Master Thesis

Development of a Broadband Circular Polarised Antenna for Over-The-Air Performance Test Applications

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Outline

- Motivation
- Introduction
- Frequency Independent Antenna
- Planar Spiral Antenna
- Simulation Results
- Measurement Results
- Conclusion
- Future Work

Motivation

- **Over The Air (OTA) Test**

  - Characterize the air interference of a mobile device.
  - Need a measurement system that can collect data on a spherical surface enclosing the DUT.

- **Broadband antenna** → GSM,UMTS & Higher order modes

- **Circular Polarized** → Unknown DUT Polarization

  - Planar Spiral Antenna
  - Conical Spiral Antenna
  - Cross Log-periodic Antenna

  → Balance feeding

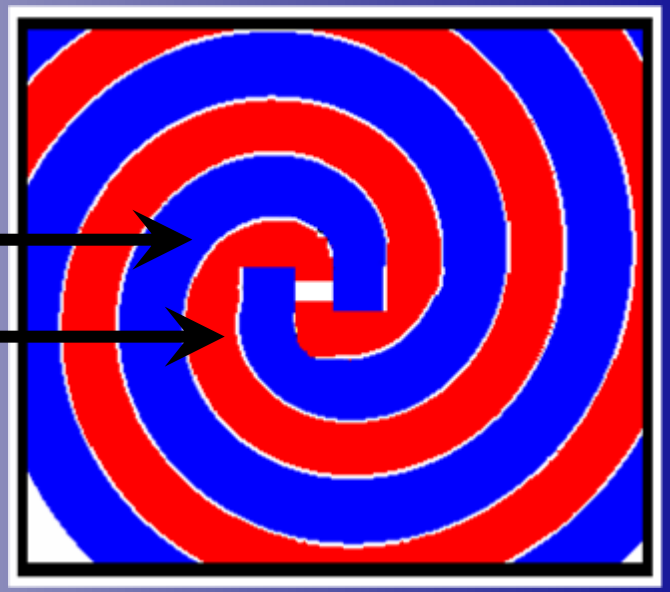
  → Unidirectional pattern

Introduction

- **Frequency Independent Antenna**

  The antenna characteristics are invariant to change of the physical size of antenna.

- **Frequency Independent Antenna Principles:**
  - **Angle principle**
  - **Truncation principle**
  - **Periodic principle**



- **Self-Complementary Structure**

$$Z_1 * Z_2 = \left(\frac{Z_0}{2}\right)^2 = (188.5)^2 \ (\Omega)$$

$$Z_1 = Z_2 = 188.5\Omega$$

Selection Process

	Planner Spiral	Conical Spiral	Cross Log Periodic
Lower Frequency Limit	$\frac{\lambda_{LF}}{2\pi}$ extend in 2D Small	$\frac{\lambda_{LF}}{2\pi}$ extend in 3D Medium	$\frac{\lambda_{LF}}{2}$ extend in 3D Large
Higher Frequency Limit	$\frac{\lambda_{HF}}{2\pi}$	$\frac{\lambda_{HF}}{2\pi}$	$\frac{\lambda_{HF}}{2}$
Polarization	-RHCP or LHCP. -Reverse winding or external feeding. -Direct result of physical shape.	-RHCP or LHCP. -Reverse winding or external feeding. -Direct result of physical shape.	-H,V,RHCP,LHCP -Switching circuit -Orthogonal elements
Power handling	SMA connector coaxial cable	SMA connector coaxial cable	SMA connector coaxial cable
BW limit	Upper frequency limit depend on how fine is the feeding	Upper frequency limit depend on how fine is the feeding	Dependent on the antenna physical size

Selection Process (Cont.)

	Planner Spiral	Conical Spiral	Cross Log Periodic
Balun	Balanced need Balun	Balanced need Balun	Balanced need Balun
Feeding Circuit	Simple feeding	Simple feeding	If the element is well aligned no need for hybrid.
Phase center	Stable	Change with Frequency	Change with Frequency
Gain over the total BW	Low	Medium	High
Coverage	Need cavity for unidirectional	Unidirectional	Unidirectional
Weight	Light	Medium	Heavy
Reproducibility	Easy	Medium	Complicate
Ranked	1	2	3

