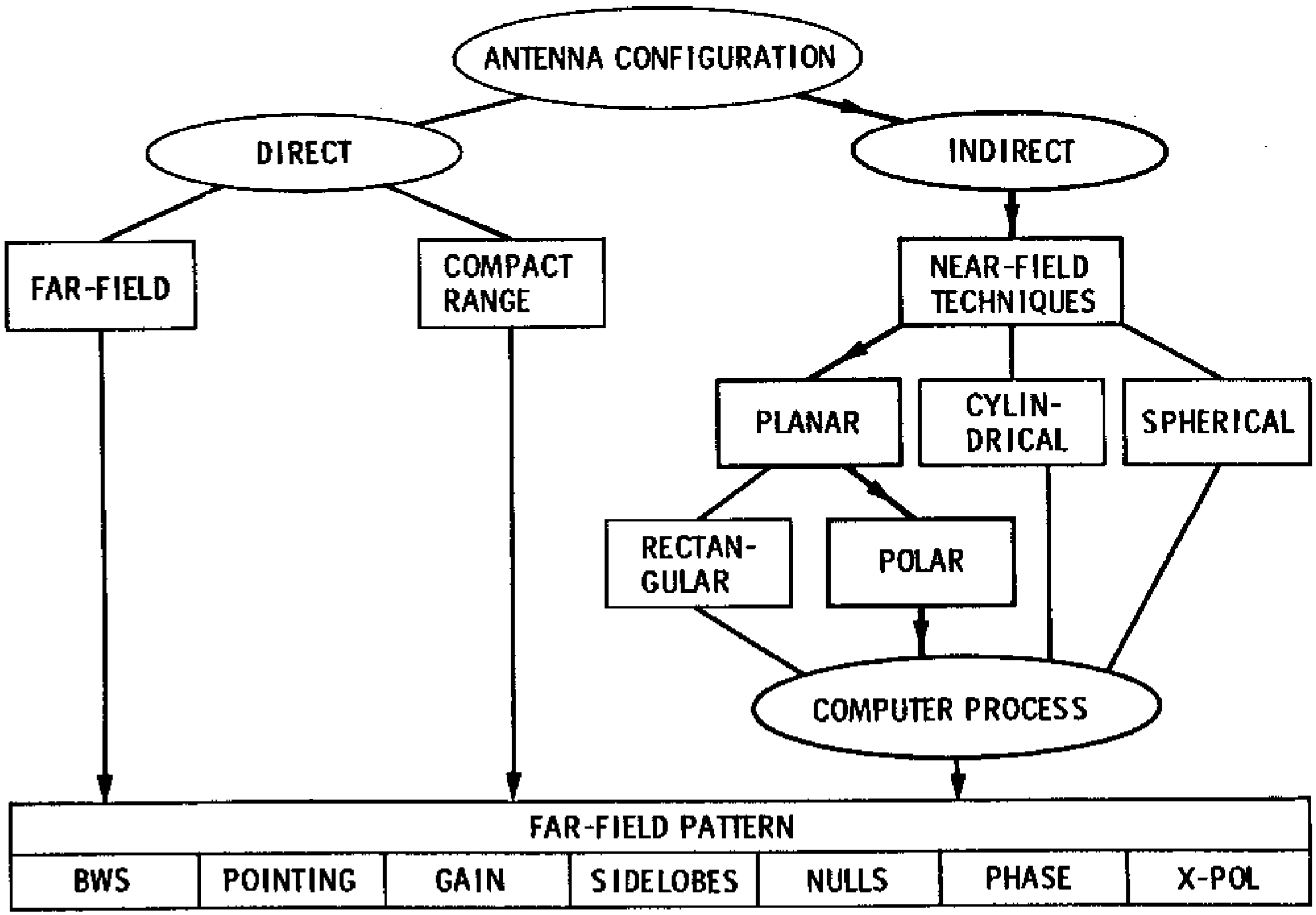




FIELDS NEAR A RADIATING ANTENNA



Categorization of Microwave Antenna Measurement



Methods of Microwave Antenna Measurement

Far-field method - Traditional

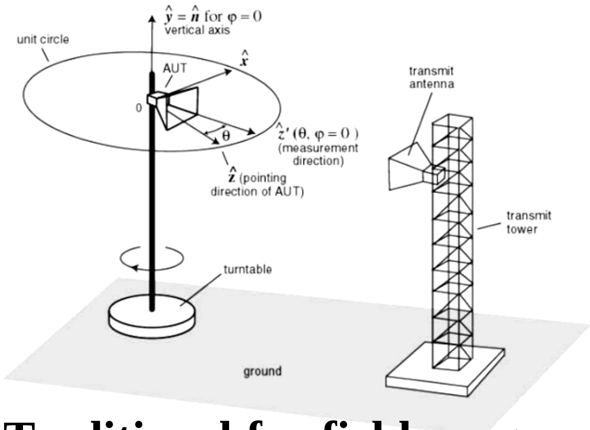
- *Well understood and most common*
- *Direct measurement of amplitude and/or phase in AUT far field region*
- *Various testing configurations*
  - *Outdoor test range*
  - *Anechoic chamber*
  - *Compact range*

Near-field methods (synthetic aperture)

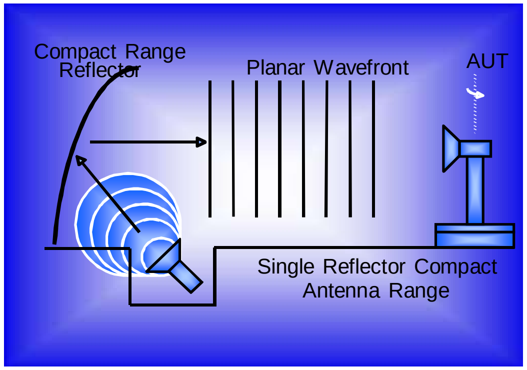
- *Mathematical calculation of far field pattern based on amplitude and phase sampled in radiating near field region*
- *Fully validated and well understood (NIST)*
- *Various testing configurations*
  - *Planar near-field*
  - *Cylindrical near-field*
  - *Spherical near-field*

TYPICAL ANTENNA MEASUREMENT SYSTEMS

Far-field measurements

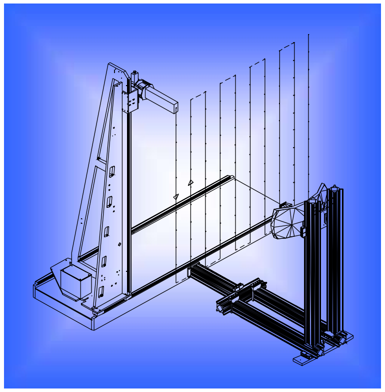


Traditional far-field range

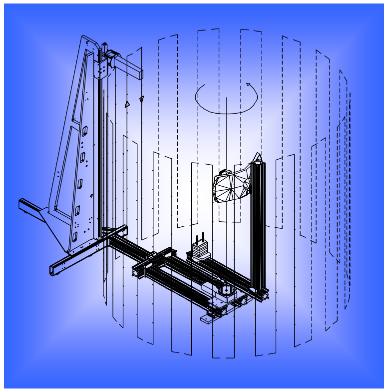


Compact range

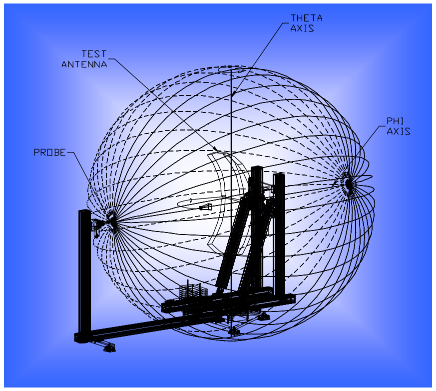
Near-field measurements



Planar



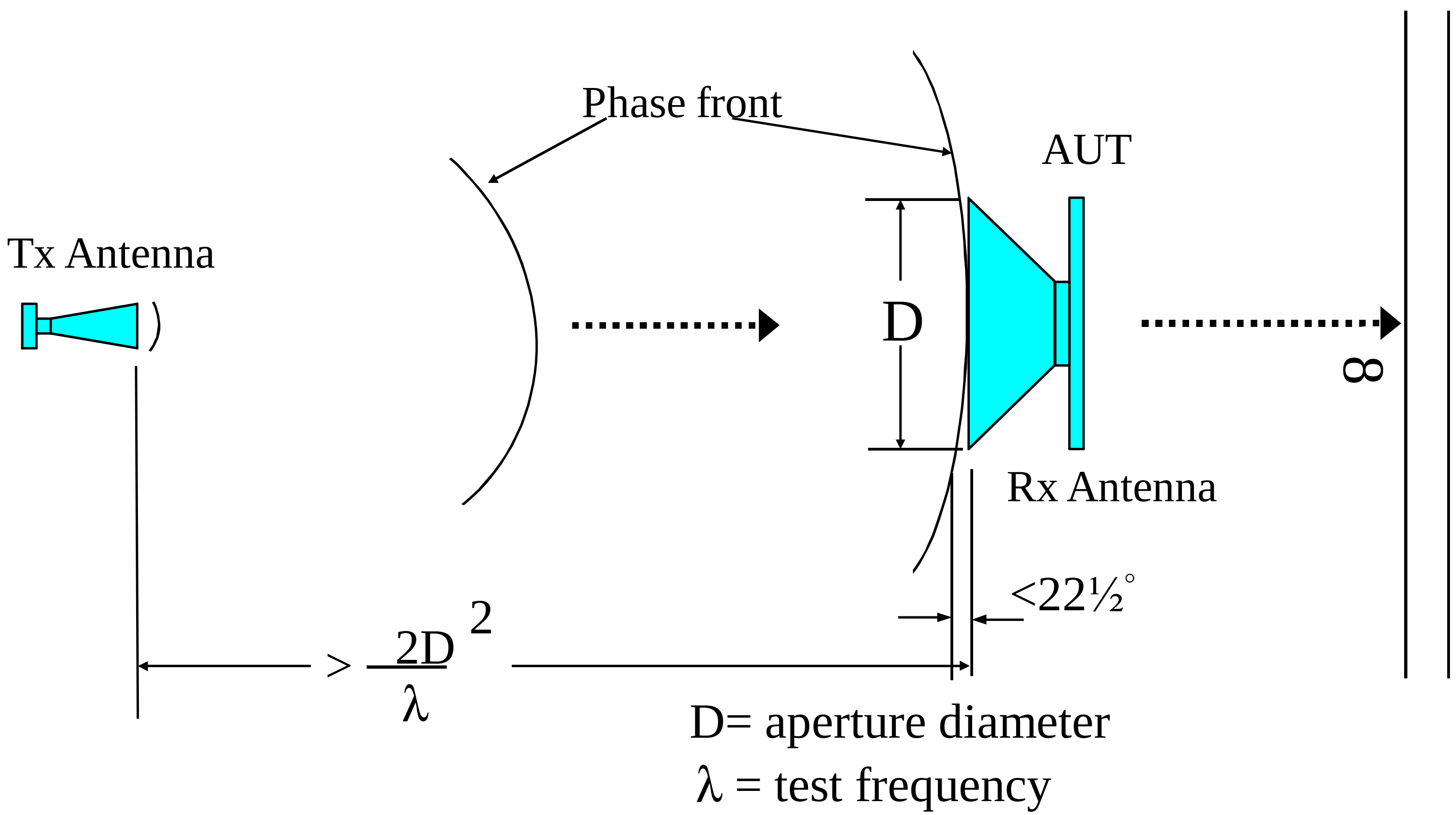
Cylindrical



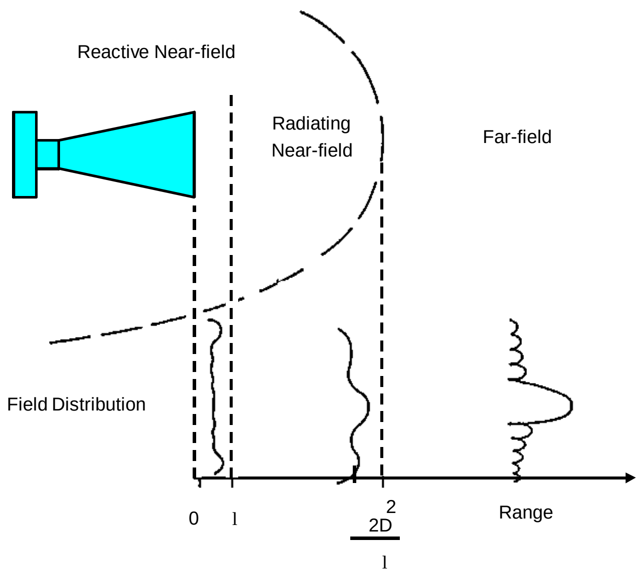
Spherical

Far-field Criteria

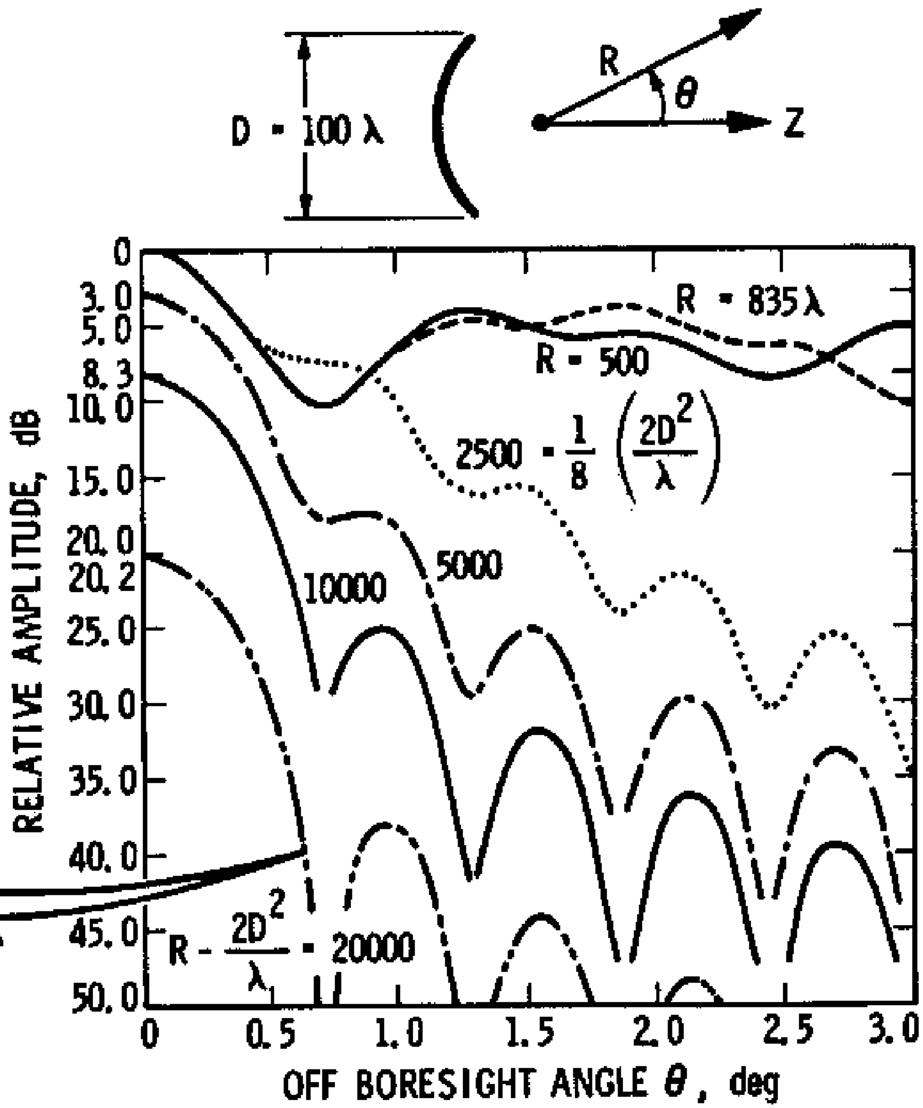
- *Sufficient antenna separation for flat phase front*
- *<22½° of phase taper across aperture*
- *<0.25 dB of amplitude taper across aperture*



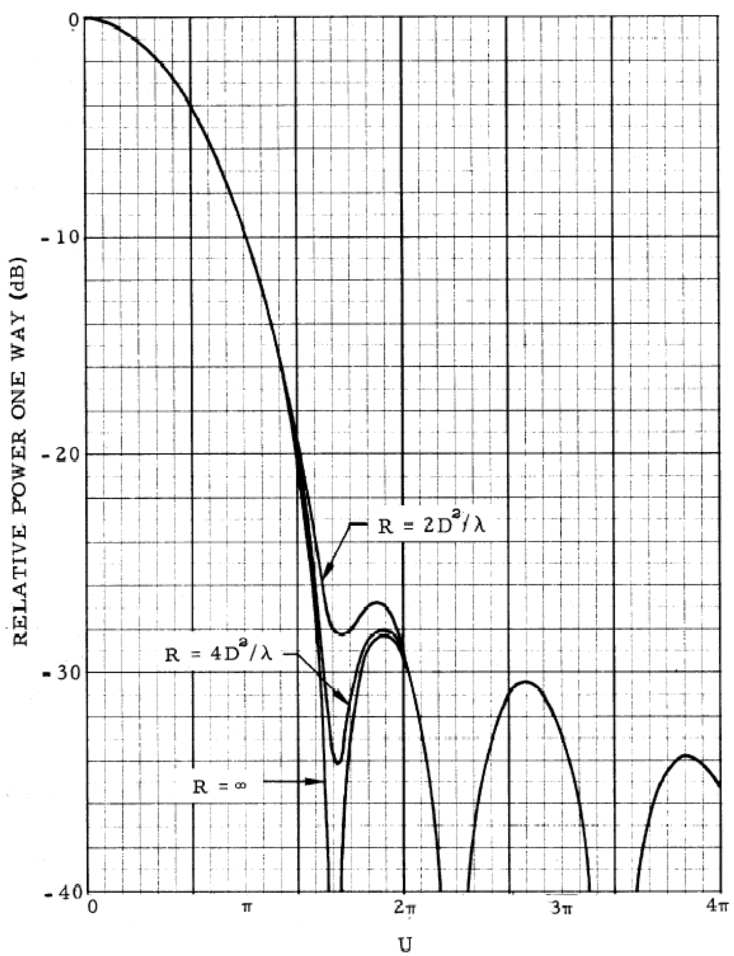
Evolution of The Far-Field Patterns

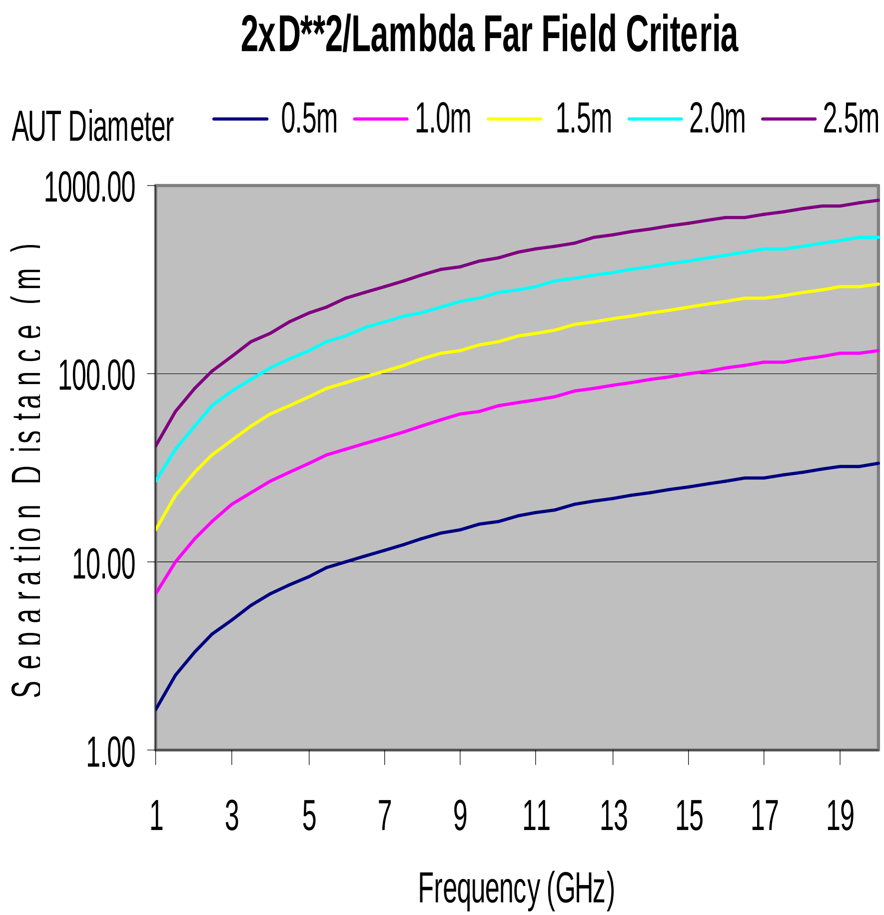


TO GET TO THE TRUE FAR-FIELD PATTERN DISTANCES AS LONG AS ($R > 2\frac{D^2}{\lambda}$ TO $8\frac{D^2}{\lambda}$) MAY BE REQUIRED.



Far-field Separation Distance

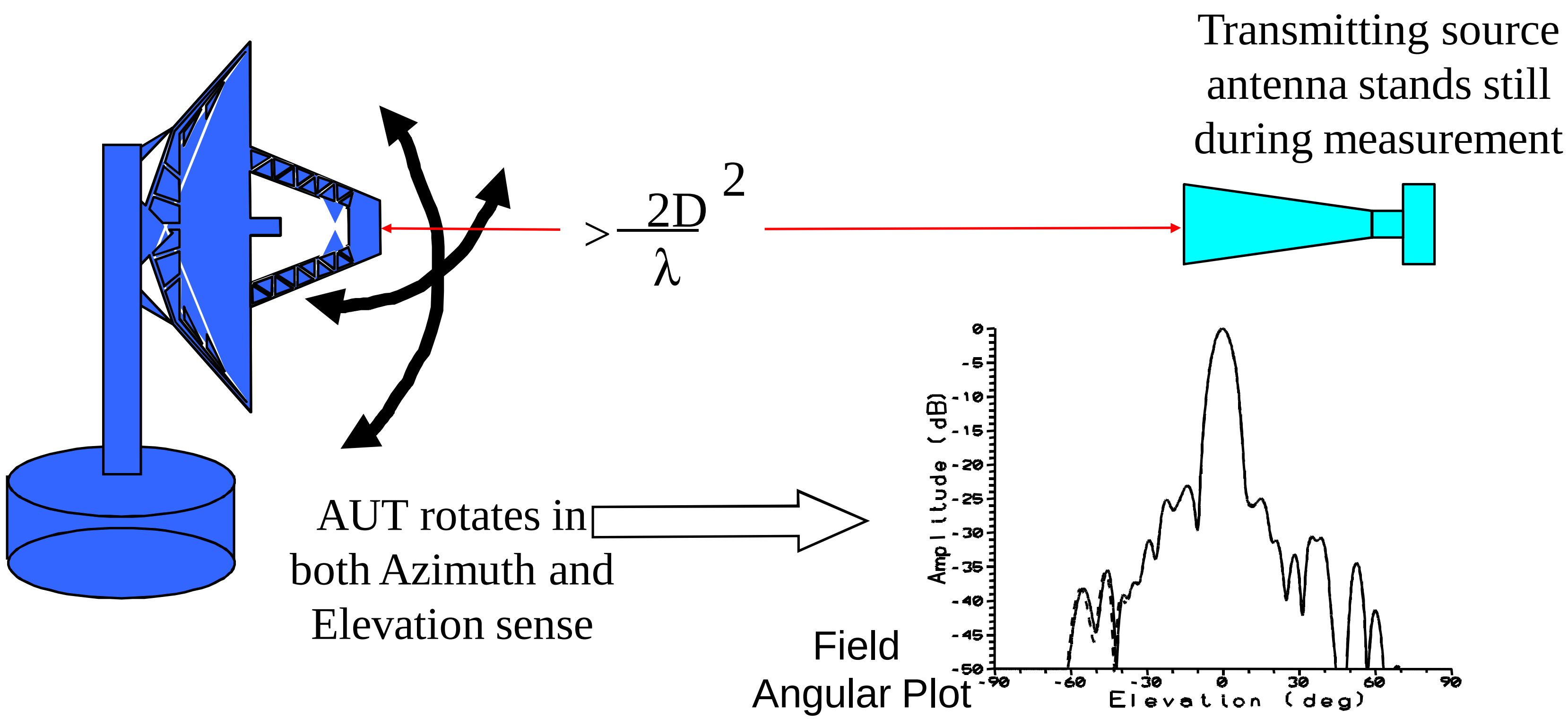




FAR-FIELD METHOD

Basic Features:

- ***Rotate antenna under test(AUT) in azimuth and elevation coordinates***
- ***AUT receives radiation irradiated from source antenna at a far-field distance***
- ***Receiver measures and records amplitude and/or phase on plotter or computer***

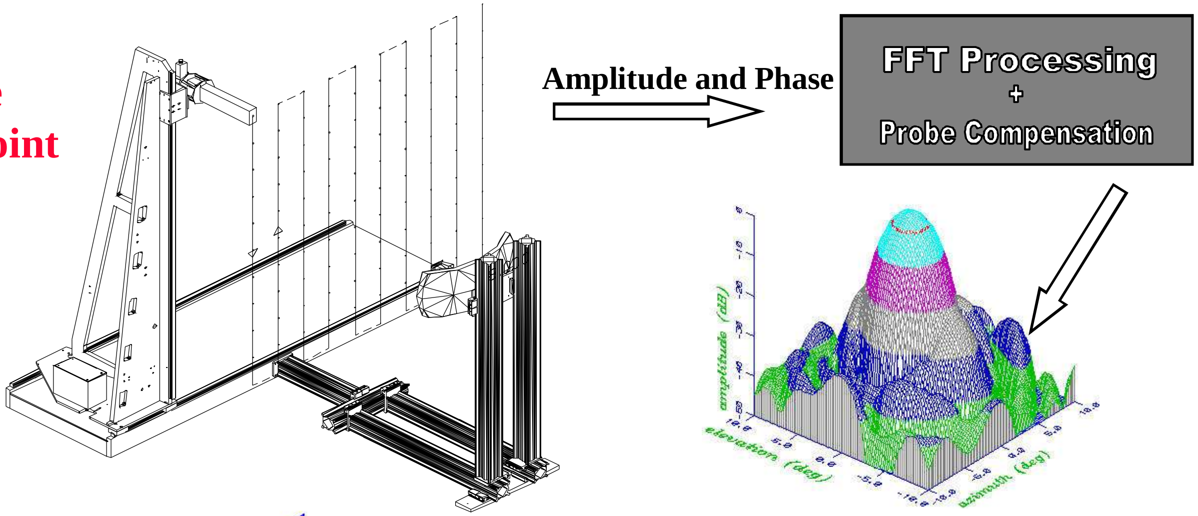


NEAR-FIELD METHOD

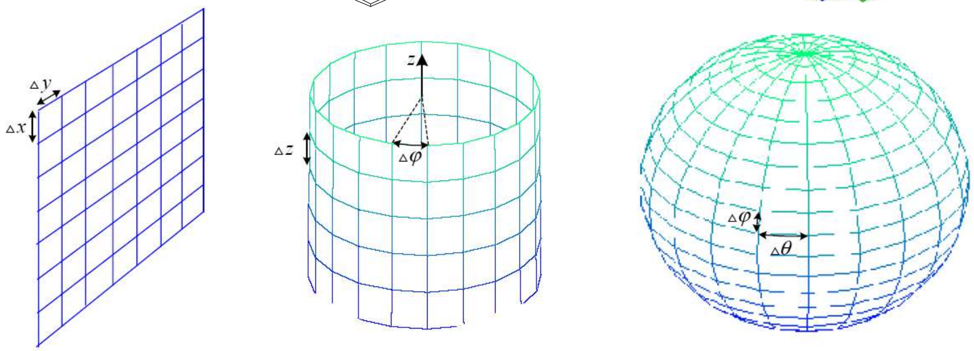
Basic Concept:

- ***Record amplitude and phase over a surface in the radiating near field (3~5λ)***
- ***Process with a near-field to far-field transformation algorithm to produce full 3-D far field data.***

Case of planar near field type scan for high-gain point-to-point wireless networking antenna measurement:



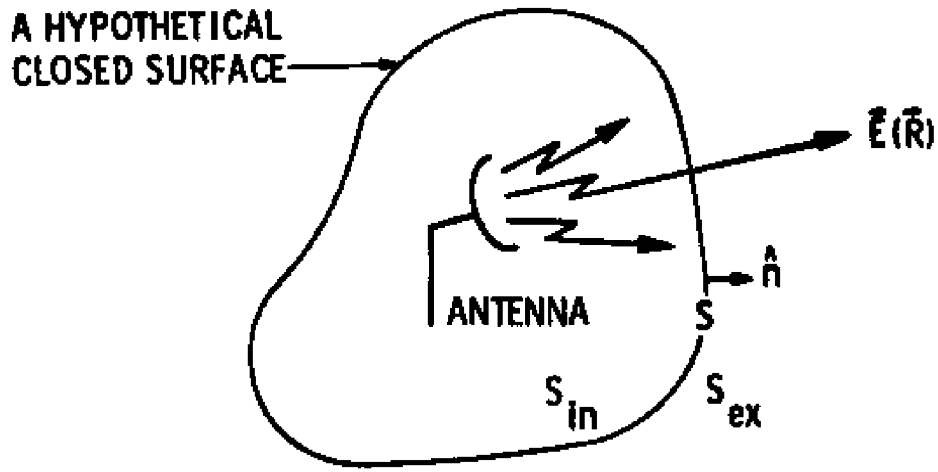
Common scan geometry for AUT near-field sampling aperture:



Near-field Measurements - Fundamental Principle

"GENERALIZED HUYGENS (1629~1695) THEOREM"

PROBLEM: GIVEN THE ANTENNA, WHAT IS THE RADIATED FIELD??



