Controlled Reception Pattern Antenna to Mitigate the Unwanted Signal

PRESENTERS

IFRAH TARIQ

SHEHROZE AMIR

ADVISOR & CO-ADVISOR

DR. UMAR KHAN

DR. NOSHERWAN SHOAIB

MOTIVATION

The motivation for this project stems from the high cost and complexity of CRPA (Controlled Reception Pattern Antenna) systems, which are currently inaccessible in Pakistan. The aim is to develop an affordable and locally sourced alternative, overcoming financial barriers and enabling the adoption of advanced positioning and navigation solutions in the country.

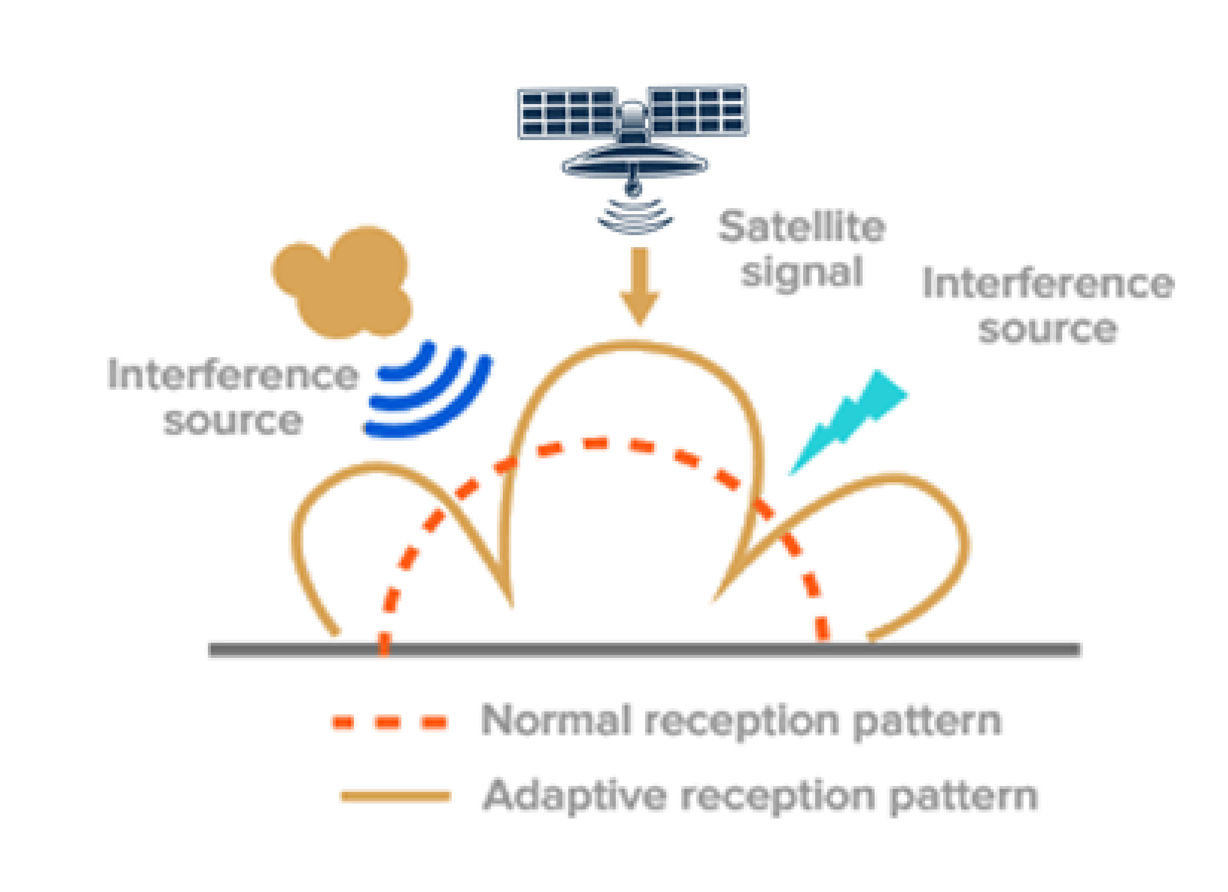
TABLE OF CONTENT

- INTRODUCTION
- APPLICATIONS
- METHODOLOGY
- DESIGN
- RESULTS
- CONCLUSION

INTRODUCTION

CRPA

- Adaptive beamsteering antenna
- Spatial Filter Characteristics
- Reception pattern Control
- Accuracy and Reliability
- Array Technology
- Critical infrastructure and systems