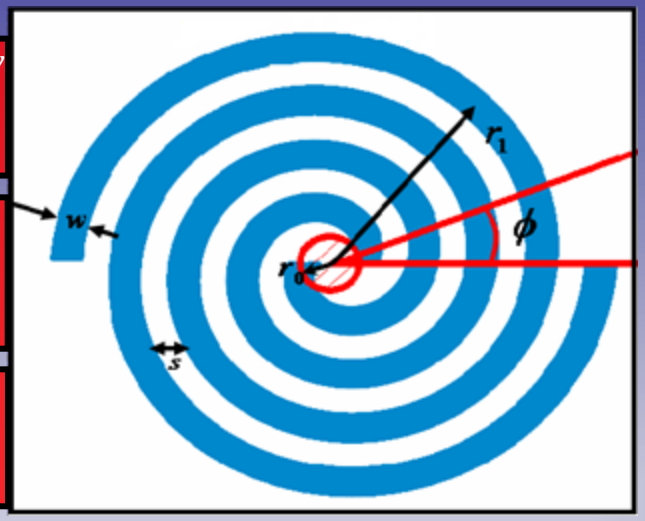
Planar Spiral

Archimedean Spiral

Self-Complementary when $\delta = \pi/2$

$$s = w = \frac{r_1 - r_0}{4N}$$

$$a = \frac{s + w}{\pi} = \frac{2w}{\pi}$$



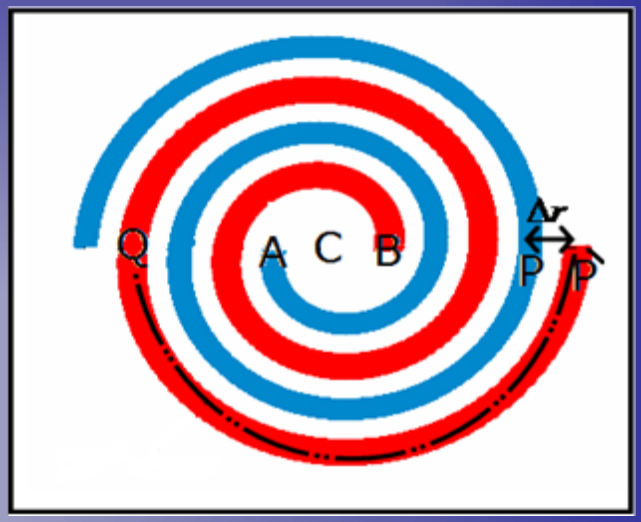
First Arm

$$r_1 = r_0(1 + a\phi)$$
$$r_2 = r_0(1 + a(\phi - \delta))$$

Second Arm

$$r_3 = r_0(1 + a(\phi - \pi))$$
$$r_4 = r_0(1 + a(\phi - \pi - \delta))$$

How Radiation happen

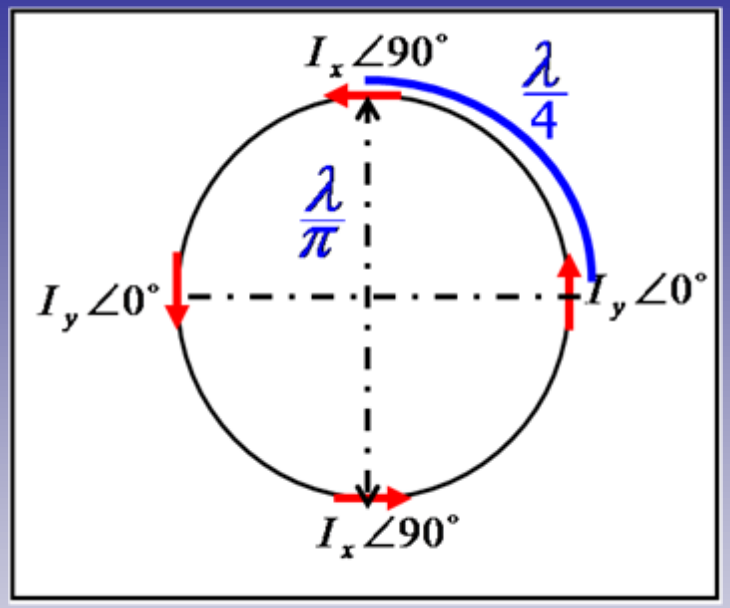


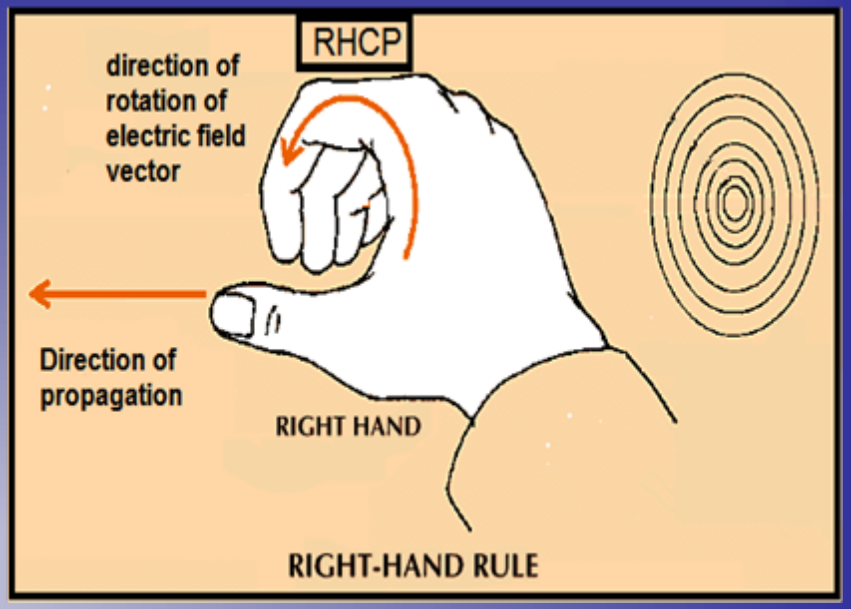
$$L_{QP'} = \pi r = \lambda/2$$

Under Antiphase feeding at points A and B Radiation happen when

$$2\pi r = \lambda$$

Circular Polarized Radiation





Circumference=λ

$|I_x| \cong |I_y|$ & $I_x \perp I_y$

I_x, I_y 90° *phase different*

RHCP Rule

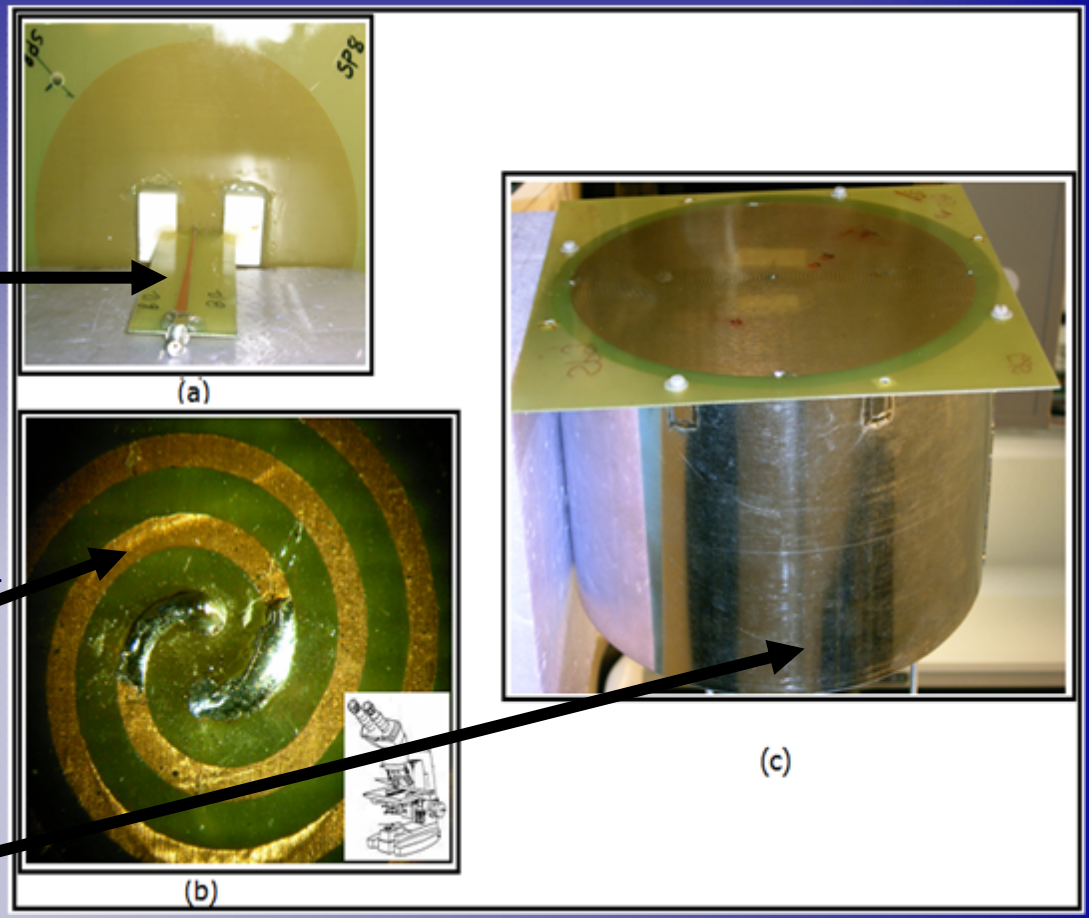
RHCP OR LHCP depend on

Rotation sense

Spiral Antenna System

Consist from 3 Units

- **Feeding circuit (Balun)**
- **Archimedean Spiral PCB**
- **Absorber loaded Cavity**



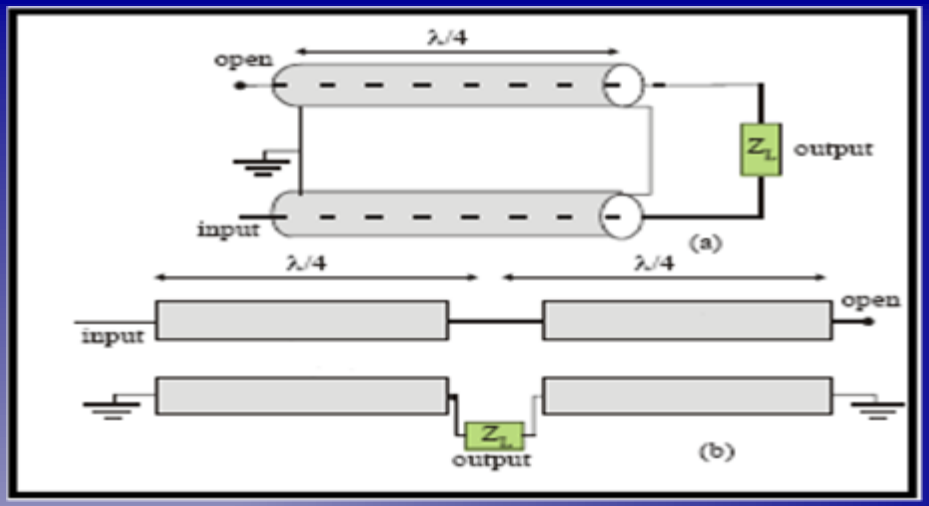
Feeding Circuit (Balun)

Balun will provide

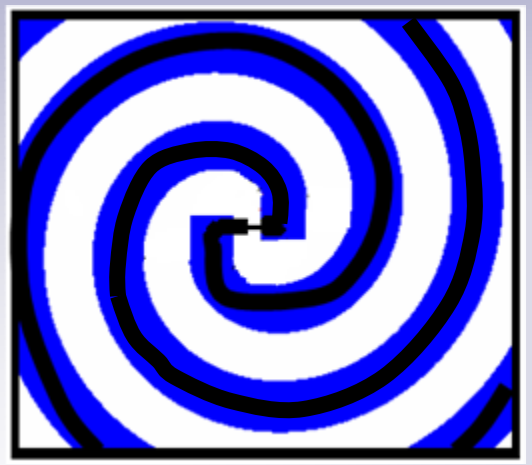
- Balanced feeding
- Impedance transformation

Baluns type

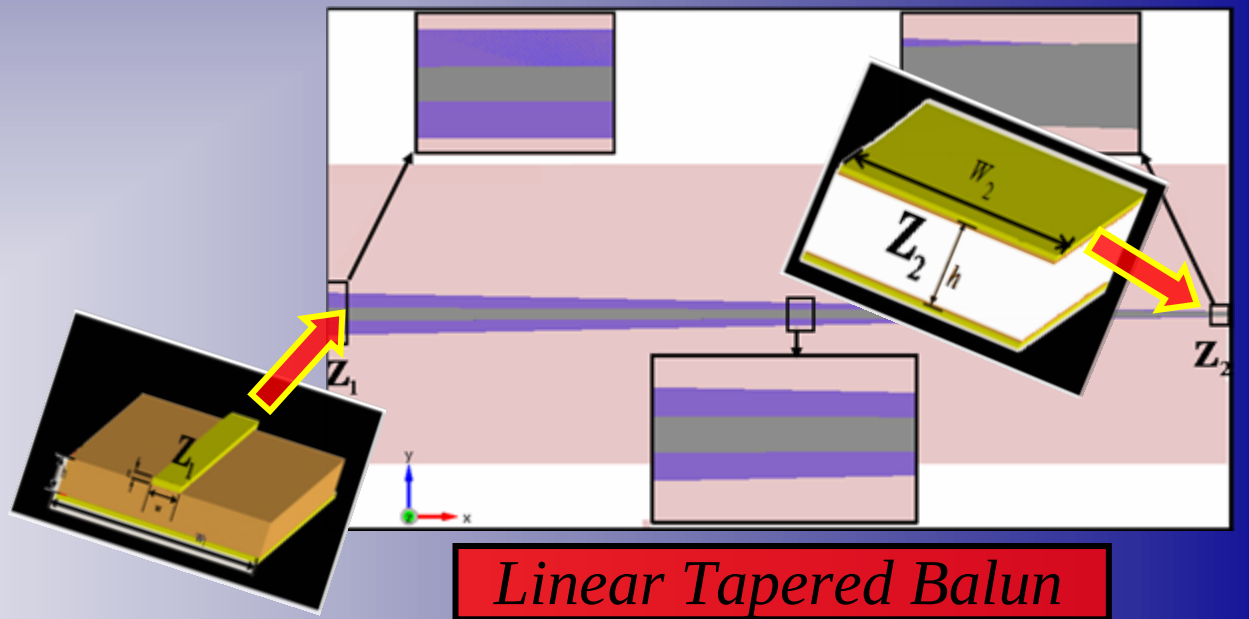
- Linear Tapered Balun
- Infinite Balun
- Marchand balun