FROM MAXWELL's EQUATION (1831-1879)

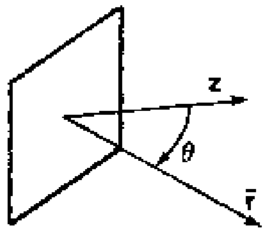
$$\vec{E}(\vec{R}) = \int\!\!\int_S \left\{ j\omega\mu_0 \left[\hat{n} \times \vec{H}(\vec{R}')\right] \cdot \bar{\bar{G}}(\vec{R}', \vec{R}) + \left[\hat{n} \times \vec{E}(\vec{R}')\right] \cdot \nabla' \times \bar{\bar{G}}(\vec{R}', \vec{R}) \right\} ds'$$

$$\vec{R} \in S_{ex}$$

OBSERVATION: TANGENTIAL FIELDS ON A CLOSED SURFACE
⇒ EXTERIOR FIELDS EXACTLY

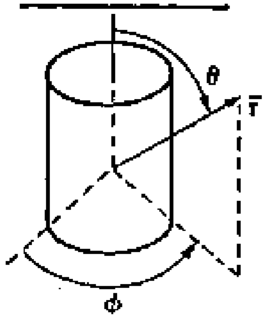
Far Electric Field, (r ð ∞)

PLANAR:



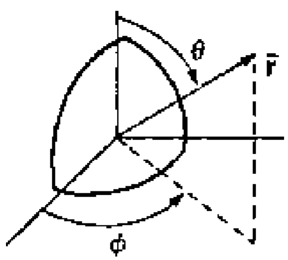
$$\bar{E}(r,\theta,\phi) = \frac{-ike^{ikr}}{r}\cos\theta\,\bar{T}(\sin\theta\cos\phi,\ \sin\theta\sin\phi)$$

CYLINDRICAL:



$$\bar{E}(r,\theta,\phi) = \frac{-2ke^{ikr}}{r}\sin\theta\sum_{m=-\infty}^{\infty}(-i)^m\left[\bar{T}_m(k\cos\theta)\right]e^{im\phi}$$

SPHERICAL:



$$\bar{E}(r,\theta,\phi) = \frac{-ie^{ikr}}{r}\sum_{n=0}^{\infty}\sum_{m=-n}^{n}(-i)^n\left[T^E_{nm}\bar{M}_{nm}(\theta) + T^M_{nm}\bar{N}_{nm}(\theta)\right]e^{im\phi}$$

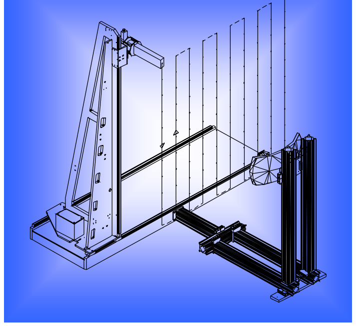
NEAR-FIELD SCAN TYPES

- ***Planar near-field***
  - ***Directional antennas***
  - ***Gain > 15 dBi***
  - ***Max angle < ±70 º***

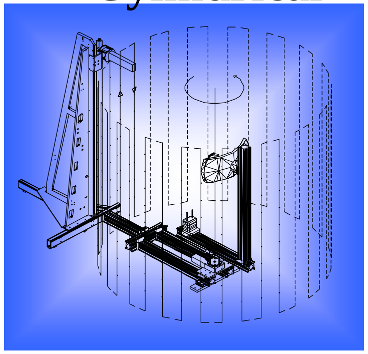
- ***Cylindrical near-field***
  - ***Fan beam antennas***
  - ***Wide side or back lobes***

- ***Spherical near-field***
  - ***Low gain antennas***
  - ***Wide or omni-directional patterns on any antennas***

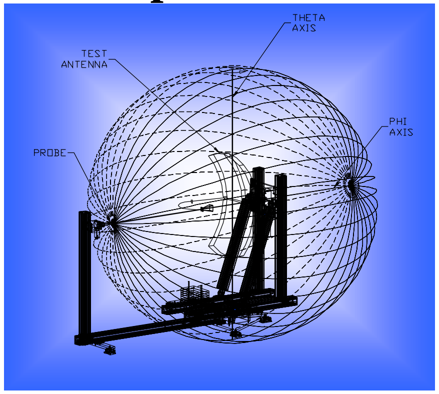
Planar



Cylindrical

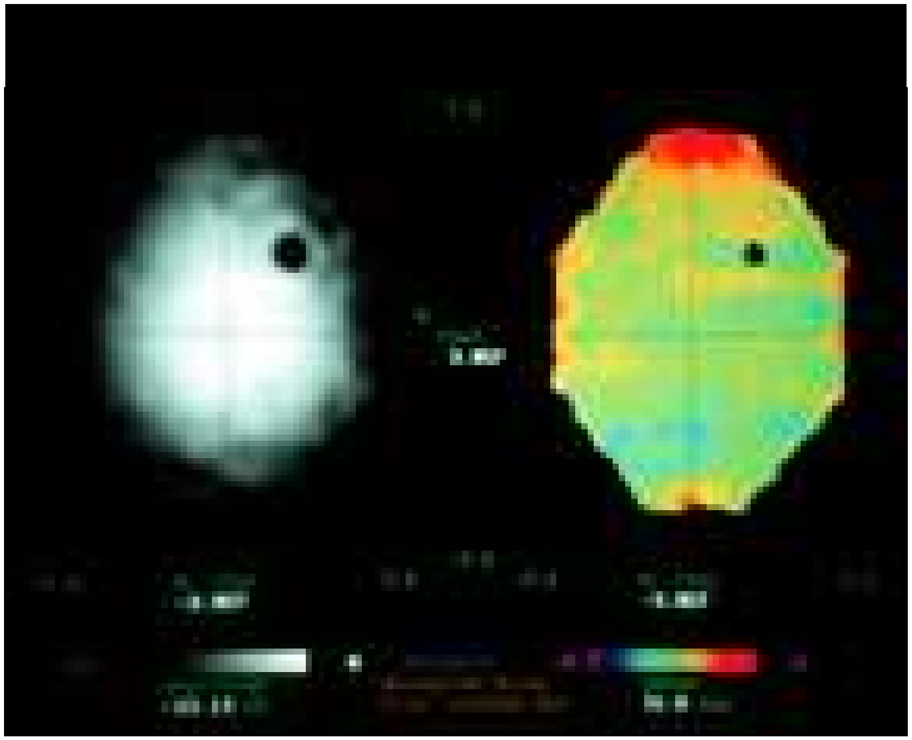


Spherical

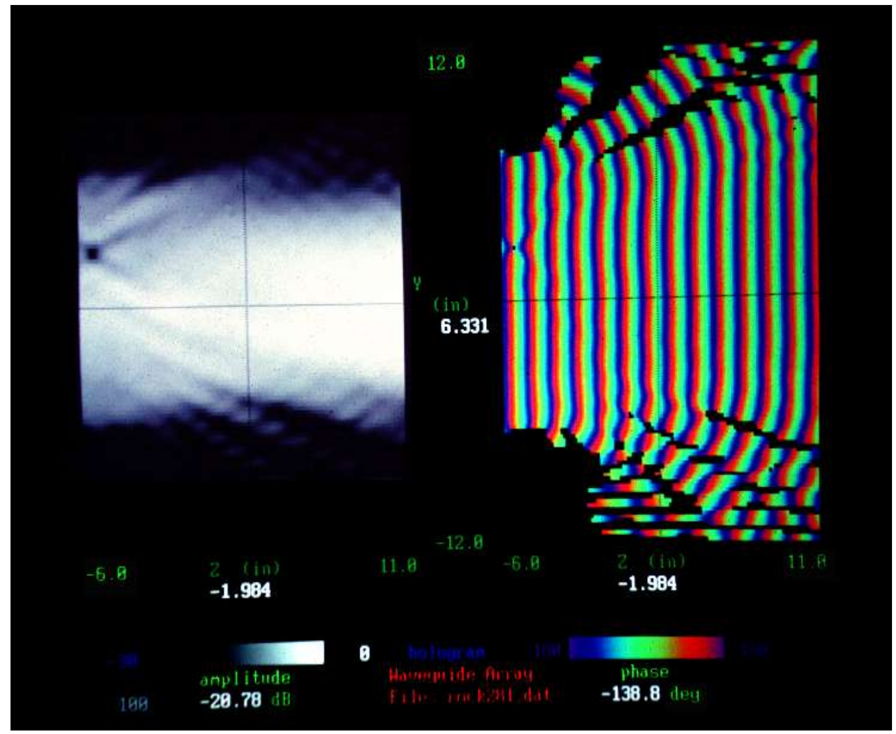


MICROWAVE HOLOGRAPHIC IMAGING

Fields across aperture

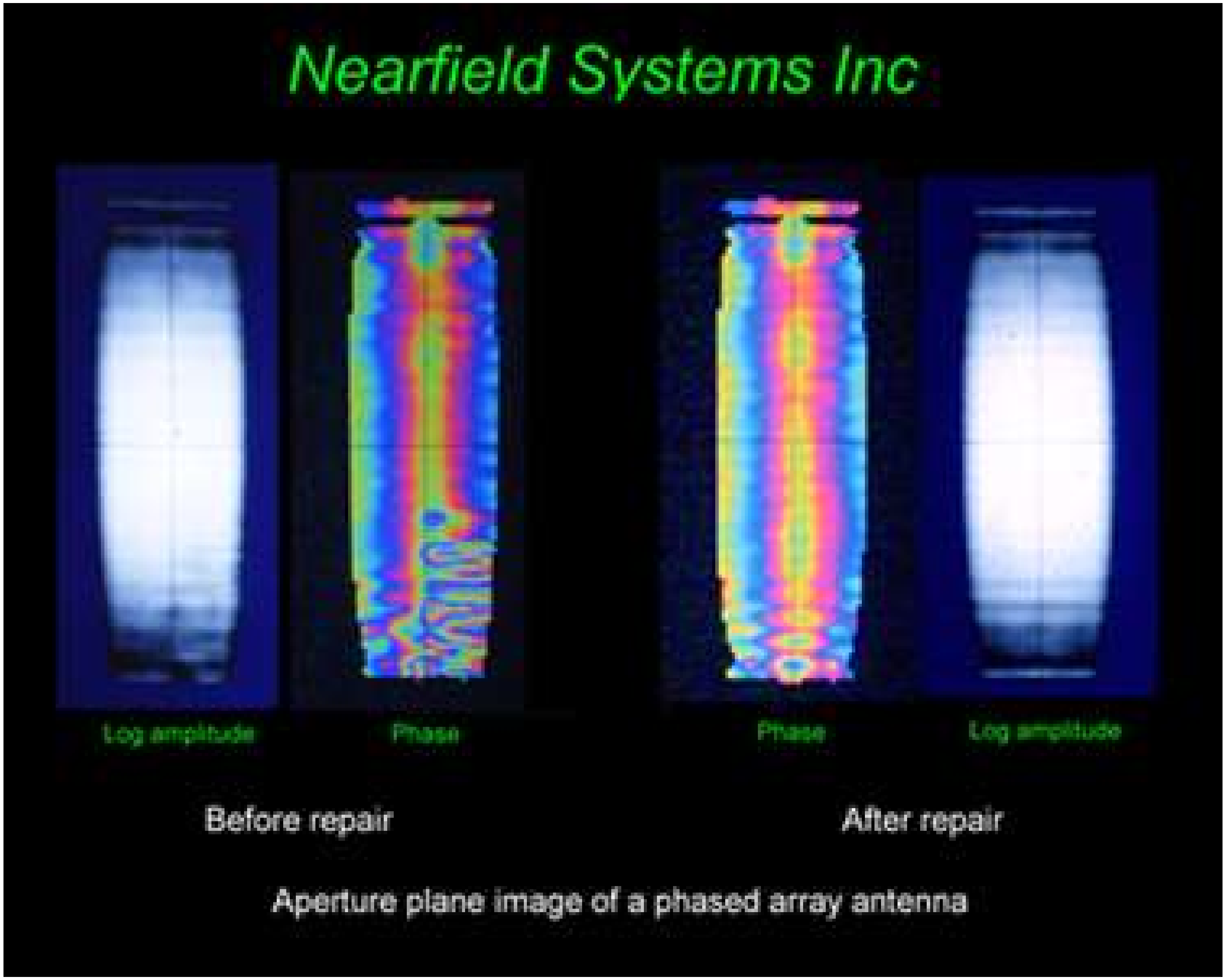


Fields normal to aperture



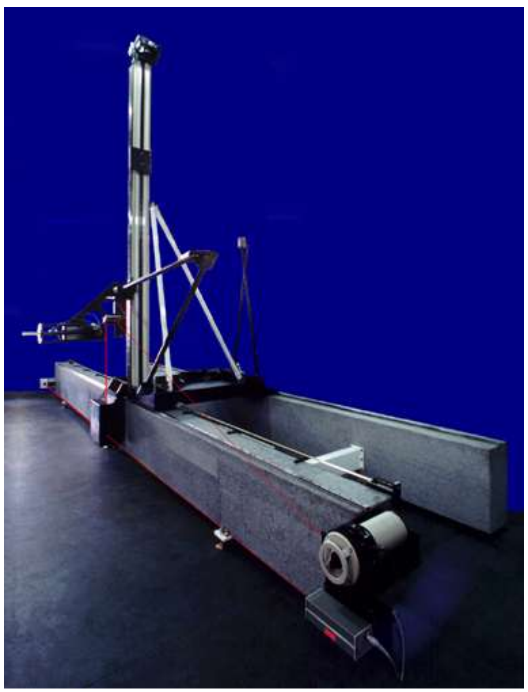
- Tuning for phased array antennas
- Reflector surface error mapping
- Aperture diagnostics for faulty array elements
- Radome system performance and diagnostics

APERTURE DIAGNOSTICS

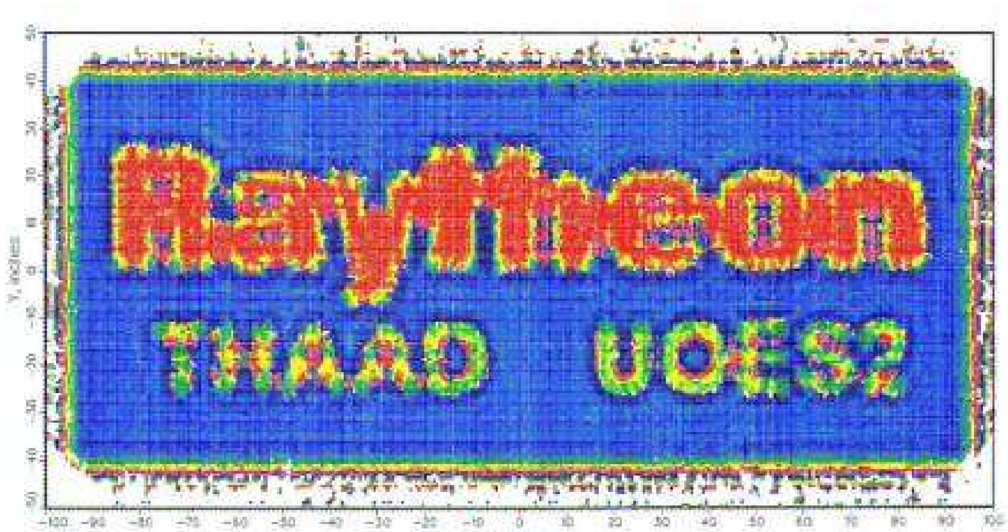


NEARFIELD AND HOLOGRAM BACK-PROJECTION

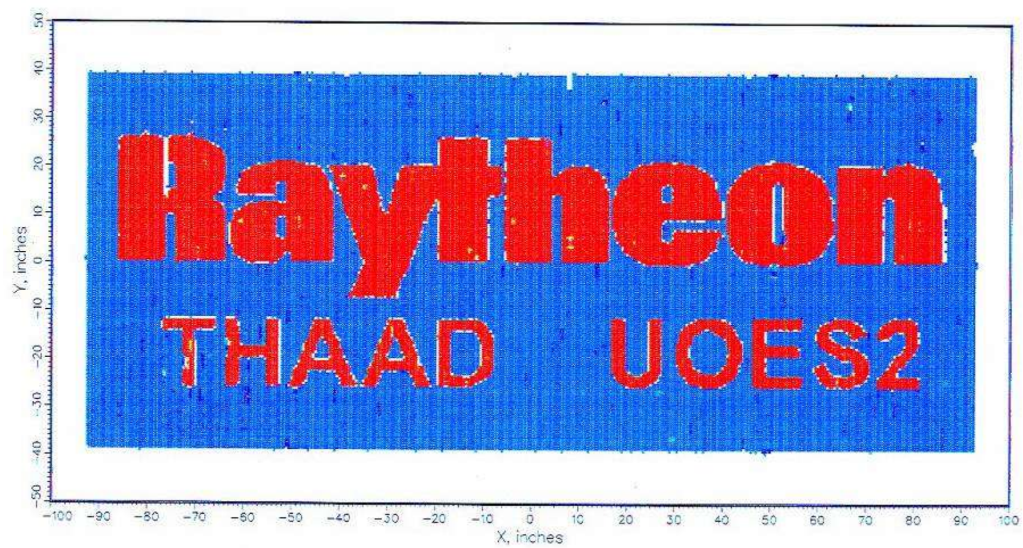
Measured phase of THAAD array at .3m distance with 25,344 active elements with 6 bit phase shifter, 6 bit attenuator in special ‘calibration’ mode



NF

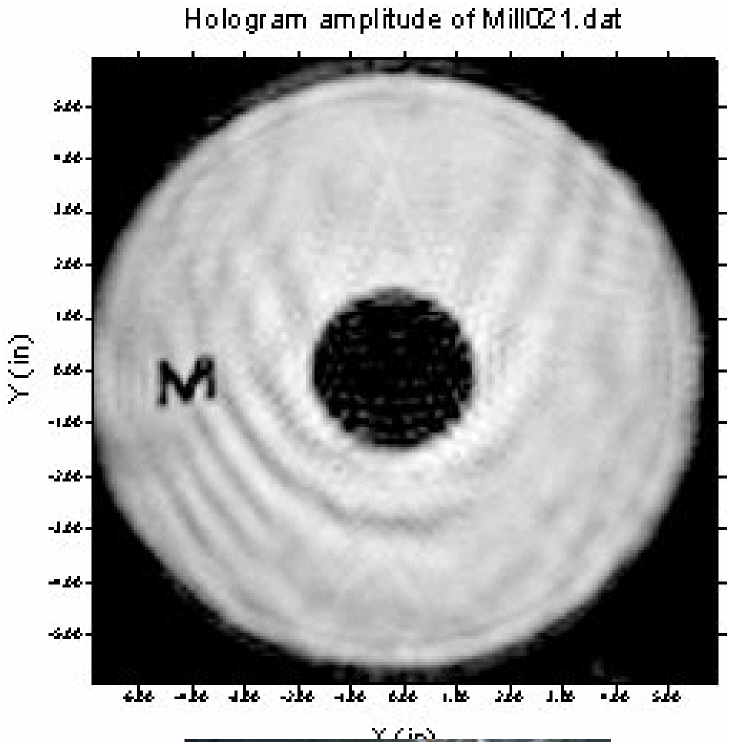


HOLO



HOLOGRAM DEMONSTRATION

- ***AUT - Millitech Lens antenna with center blockage***
- ***Test frequency - 94 GHz***
- ***NSI 901V-3x3 scanner system with Agilent 85301C RF system***
- ***Lens aperture corrupted with the letter "M" with aluminum tape***
- ***Hologram processed at 9 Z positions over the 19 lambda distance from measurement plane back to lens aperture***



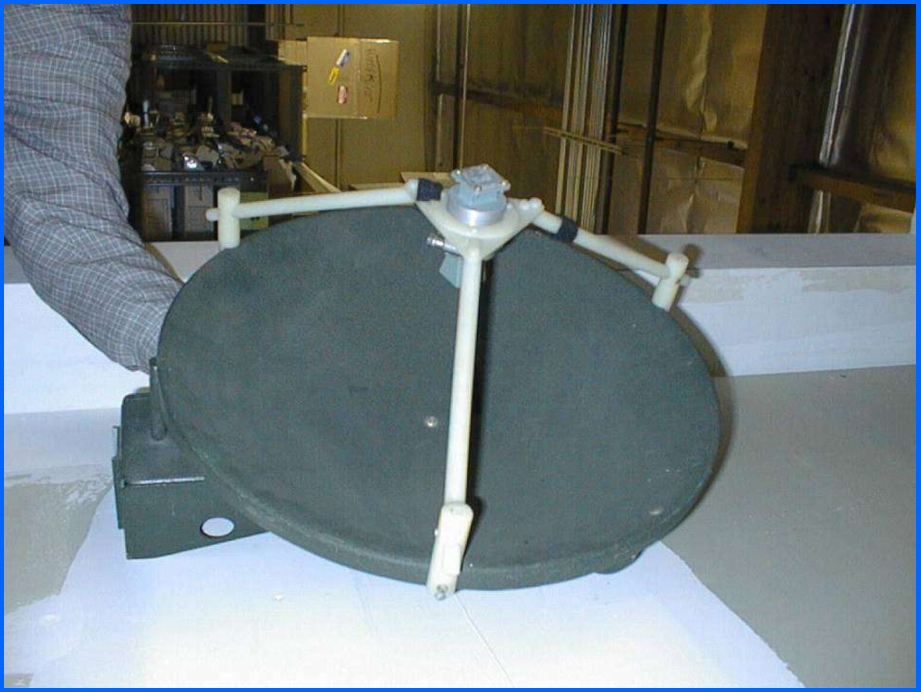
ANTENNA MEASUREMENT FACILITIES FOR MICROWAVE COMMUNICATION APPLICATIONS

Horn Antenna: Directional, Moderate Gain

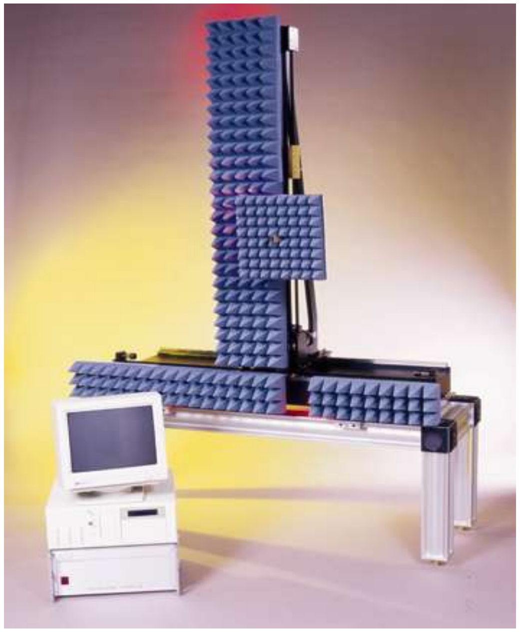
ANTENNA TYPE	TYPICAL GAIN	PLANAR SUITABILITY	CYLINDRICAL SUITABILITY	SPHERICAL SUITABILITY	FAR-FIELD SUITABILITY
Horn	16 dBi	Good	Good	Good	Good

Reflector Antenna: High Gain, Highly Directional

ANTENNA TYPE	TYPICAL GAIN	PLANAR SUITABILITY	CYLINDRICAL SUITABILITY	SPHERICAL SUITABILITY	FAR-FIELD SUITABILITY
Small reflector	> 25 dBi	Good	Good	Good	Good

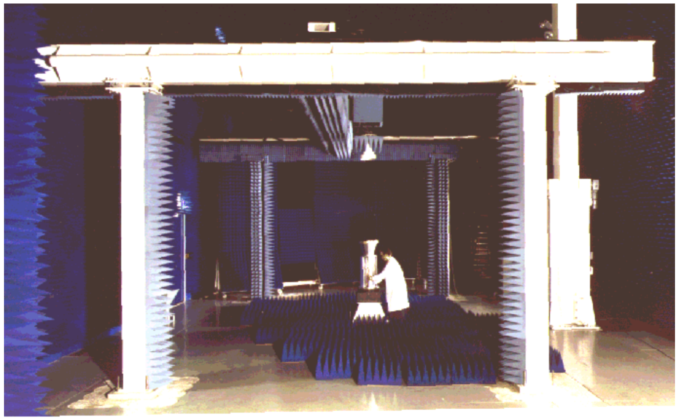


Examples of Planar Near-field Systems



1m x 1m (3'x3')
Vertical Planar NF

2.4m x 2.4m (8'x8')
Vertical Planar NF



7m x 7m (22'x22')
Horizontal Planar NF

Smart Antennas: Directional, Dynamic Beam Steering

ANTENNA TYPE	TYPICAL GAIN	PLANAR SUITABILITY	CYLINDRICAL SUITABILITY	SPHERICAL SUITABILITY	FAR-FIELD SUITABILITY
Electronically Beam Steered Smart Ant	> 10 dBi	Depending on actual antenna configuration and gain	Good	Good	Good

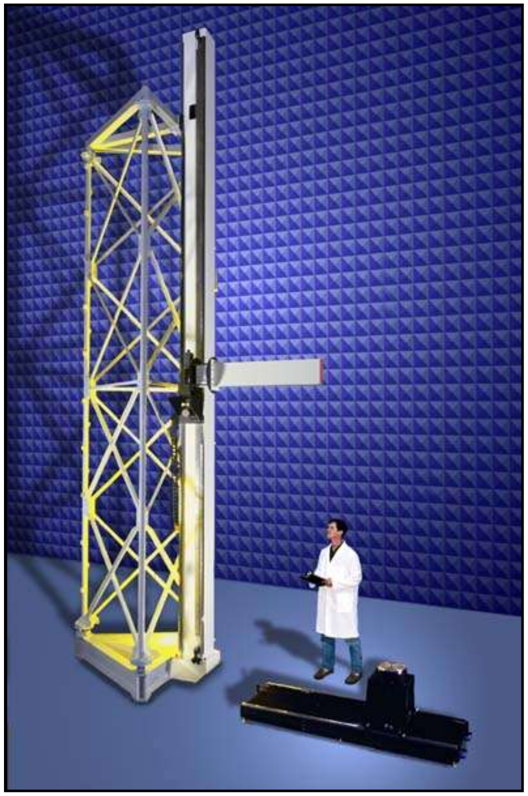
PCS Base Station Antenna: Sector Beam

ANTENNA TYPE	TYPICAL GAIN	PLANAR SUITABILITY	CYLINDRICAL SUITABILITY	SPHERICAL SUITABILITY	FAR-FIELD SUITABILITY
PCS base station	12 dBi	Not suitable	Ideal	Fair	Good

Cylindrical Near-Field Systems for Fan-Beam Antennas

1.5m (5') Cylindrical NF

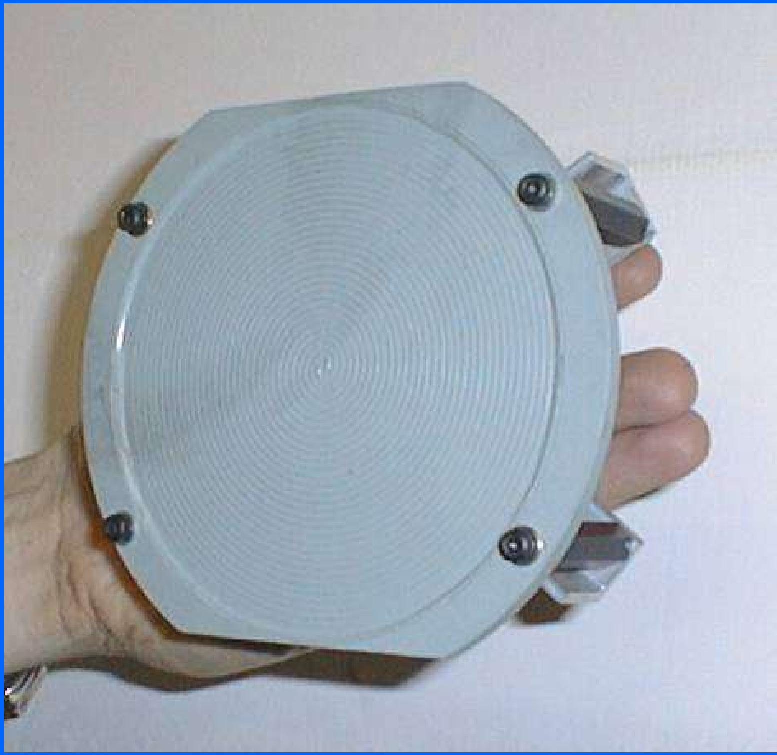
2.4m (8') Cylindrical NF



7m (22') Cylindrical NF

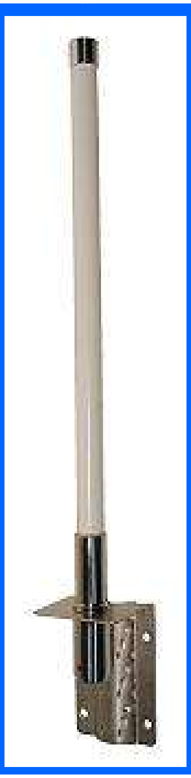
Patch Spiral or Conical Antenna: Wide Beam Coverage, Ultra-wide Bandwidth

ANTENNA TYPE	TYPICAL GAIN	PLANAR SUITABILITY	CYLINDRICAL SUITABILITY	SPHERICAL SUITABILITY	FAR-FIELD SUITABILITY
Patch or conical	6 dBi	Not suitable	Fair	Good	Good



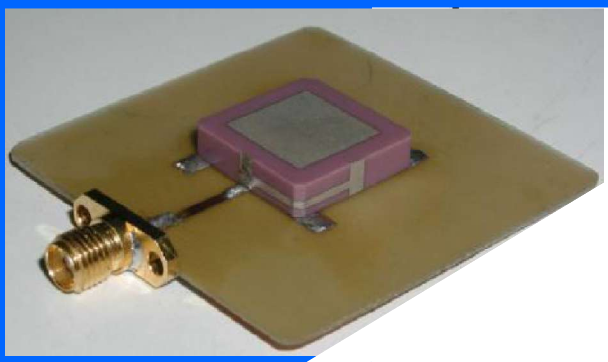
Dipole/Monopole Antennas: Omni-Directional for AP

ANTENNA TYPE	TYPICAL GAIN	PLANAR SUITABILITY	CYLINDRICAL SUITABILITY	SPHERICAL SUITABILITY	FAR FIELD SUITABILITY
Omni-directional Dipole / Monopole	<10 dBi	Not suitable	Fair	Good	Good