APPLICATIONS

WIFI PERFORMANCE ENHANCEMENT

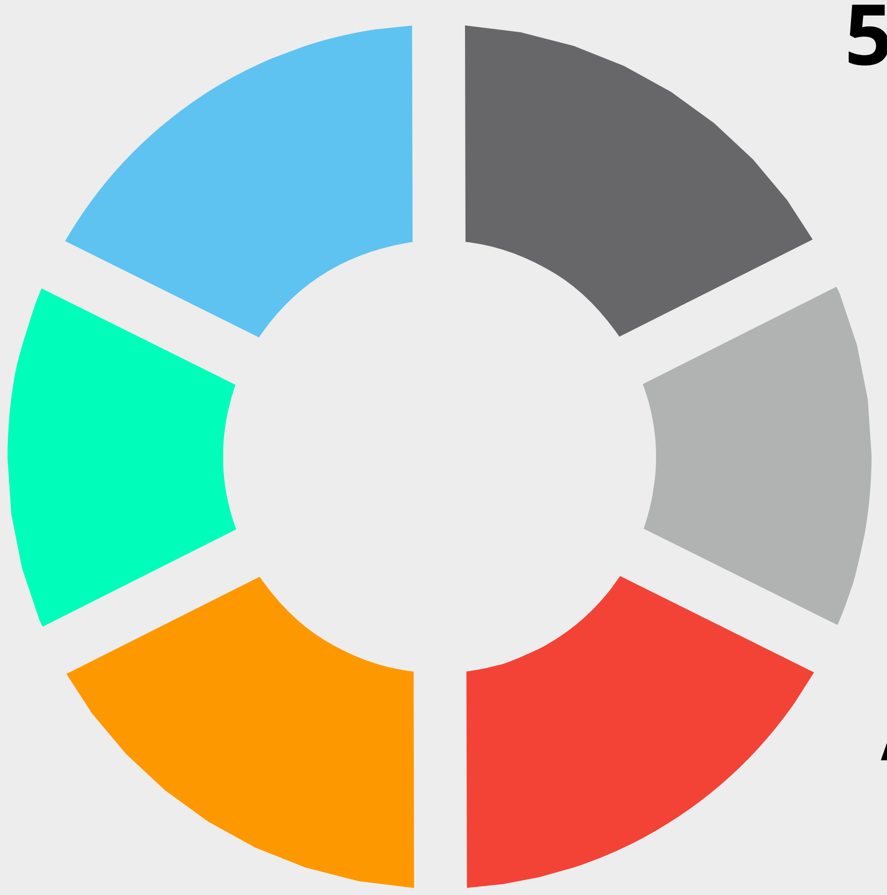
5G COMMUNICATION

UNWANTED SIGNALS SUPPRESSION

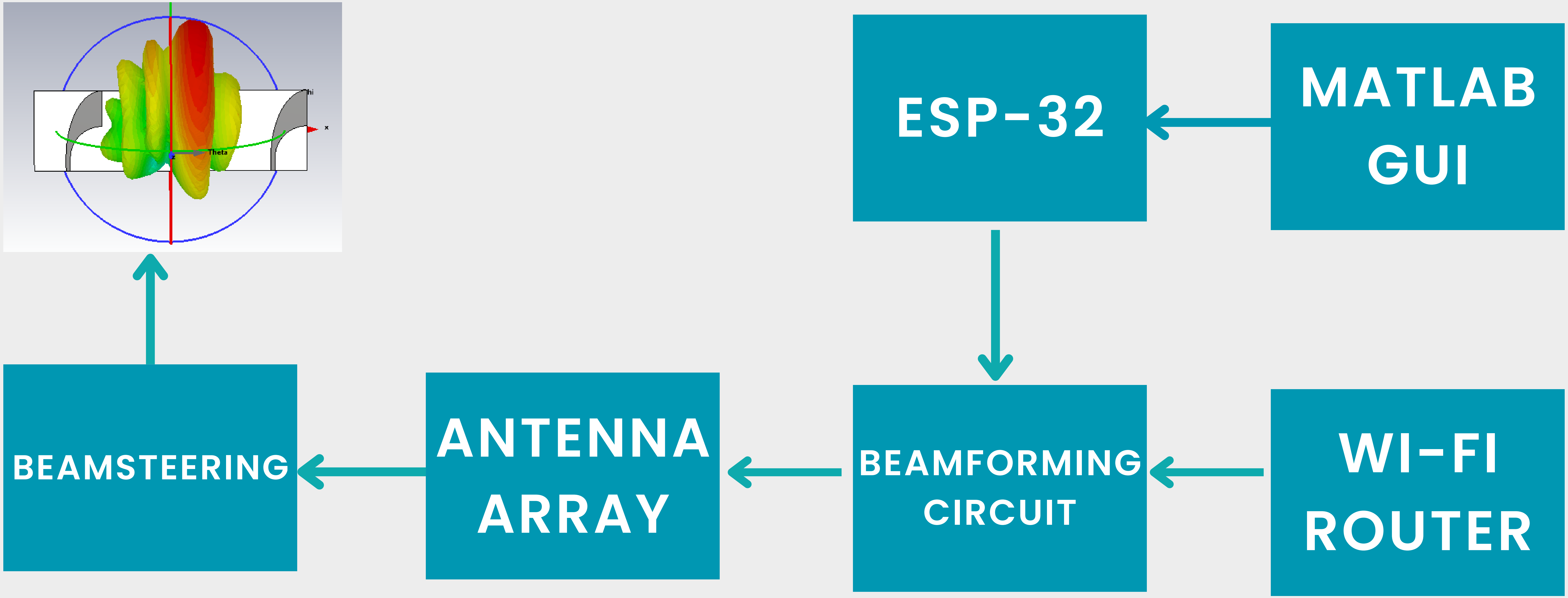
SATELLITE COMMUNICATIONS

GPS NAVIGATION

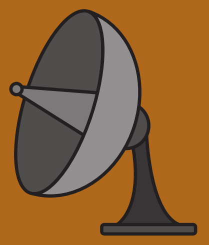
AVIATION AND MILITARY



BLOCK DIAGRAM

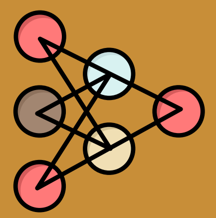


METHODOLOGY



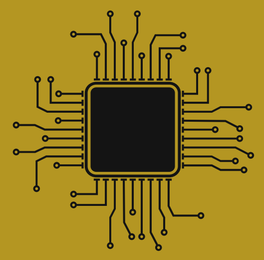
1

Design of Antenna Array



2

Phase Shifter Algorithm



3

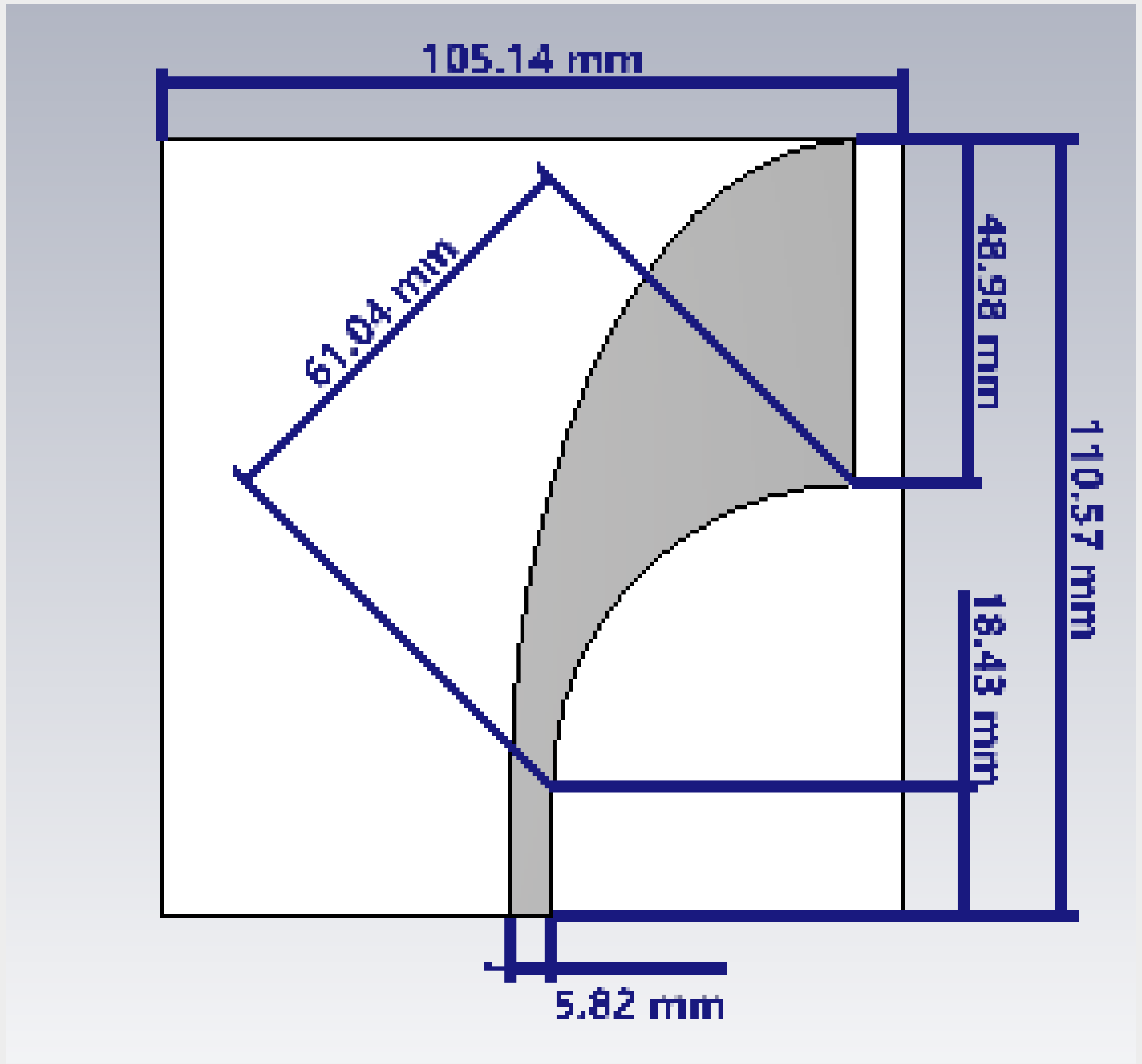
Beamforming Circuit Design

4

Fabrication and Testing

5

Automation



DESIGN OF ANTIPODAL VIVALDI ANTENNA

- Two tapered arms connected at the center and flared at the edges.
- Compact size, wide bandwidth and stable radiation pattern.

$$y = c_1 e^{Rx} + c_2$$

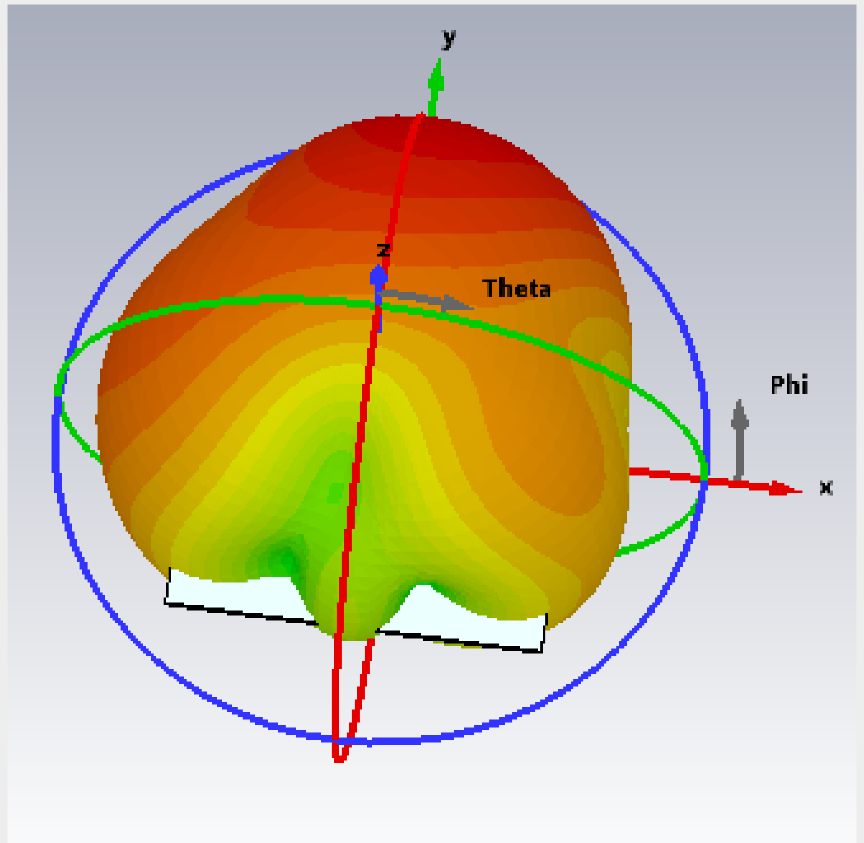
$$c_1 = \frac{y_2 - y_1}{e^{Rx2} - e^{Rx1}}$$