Marchand Balun

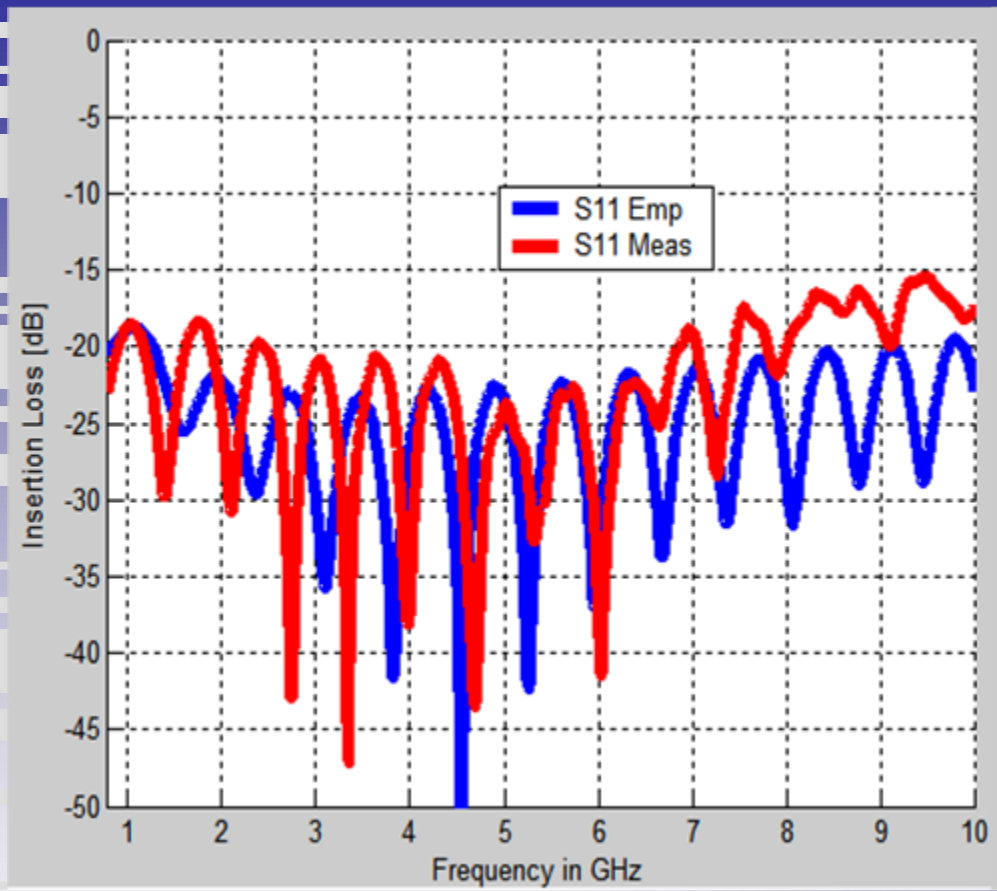


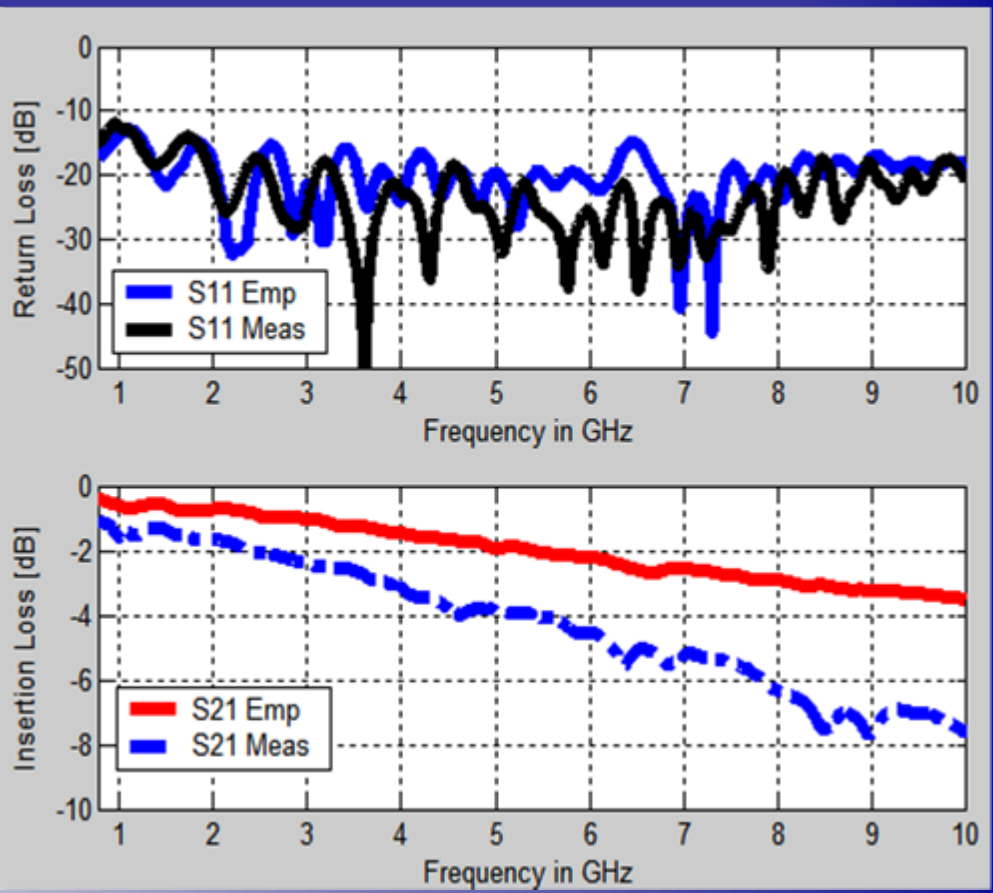
Infinite Balun



Linear Tapered Balun

Balun Simulation and Measurement

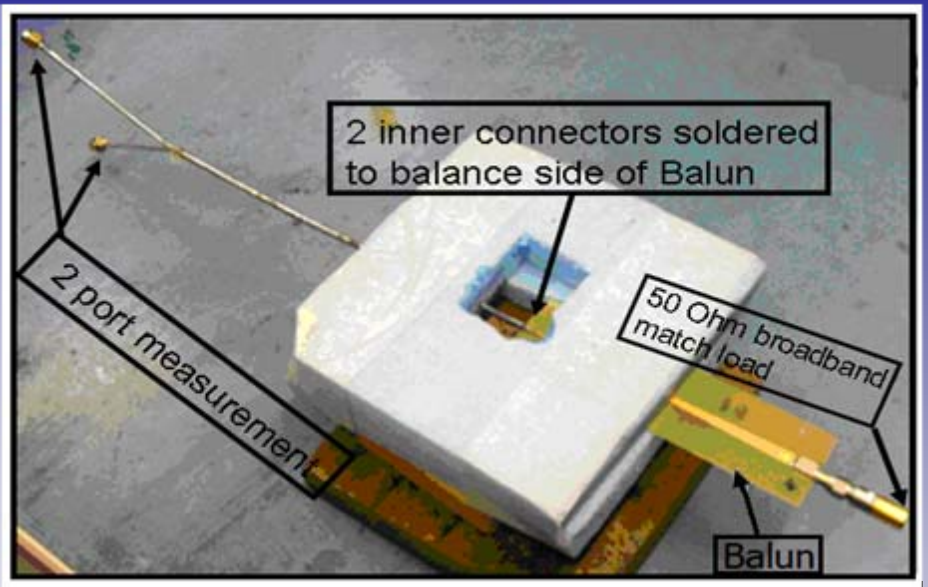


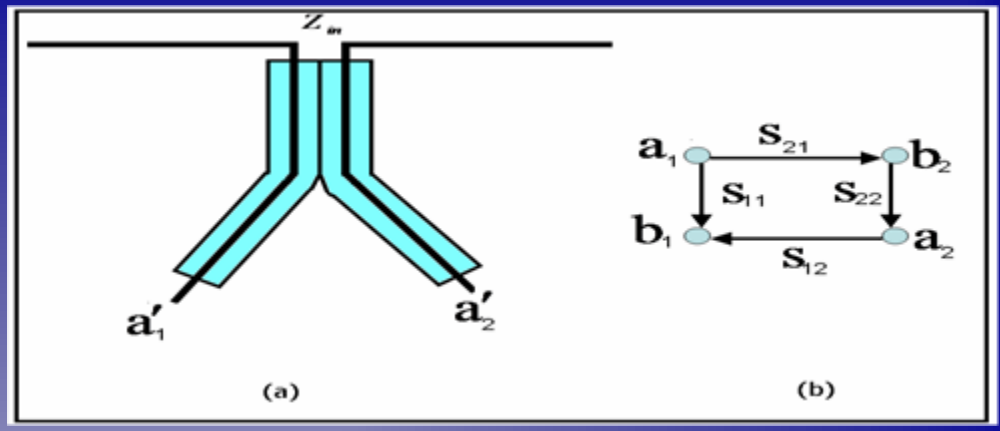


Measurement and Simulation results for Single balun

Measurement and Simulation results for B2B balun

Measurement Verification



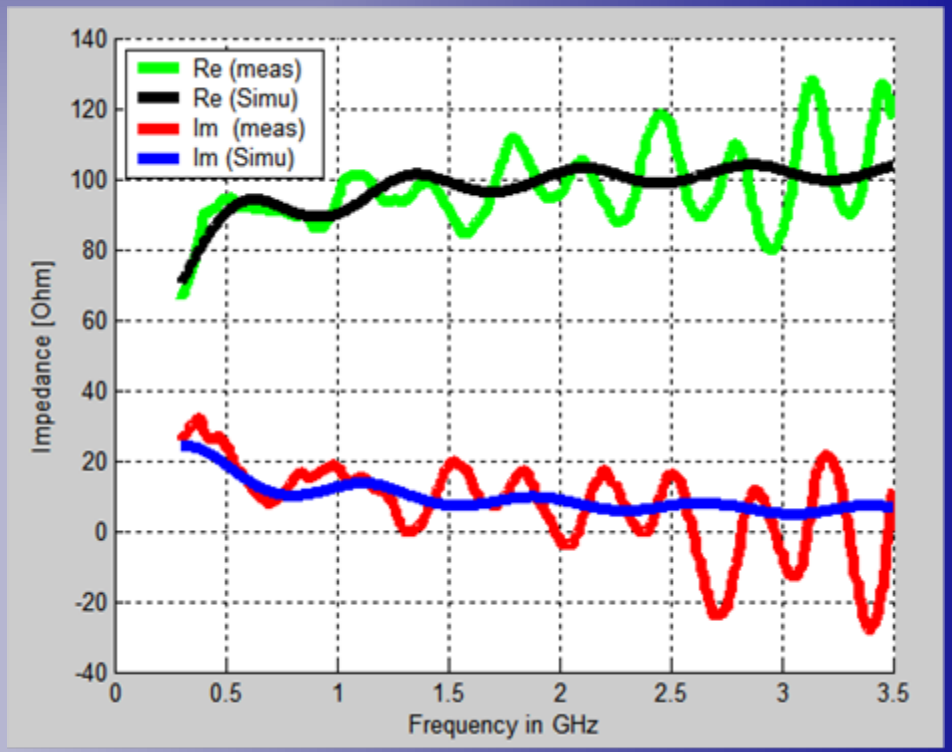


$S_{11}=S_{22}$, $S_{21}=S_{12}$ $\Leftarrow$ Symmetry

$a_1=-a_2$ $\Leftarrow$ Balanced feed

$$\Gamma=S_{11}-S_{21}$$

$$Z_{in}=2Z_0\frac{1+\Gamma}{1-\Gamma}=100\frac{1+S_{11}-S_{21}}{1-S_{11}+S_{21}}$$



Antenna Parameters and Simulation

1: Spiral rate of growth (a)

Improved in AR for tight spiral growth of rate (small value of a)

2: Conductor spacing (w)