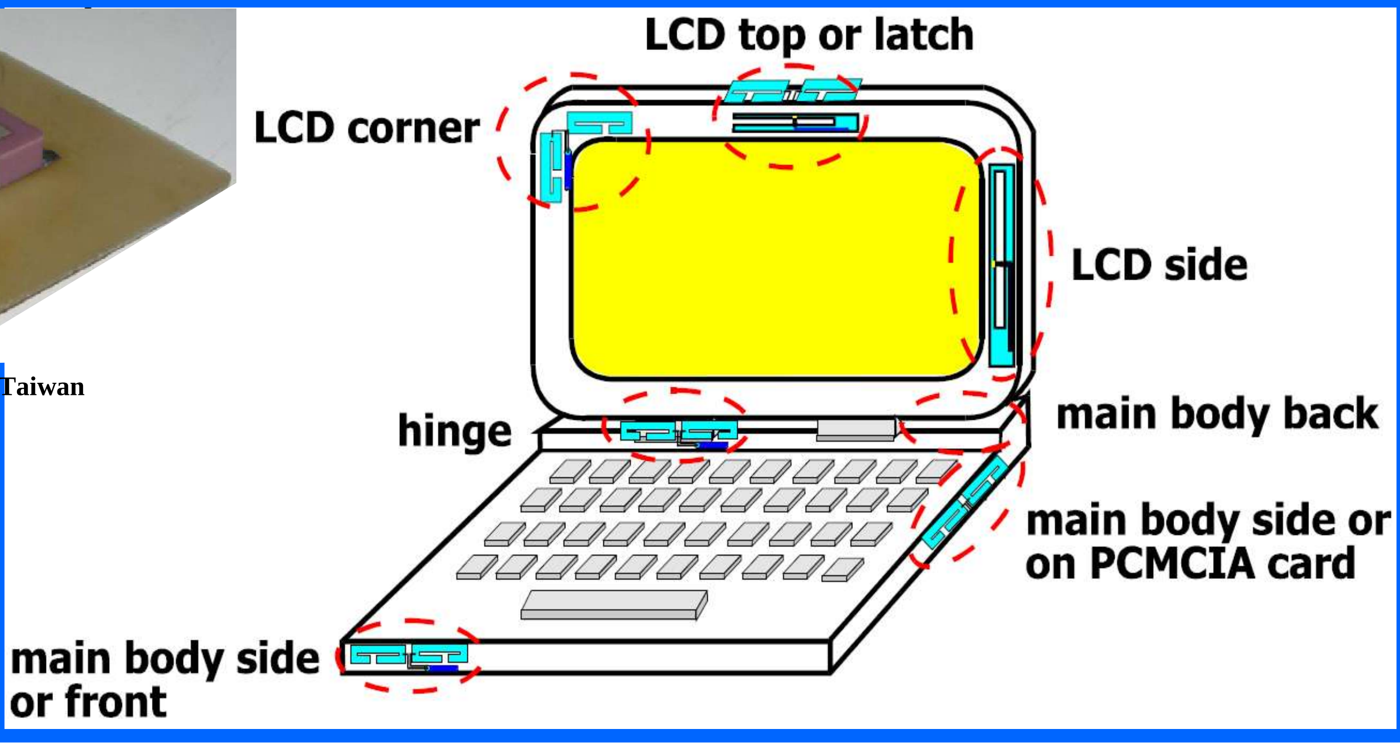


Planar Antennas: Printed Dipoles/Monopoles/Slot Antennas/ PIFAs/Chip Antennas for Clint Devices of Wireless Communication

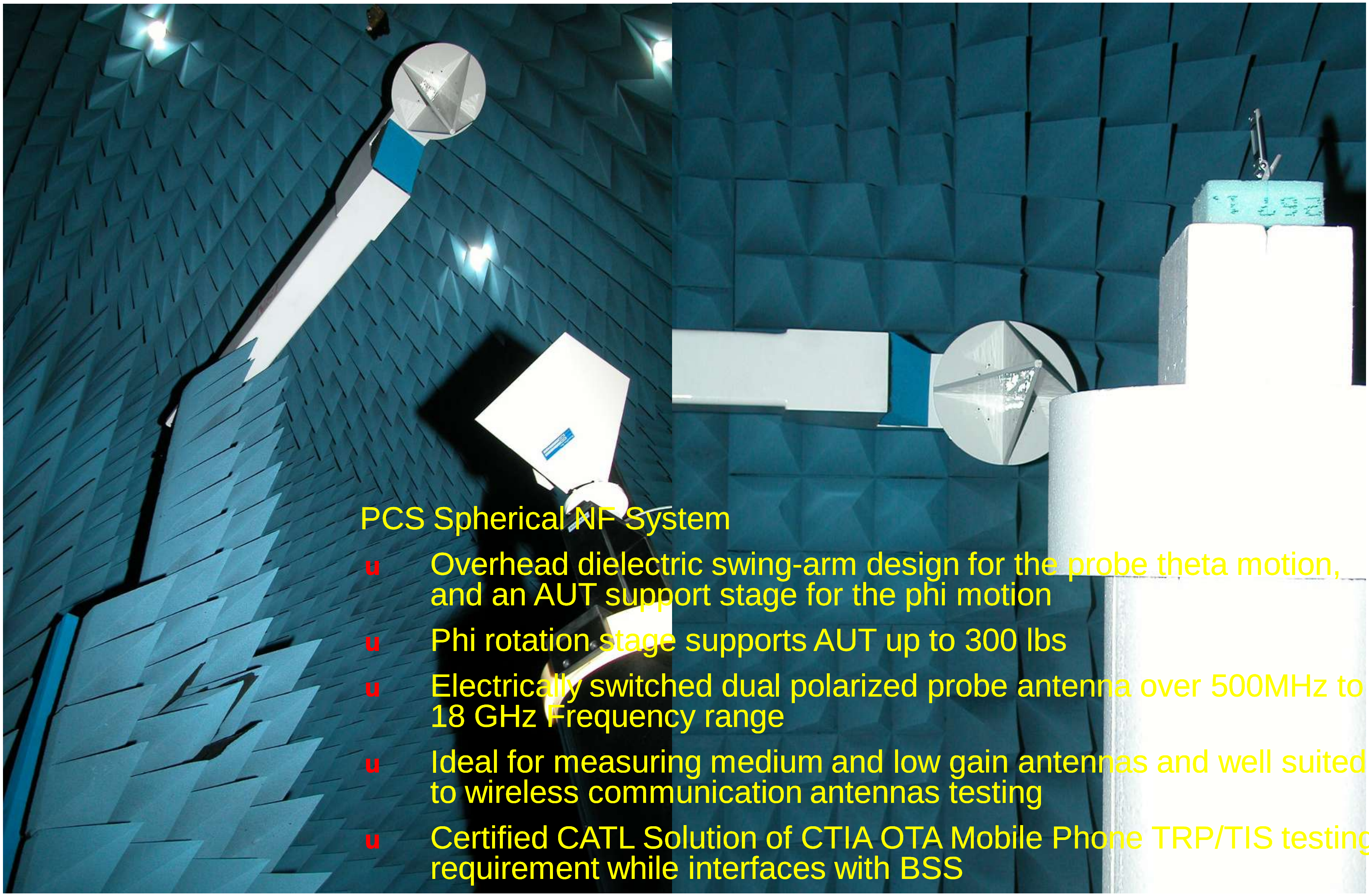
ANTENNA TYPE	TYPICAL GAIN	PLANAR SUITABILITY	CYLINDRICAL SUITABILITY	SPHERICAL SUITABILITY	FAR-FIELD SUITABILITY
PIFA microstrip antenna, chip antenna, PCB antenna (SMT)	~ 0 dBi	Not suitable	Not suitable	Good	Good



Source: Prof K. L. Wong, NSYSU Taiwan



Spherical Near-Field Scanning System for Low Gain Wireless Communication And Mobile Handsets Antennas Testing

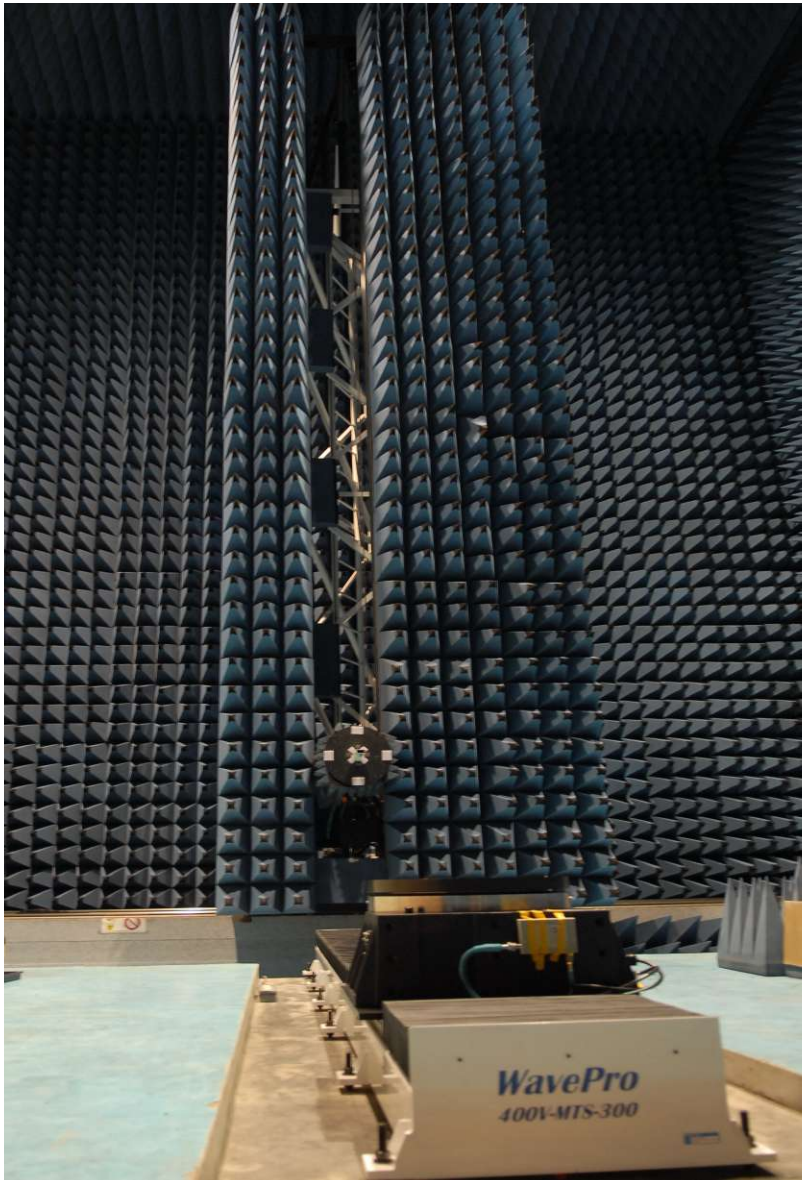


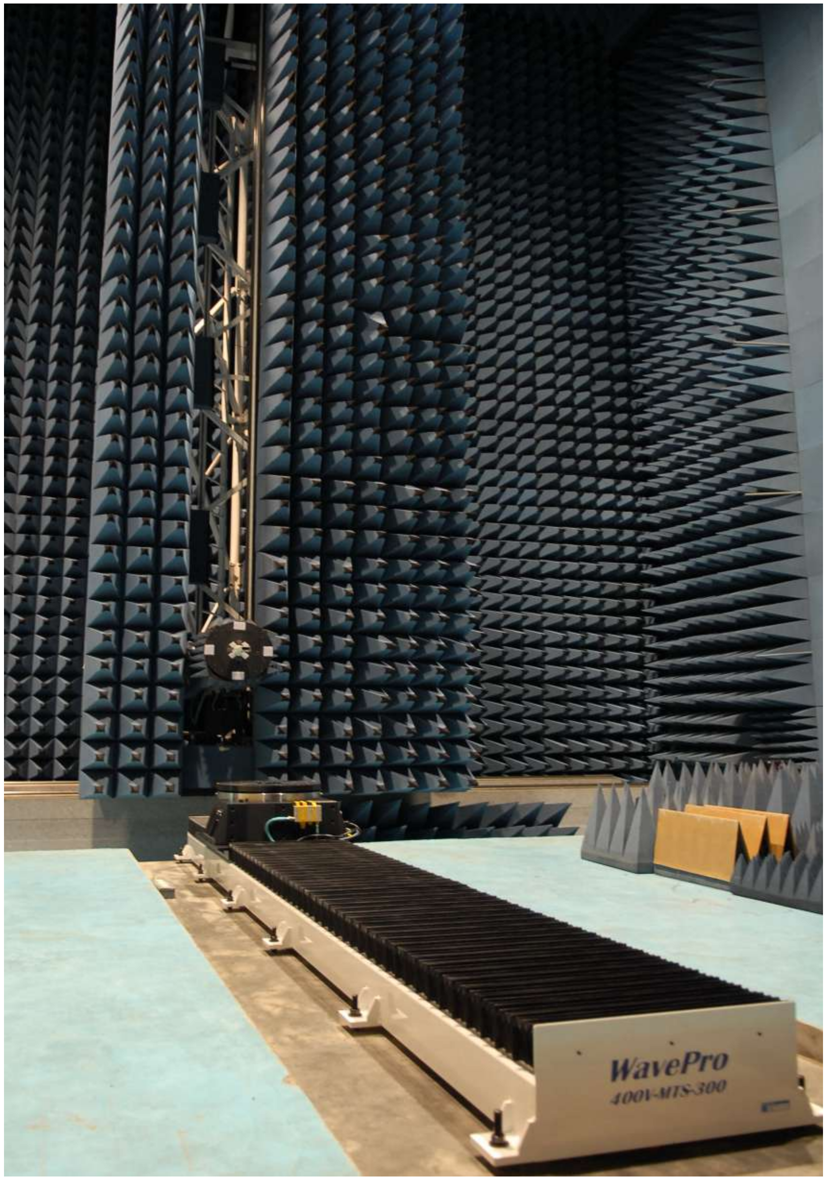
PCS Spherical NF System

- Overhead dielectric swing-arm design for the probe theta motion, and an AUT support stage for the phi motion
- Phi rotation stage supports AUT up to 300 lbs
- Electrically switched dual polarized probe antenna over 500MHz to 18 GHz Frequency range
- Ideal for measuring medium and low gain antennas and well suited to wireless communication antennas testing
- Certified CATL Solution of CTIA OTA Mobile Phone TRP/TIS testing requirement while interfaces with BSS

EXAMPLES OF MEASUREMENT FACILITIES FOR MICROWAVE ANTENNAS

CSIST Antenna Systems Section 23'X22' Vertical Planar Near-Field System with Cylindrical Scanning Add-On

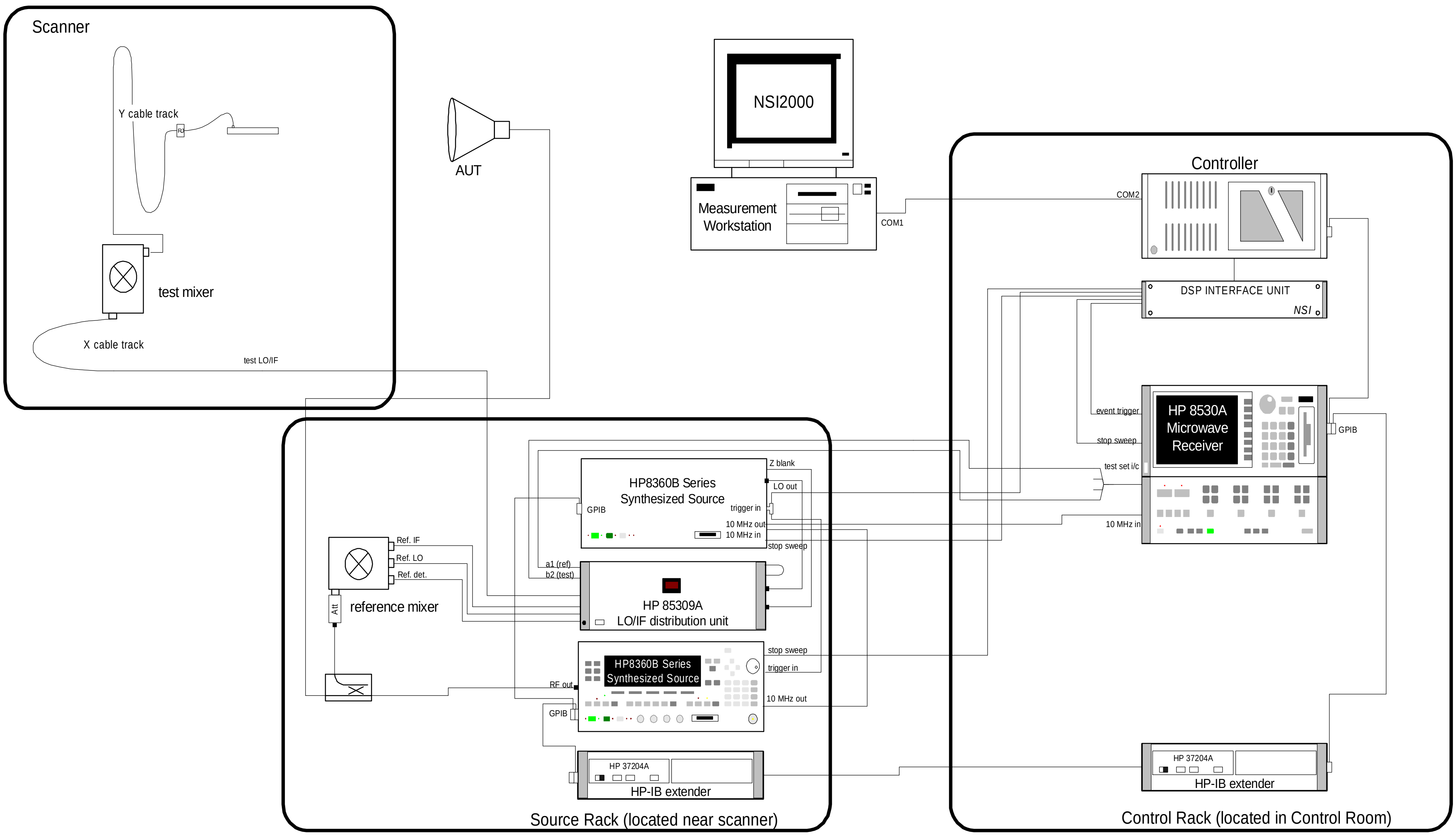




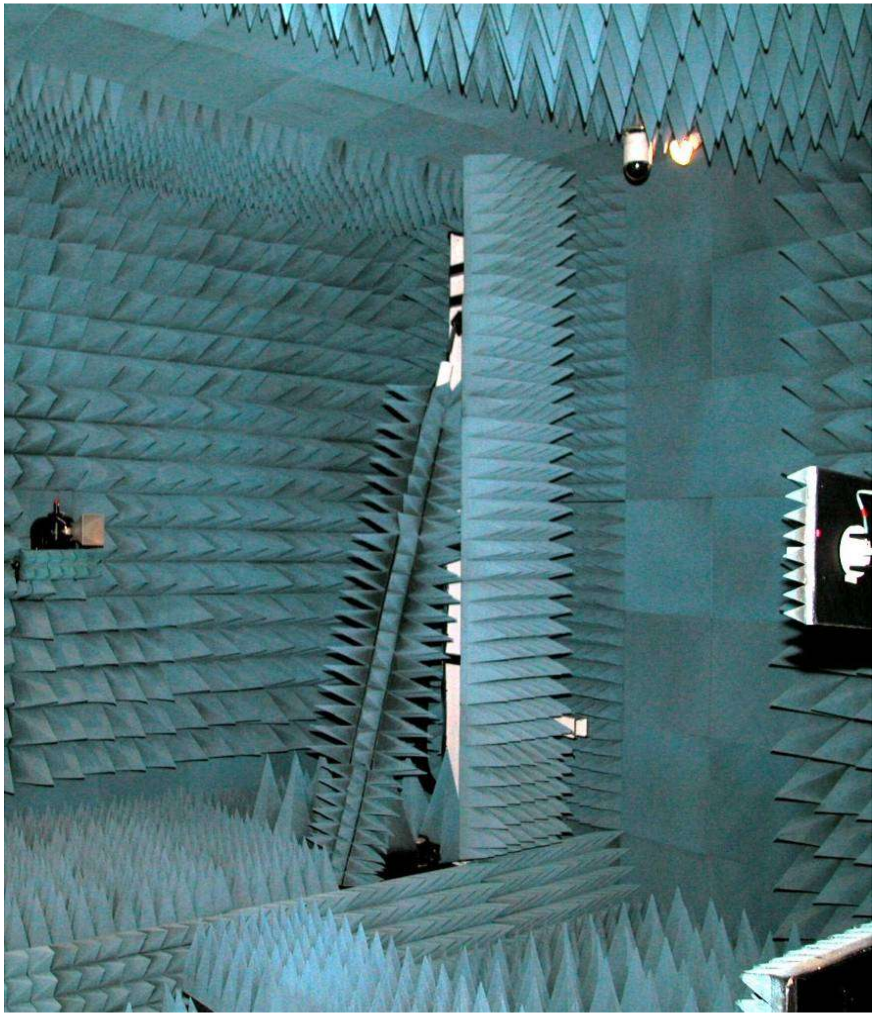
CSIST Planar Vertical Nearfield Range System Overview

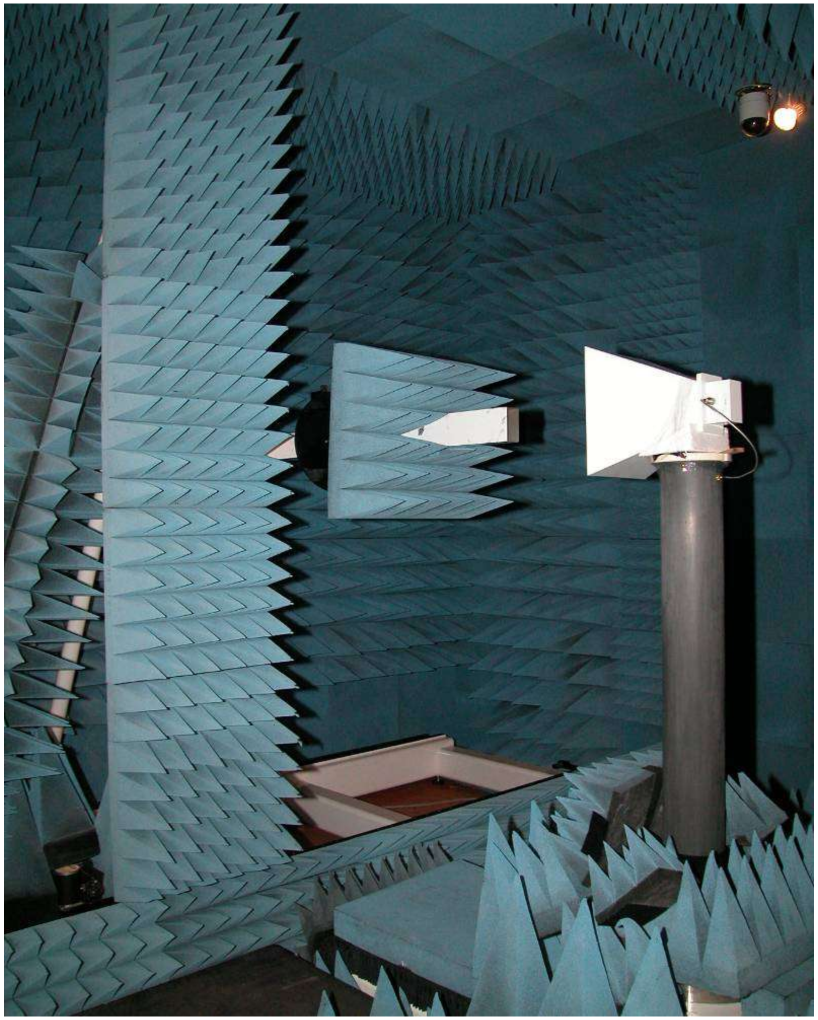
- ***Scanner Subsystem***
  - *Vertical XY scanner, 20 ft x 22 ft scan area*
  - *Planar nearfield measurement capability*
  - *Stepper motor control for X, Y, Z, and Polarization axes*
  - *Two retro-tracker stages for optics subsystem*
  - *Cylindrical Scanning Capability Add-on with RT-500 AUT table*
- ***RF Subsystem***
  - *RF Subsystem based on Agilent 85301B Antenna Measurement System*
  - *0.3 GHz to 18 GHz frequency range, fundamental mixing*
  - *Inner- and Outer-loop frequency switching*
  - *Capable of controlling RF switches in inner or outer loop*
  - *Two 24-bit interfaces (804 and 812)*
- ***Computational Subsystem***
  - *NSI2000 Windows Software on Windows NT Workstation*
  - *Includes scanner controller & GPIB drivers for RF equipment*

CSIST Vertical Planar Nearfield Range System RF Block Diagram



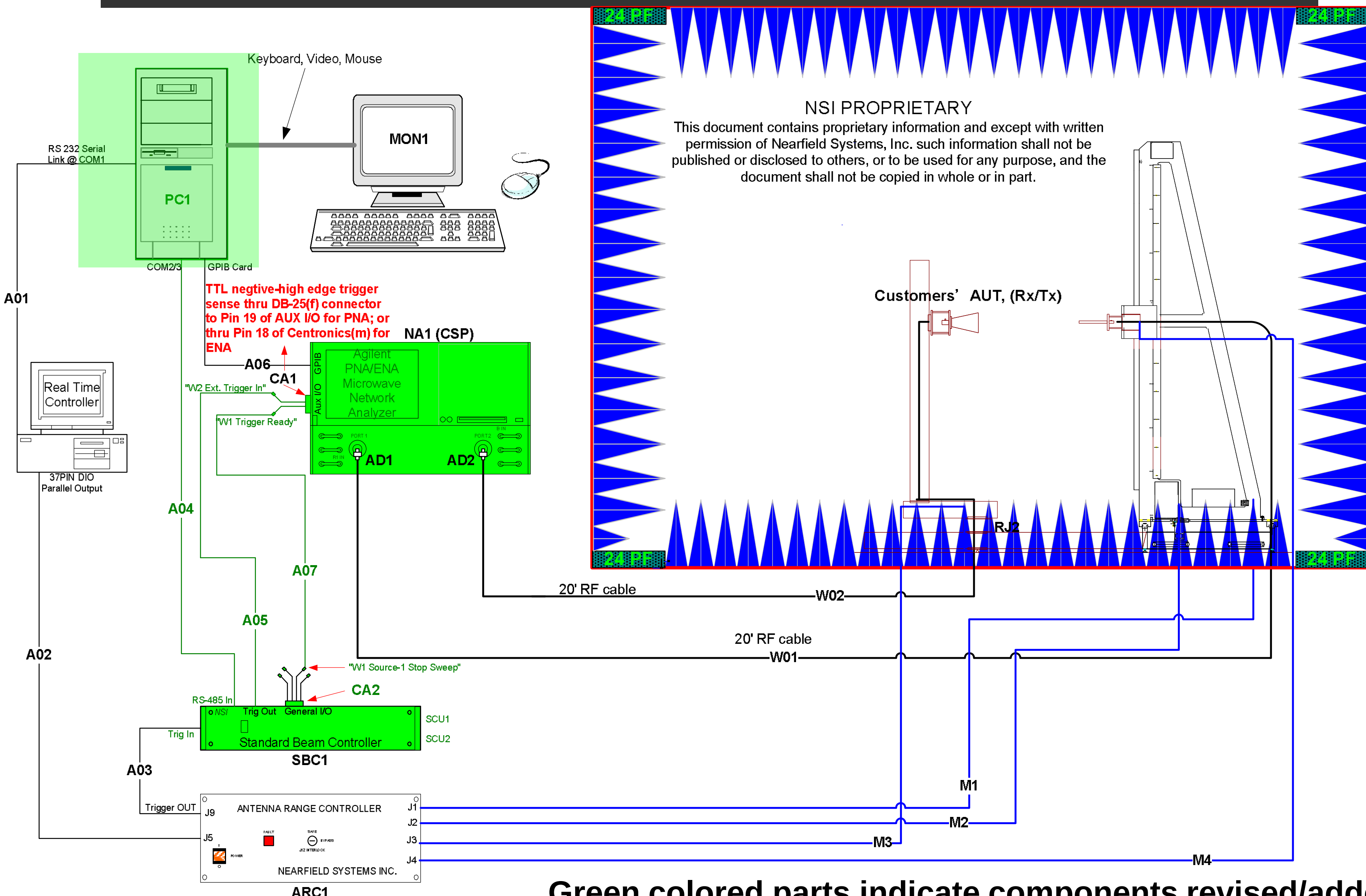
CTL Hybrid Type Antenna Test Range with Indoor Far-field Mode, Planar Near-field Mode, and Cylindrical Near-field Mode





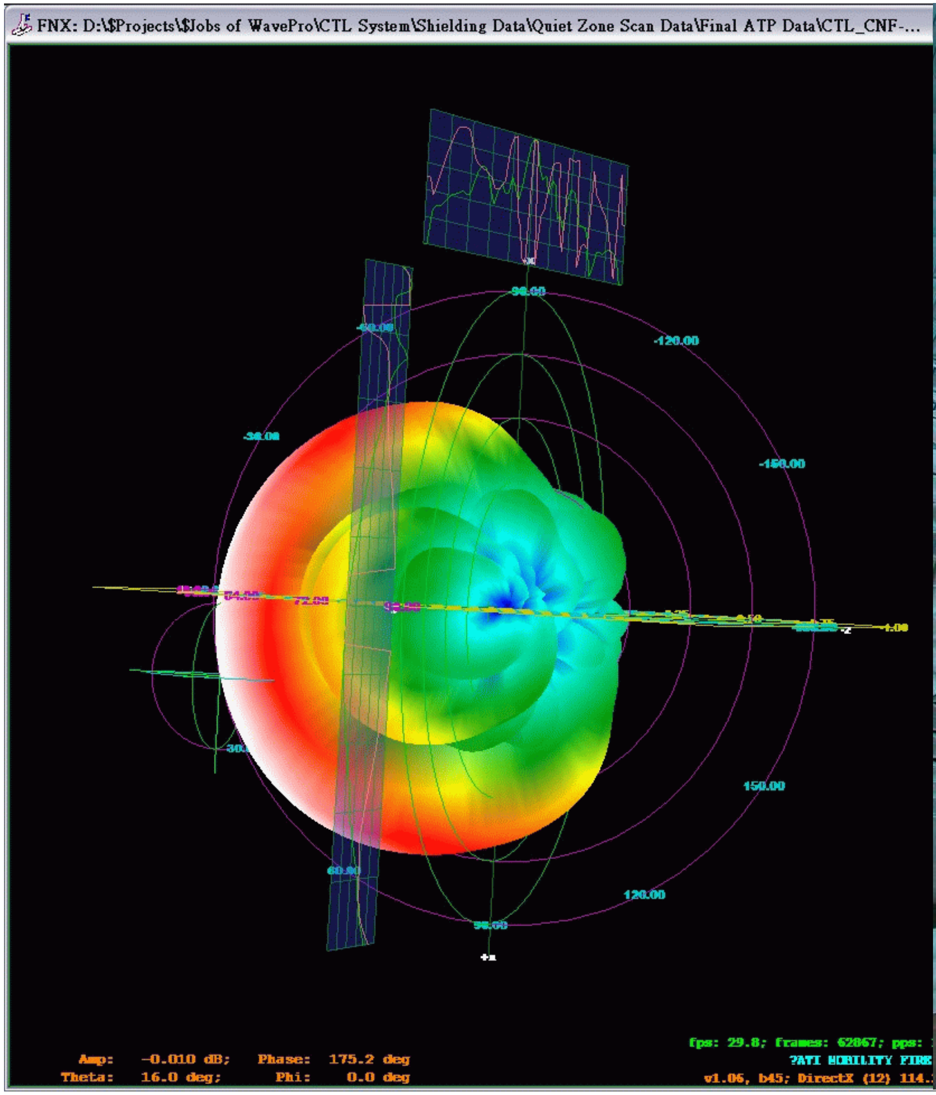
Near-field

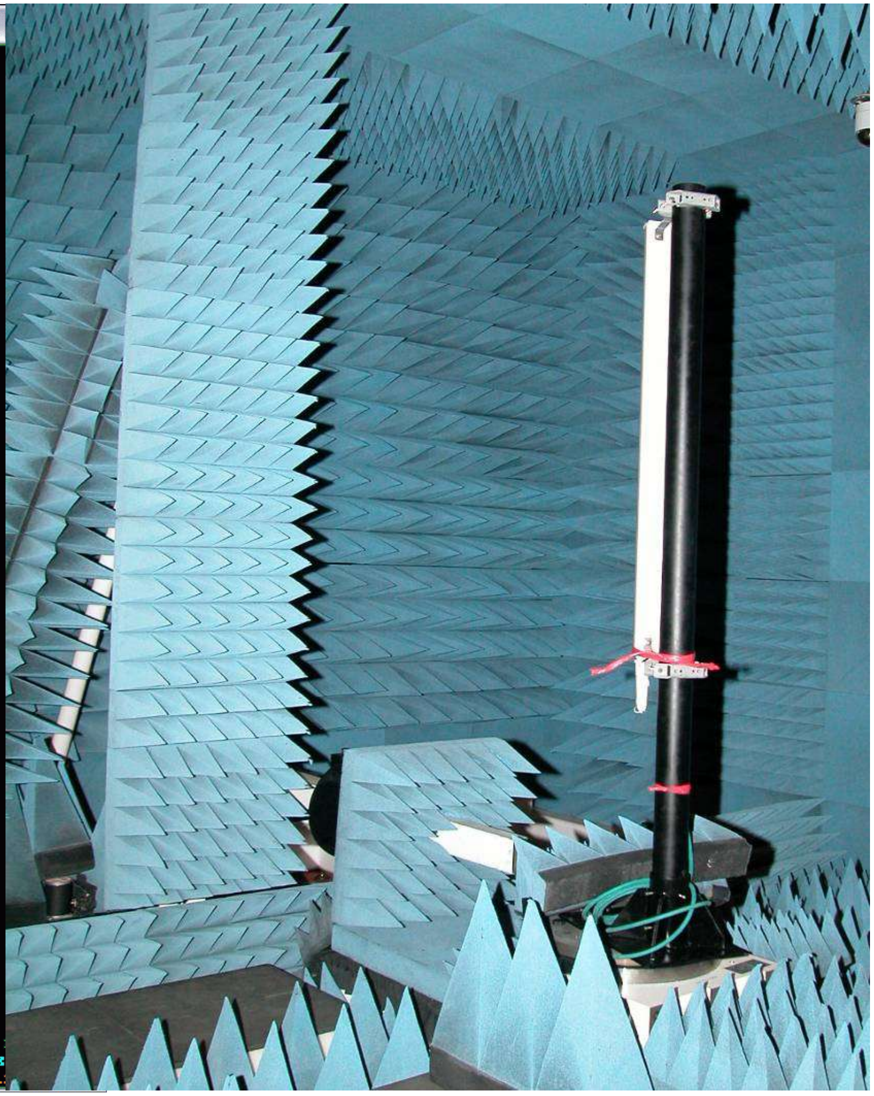
New Configuration for CTL NSI300V Vertical Near-field Measruement System Using Agilent PNA Network Analyzer



Green colored parts indicate components revised/added!