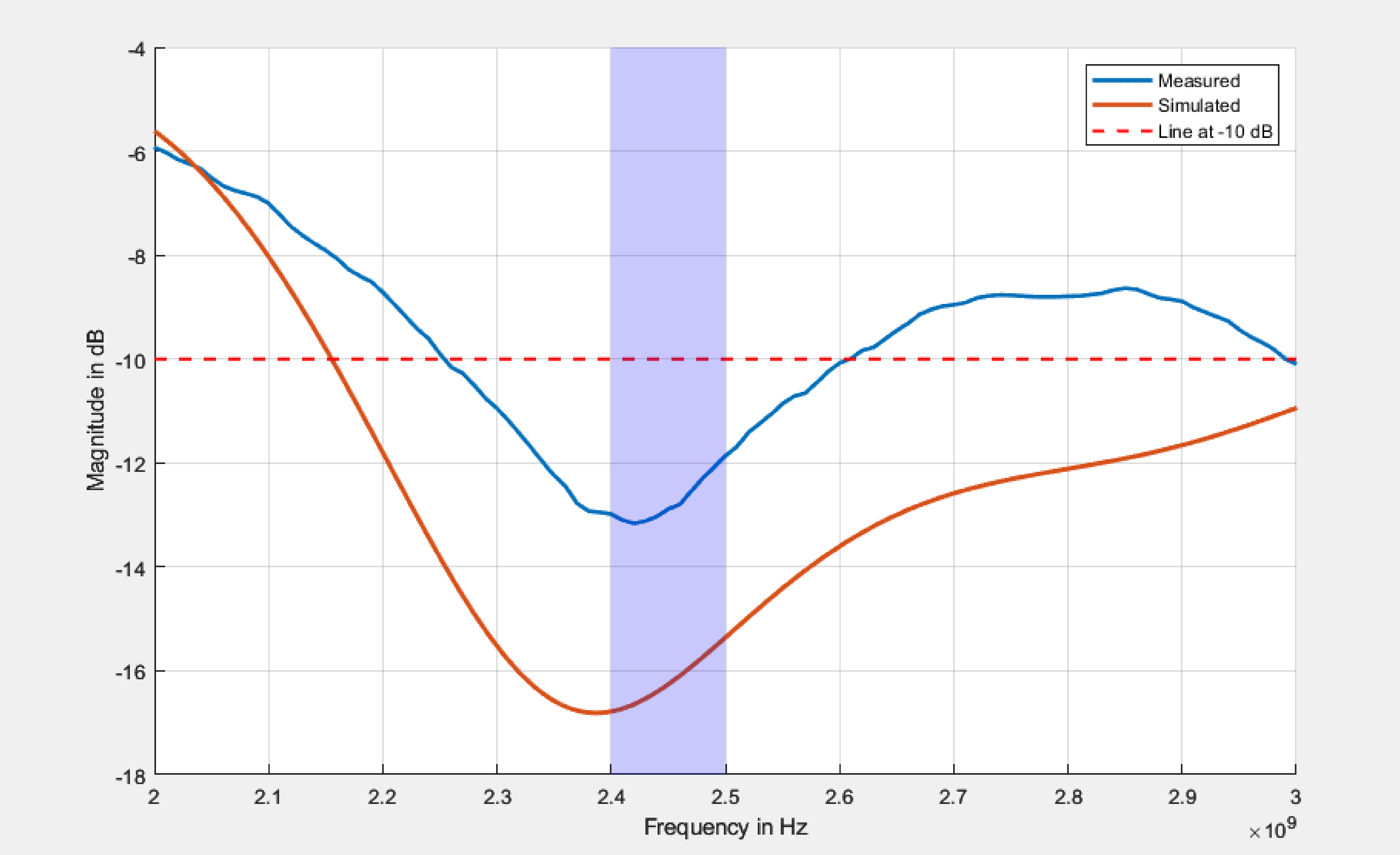
$$c_2 = \frac{y_1 e^{Rx2} - y_2 e^{Rx1}}{e^{Rx2} - e^{Rx1}}$$

PARAMETRES	VALUES
X FOCAL POINT	48.98
Y FOCAL POINT	92.14

CIRCLE RADIUS	43.16
FEED LENGTH	18.43
FEED WIDTH	5.818

RESULTS OF ANTIPODAL VIVALDI ANTENNA





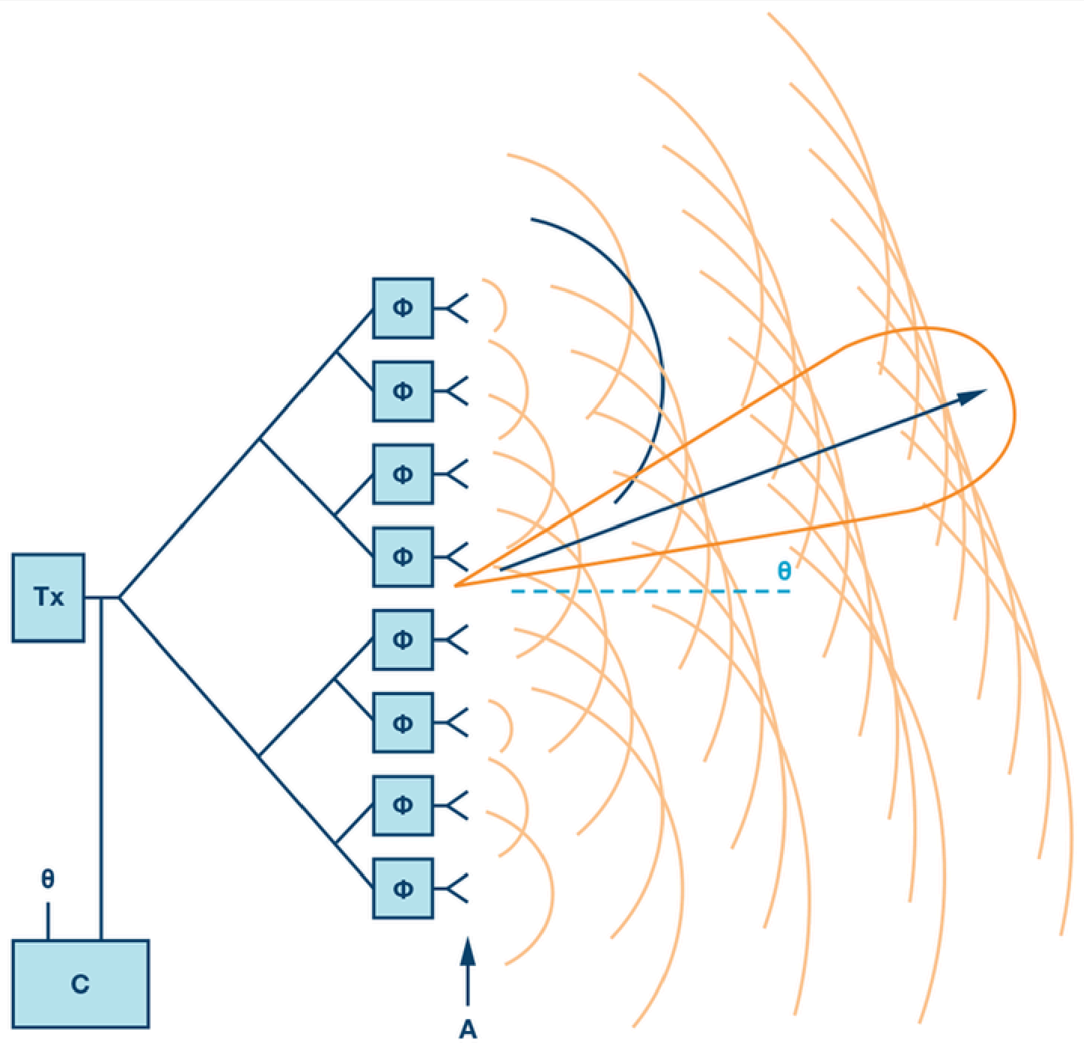
PHASED ARRAY THEORY

- The total field of an array is determined by the vector sum of the field radiated by each element
- In the desired direction, the fields add constructively to give high gain
- In other directions, fields add destructively