Self-Complementary or No Self-Complementary control the impedance of antenna

3:Feed structure

$r_0 = w$ *will provide flat resistance and close to zero reactance*

4: Spiral diameter

$D_{max} > \lambda/\pi$

Activate High order modes

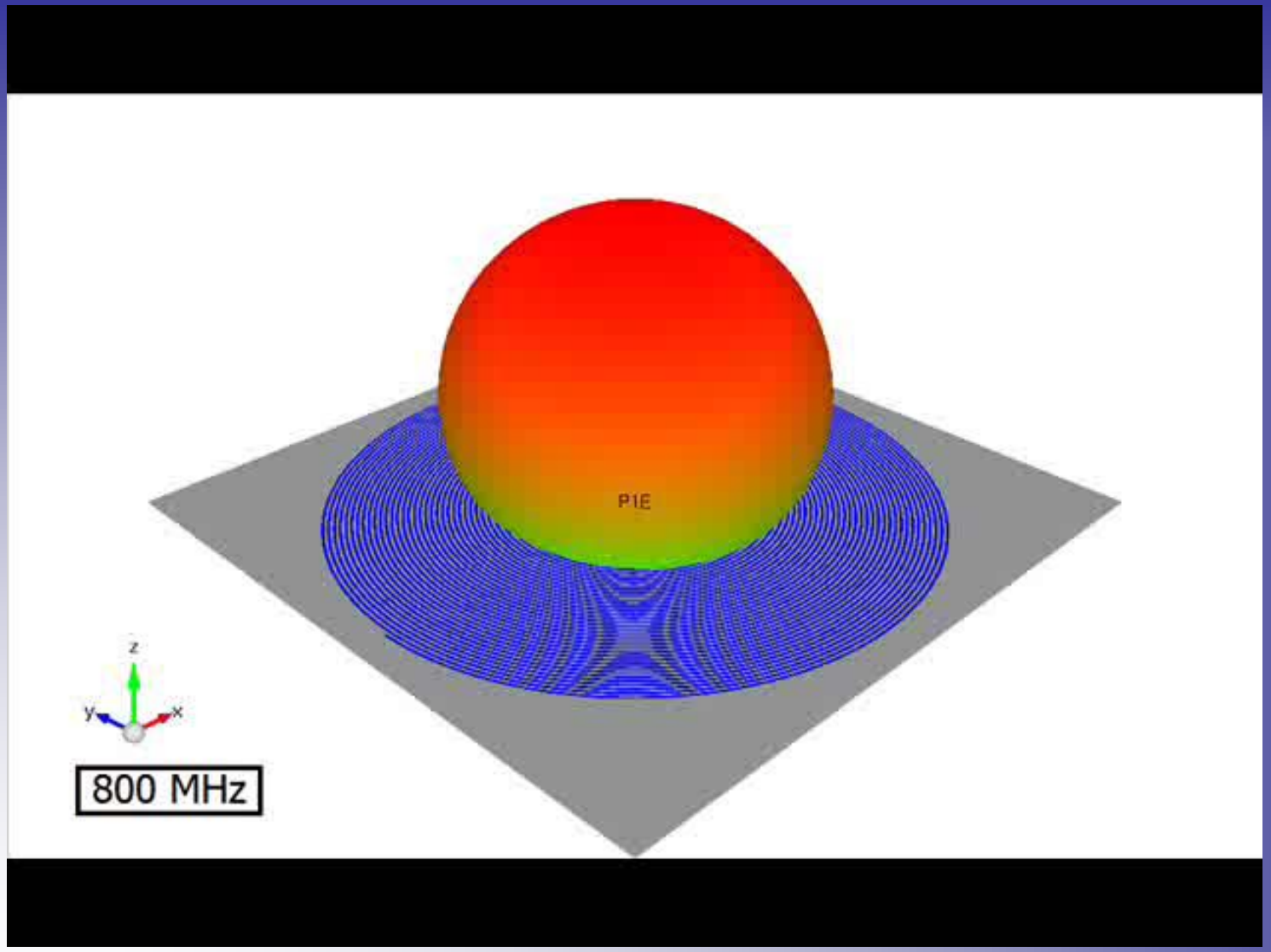
Pattern distortion

$D_{max} < \lambda/\pi$

Reduced Gain

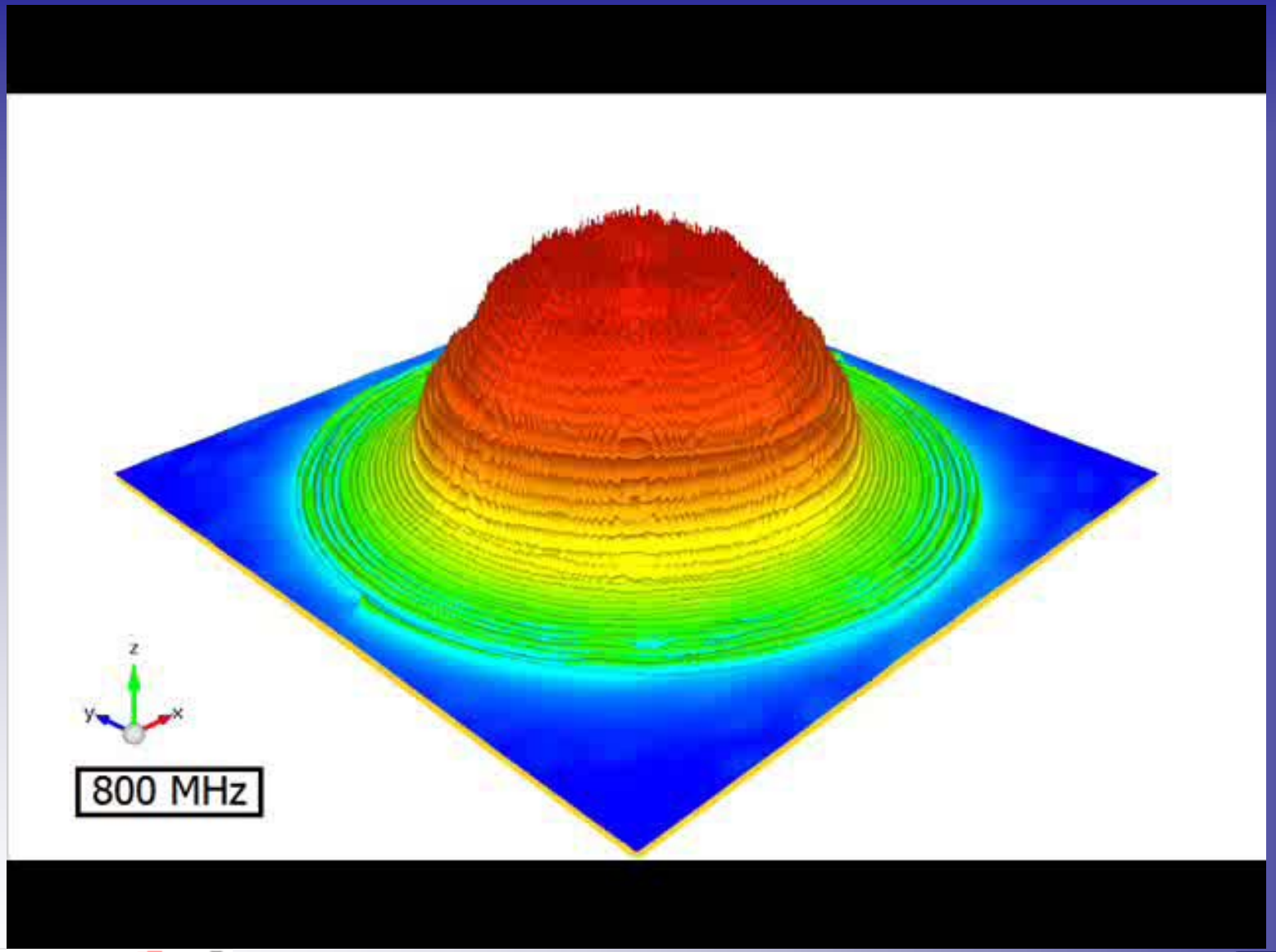
Increased AR

3D Far-Field pattern Simulation



RHCP far field radiation pattern (Simulation)