3-D Cylindrical Near-field Measurement Example For Wireless Networking Base Station Antenna

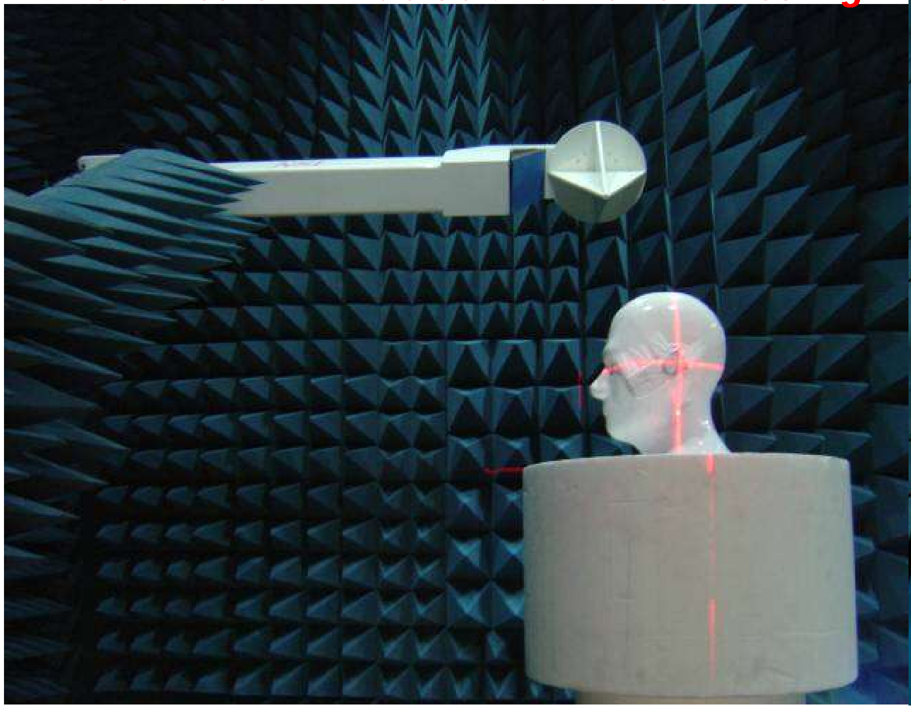




NSI-700S-90 System For 3D Spherical Near-field Antenna Measurement & CTIA Mobile Handsets OTA TRP/TIS Testing

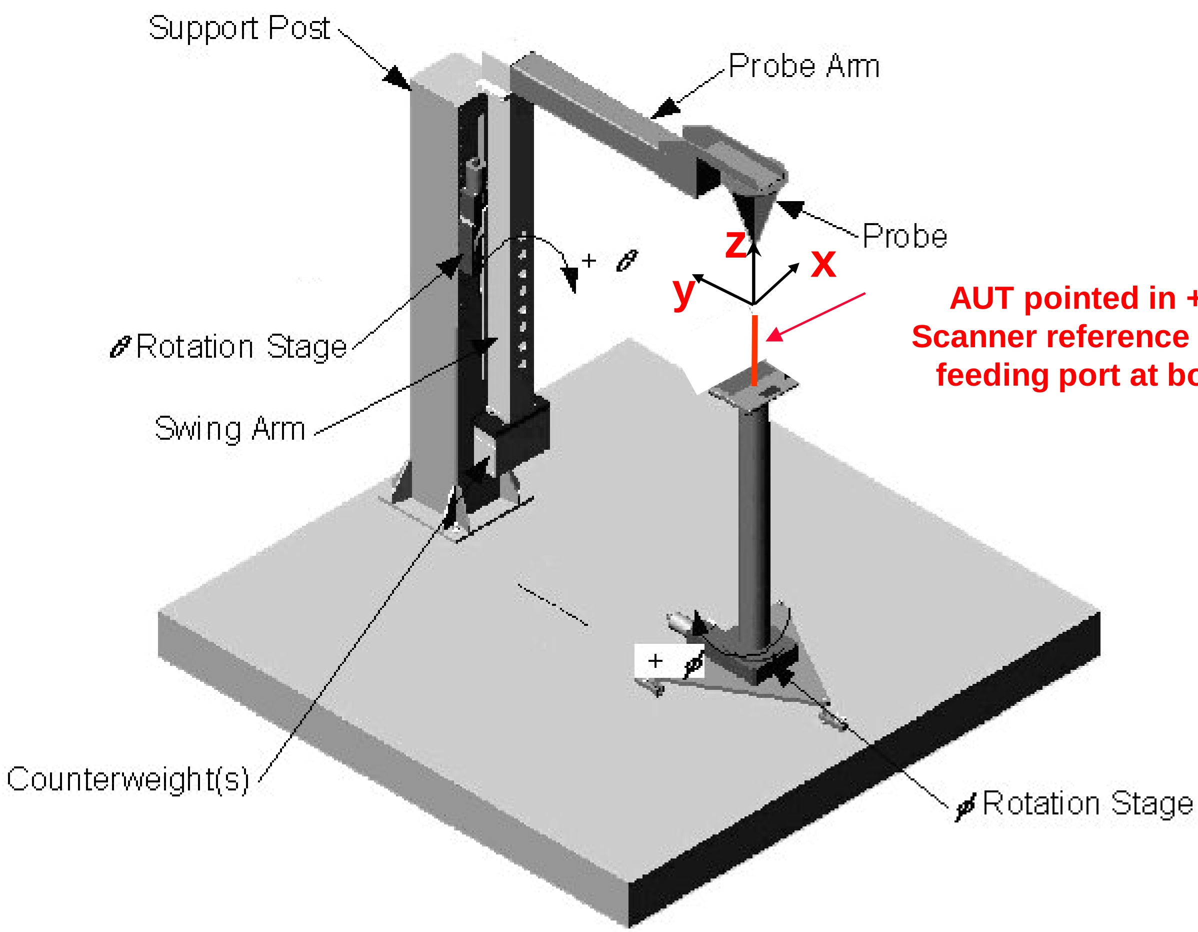
PCS Spherical NF System

- ***Overhead dielectric swing-arm design for the probe theta motion, and an AUT support stage for the phi motion***
- ***Phi rotation stage supports AUT up to 300 lbs***
- ***Electrically switched dual polarized probe antenna over 500MHz to 18 GHz Frequency range***
- ***Ideal for measuring medium and low gain antennas and well suited to wireless communication antennas testing***
- ***Sufficient Far-field Distance Complying with CTIA OTA Mobile Phone TRP/TIS testing requirement while interfaces with BSS: Certified CATL Lab Solution for OTA Testing***

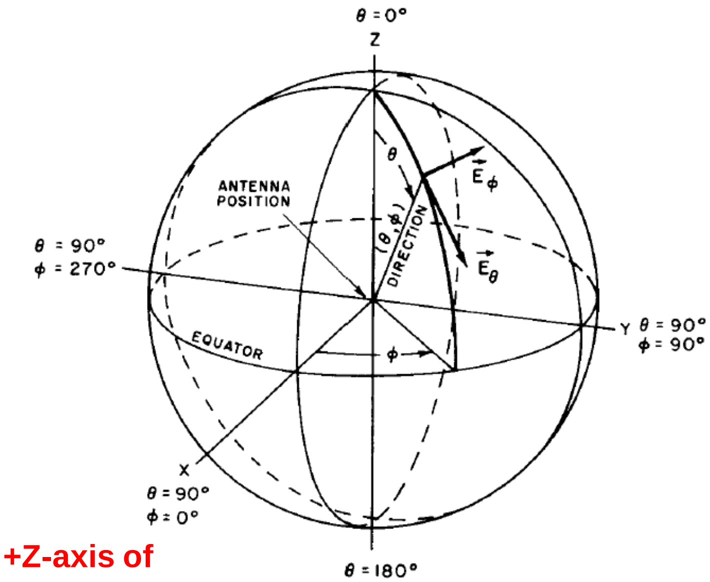


3-D Spherical Measurement System Coordinate And Associated Orthogonal Polarization Components of Electric Field Vector : Eθ / Eϕ

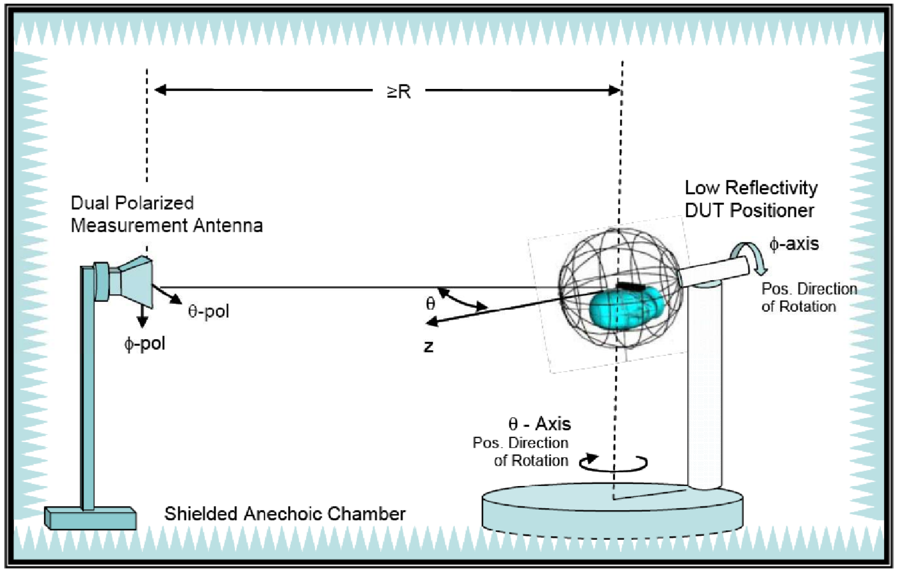
Coordinate System of AUT Mounting Orientation in 3D Swing-Arm Spherical Near-field Scanning System



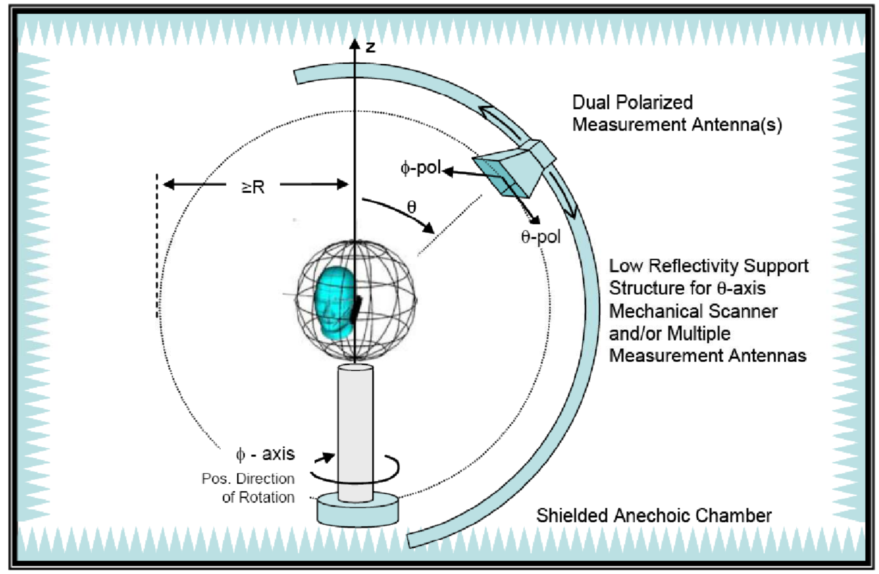
AUT pointed in +Z-axis of Scanner reference coordinate; feeding port at bottom side



Alternative Configurations For Spherical Scanning



Combined Axes Configuration Using Roll/Az Positioner

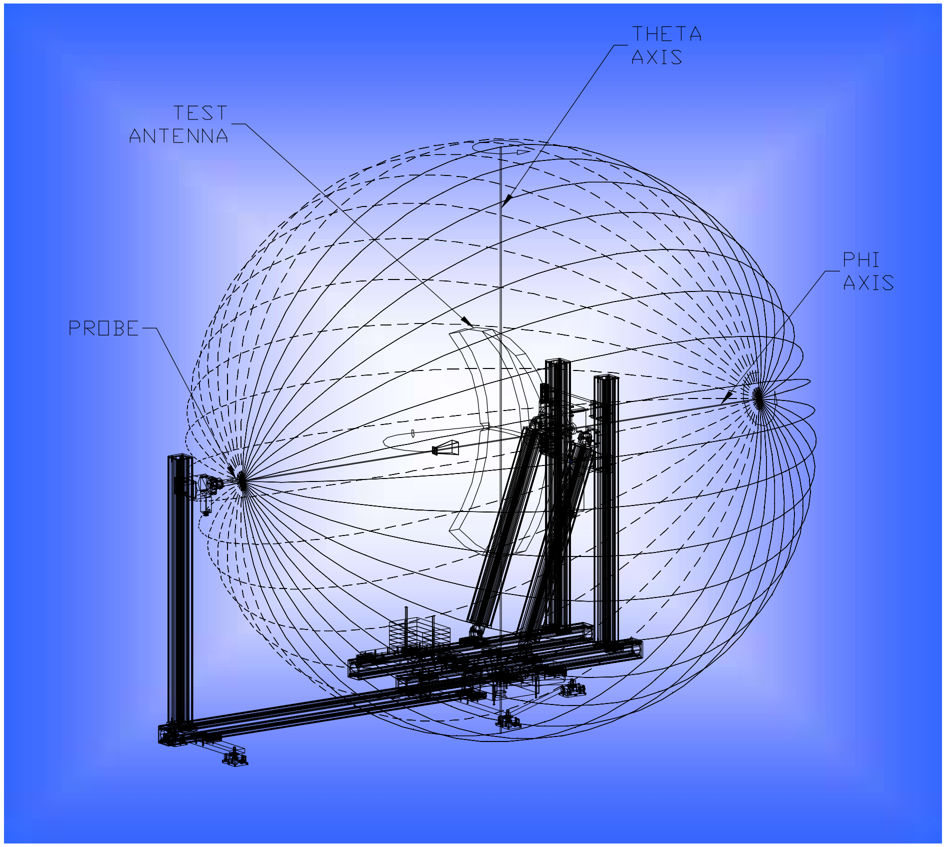


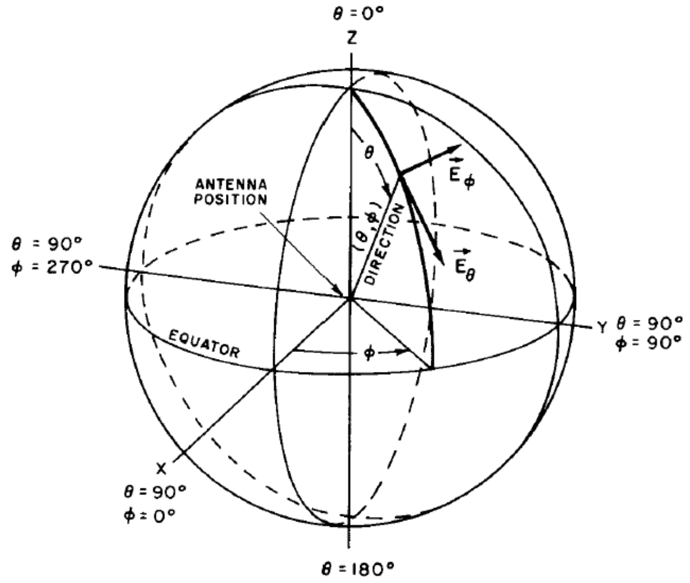
Distributed Axes Configuration with Dielectric Swing Arm

	Great Circle Cut Configuration	*Conical Scan Cut Configuration*
Positionner Interaction	Poor	Good
Extendable DUT Size	Poor	Easy
Test Distance Adjustment	Yes	No

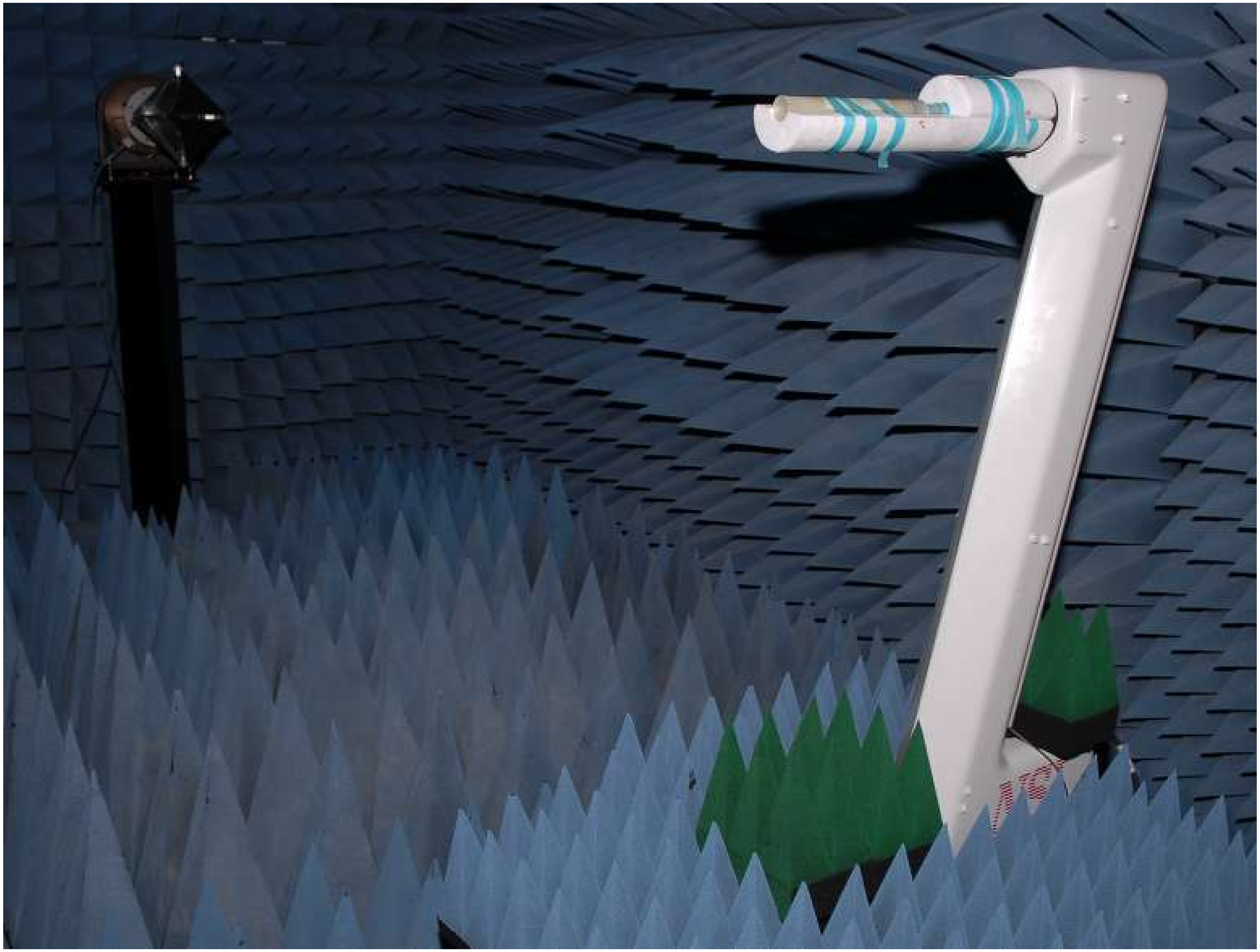
3-D Spherical Measurement System Coordinate And Associated Orthogonal Polarization Components of Electric Field Vector : Eθ / Eφ

Coordinate System of AUT Mounting Orientation in NSI-800F-3D Far-field Scanning System



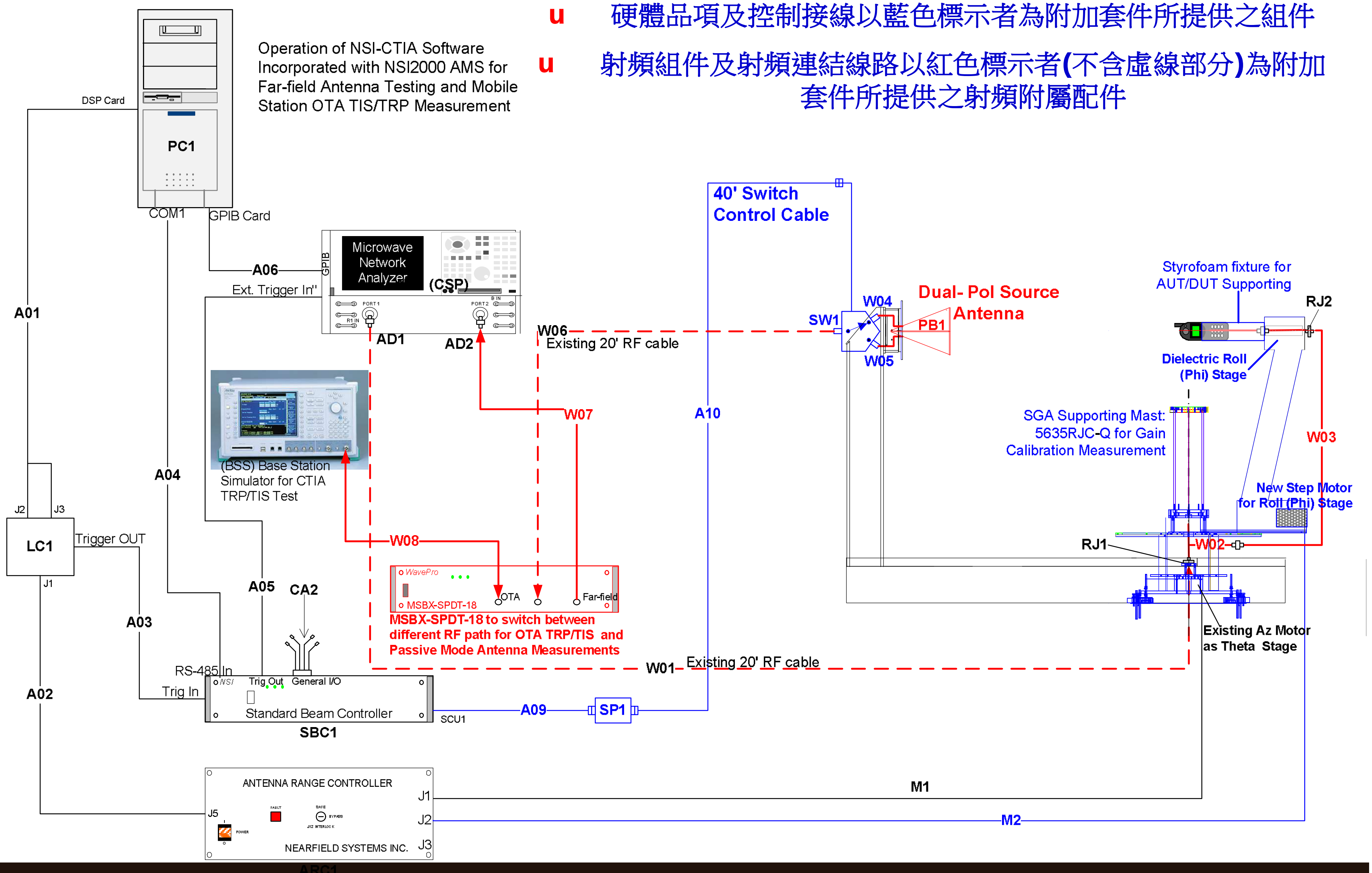


NSI 800F-10-3D Far-Field Measurement System for Passive Mode Antenna Performance Measurement



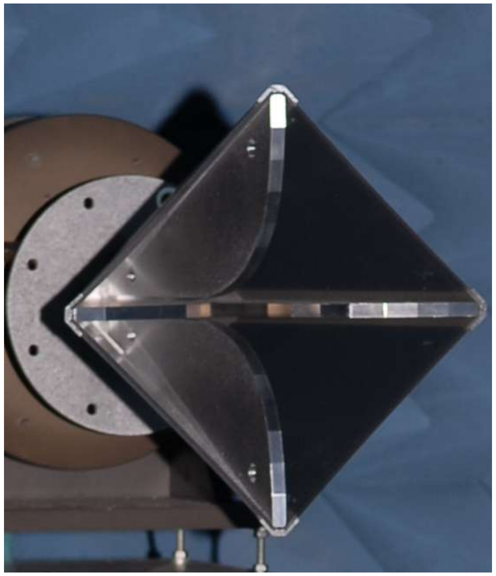
NSI-800F-10-Roll
附加套件之主/被動模式系統量測架構圖

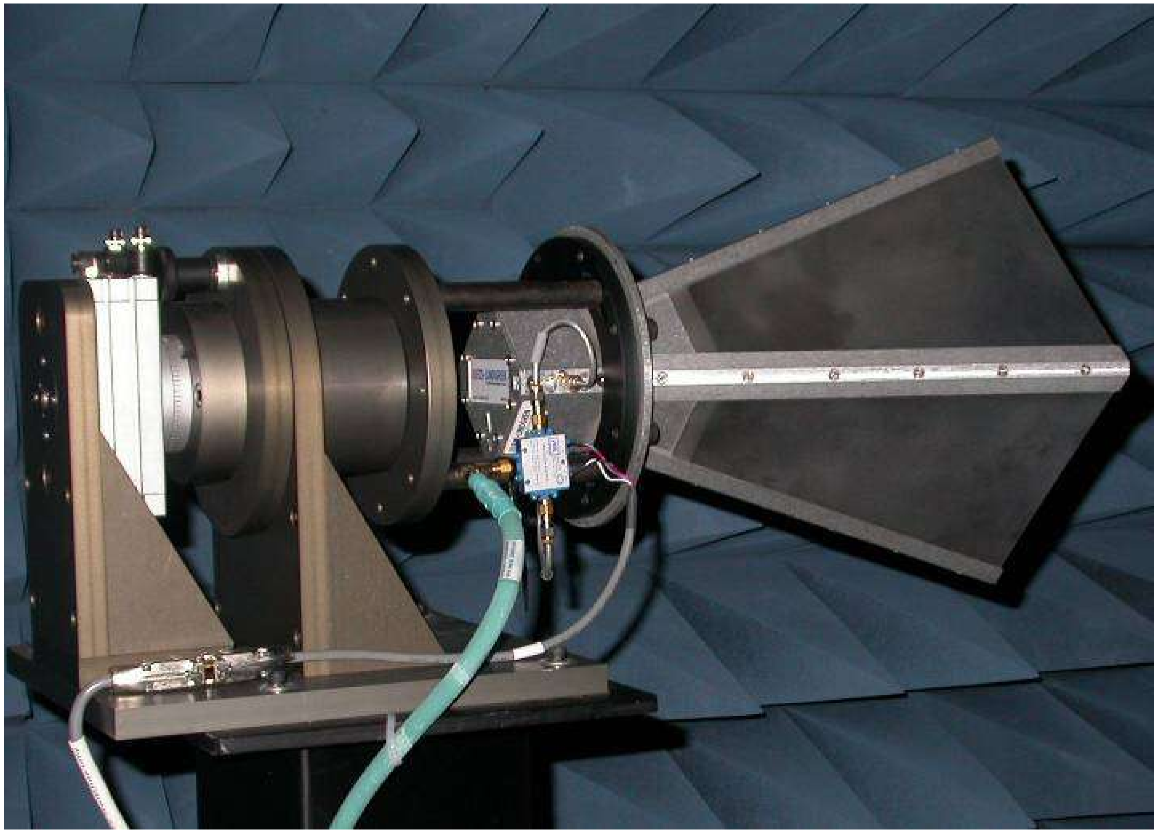
- 硬體品項及控制接線以藍色標示者為附加套件所提供之組件
- 射頻組件及射頻連結線路以紅色標示者(不含虛線部分)為附加套件所提供之射頻附屬配件