$$\Psi = k * d * \cos\theta + \beta$$

E=E(single element)* Array Factor

$$\mathrm{AF} = \sum_{n=1}^{N} e^{j(n-1)\Psi}$$



ARRAY FACTOR CALCULATION

PHASE ARRAY

$$\Psi = kd\cos\theta + \beta$$

$$\beta = kd\cos\theta_o$$

$$\beta = \frac{\pi}{4}\cos\theta_o$$ Where θ_o is beam steering angle

$$\Psi = \frac{\pi}{4}\cos\theta + \frac{\pi}{4}\cos\theta_o$$

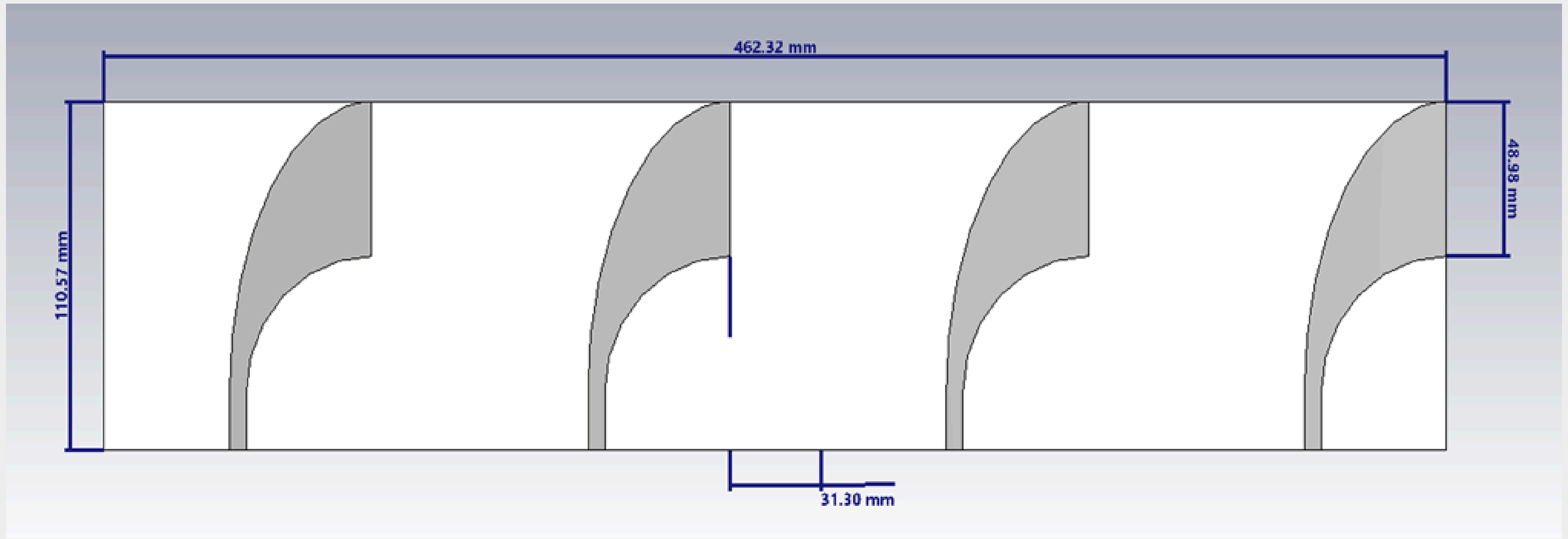
$$AF = \sum_{n=1}^{N} e^{j(n-1)\Psi}$$

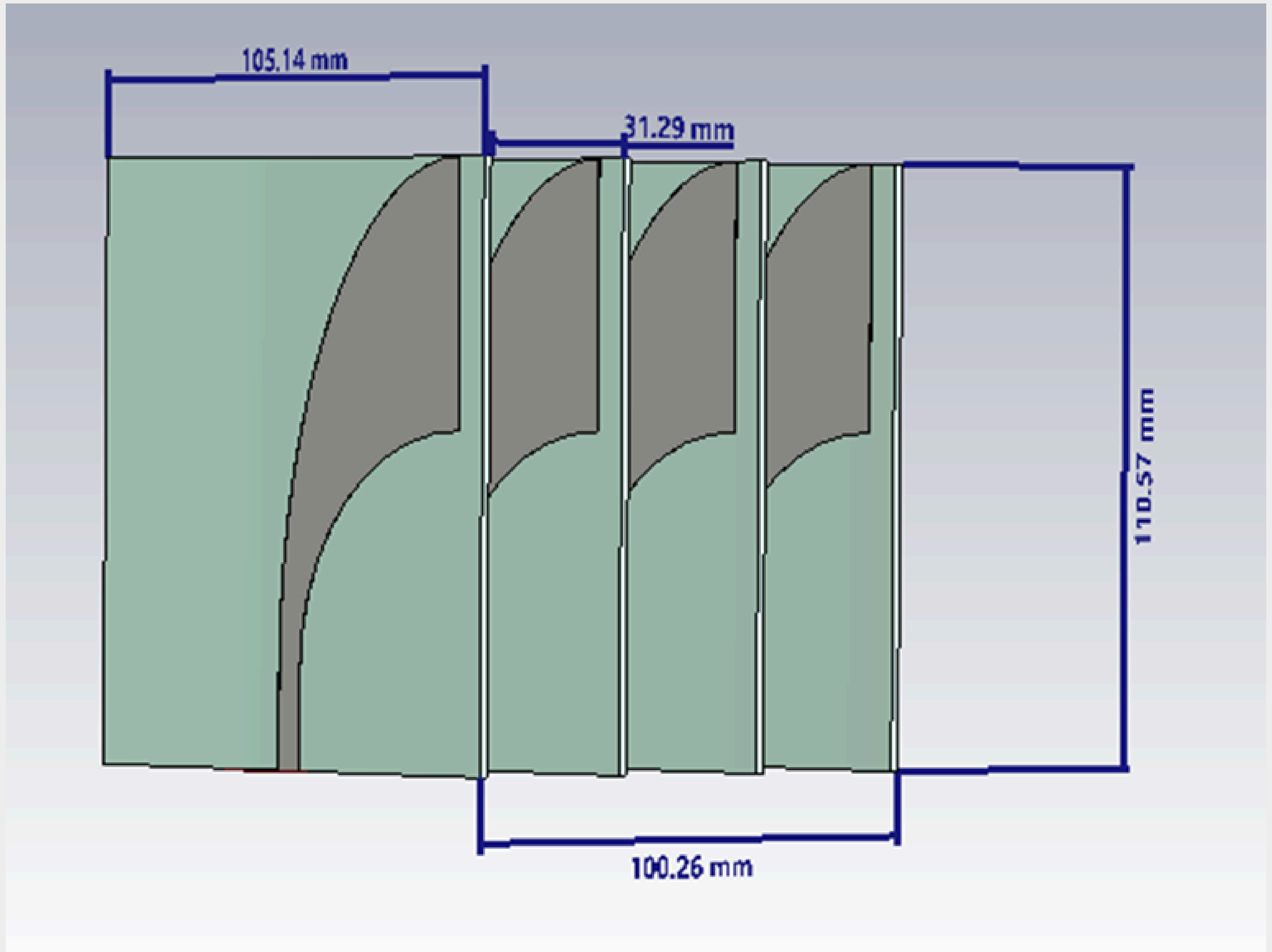
$$= 1 + e^{j\Psi} + e^{2j\Psi} + e^{3j\Psi}$$

MATLAB CODE

```
theta_zero = 90;
An = 1;
j = sqrt(-1);
AF = zeros(1,360);
for theta=1:360

    % change degree to radian
    deg2rad(theta) = (theta*pi)/180;
    %array factor calculation
    for n=0:N-1
        AF(theta) = AF(theta) + An*exp(j*n*2*pi*d* ...
      (cos(deg2rad(theta))-cos(theta_zero*pi/180))) ;
    end
    AF(theta) = abs(AF(theta));
end
aff=10.^(cxz1/10);
aaa=10*log((AF.*aff)/4);
% plot the array factor
polar_dB_N(theta1+theta_zero,aaa,-30,15,4,'-r');
title("Array Factor at 60 Degrees")
```





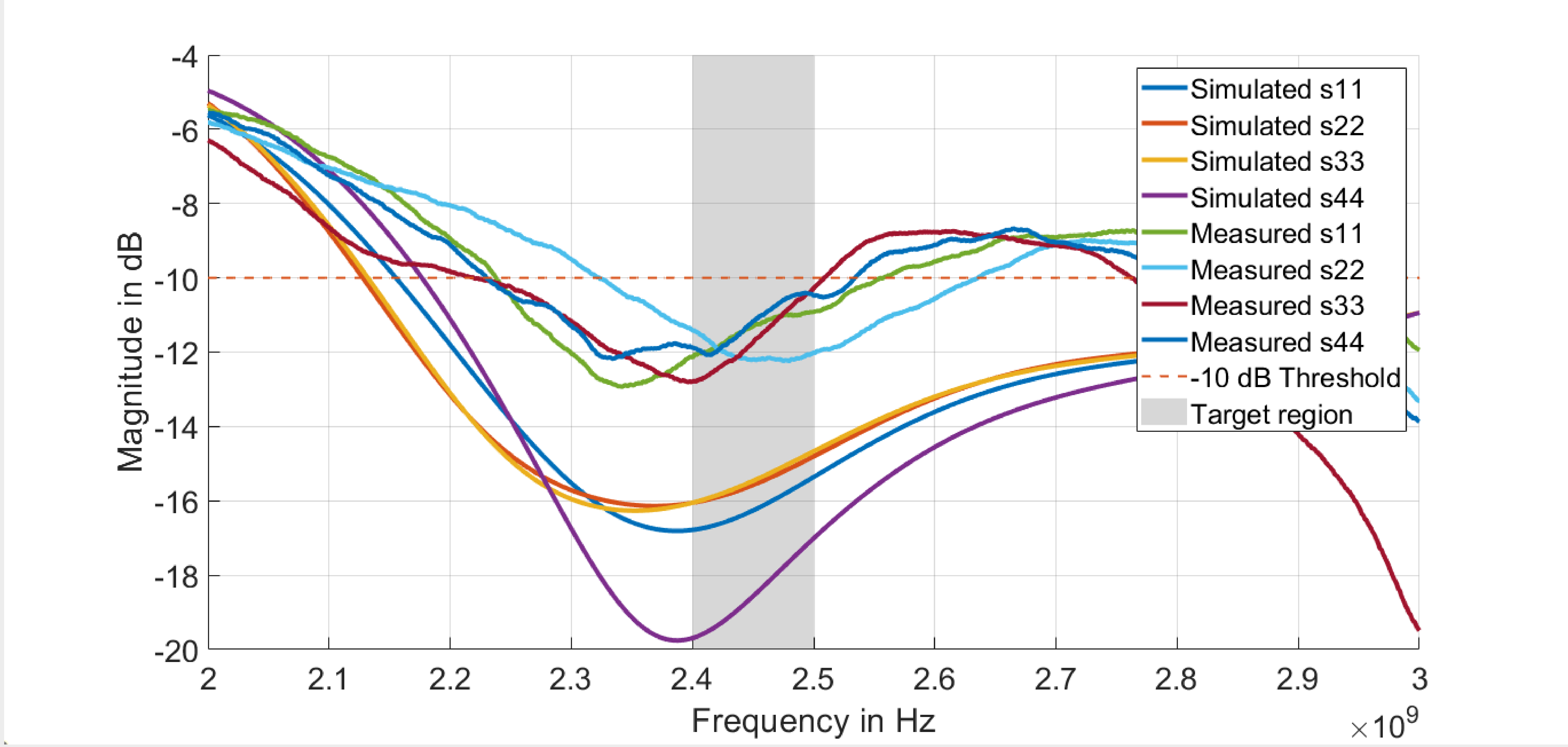
DESIGN OF VIVALDI ARRAY

- Set of directional antennas designed for radar and communication systems
- Size, spacing, and placement carefully considered for optimized performance
- More gain and directional behavior
- Spacing of $\lambda/8$=31.25mm