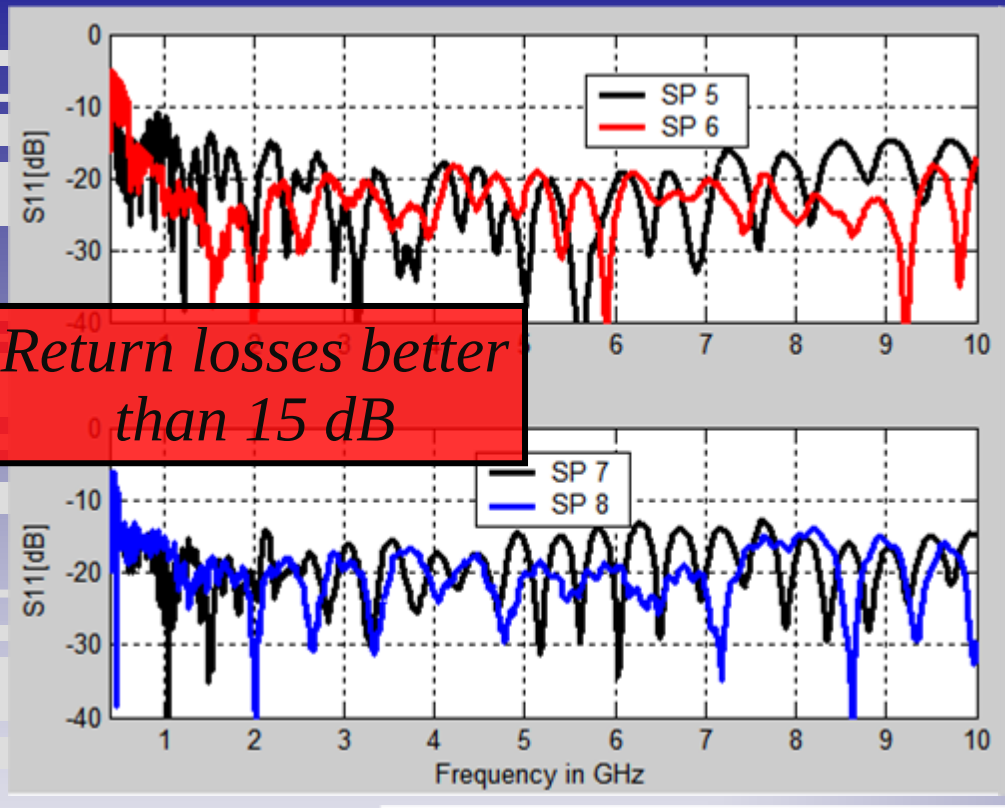
Current Distribution Simulation



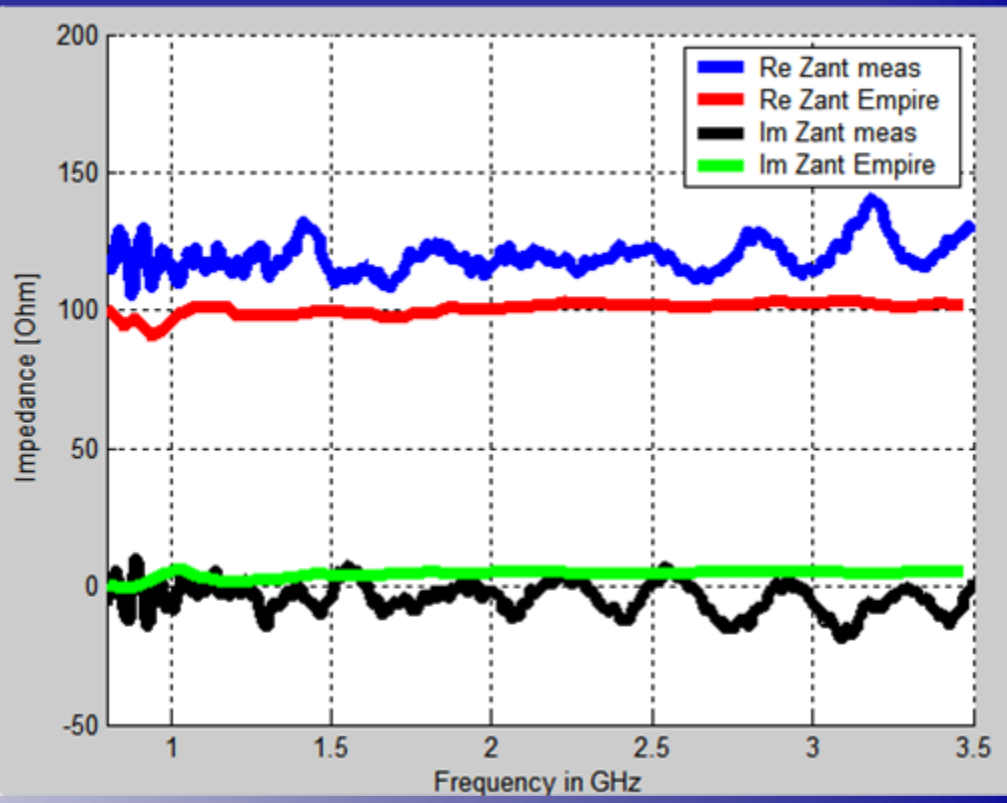
Current Density Distribution (Simulation)

Active Region Concept

Antenna Measurement



Return losses better than 15 dB

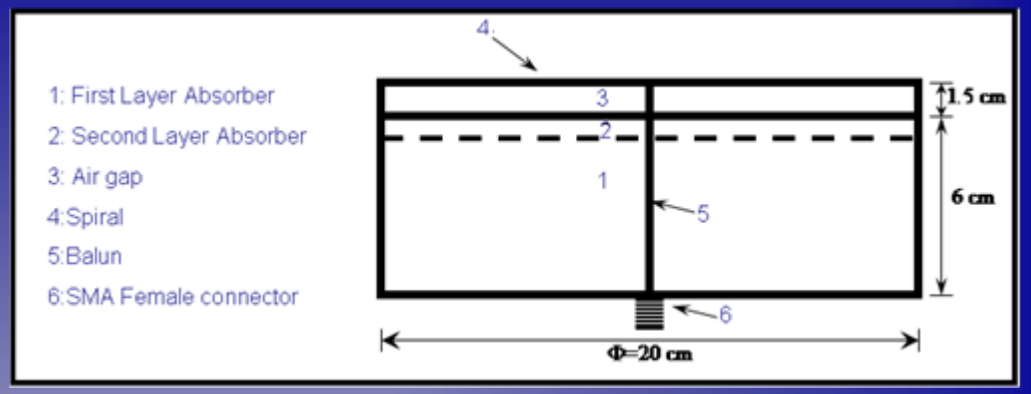


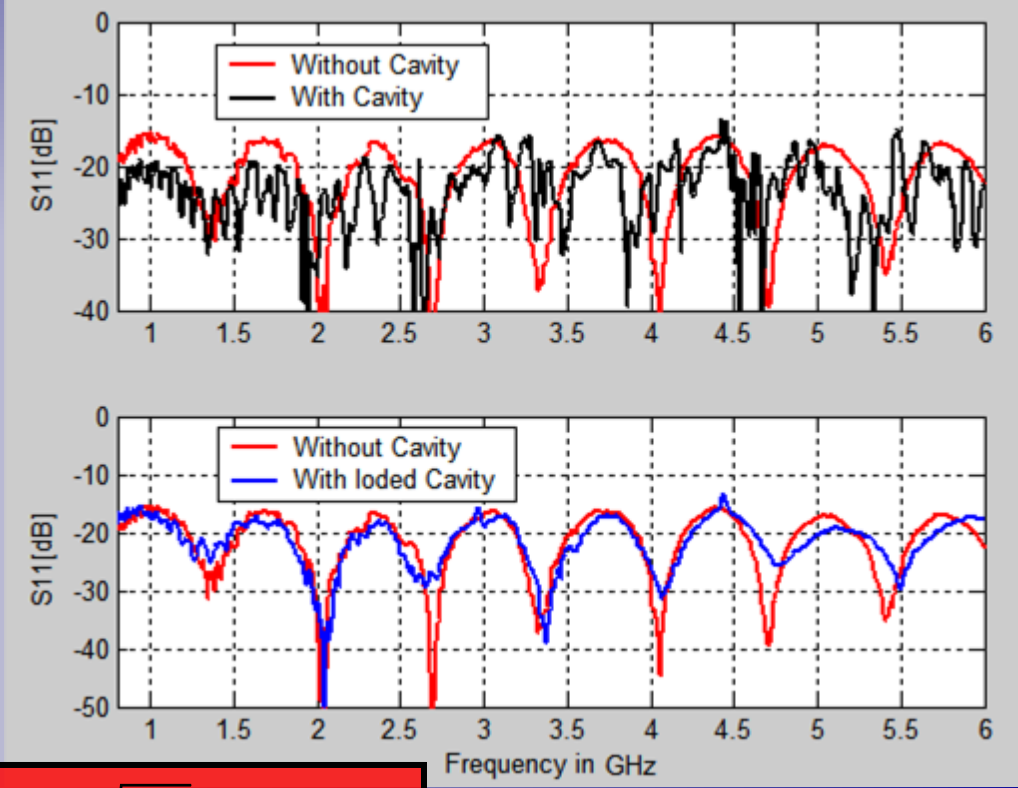
	SP5	SP6	SP7	SP8 LHCP	SP9 RHCP
Number of turns	22	22	56	28	
Spiral rate (µm)	658	510	260	510	
Arm width (µm)	1000	800	410	800	
Outer Radius (cm)	9.1	7.1	9.1	9.1	

Antenna impedance using two ports measurement.

Cavity

- **Unloaded cavity**
  - When high gain need
  - Narrow bandwidth
- **Absorber loaded cavity**
  - Gain reduction not critical
  - Wide bandwidth
- **Cavity Dimension**
  - Depth λ /4 at lower frequency
  - Diameter 1.05 spiral diameter
- **Absorber material**

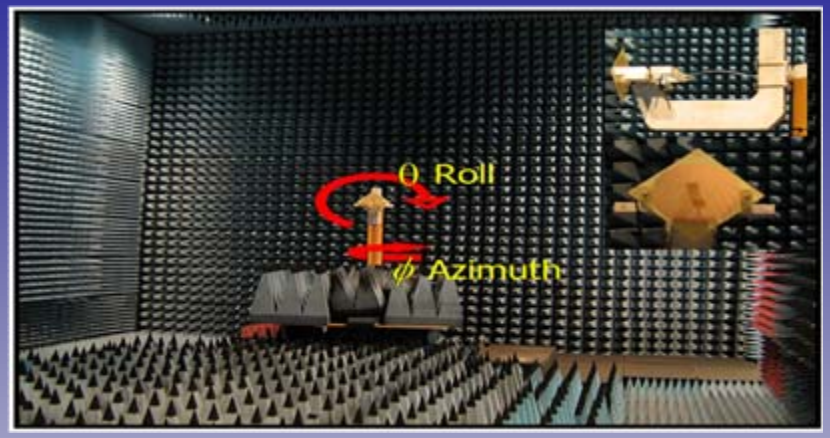




$$\mu_r = \mu_r' - j\,\mu_r'' = \varepsilon_r = \varepsilon_r' - j\,\varepsilon_r''$$

$$Z = \sqrt{\frac{\mu}{\varepsilon}} = \sqrt{\frac{\mu_0}{\varepsilon_0}}\sqrt{\frac{\mu_r}{\varepsilon_r}} = 377\sqrt{\frac{\mu_r}{\varepsilon_r}} = 377\Omega$$