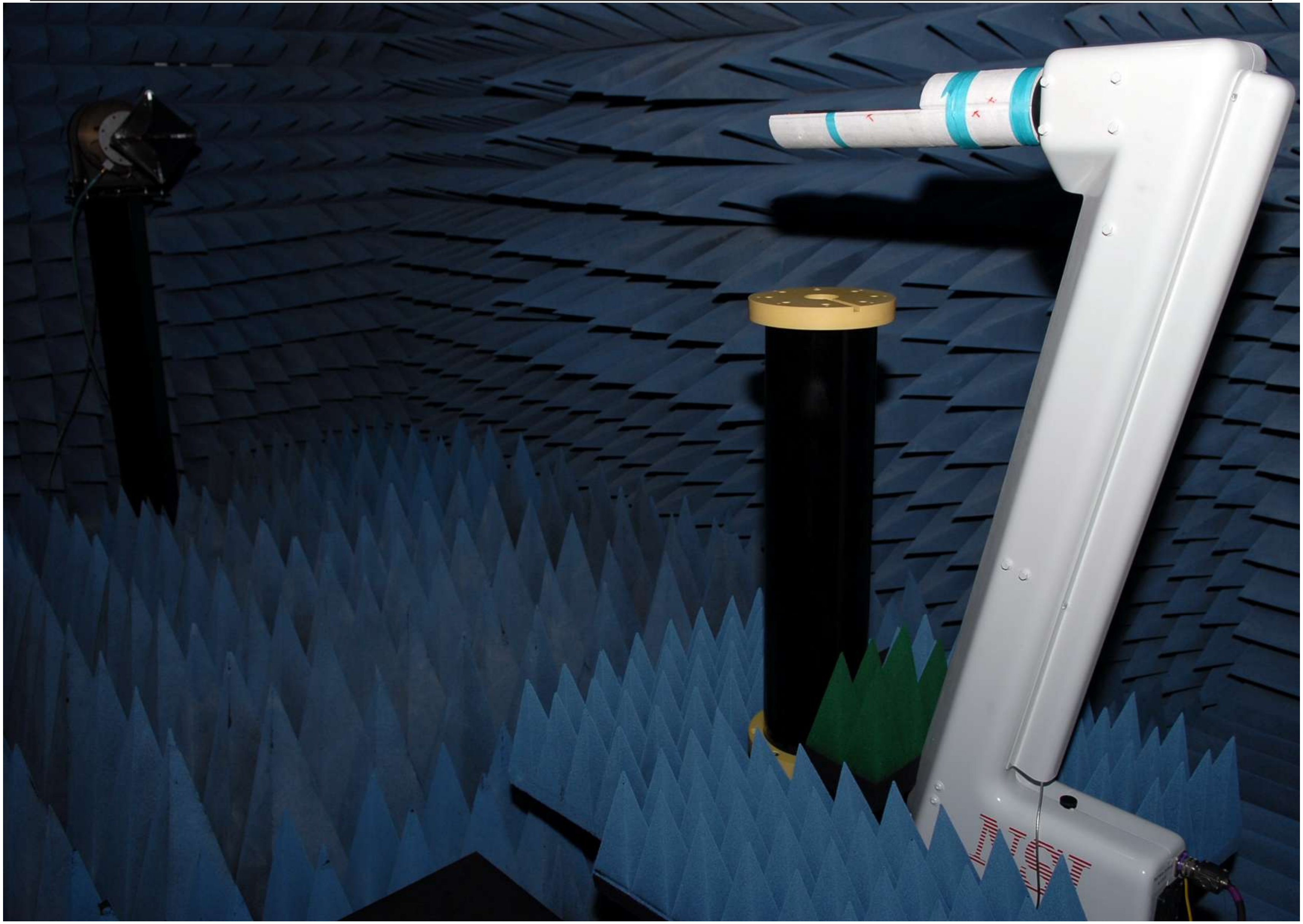
NSI-RF-DH-06A Dual Polarized Quad-Ridged Wide Band Source Horn (Probe) Antenna

- **NSI-RF-DH-06A**雙極化對角號角天線提供從**700 MHz**至**6 GHz**頻率範圍內水平及垂直極化方向待測天線之場型量測訊號收發能力
- 配合內含**NSI-SP-1231**雙通道**PIN SWITCH**驅動套件，可使此雙極化天線於既有**NSI 3D**量測控制架構下，以約**100 μs**之切換間隔快速量取水平及垂直極化之天線場型訊號

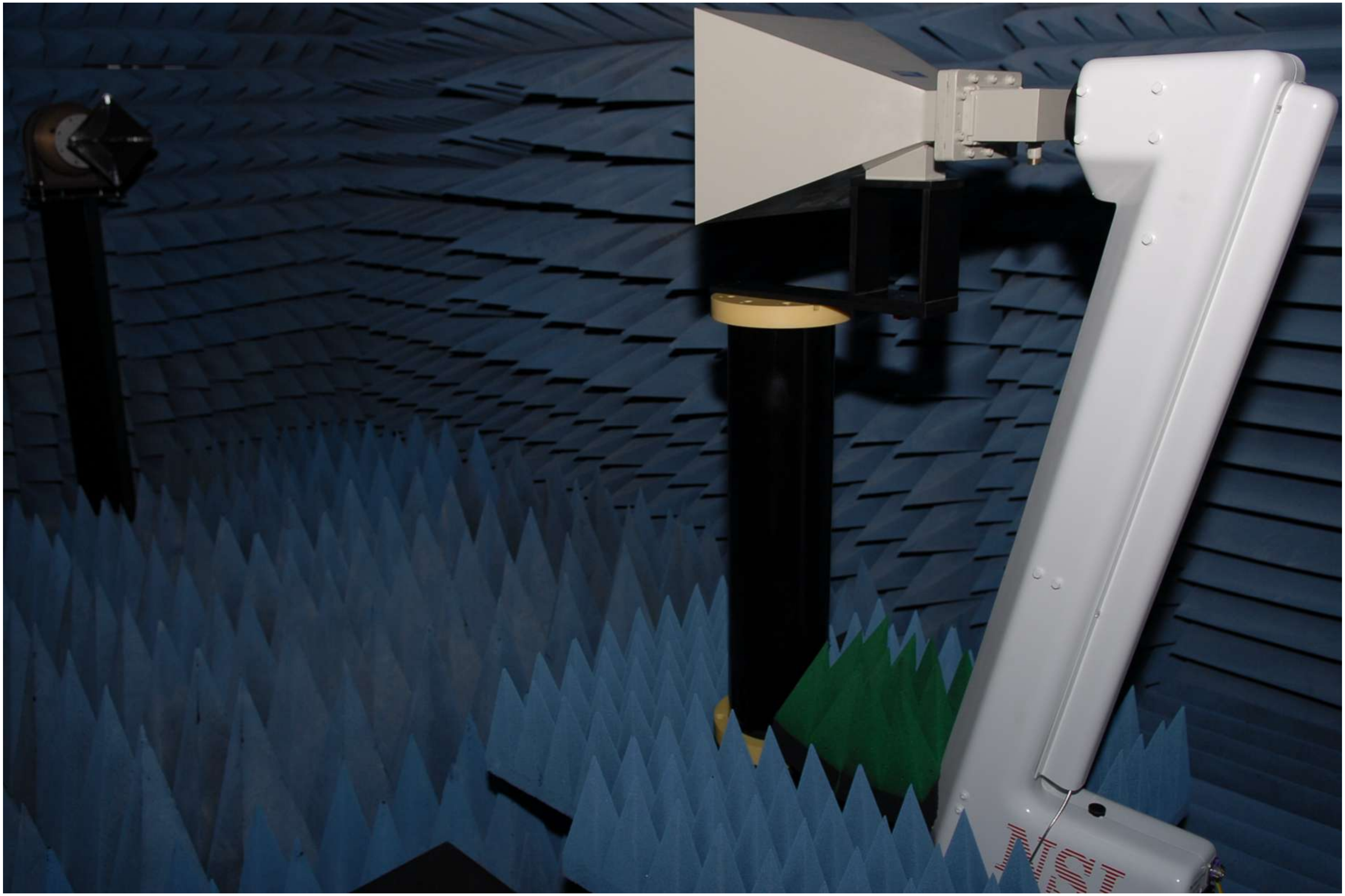




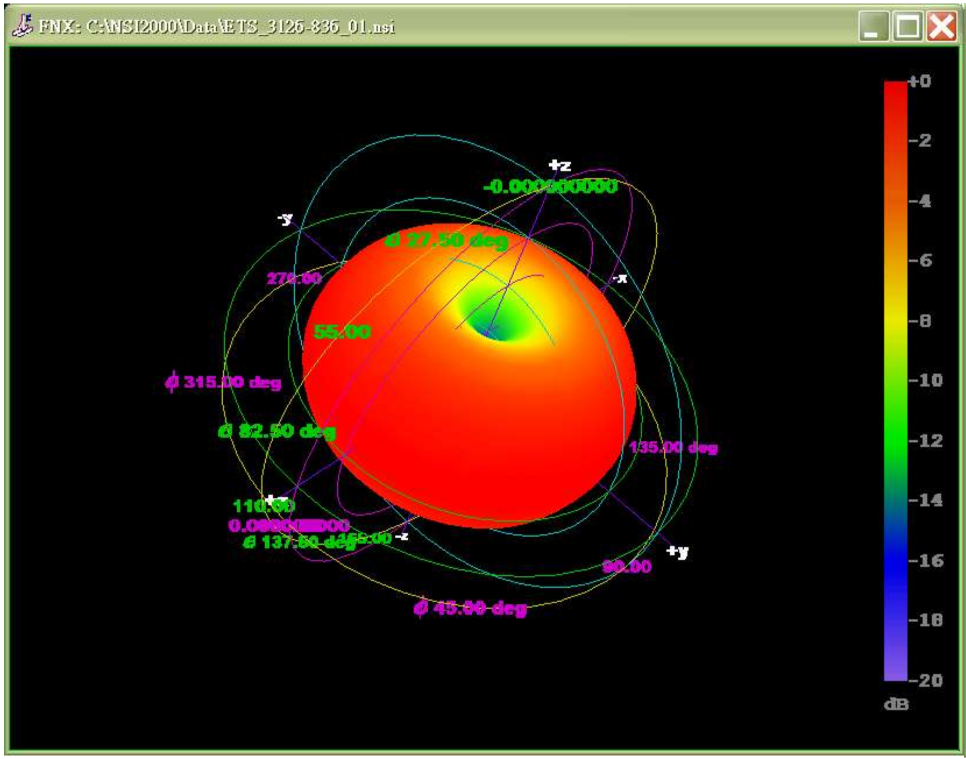
NSI 800F-10 Roll Axis 附加套件之對應遠場量測架構應用於天線被動模式特性量測之實際狀況



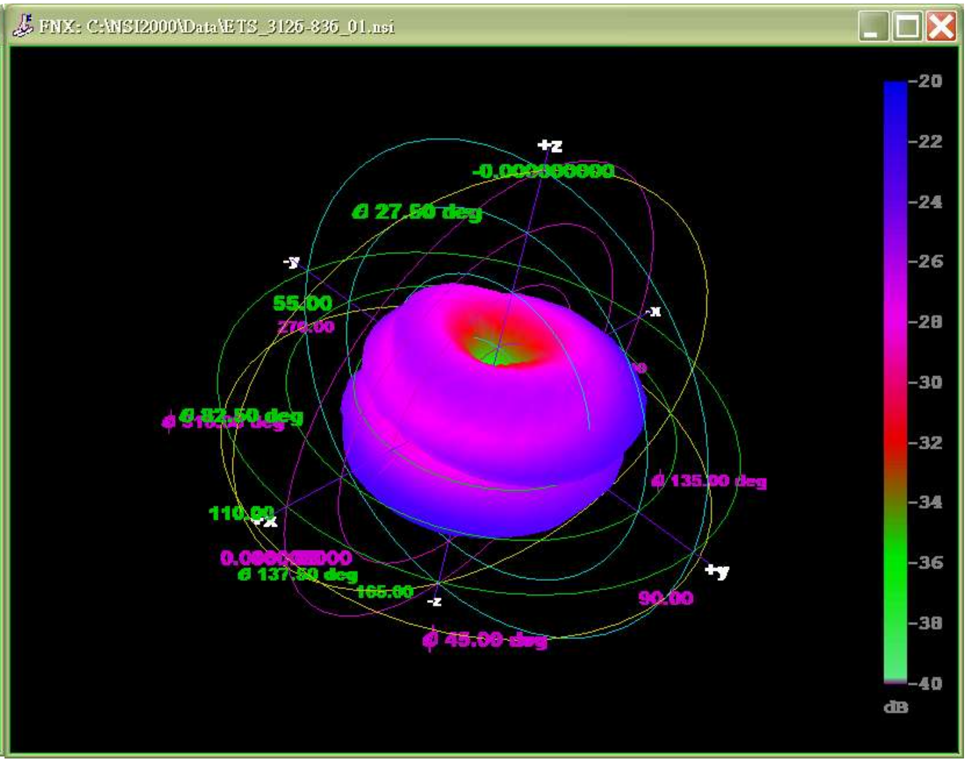
NRL4433標準號角天線應用於天線被動模式增益校正標準之實際狀況



3D Patterns of E-theta & E-Phi Polarization Components for Sleeve Dipole Antenna @ 850 MHz

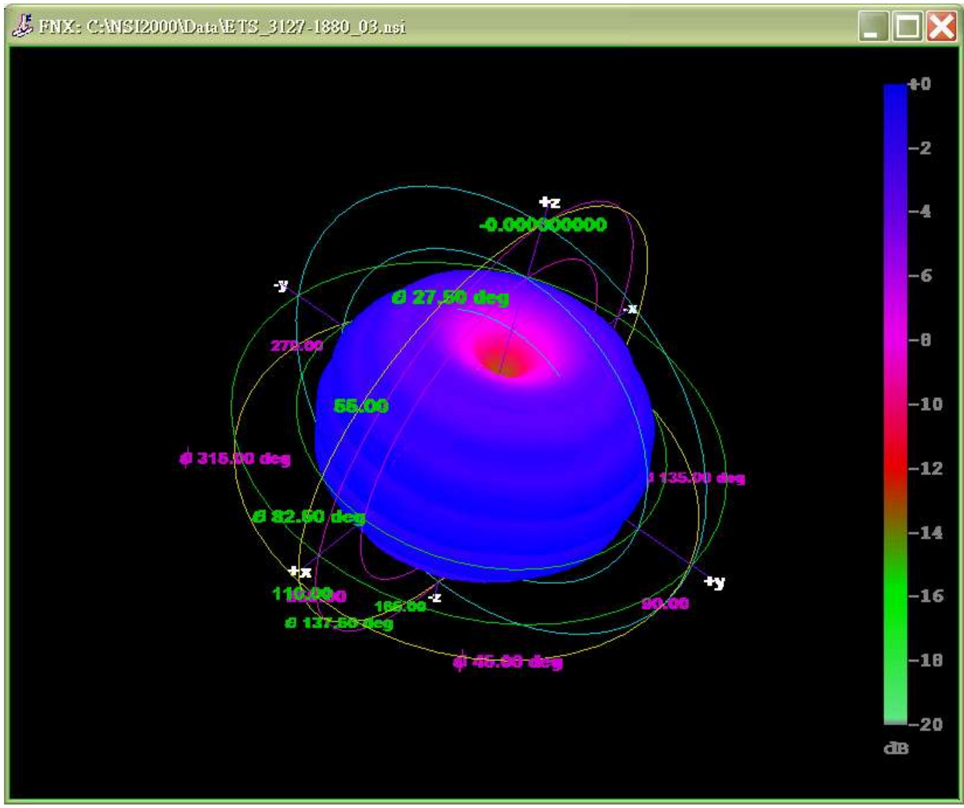


E-Theta Polarization Component

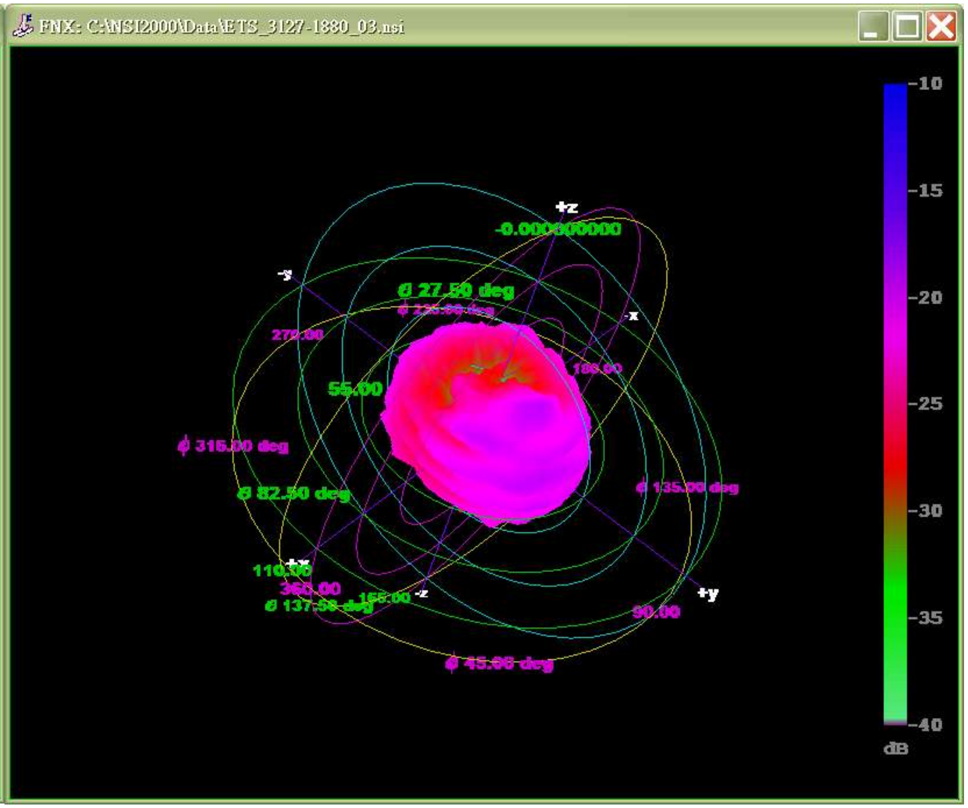


E-Phi Polarization Component

3D Patterns of E-Phi & E-Theta Polarization Component for Magnetic Loop Antenna @ 1880 MHz



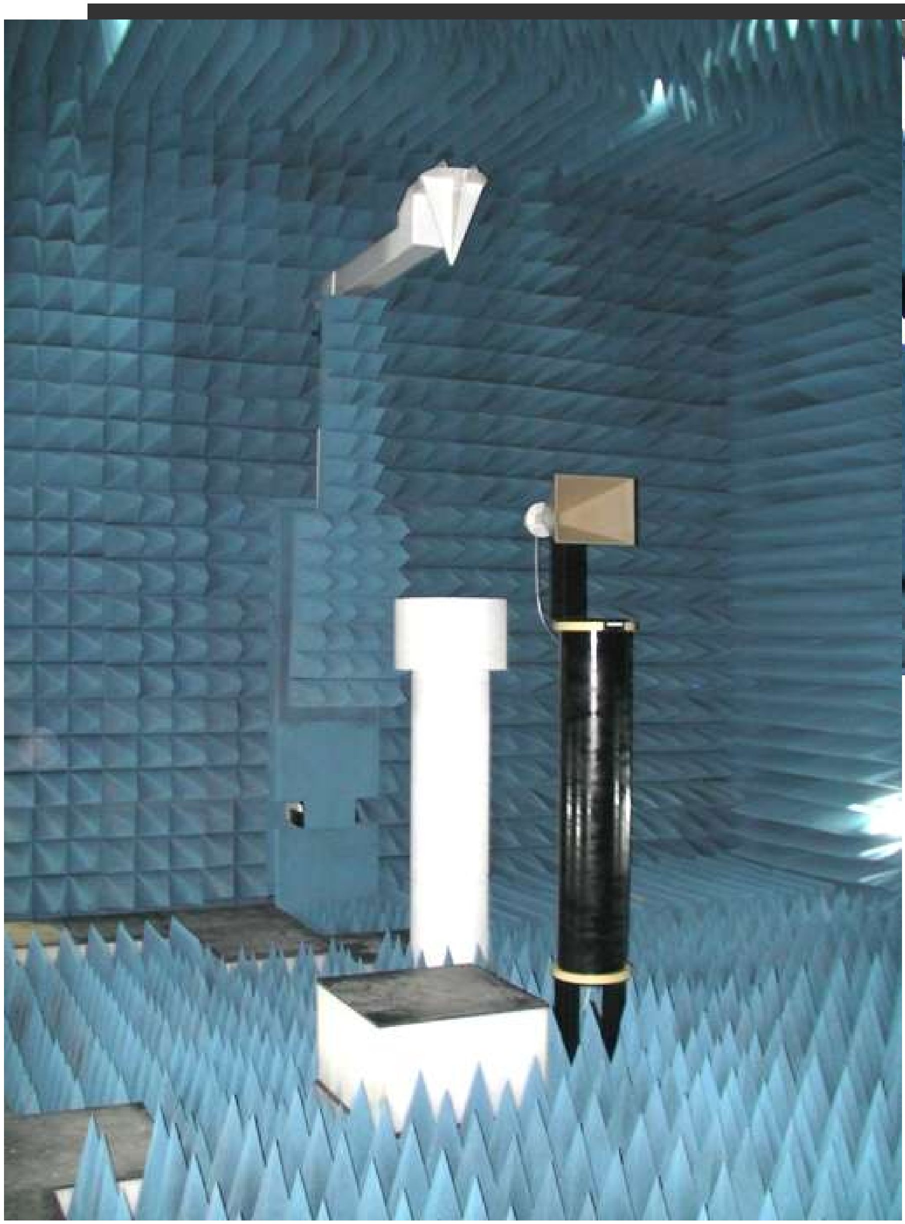
E-Phi Polarization Component

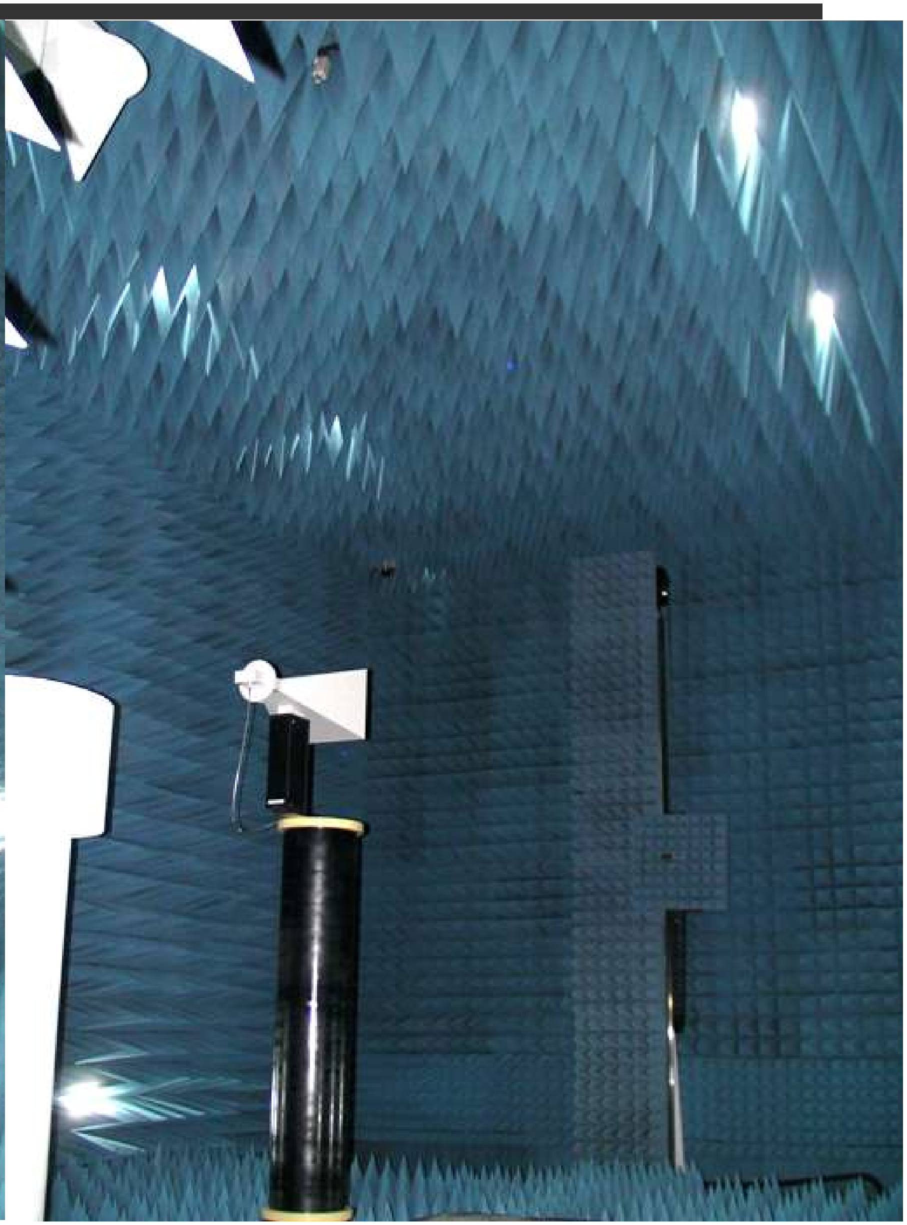


E-Theta Polarization Component

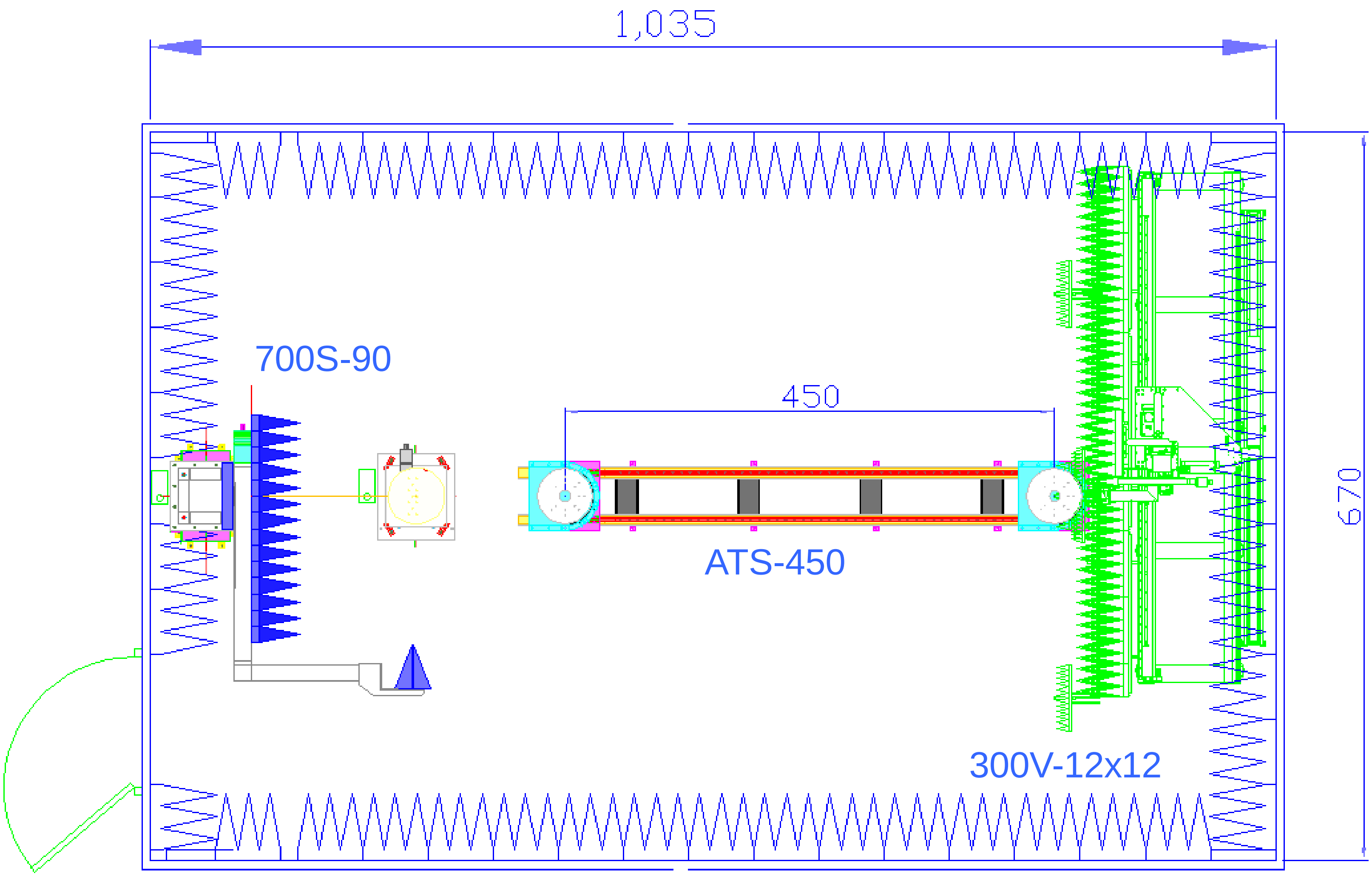
YZU Hybrid Modes Antenna Measurement Range