$$\lambda = \frac{c}{f\sqrt{\varepsilon_r}}$$

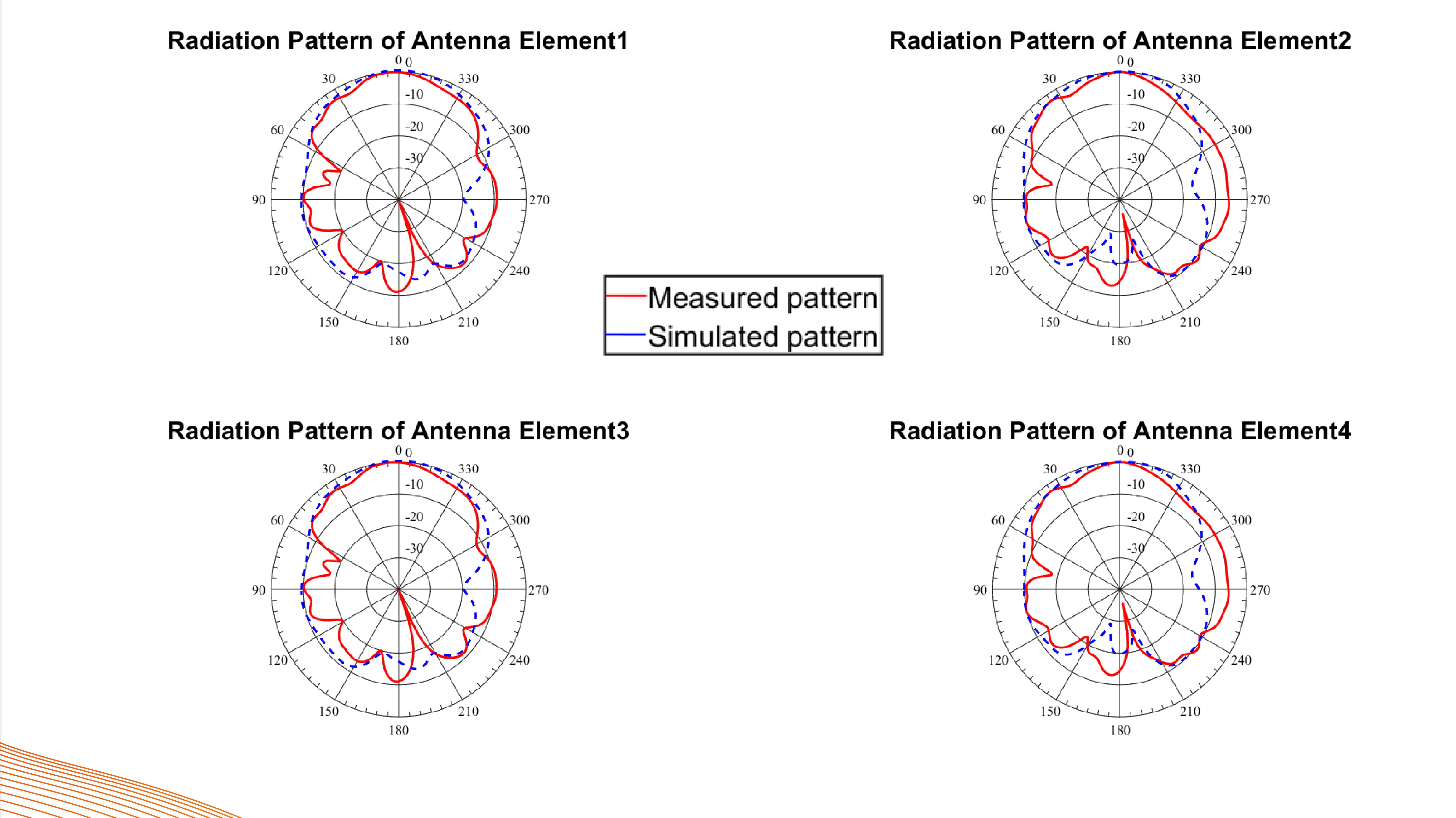
HORIZONTAL ARRAY RESULTS

S-PARAMETERS



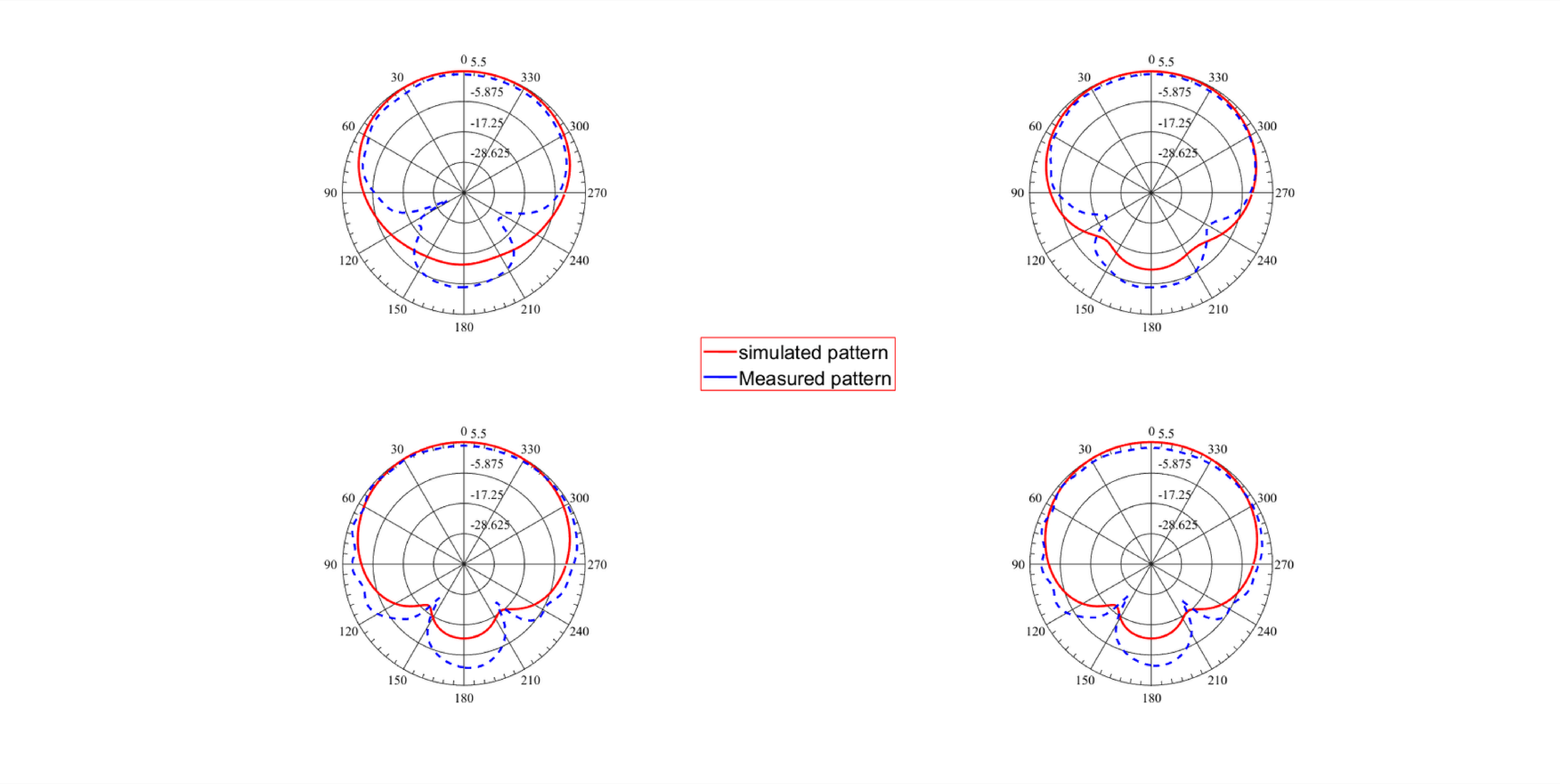
HORIZONTAL ARRAY RESULTS

FARFIELD RESULTS AZIMUTHAL PLANE



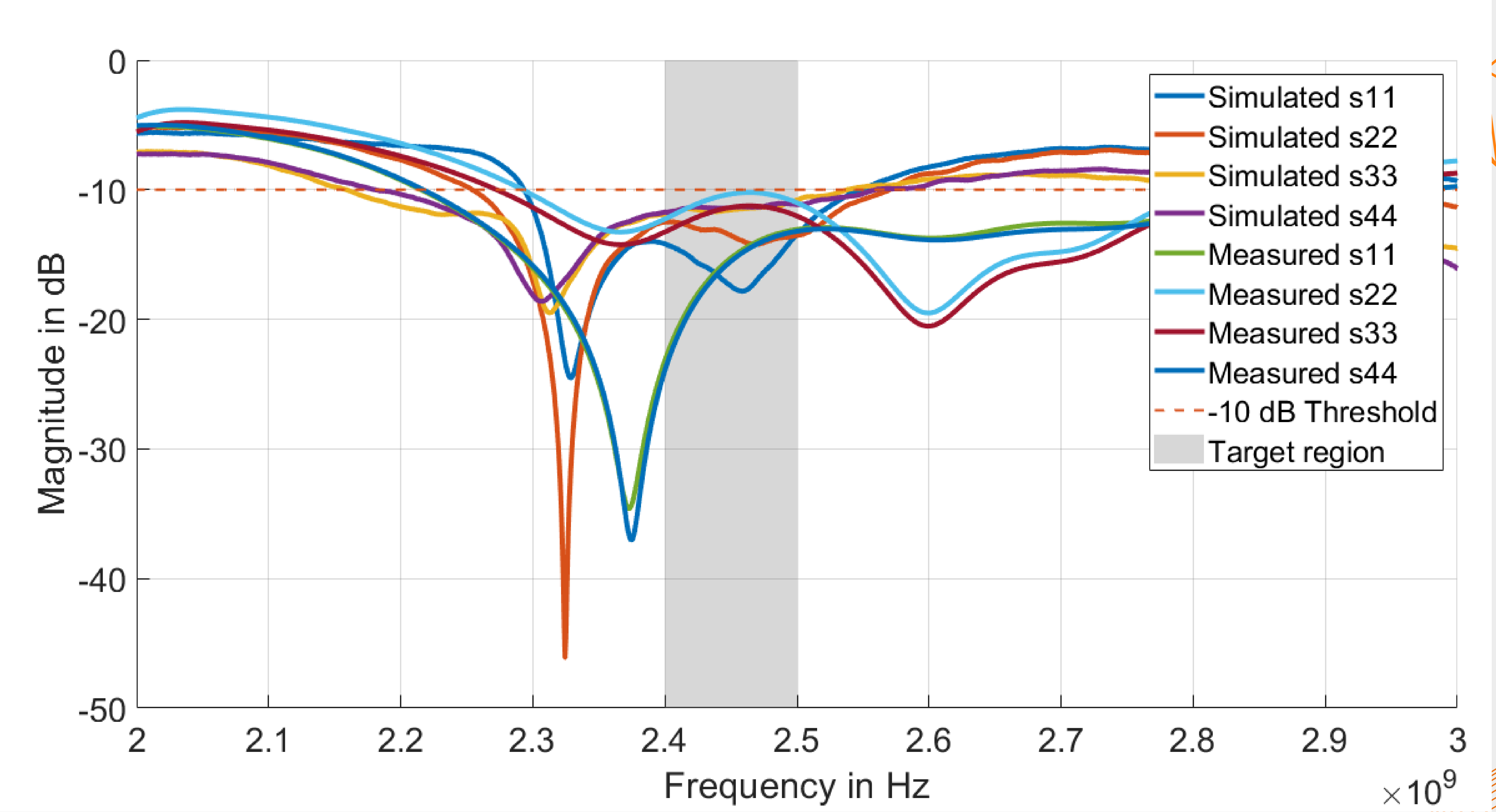
HORIZONTAL ARRAY RESULTS