Antenna Measurement In Anechoic Chamber

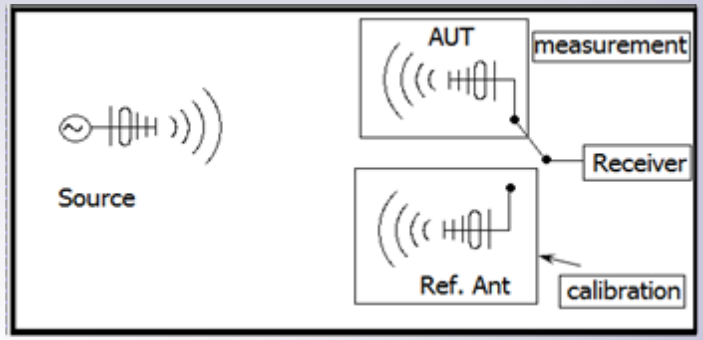


L/H/W=12/5.5/8 m

From 0.4 up to 64 GHz

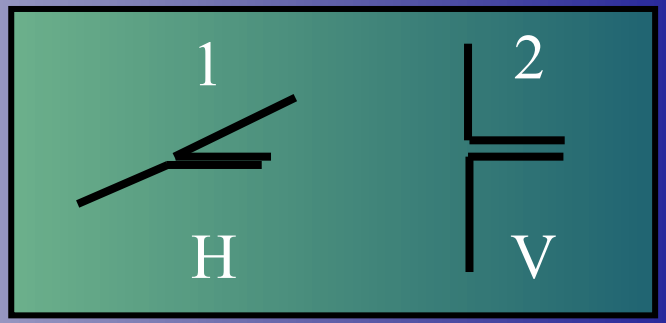
Gain Measurement

Gain Transfer method

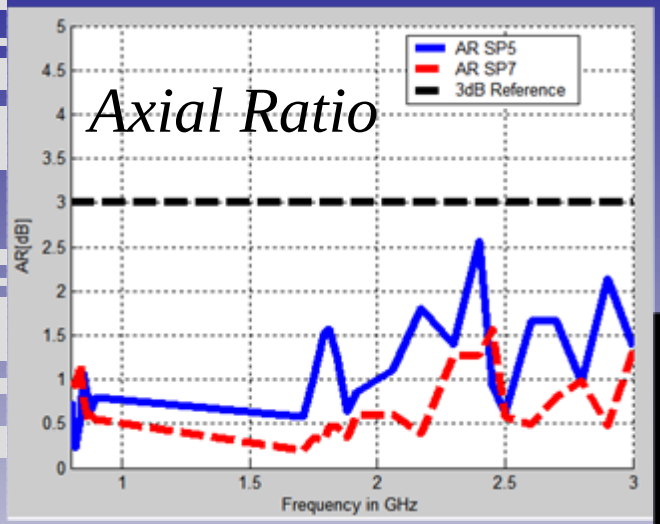


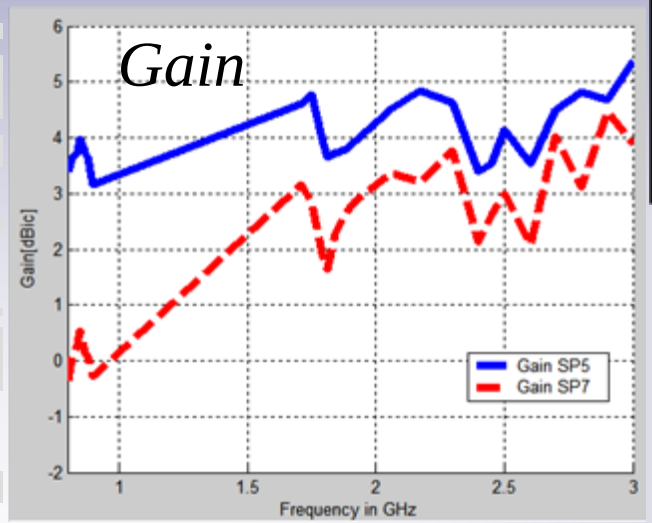
Polarization Measurement

Polarization Pattern Method

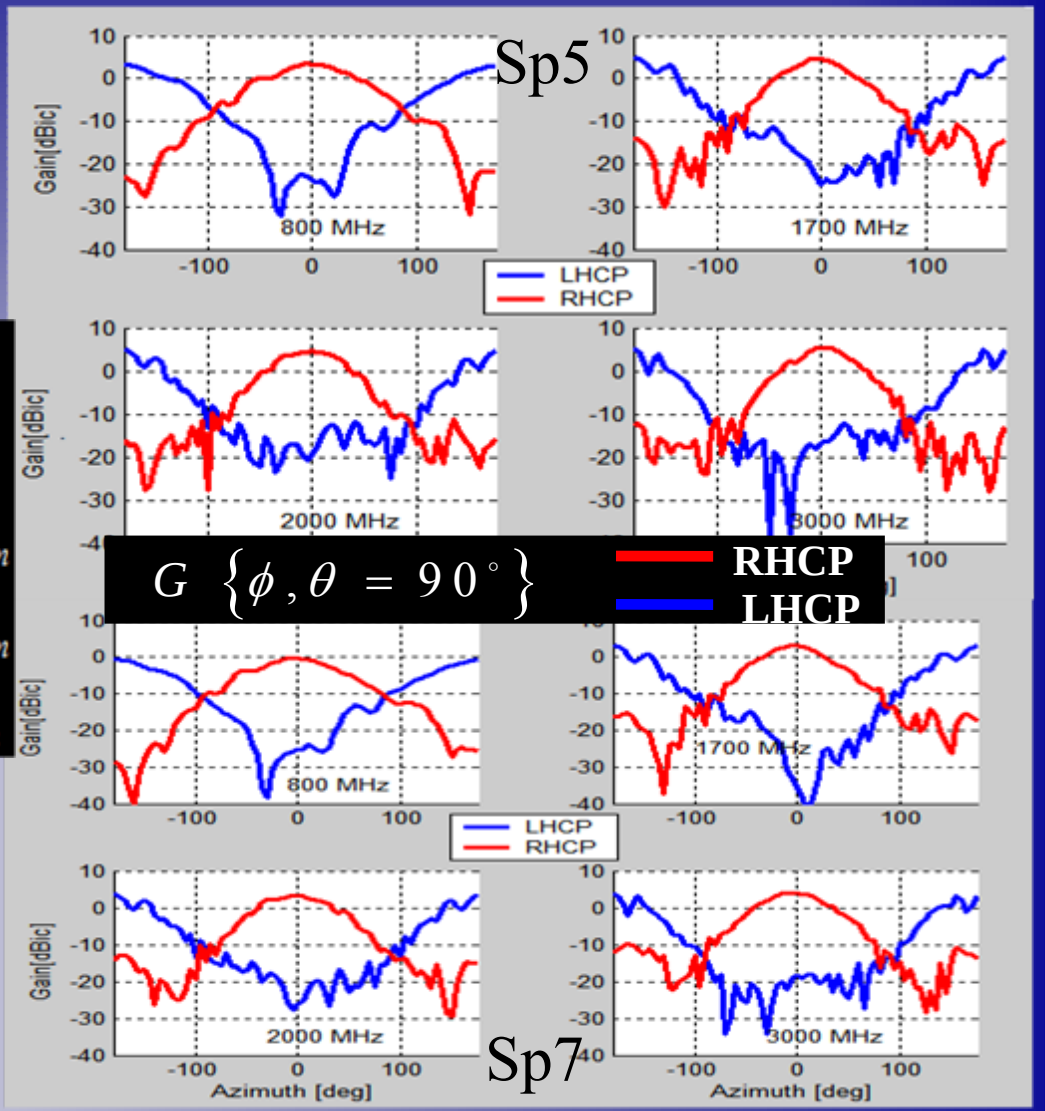


Sp5 and Sp7 Measurement Results

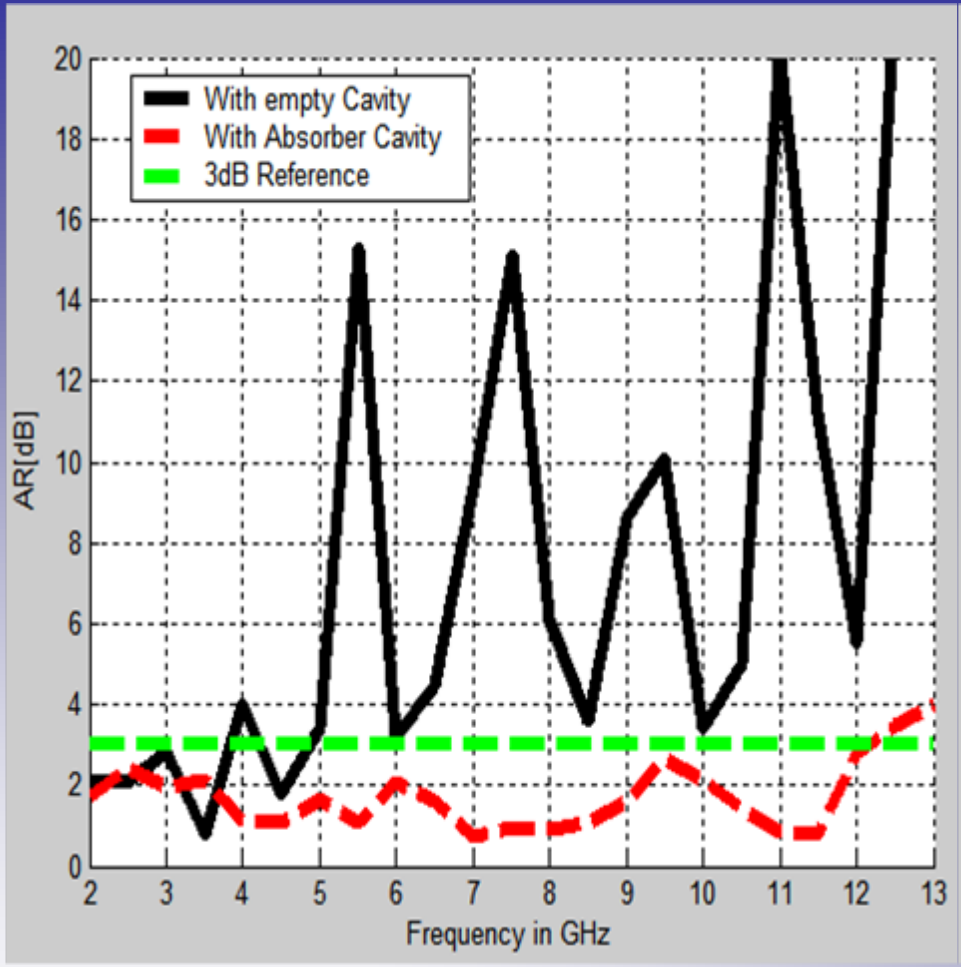


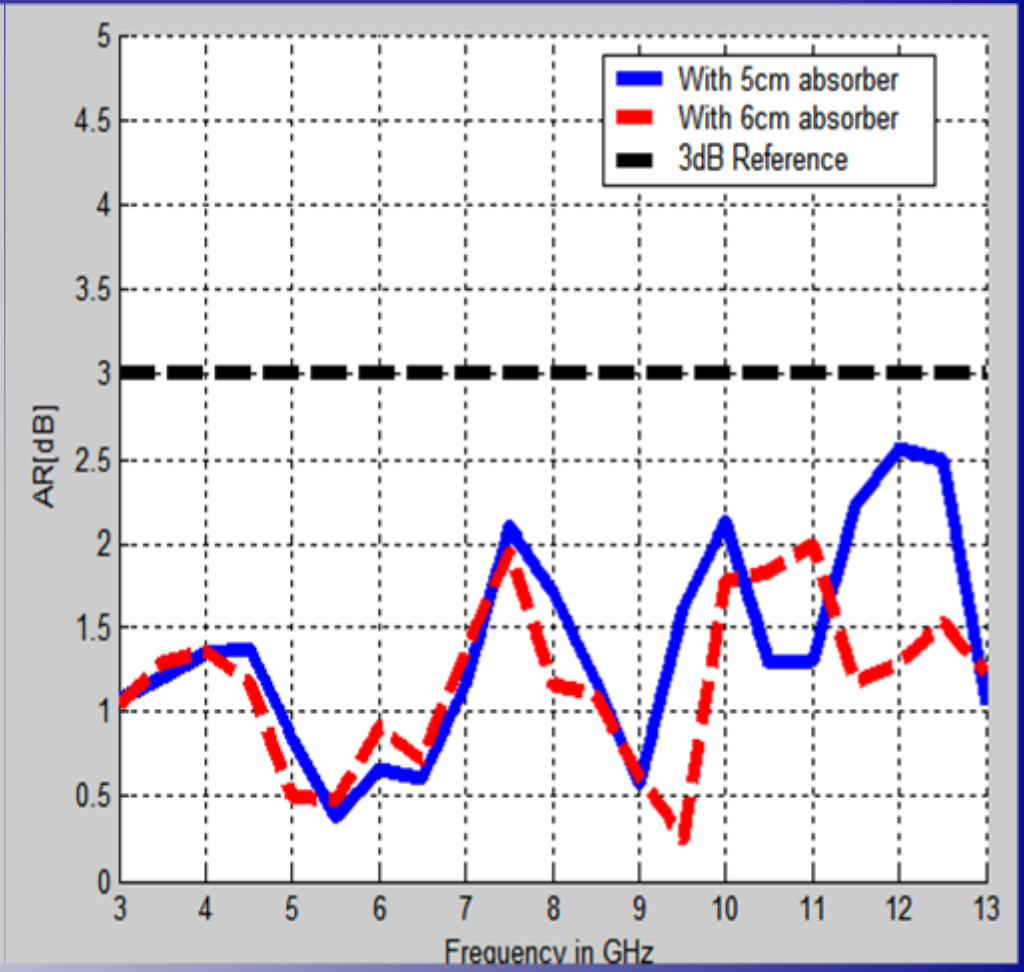


	Sp5	Sp7
N	22	56
a	658μm	260 μm
w	1000 μm	410 μm
d	9.1cm	9.1cm



Measurement with Cavity

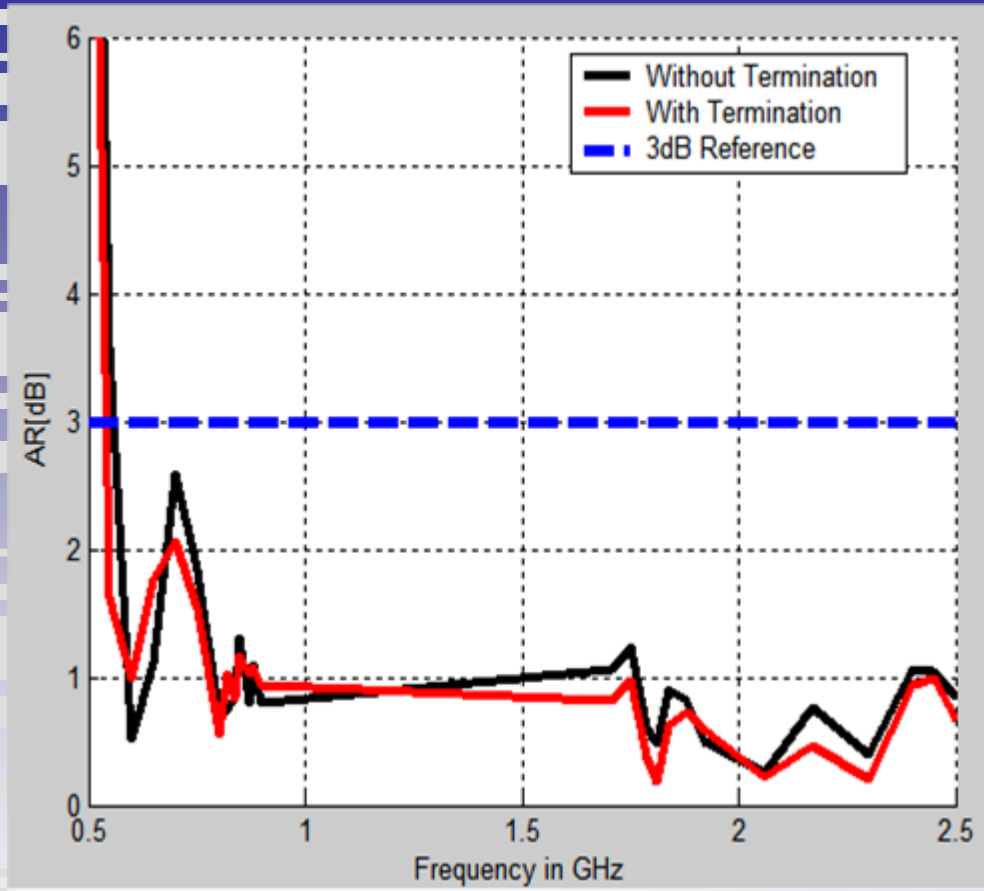


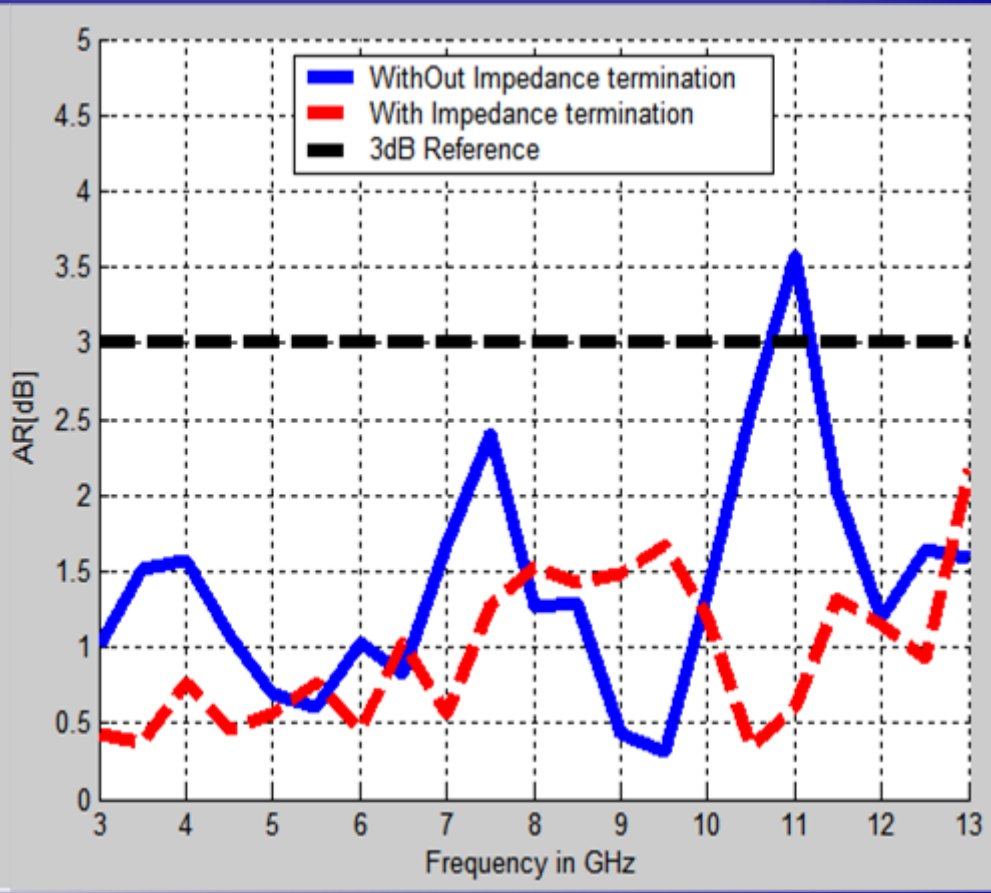