YZU Hybrid Modes Antenna Measurement Range

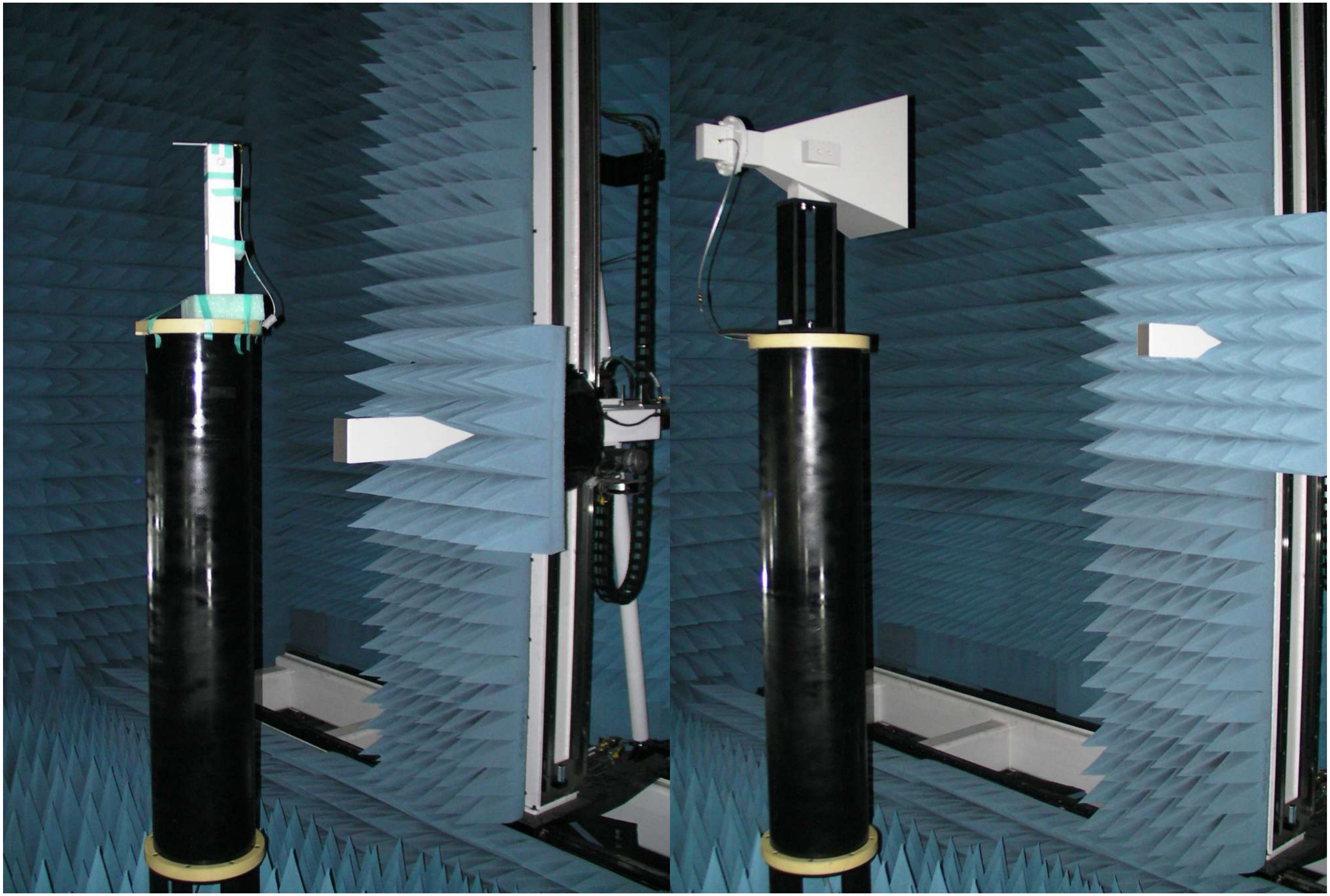




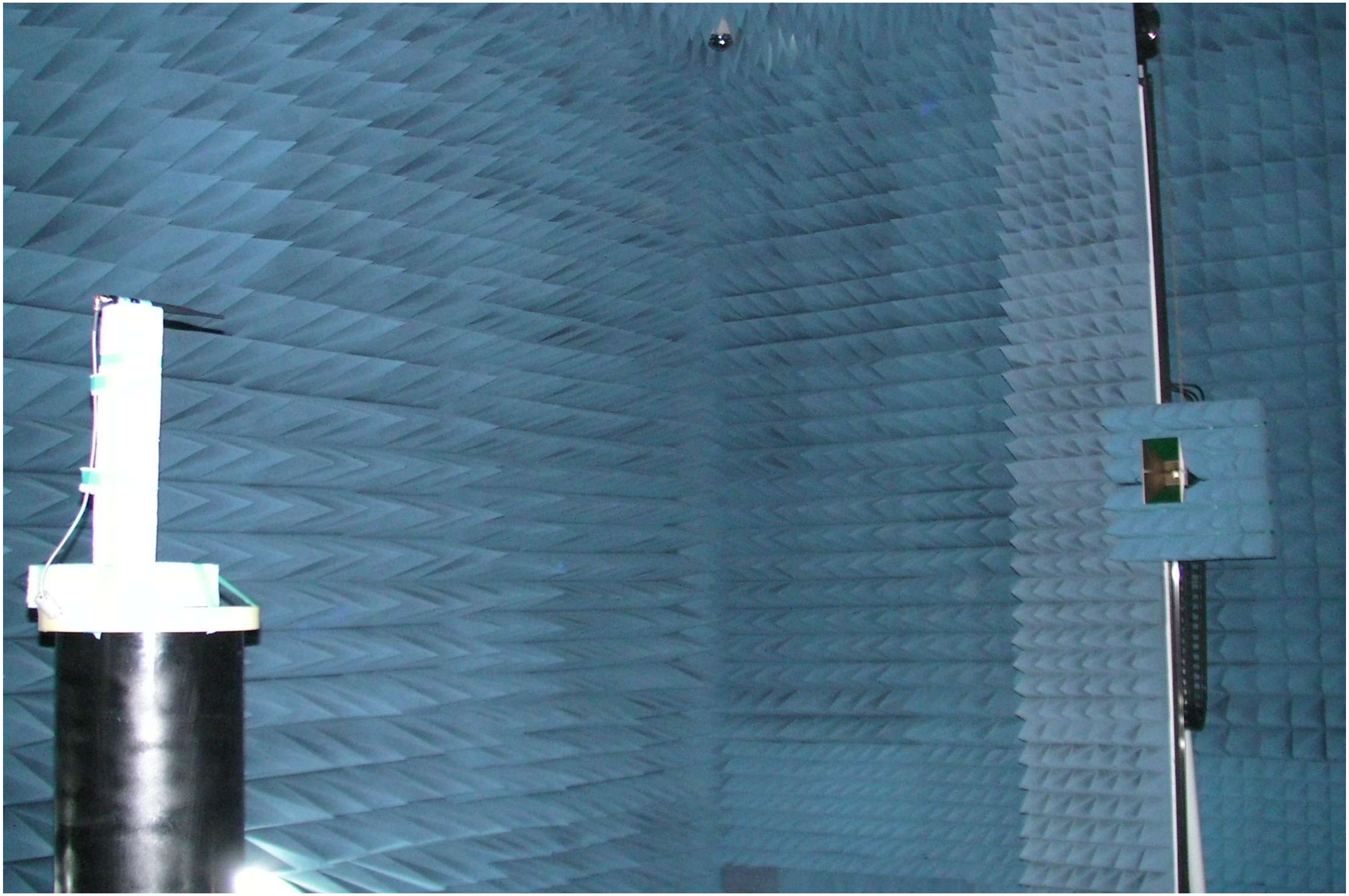
Facility and Range Layout



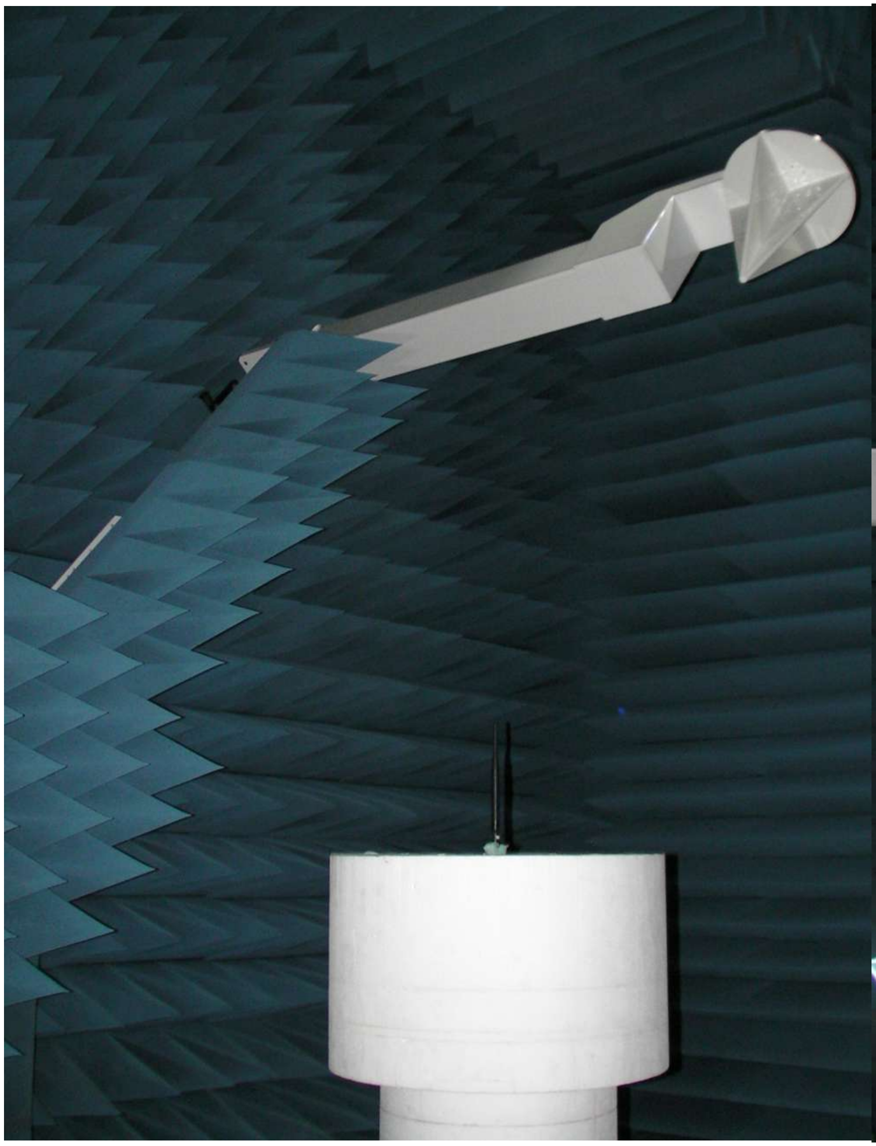
Cylindrical Near-Field Scanning And Planar Near-Field Scanning Antenna Performance Characterizations

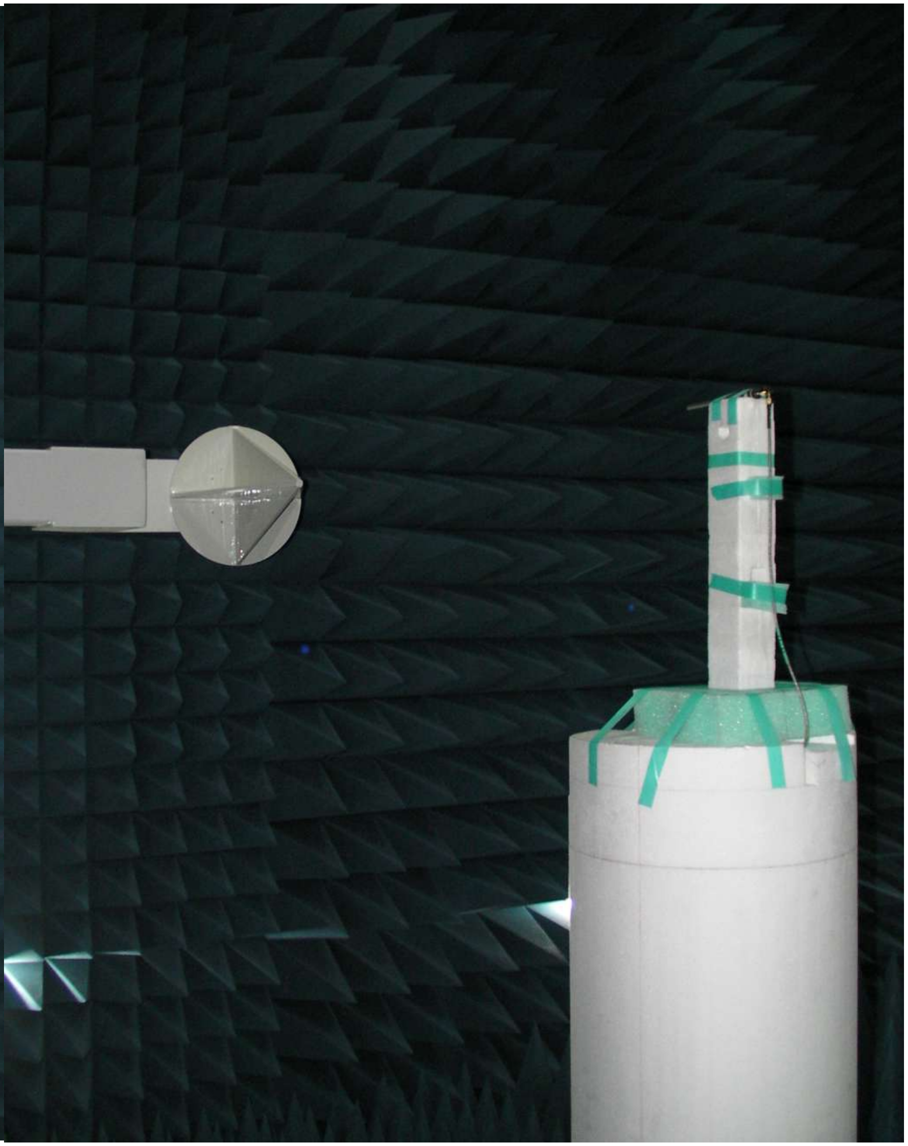


2D Far-Field Scanning Antenna Performance Characterization

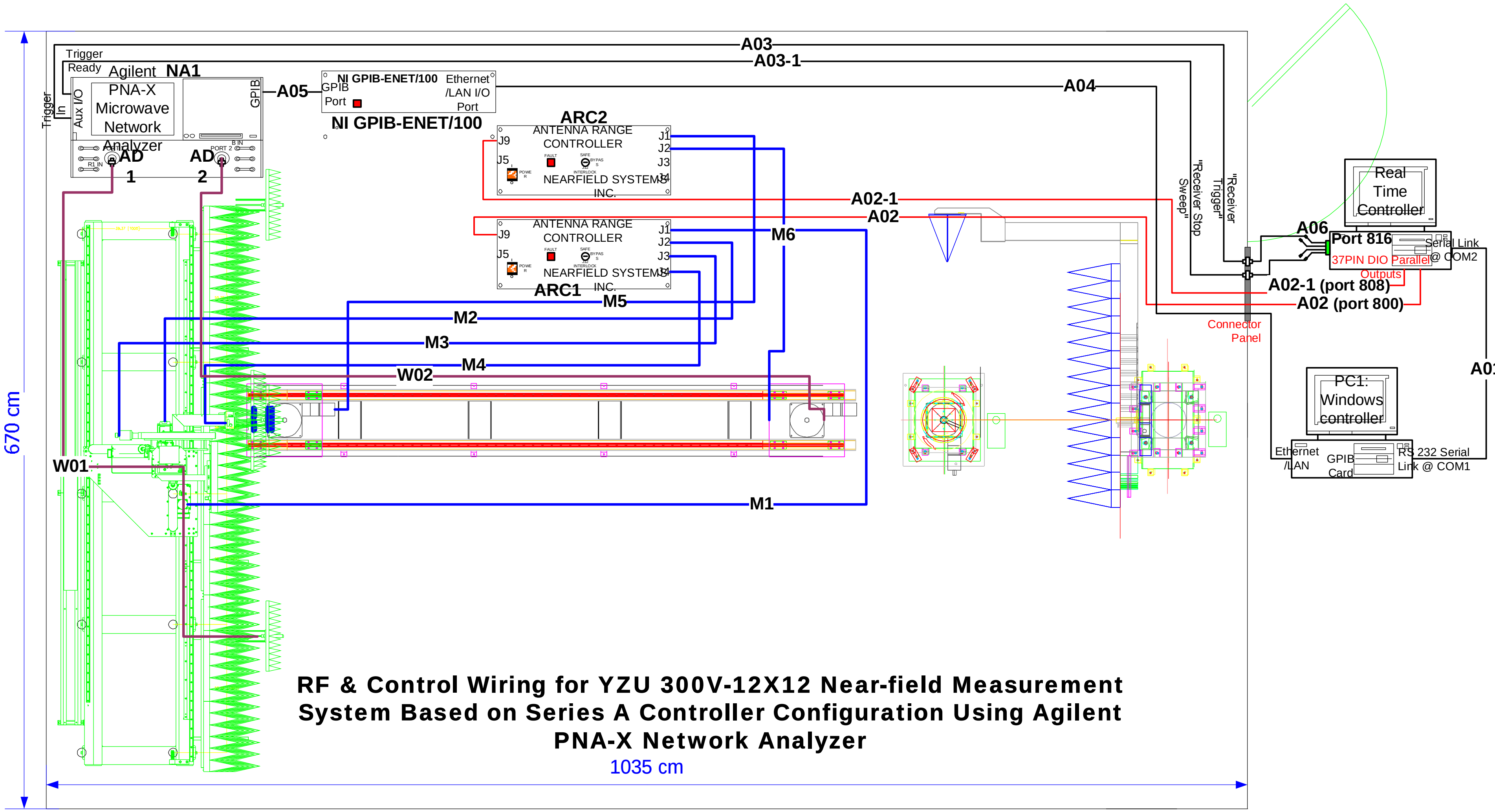


Spherical Near-Field Scanning And 3D Far-Field Scanning (Small Antenna Only) Antenna Performance Characterizations



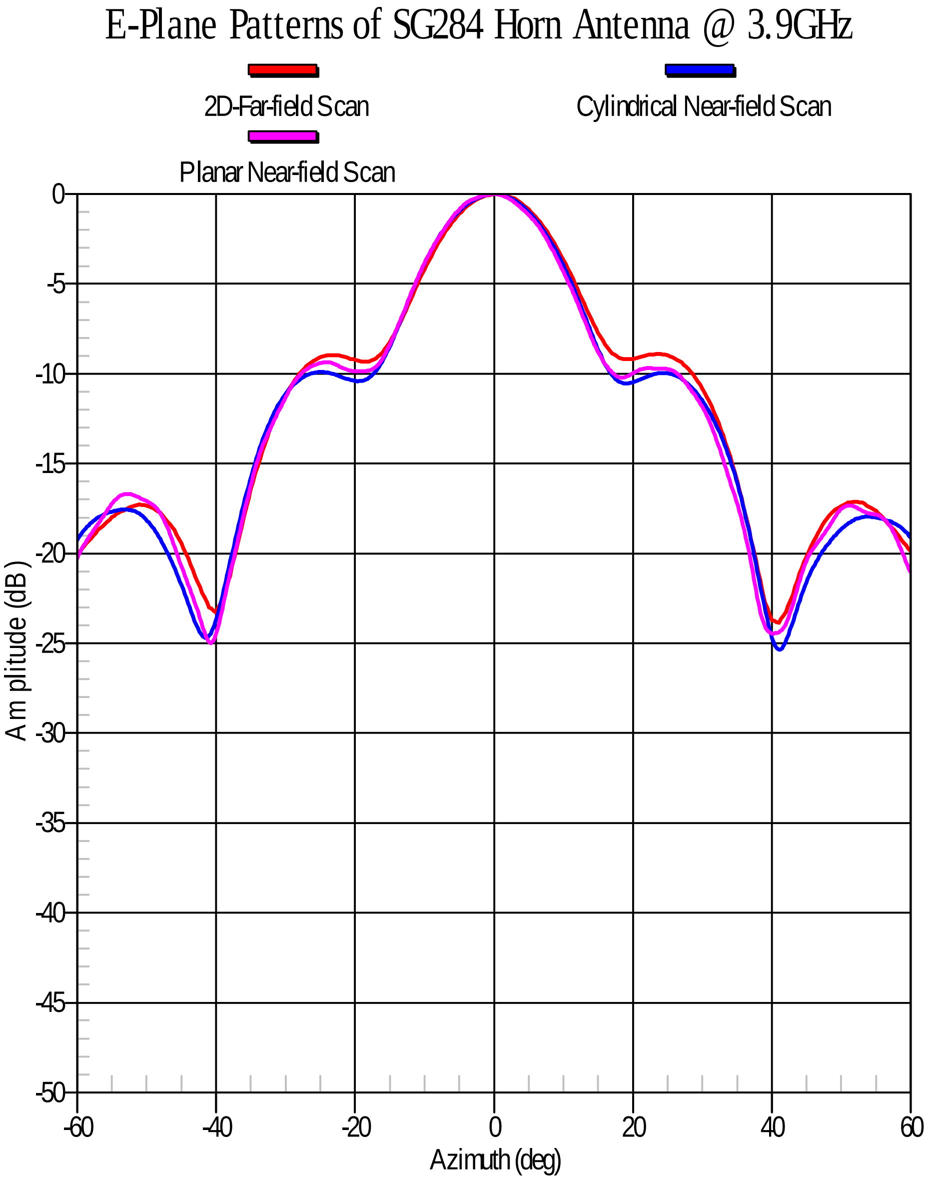


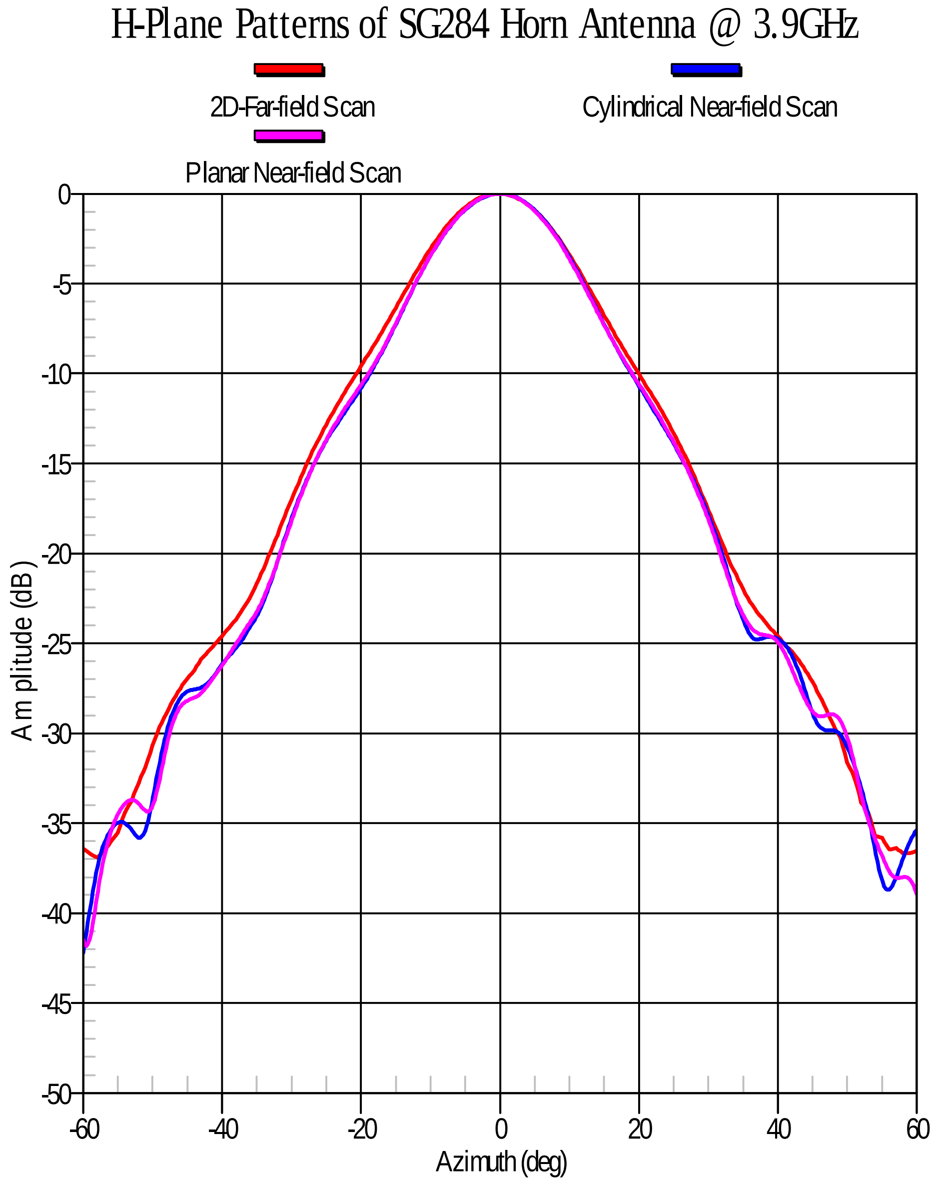
System Wiring for Planar/Cylindrical/Far-Field Near-field Antenna Scanning (Control & Wiring Using PNA-X Configuration)



Top View

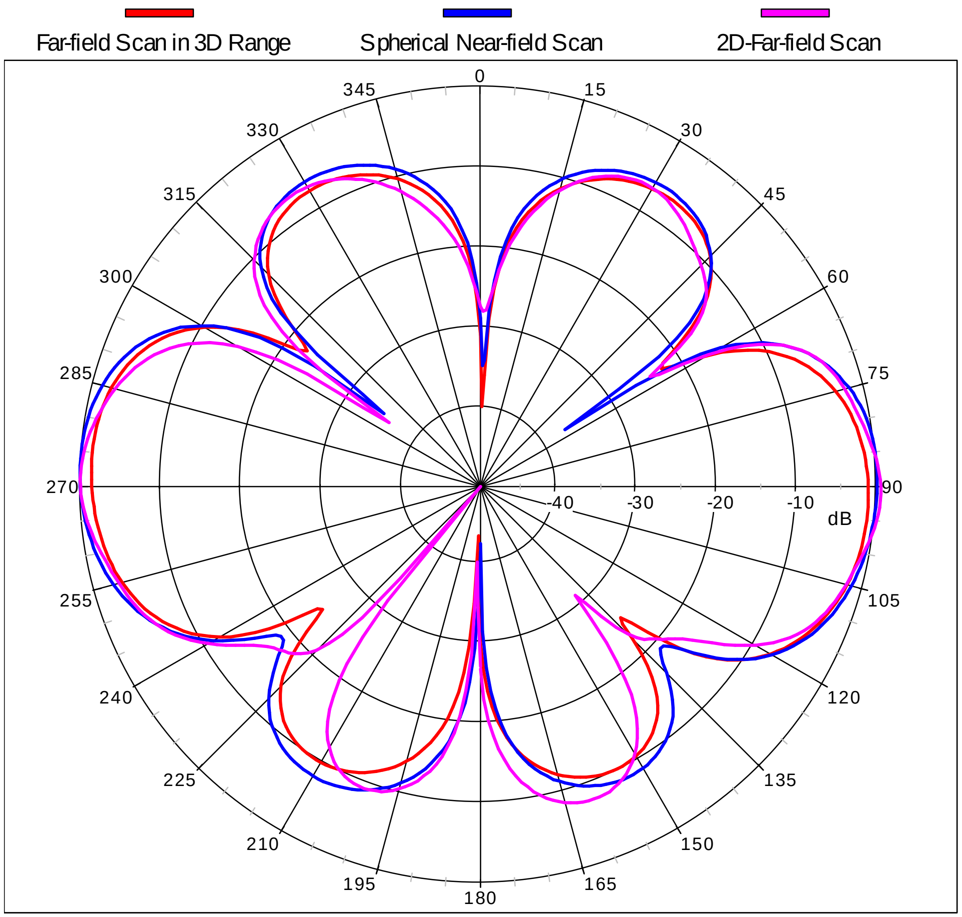
Measurement Consistency of Near-Field and Far-Field Scanning Modes



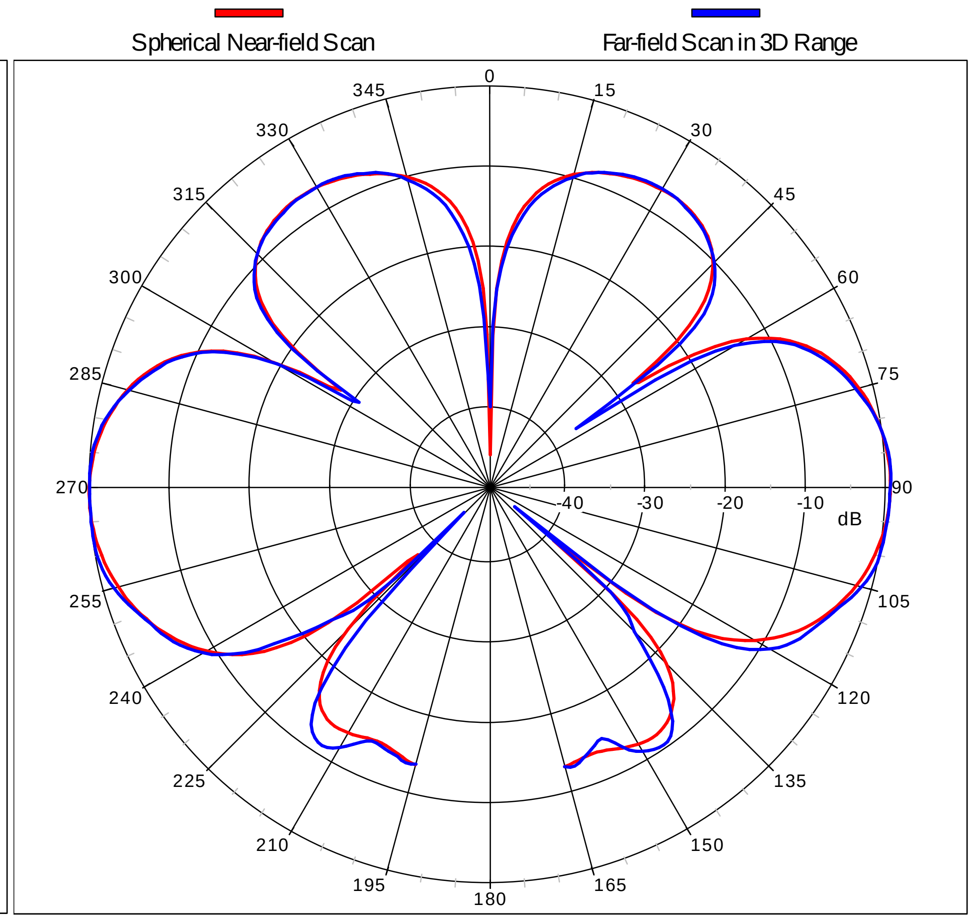


Measurement Consistency of Near-Field and Far-Field Scanning Modes

2.4GHz 5 dBi Dipole E-plane Pattern Comparison



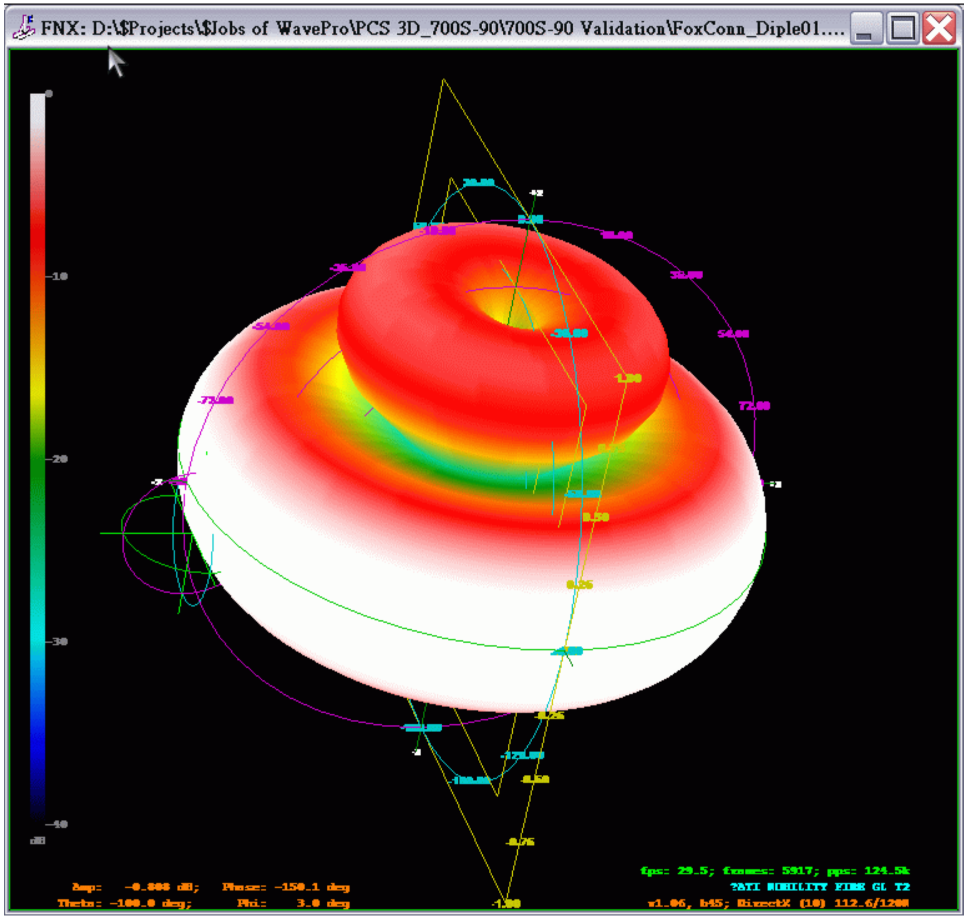
2.4GHz 5 dBi Dipole E-plane Pattern Comparison