FARFIELD RESULTS ELEVATION PLANE



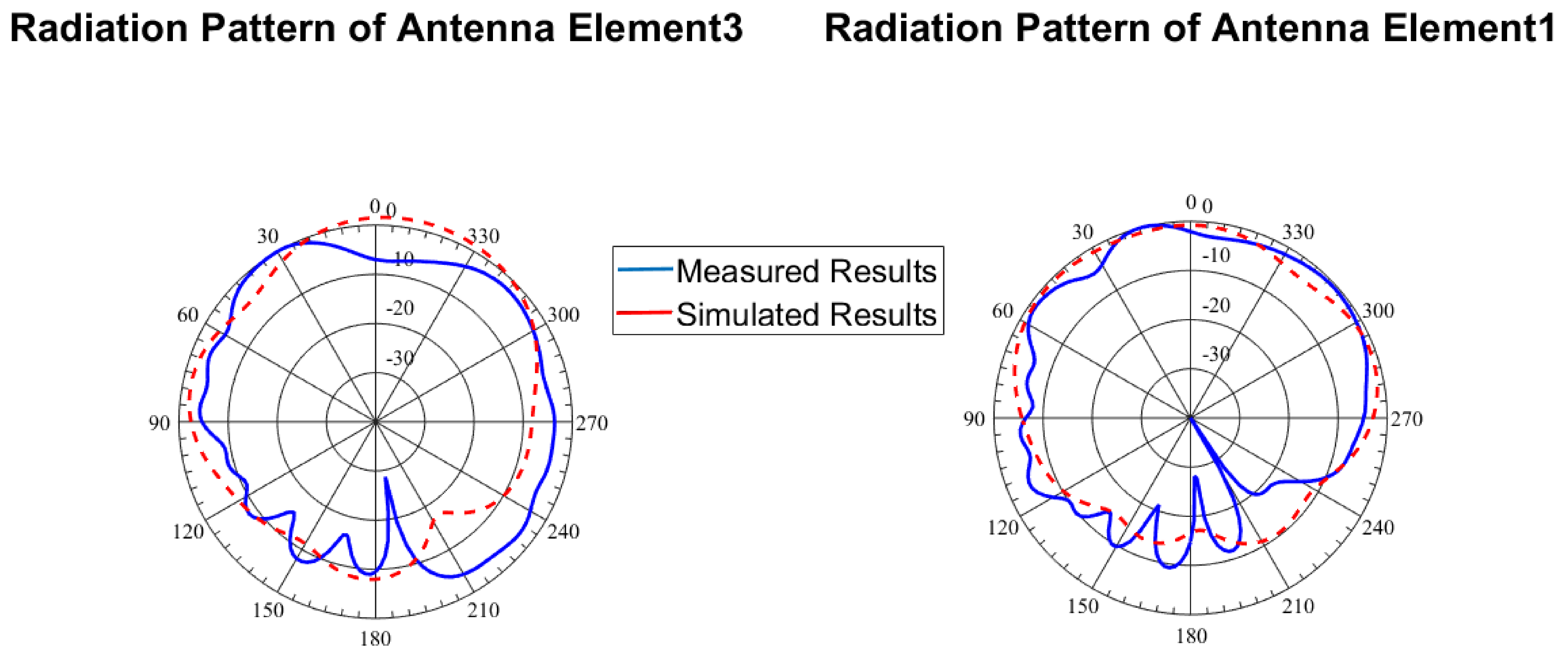
VERTICAL ARRAY RESULTS

S-PARAMETERS

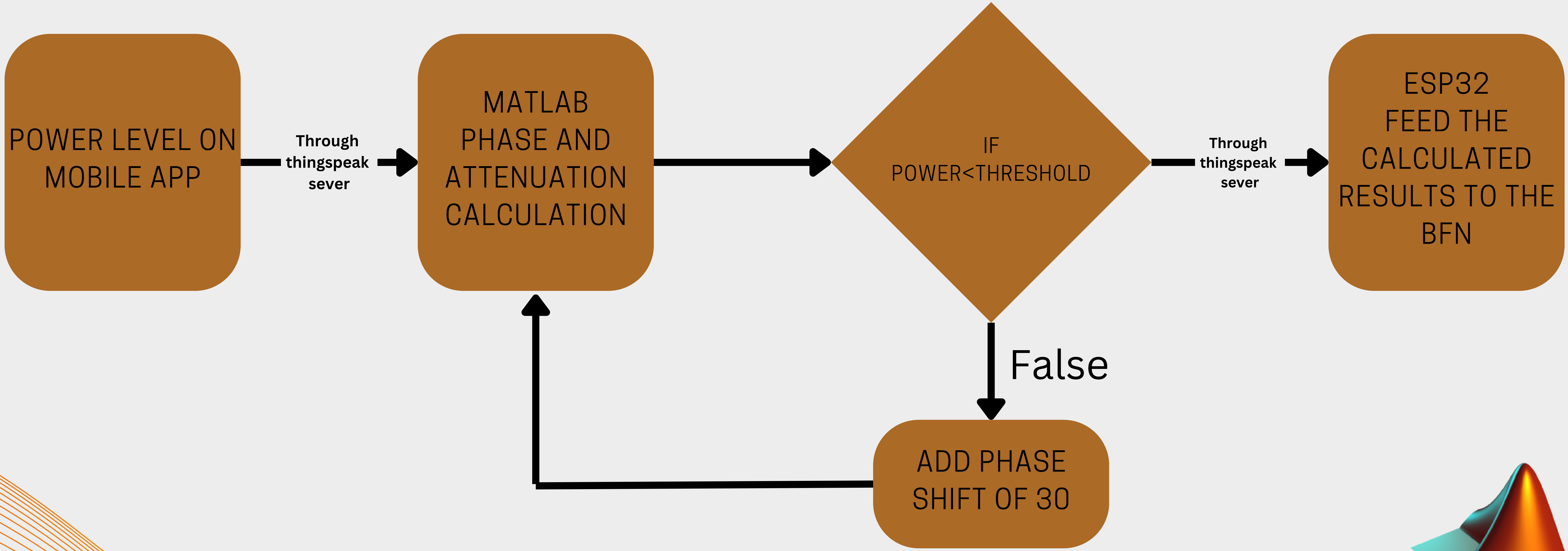


VERTICAL ARRAY RESULTS

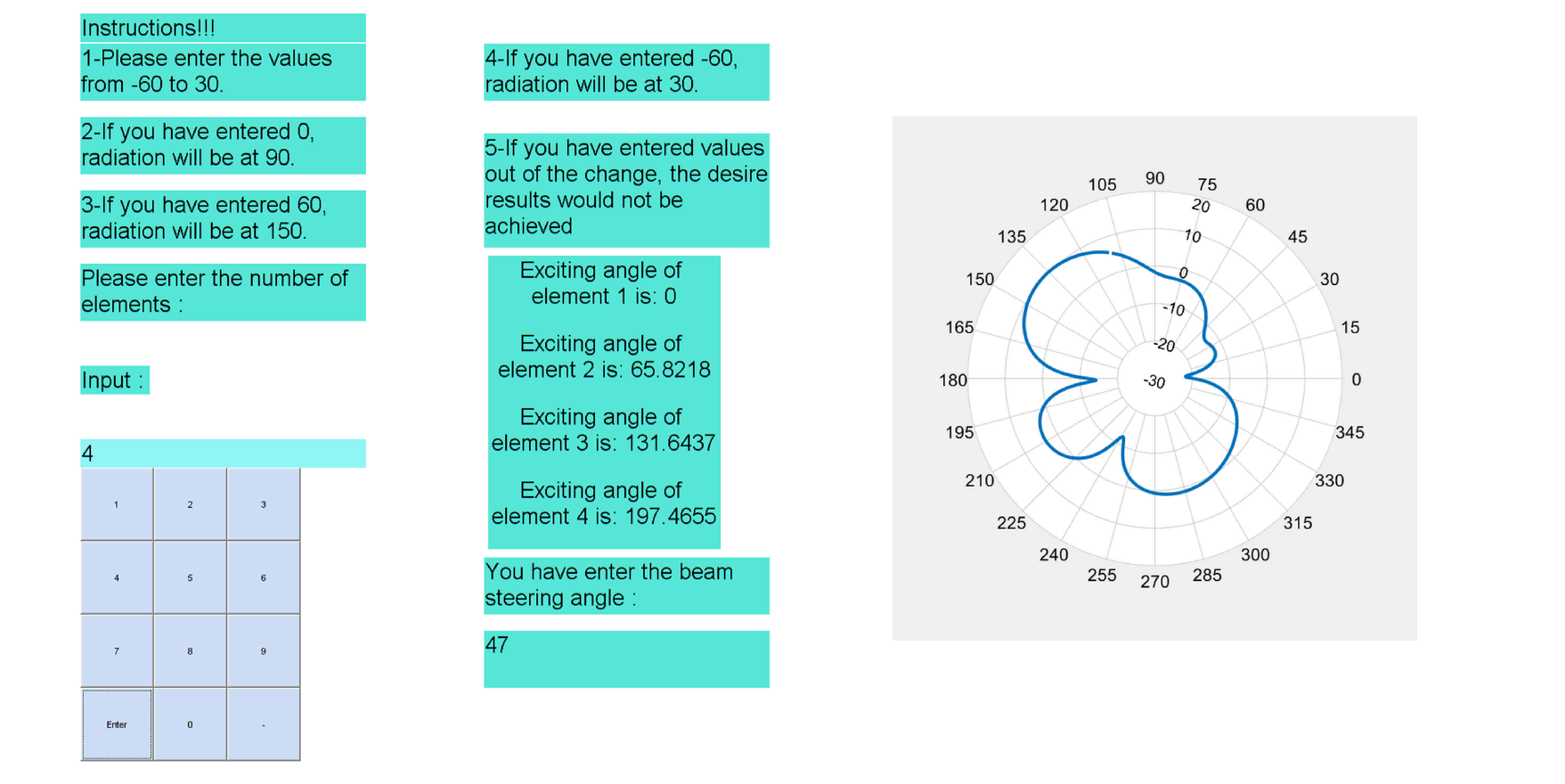
FARFIELD RESULTS AZIMUTHAL PLANE



PHASE SHIFTER ALGORITHM