Empty & loaded Cavity

Diff. Absorber length

Measurement with Resistance Termination

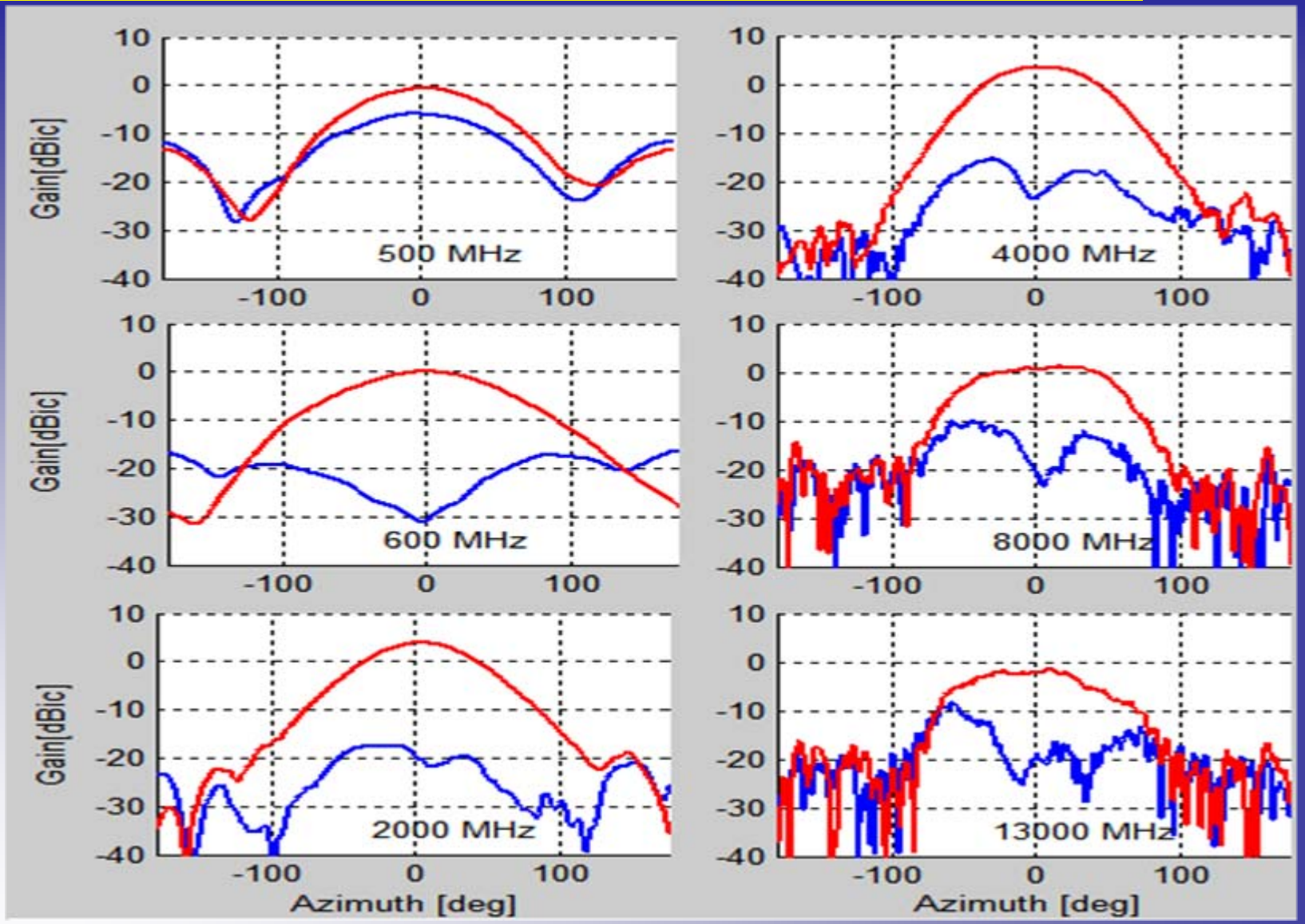




Termination improved Low Frequency range

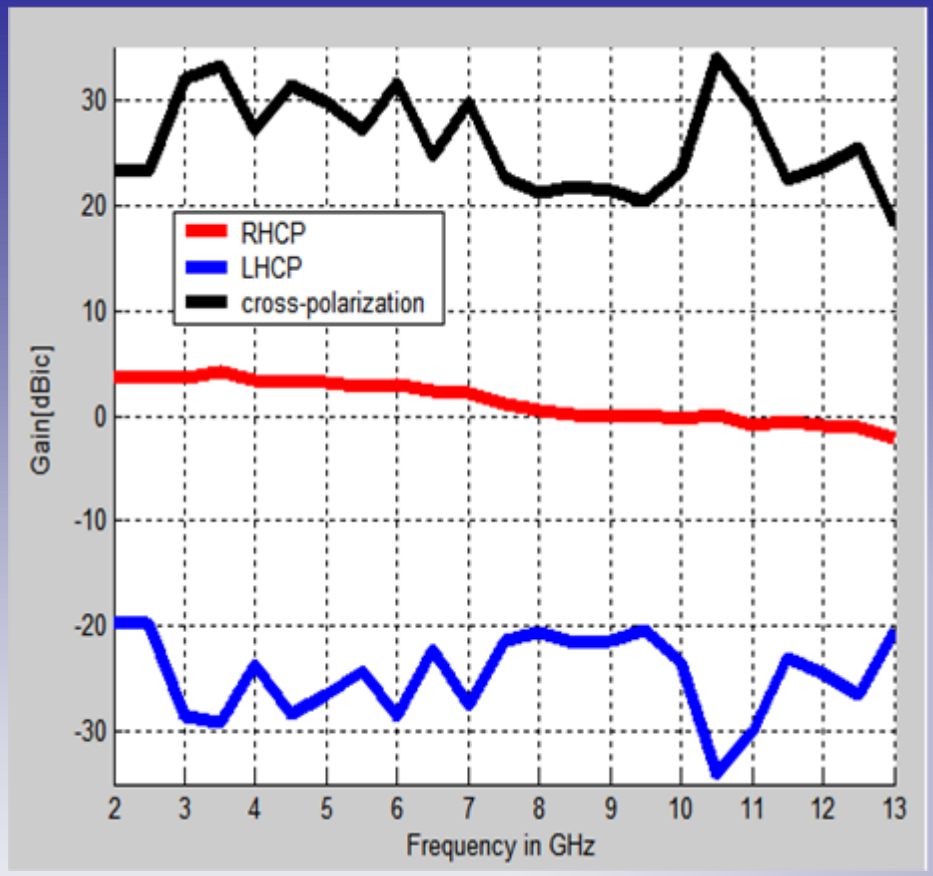
Axial Ratio With and Without Impedance Termination

Far-Field Measurement For Final Version

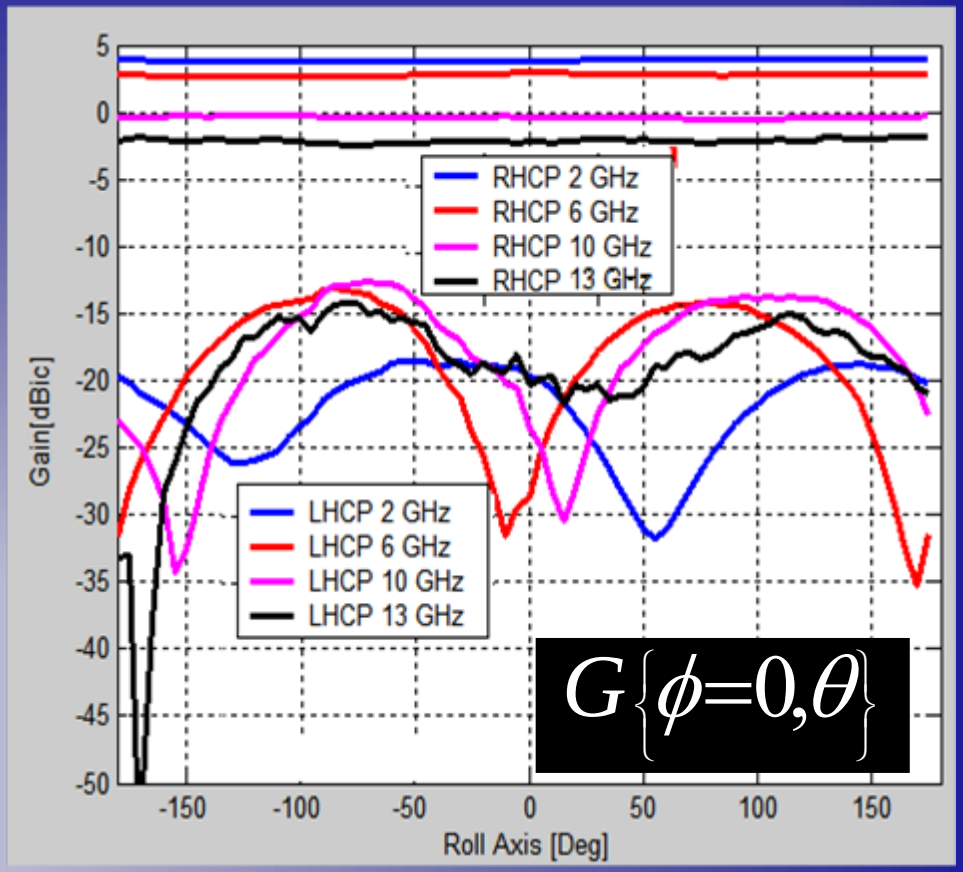


$G\{\phi, \theta = 90^\circ\}$ RHCP LHCP

Cross-Polarization



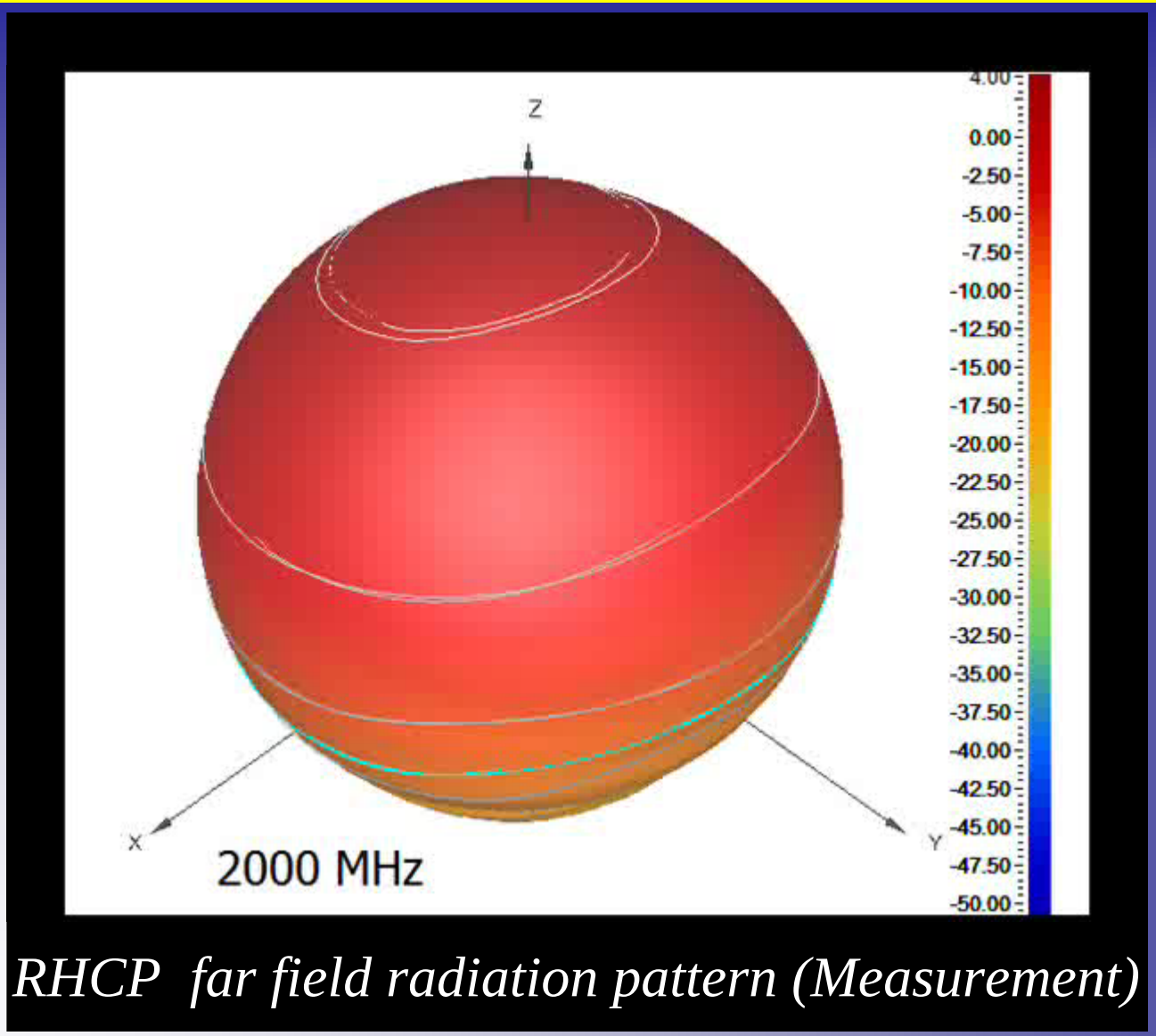
Omnidirectional Pattern



Cross-Polarization better than 20dB

Omnidirectional pattern in the spiral plane

3D Far-Field Radiation Pattern Measurement



RHCP far field radiation pattern (Measurement)

Conclusion

- RHCP antenna worked (0.6 < f/GHz < 13)
- Two arms Archimedean spiral antenna was shown many desirable characteristic.
- Microstrip tapered balun provides a balance feeding and impedance transformation
- An unidirectional pattern achieved using absorber loaded cavity.
- The numerical results were confirmed by measurements.
- As a result the developed antenna worked well for OTA measurement test.

Future Work

- Reduce the spiral size using slow wave techniques or absorber painting at the open end of spiral.
- Improve and reduce balun size.
- Decrease the cavity depth by thinner absorber loading
- Benefit of the new MetaFerrite material for reducing the antenna size.

Thank You for Your Attention

Questions

Questions