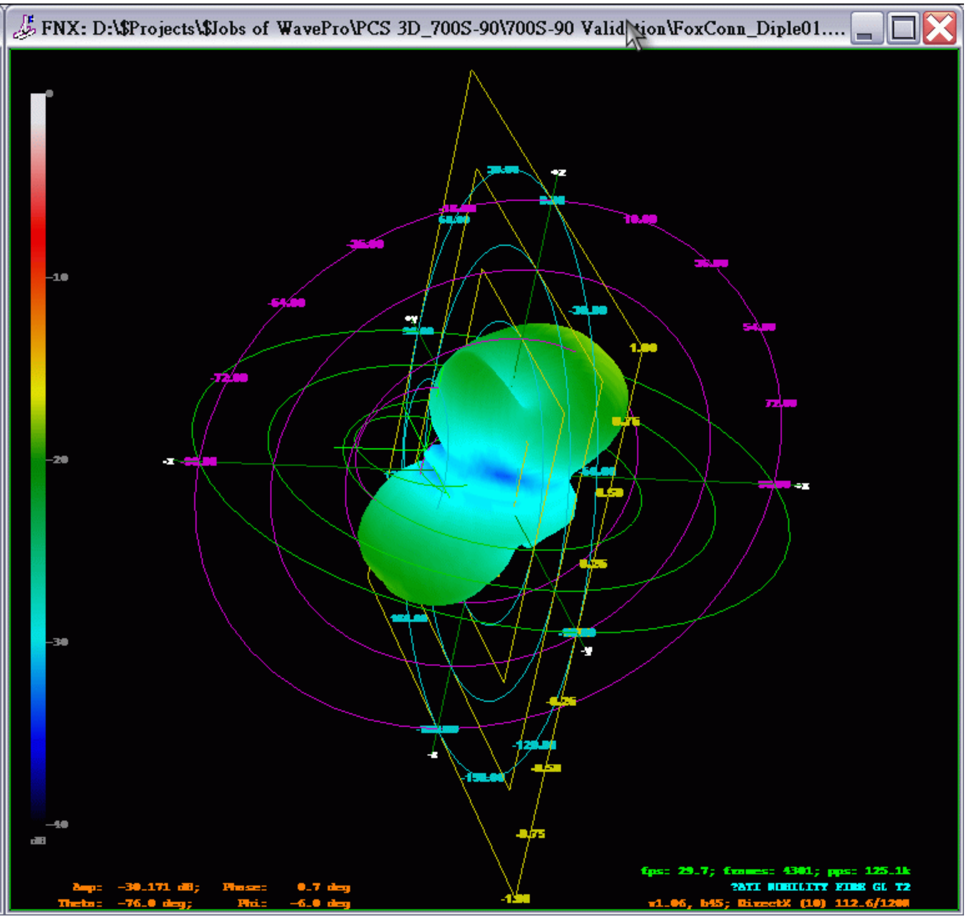


Antenna Patterns vs. Antenna Polarizations

The Choice of Coordinate Systems

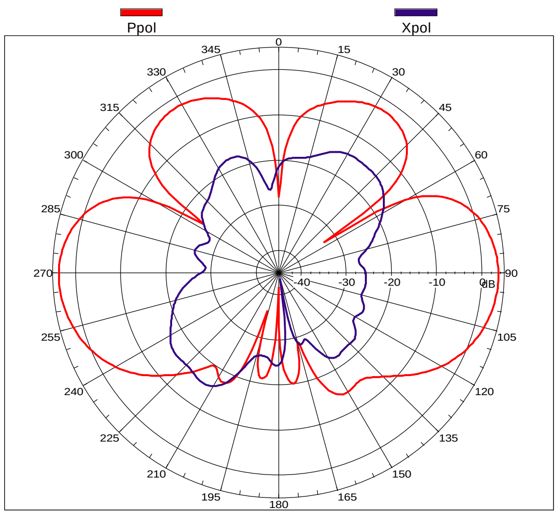
3-D E_{θ} & E_{ϕ} Component Patterns of An Imperfect Dipole Antenna @2.4GHz



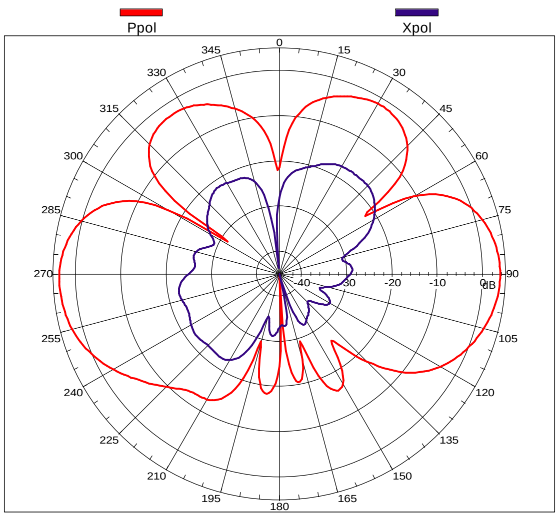


2-D E_θ & E_ϕ Polarization Patterns of An Imperfect Dipole Antenna @2.4GHz

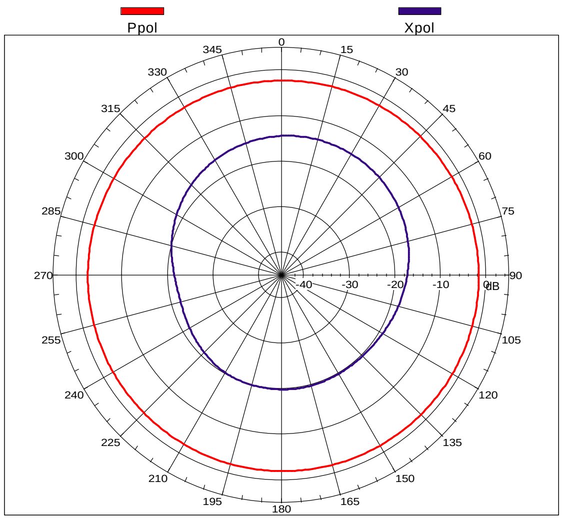
Ludwig 2 Theta-Phi Pol Sense of FoxConn_Diple @2.4Ghz
V-Cut @ Phi=0 deg



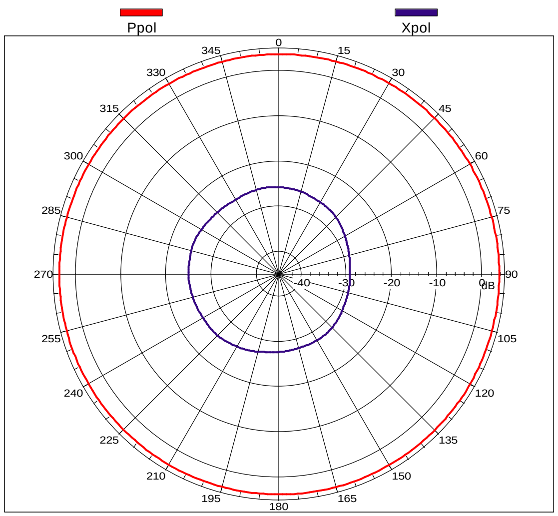
Ludwig 2 Theta-Phi Pol Sense of FoxConn_Diple @2.4Ghz
V-Cut @ Phi=90 deg



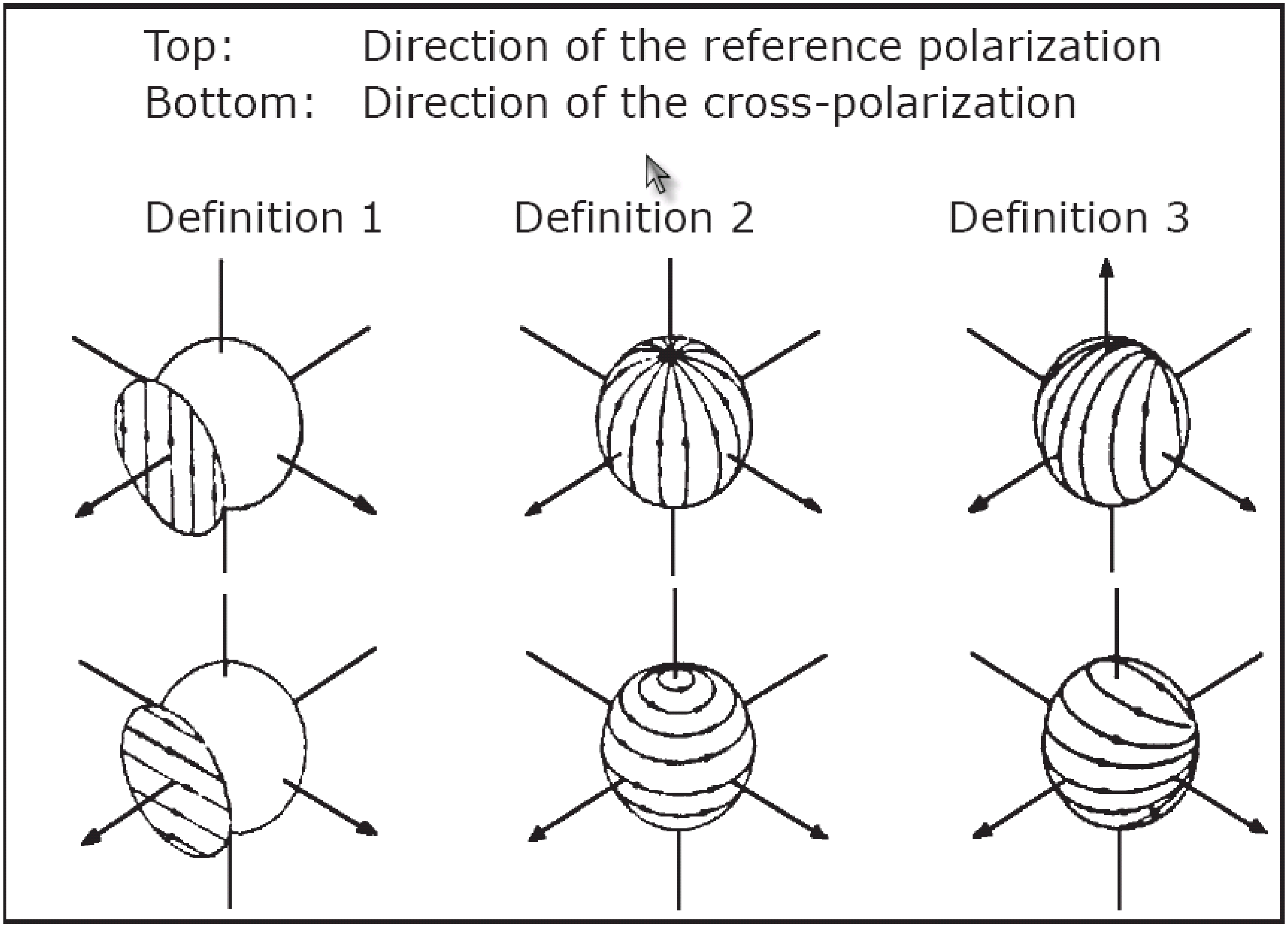
Ludwig 2 Theta-Phi Pol Sense of FoxConn_Diple @2.4Ghz
H-Cut @Theta=35 deg



Ludwig 2 Theta-Phi Pol Sense of FoxConn_Diple @2.4Ghz
H-Cut @Theta=90 deg



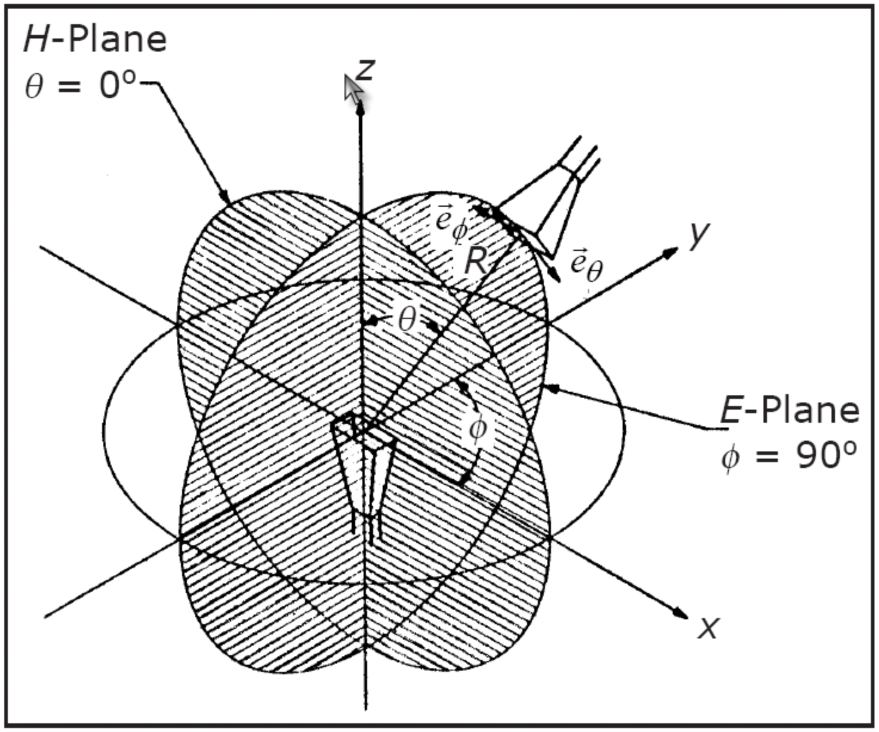
Definition of Cross-Polarization by A. C. Ludwig



The three definitions of linear polarization

Ludwig 3 (L-3) Type Definition of Cross-Polarization

The directions of the co- and cross-polarization are defined by cuts which are obtained by standard antenna measurement practice applying a turntable.



Coordinate system for standard antenna measurements

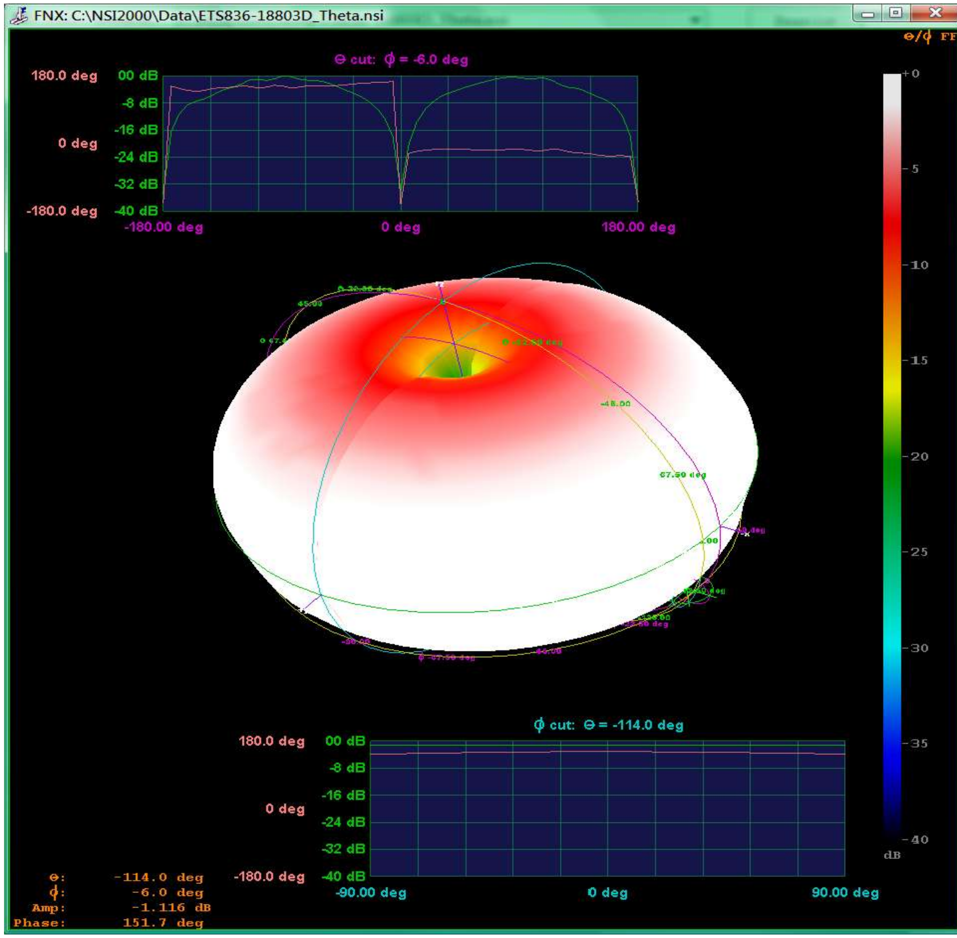
The direction of co-polarization is defined here by the orientation of the polarization vector at θ=0°. The cross-polarization is than obtained by rotation of the range antenna by ϕ = 90°.

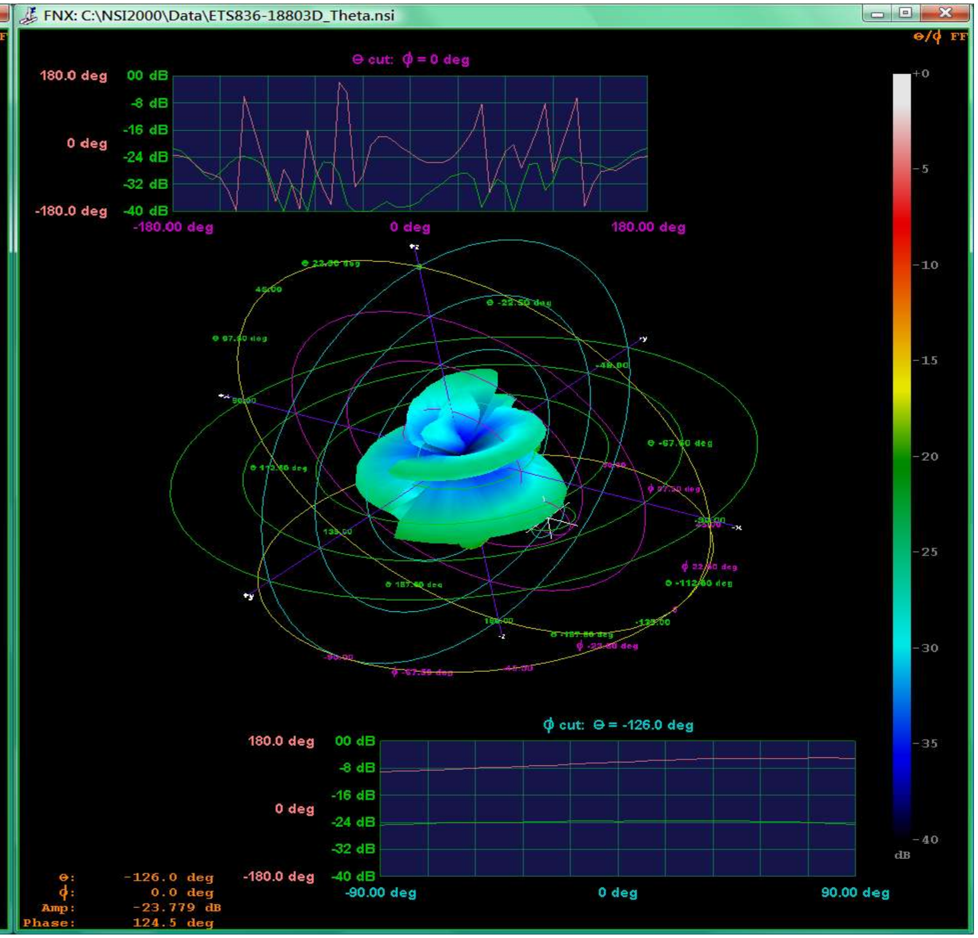
For the case shown in the figure to the left the co-polarization is oriented in the *y*-direction and the following copol and xpol pattern will be measured:

$$C_{\text{copol}} = E(\theta,\phi)\left\{\sin\phi\,\vec{e}_\theta + \cos\phi\,\vec{e}_\phi\right\} \qquad \vec{C}_{copol}\Big|_{f=0} = E(q,f=0)\vec{e}_f \sim \vec{e}_y$$

$$C_{\text{xpol}} = E(\theta,\phi)\left\{\cos\phi\,\vec{e}_\theta - \sin\phi\,\vec{e}_\phi\right\} \qquad \vec{C}_{xpol}\Big|_{f=90} = E(q,f=90)\vec{e}_q \sim \vec{e}_x$$

3-D L-2 E_θ & E_ϕ Polarization Component Patterns of A Sleeve Dipole Antenna @ 1.7 GHz

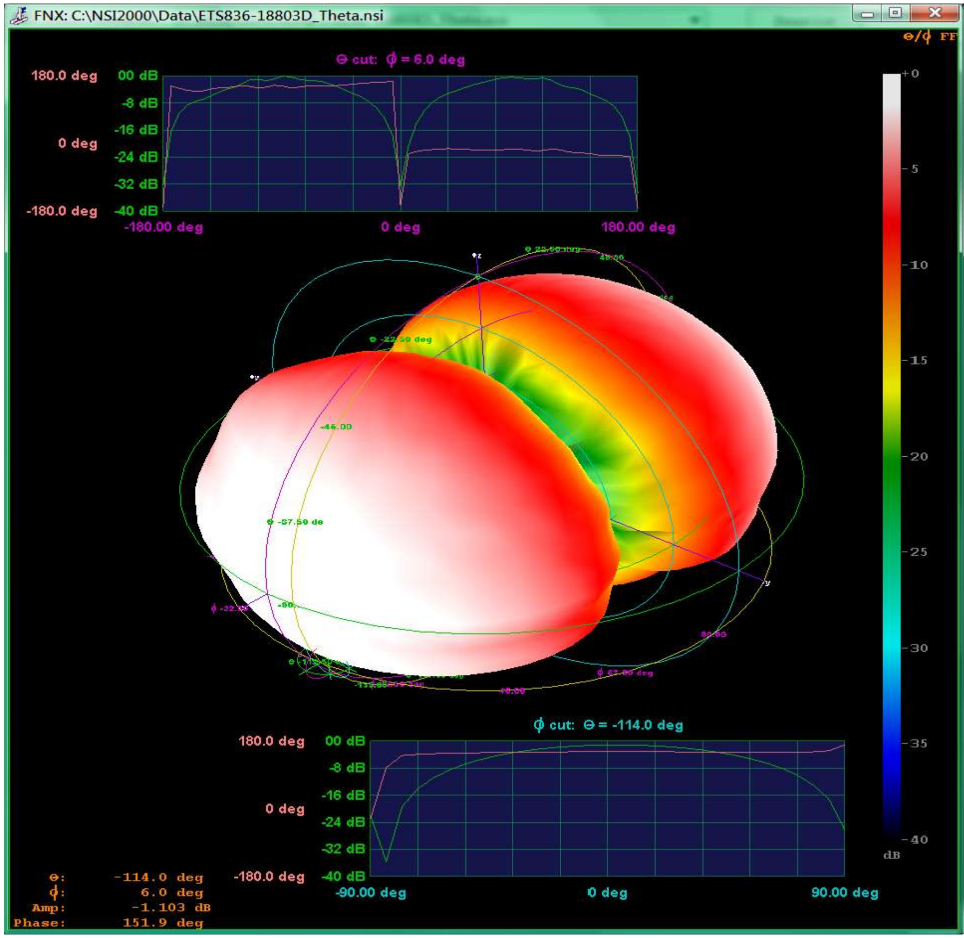


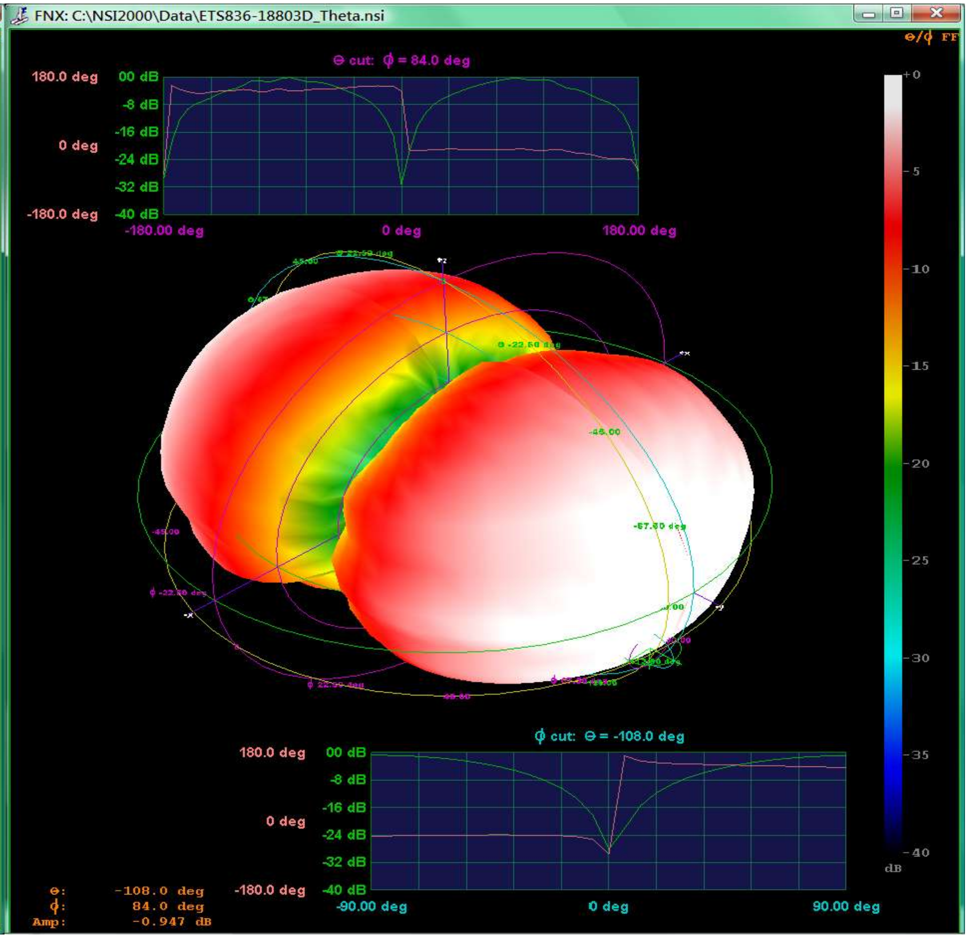


E_q/Co-Pol

E_f/X-Pol

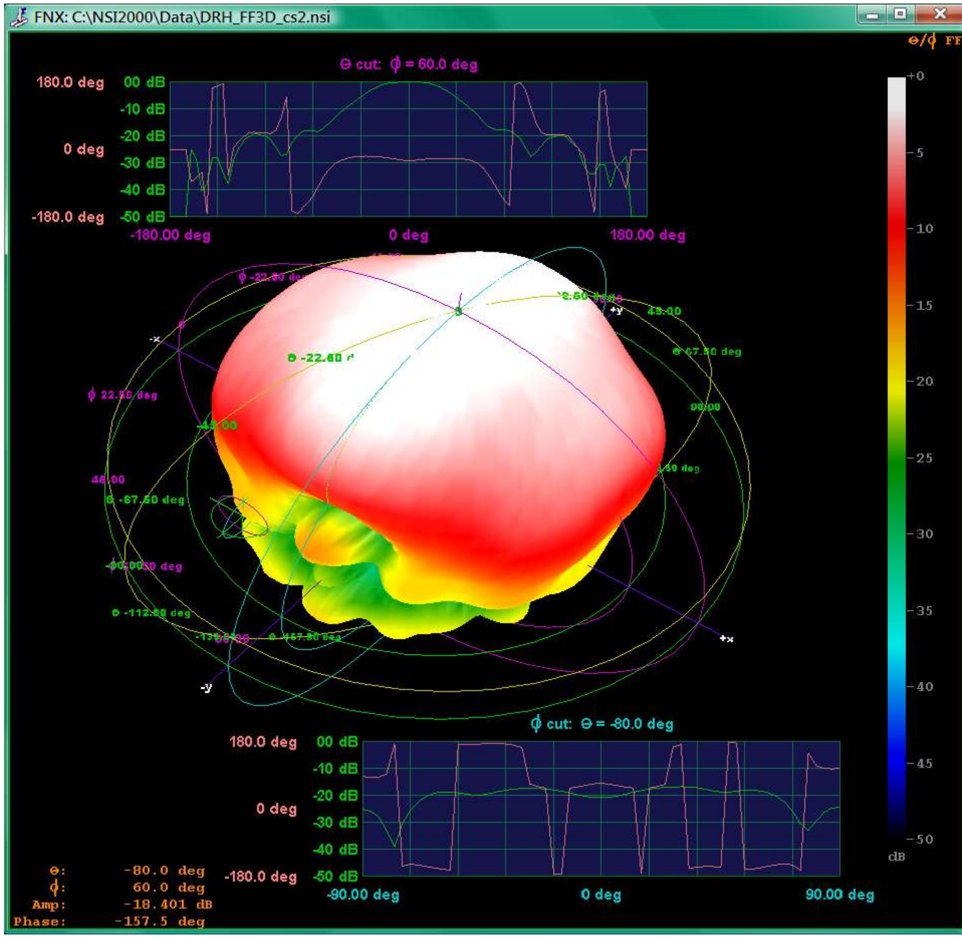
3-D L-3 Polarization Component Patterns of A Sleeve Dipole Antenna @ 1.7 GHz