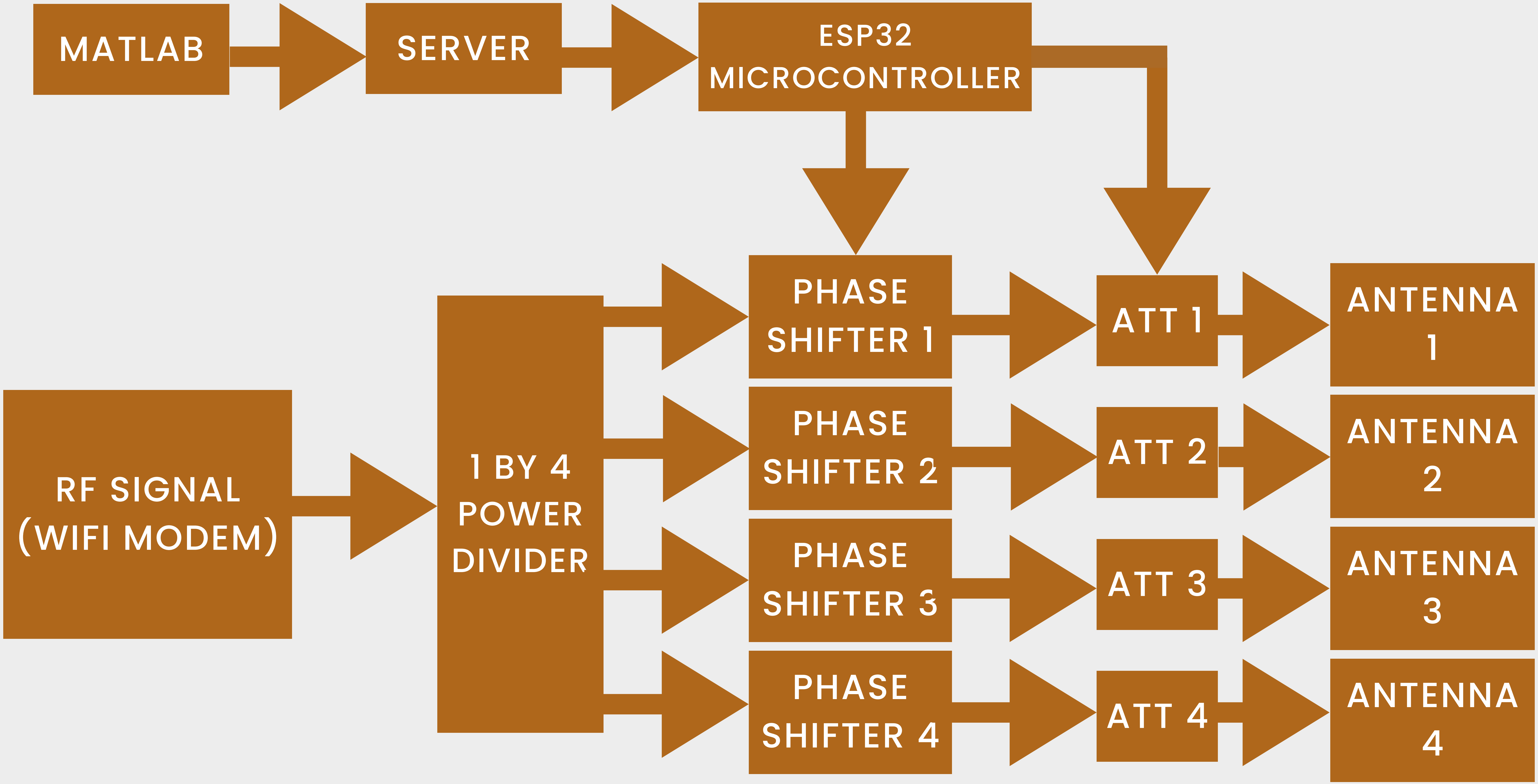


PHASE SHIFTER GUI



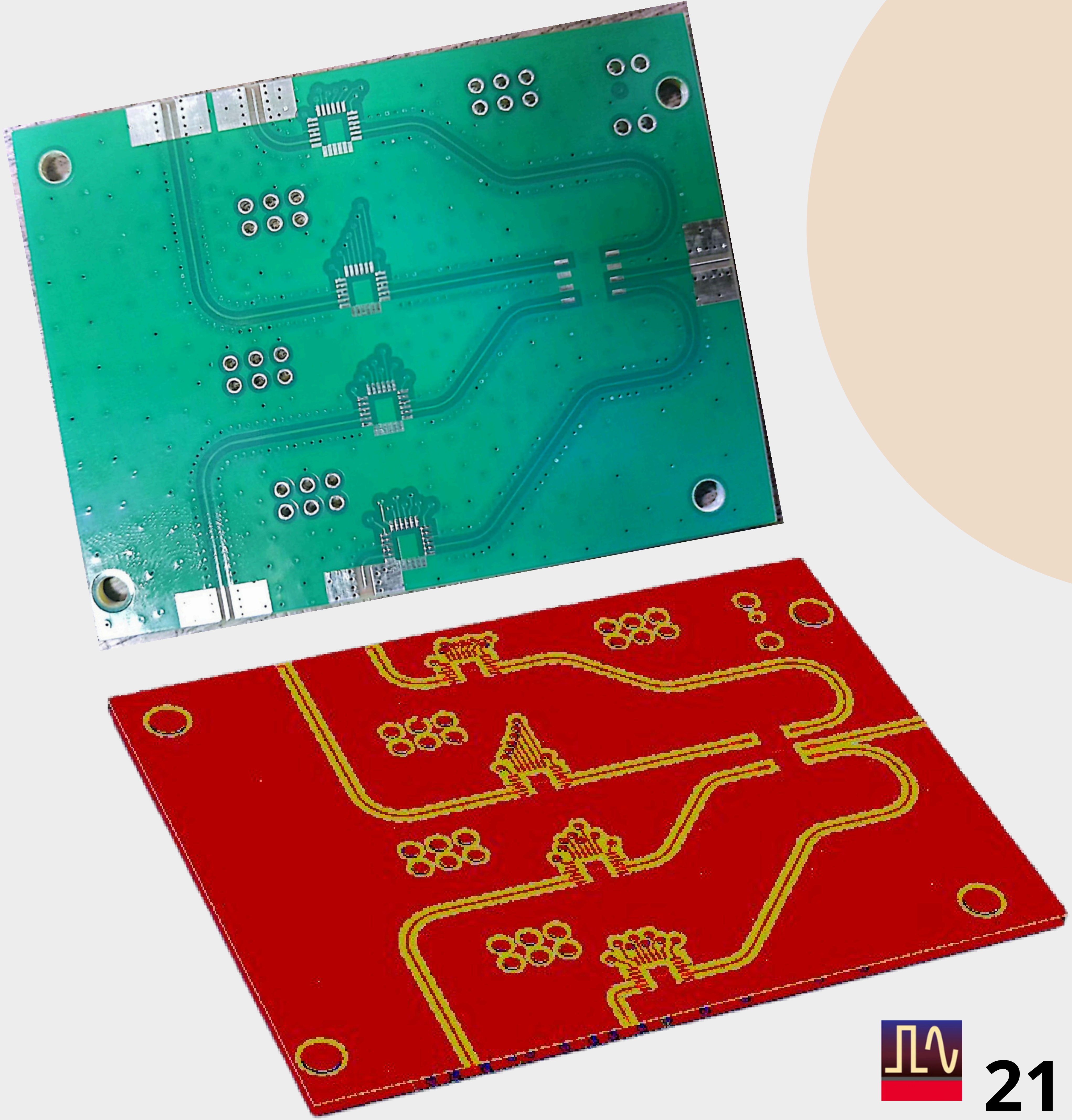
- MATLAB GUI controls the beamforming IC
- Generates excitation angle from beamforming angle
- Provides 6-bit binary sequence for beamforming control
- User-friendly GUI developed for ease of use