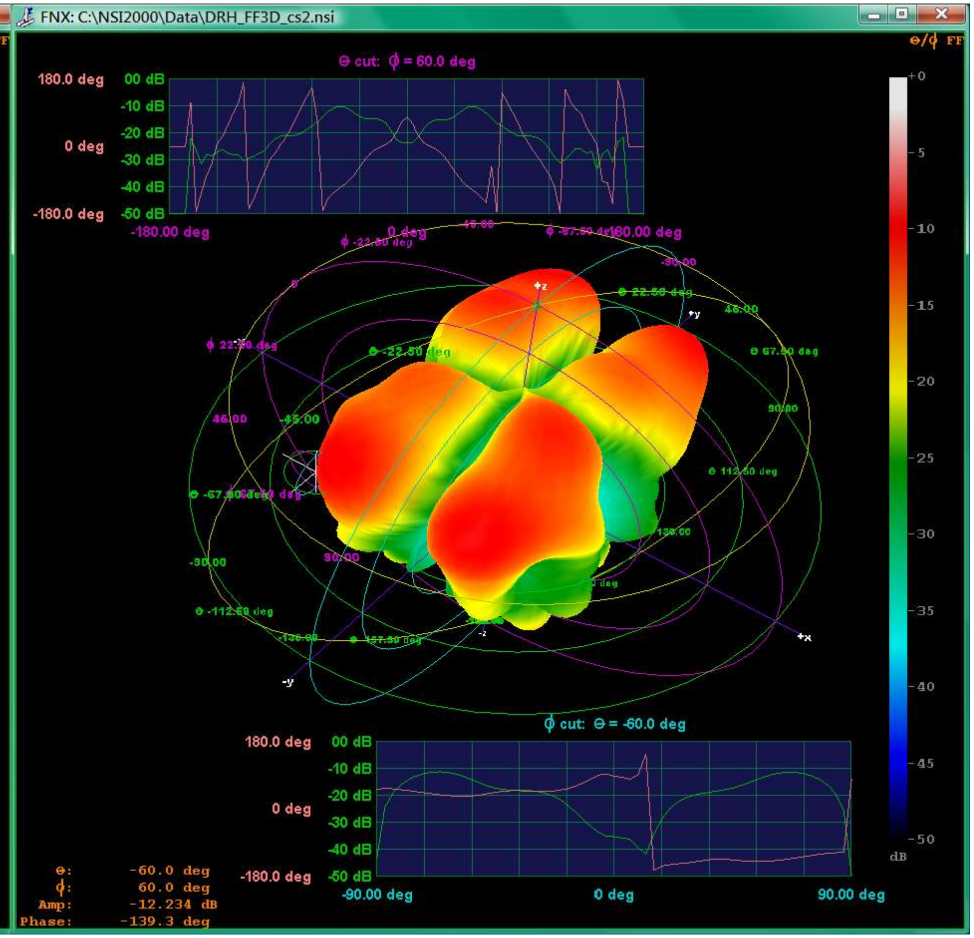


E_h-Pol E_v-Pol

3-D L-3 Polarization Component Patterns of A Horn Antenna @ 4GHz

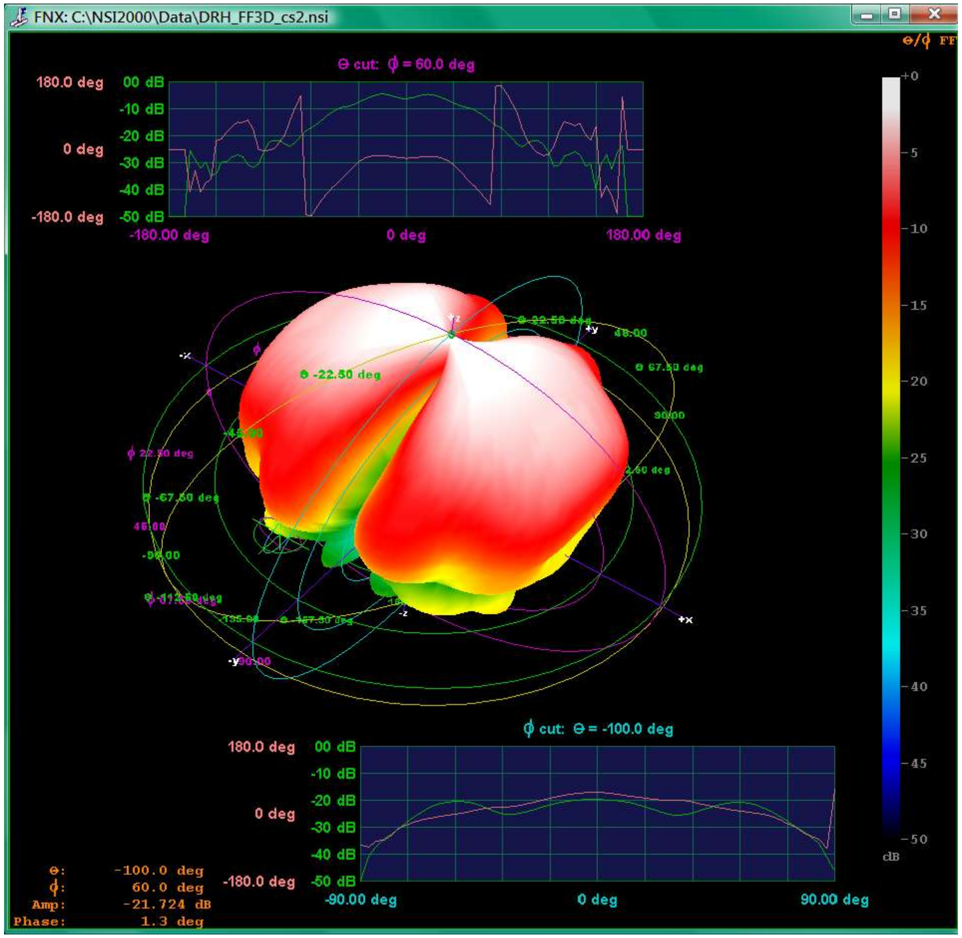


Co/E_h-Pol

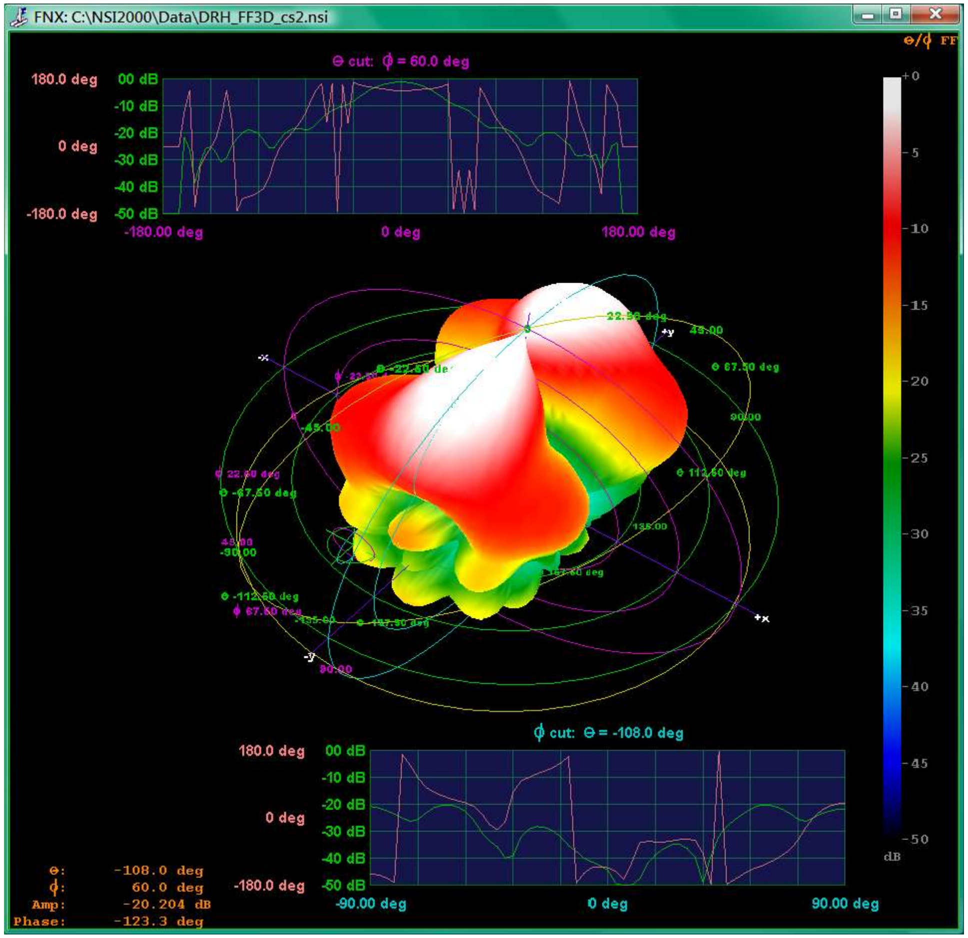


X/E_v-Pol

3-D L-2 E_θ & E_ϕ Polarization Component Patterns of A Horn Antenna @ 4GHz

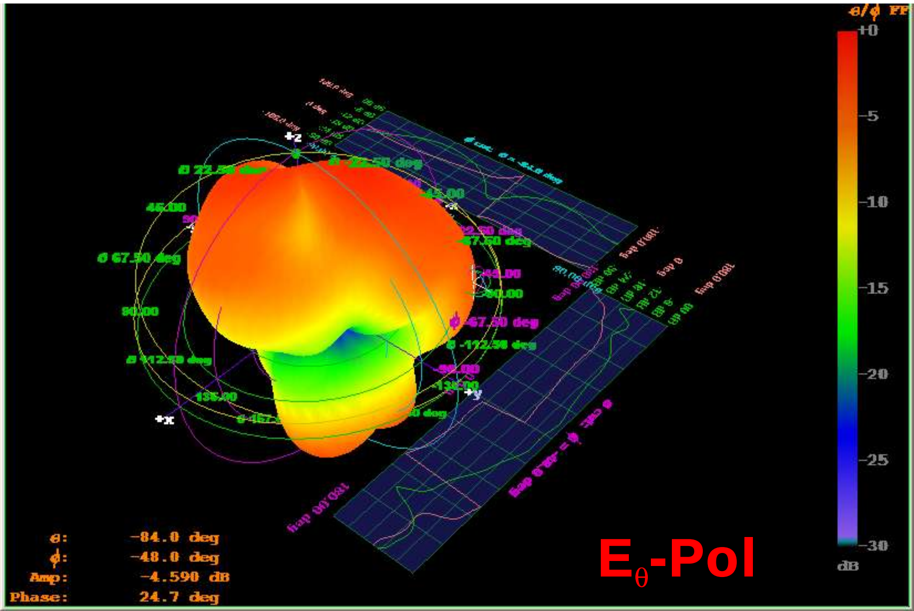


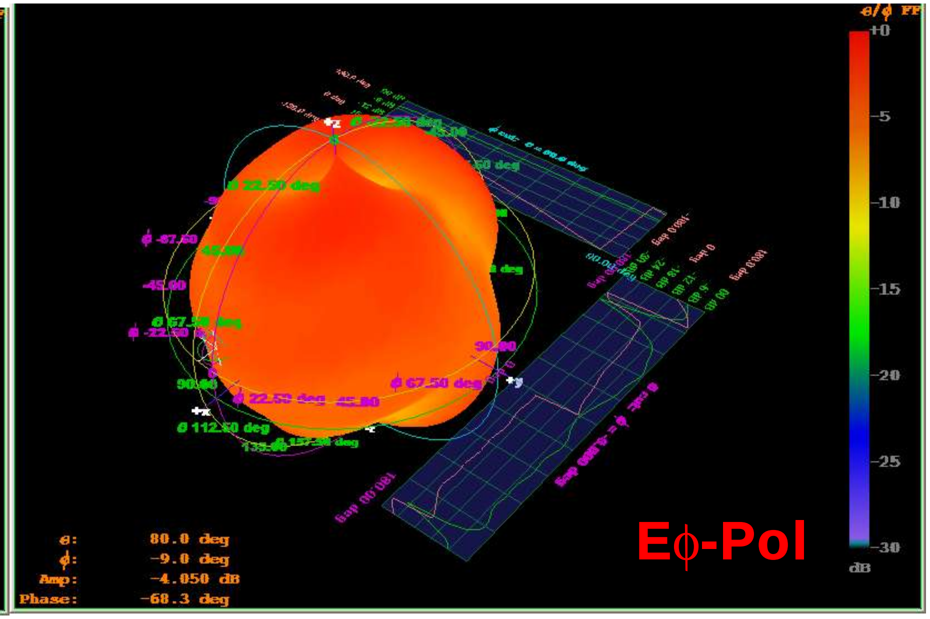
E_θ-Pol

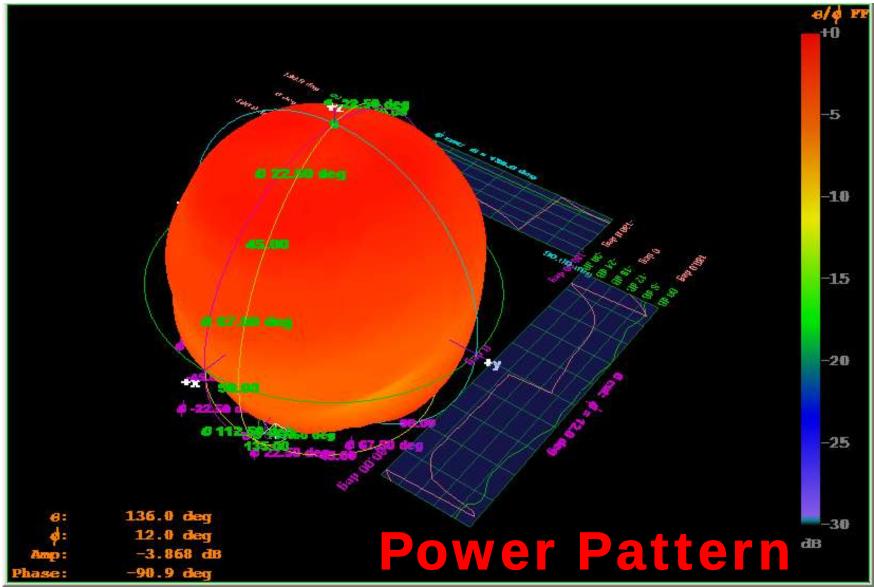


$E\phi$-Pol

Antenna Power Pattern & Polarization Patterns: Case of A Patch Antenna



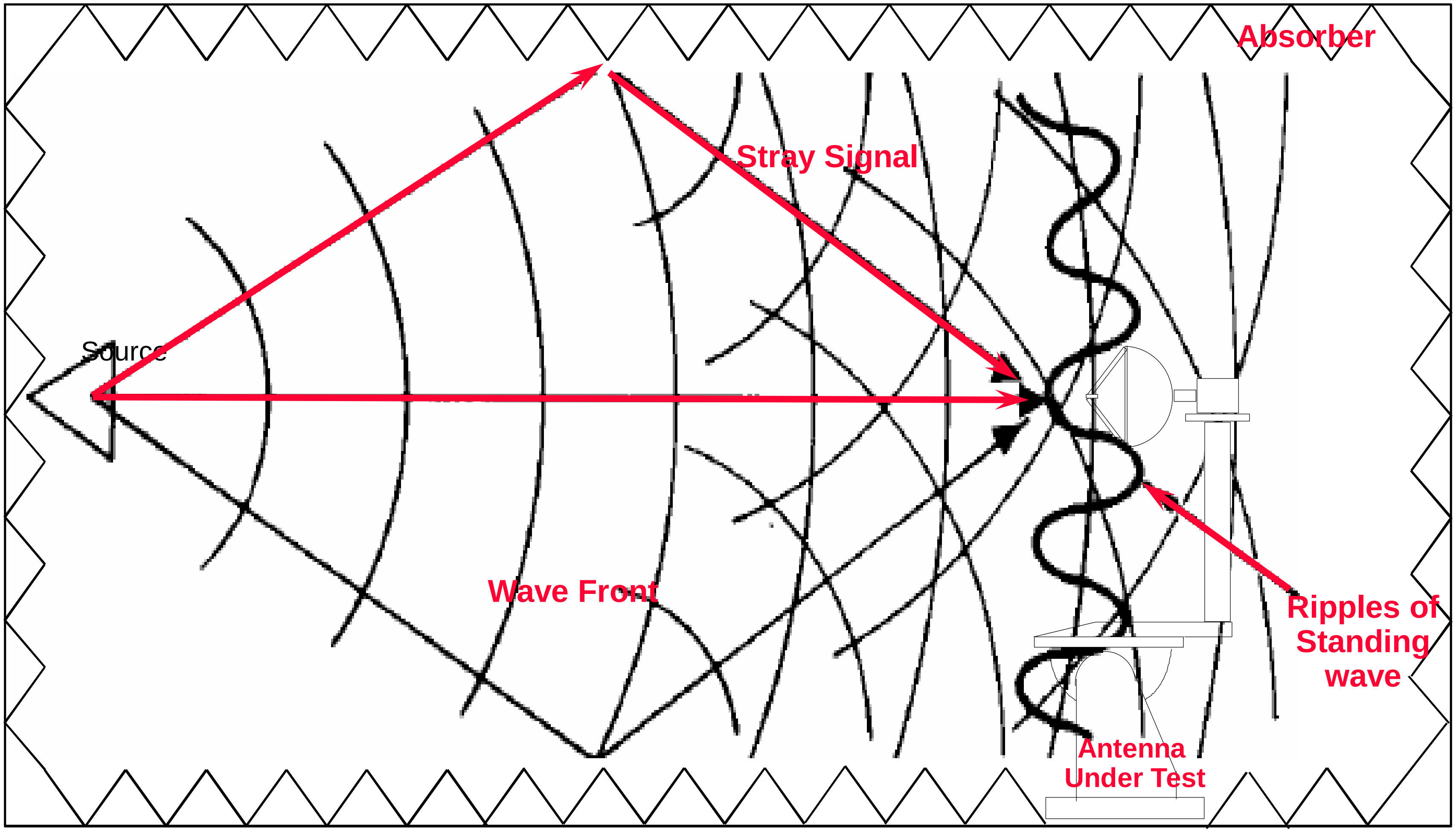




MAJOR FACTORS THAT AFFECT WIRELESS COMMUNICATION ANTENNA MEASUREMENT RESULTS

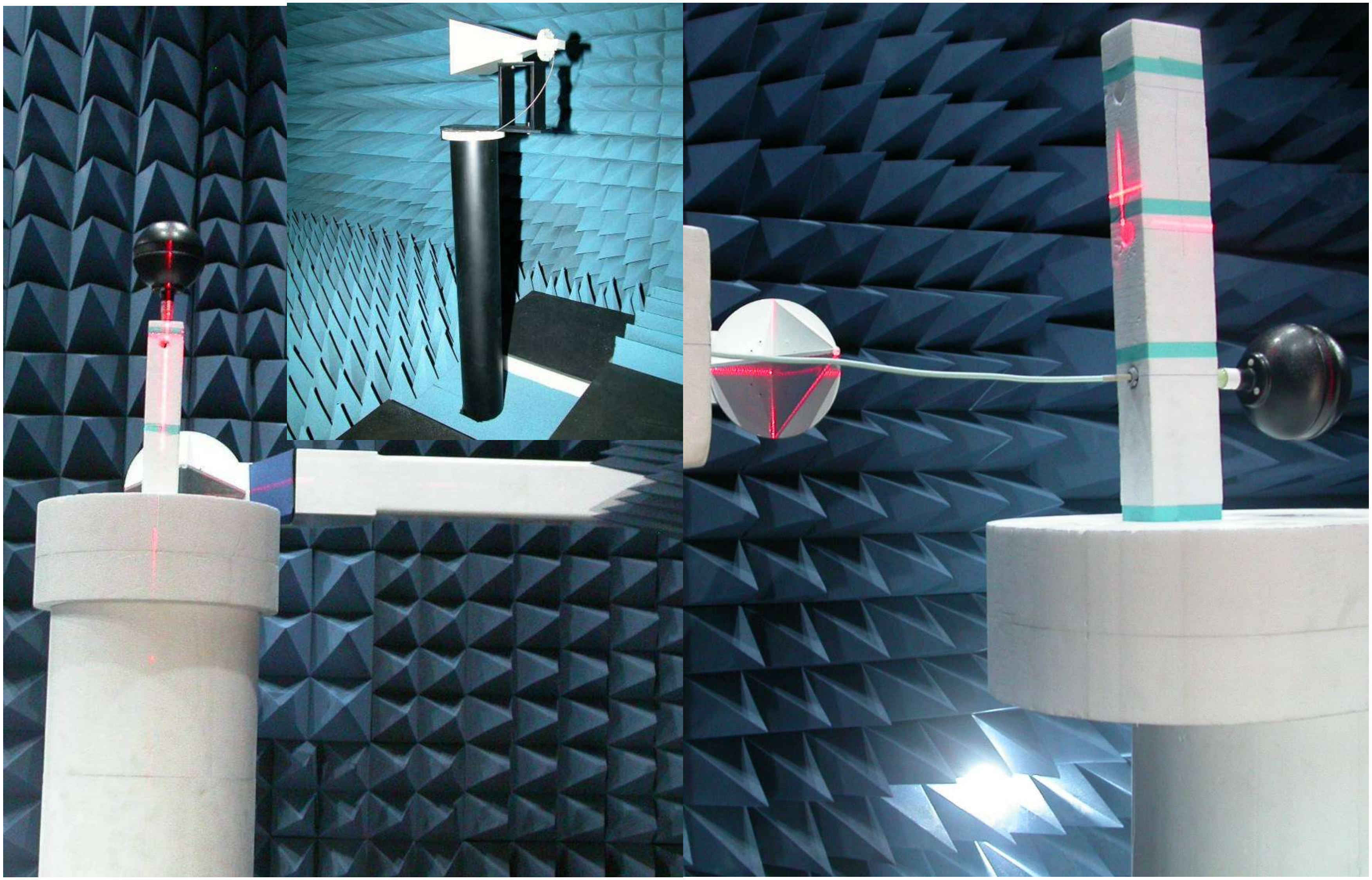
- ***Quiet Zone Ripple Due to Multi-path Signal Interference***
  - ***Critical to electrically large antenna in far-field measurement range***
- ***AUT Supporter***
  - ***Critical to low gain antenna***
  - ***Applying a low dielectric material made AUT supporter.***
- ***Feeding Cable***
  - ***Critical to low gain antenna***
  - ***Due to coupling between feeding cable and AUT with unbalanced circuit design***
  - ***Use a 3D antenna measurement configuration to minimize needs of change AUT to Feeding cable orientation***
- ***System Sensitivity/Dynamical Range***
  - ***Critical to low gain antenna***
  - ***To improve the system sensitivity***
    - **Increase the radiating power and reduce IF band width**
    - **Decrease the path loss or increase # of average during measurement**
    - **Using phase lock loop receiver (VNA) instead of power meter with SA**

Quiet Zone Ripples In Anechoic Chamber

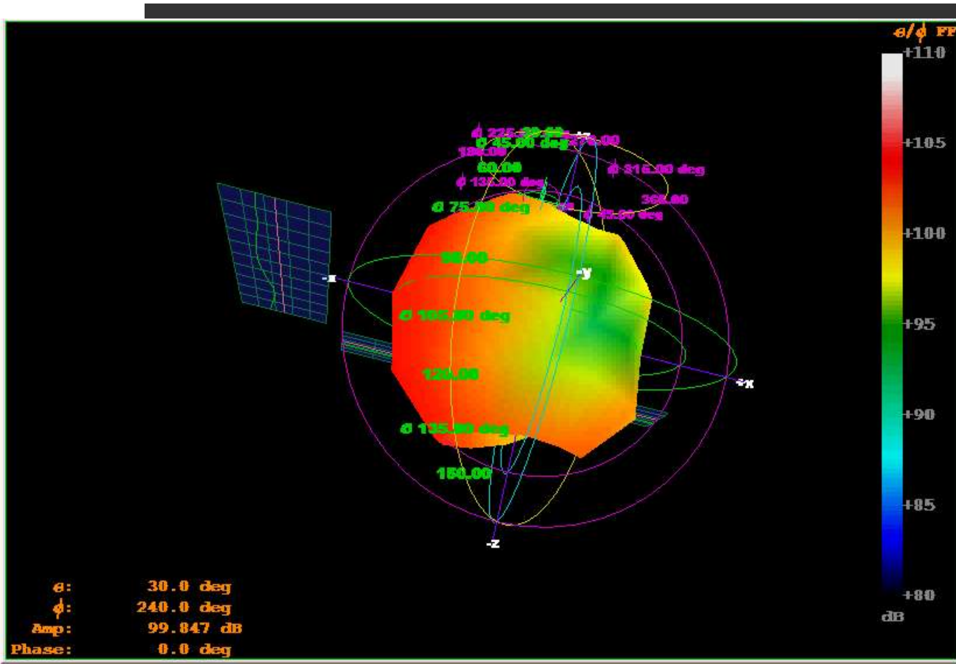


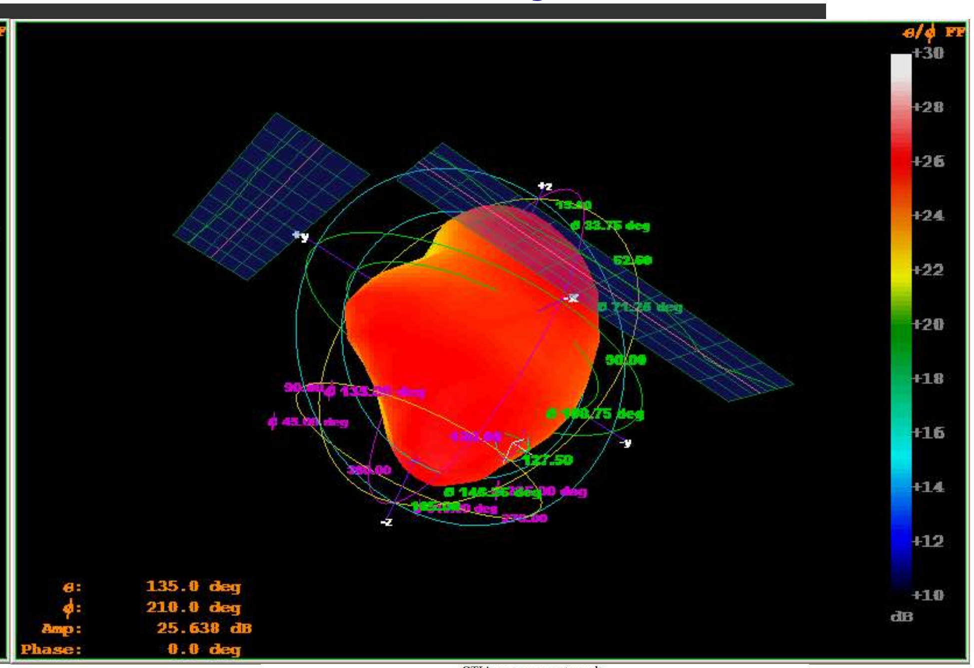
Far-field

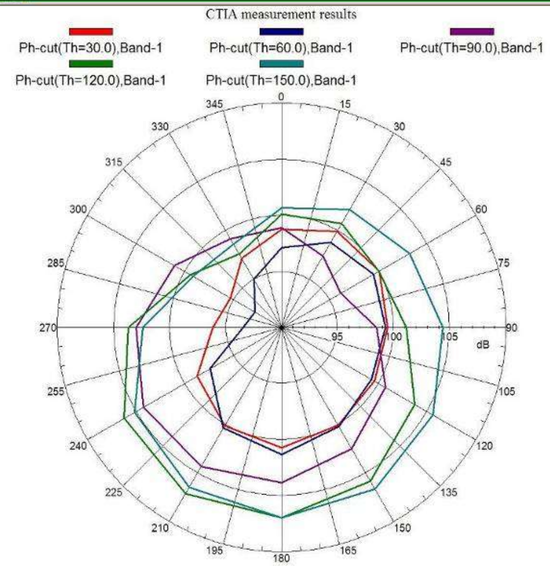
AUT Supporter/Feeding Cable : A Major Mutual-Coupling Source for Low Gain Antenna Measurement Results

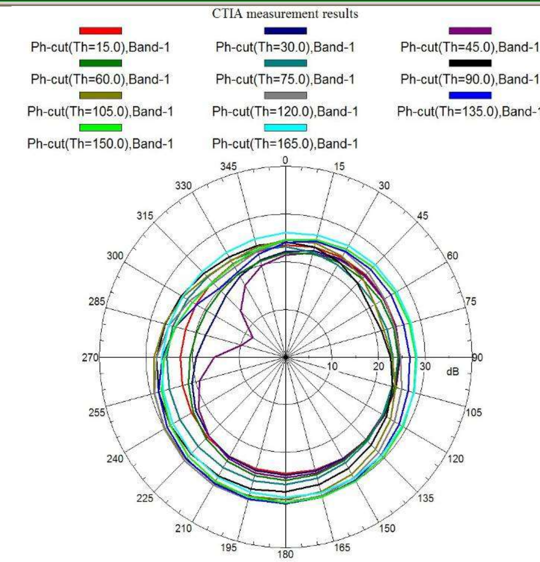


Application of 3D Scanning to Active Mode Measurements: Mobile Stations Power Pattern and Sensitivity Pattern









WHY GOES 3D MEASUREMENT SOLUTIONS FOR WIRELESS COMMUNICATION ANTENNAS CHARACTERIZATION ?

- Patterns being mostly very low gain with very wide angular coverage or omni-directional and/or requiring making use of polarization/space diversity for better communication quality
- Measurement of very low gain antennas at specific frequency range are highly susceptible to coupling between AUT to feeding cable and AUT to the supporting structure
- Low dielectric supporting material, good matching of feeding cable to AUT with unique and rigid way of RF cable routing are essential for consistent pattern measurement results
- Use a 3D ANTENNA MEASUREMENT CONFIGURATION to minimize needs of change AUT to feeding cable orientation for CONSISTENT MEASUREMENT RESULTS

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