BEAMFORMING BLOCK DIAGRAM



BEAMFORMING CIRCUIT DESIGN

- Phase and att of signal adjustment to create directional beam
- Digital control
- Highly adaptive and can provide precise control upto 5.6 degrees per element over the beam direction
- 4 Layer PCB
- CPWG Technology
- insertion loss of 4dB



PHASE SHIFTER IC MAPS-010164

Digital Phase Shifter
6-Bit, 2.3 - 3.8 GHz Rev. V3

Features

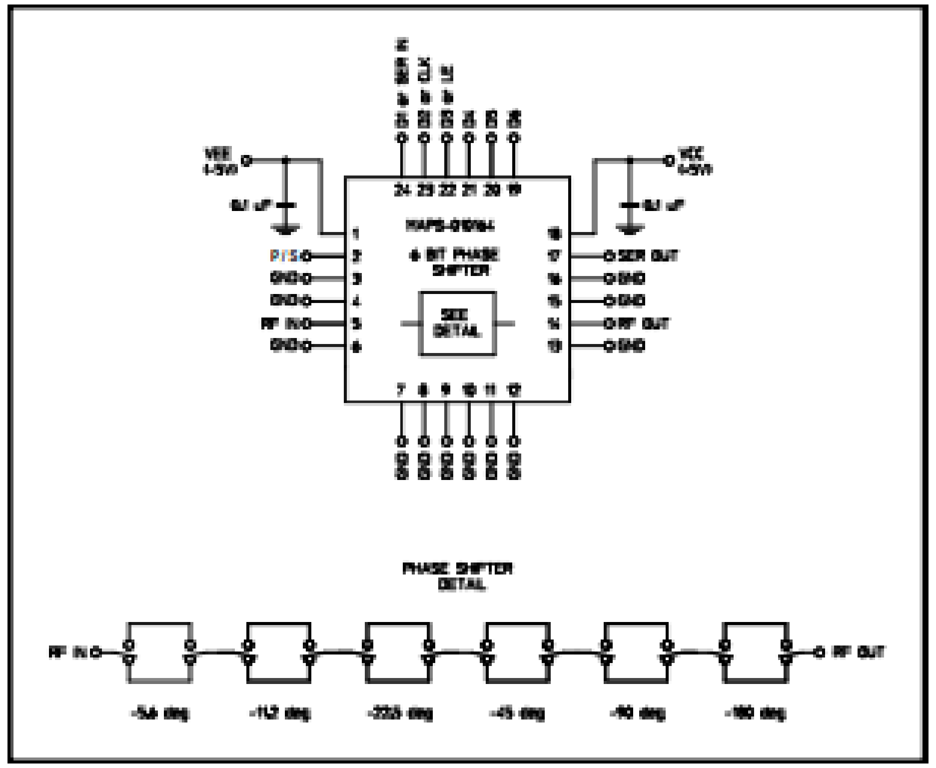
- 6 Bit Digital Phase Shifter
- 360° Coverage with LSB = 5.6°
- Integrated CMOS Driver
- Serial or Parallel Control
- Low DC Power Consumption
- Minimal Attenuation Variation over Phase Shift Range
- 50 Ω Impedance
- EAR99
- Lead-Free 4 mm 24-Lead PQFN Package
- RoHS* Compliant

Description

The MAPS-010164 is a GaAs pHEMT 6-bit digital phase shifter with an integrated CMOS driver in a 4 mm PQFN plastic surface mount package. Step size is 5.6° providing phase shift from 0° to 360° in 5.6° steps. This design has been optimized to minimize variation in attenuation over the phase shift range.

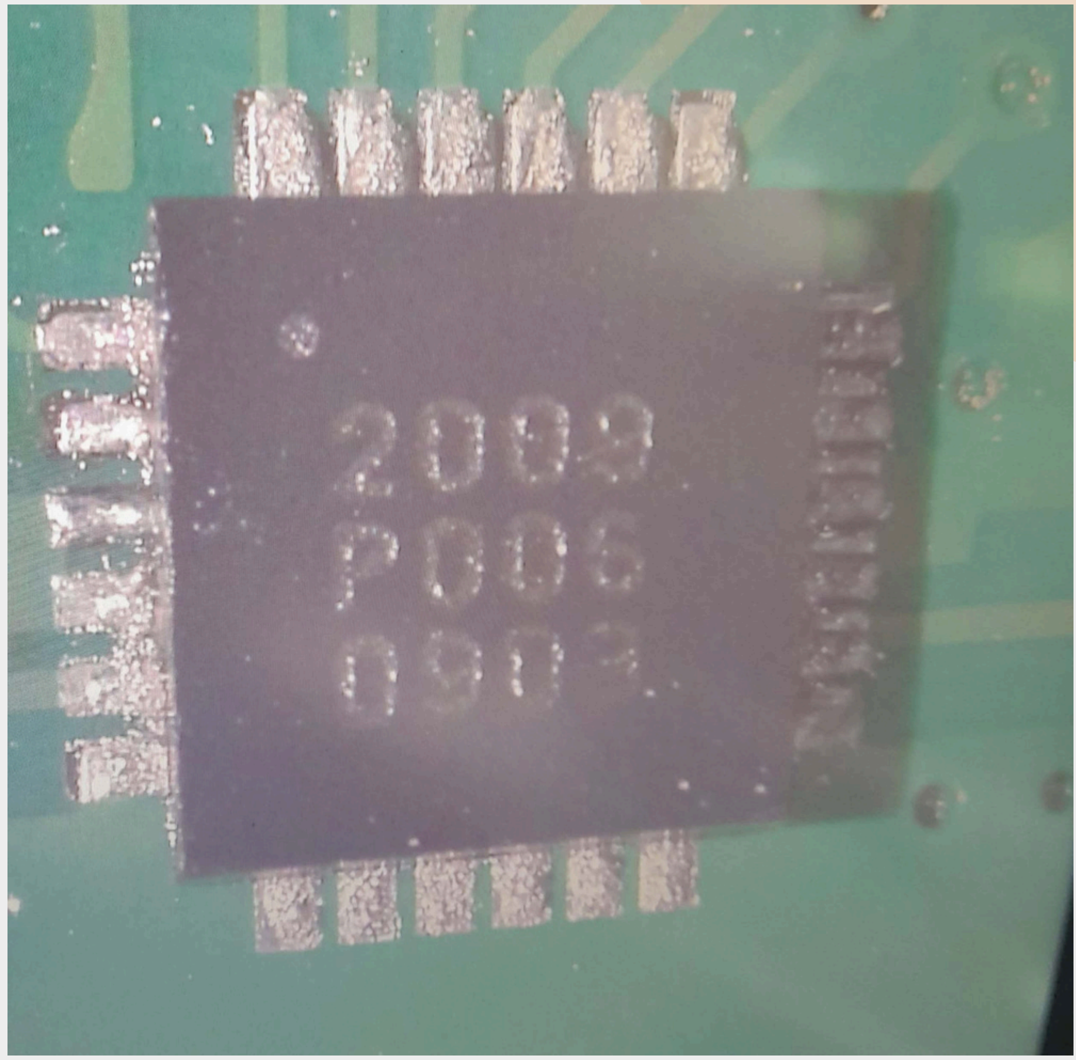
The MAPS-010164 is ideally suited for use where high phase accuracy with minimum loss variation over the phase shift range are required. The 4 mm PQFN package provides a smaller footprint than is typically available for a digital phase shifter with an internal driver. Typical applications include communications antennas and phased array radars.

Functional Schematic



Pin Configuration [2]

Pin No.	Function	Pin No.	Function
1	VEE	13	GND
2	P/S	14	RF OUT
3	GND	15	GND
4	GND	16	GND
5	RF IN	17	SER OUT



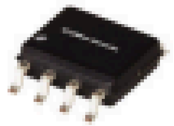
4X1 POWER DIVIDER IC BP4U1

Surface Mount

Power Splitter/Combiner

4 Way-0° 50Ω 1850 to 3000 MHz

BP4U1+



Generic photo used for illustration purposes only

CASE STYLE: XX211

+RoHS Compliant
The +Suffix identifies RoHS Compliance. See our web site for RoHS Compliance methodologies and qualifications

Available Tape and Reel at no extra cost

Reel Size	Devices/Reel
7"	20, 50, 100, 200, 500, 1000
13"	2000

Maximum Ratings

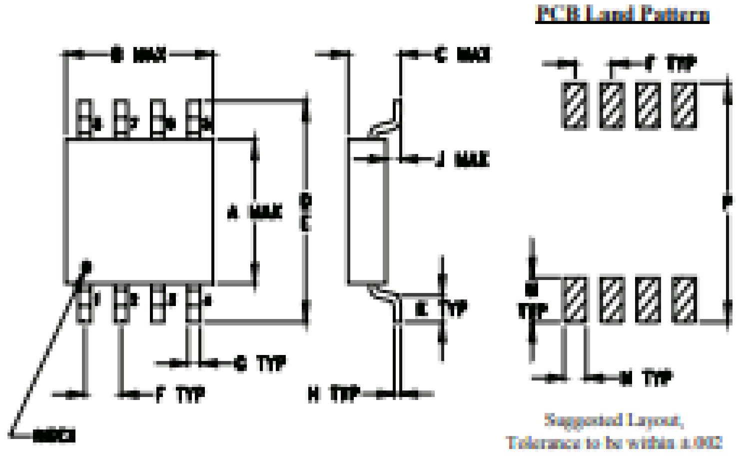
Operating Temperature	-40°C to 85°C
Storage Temperature	-65°C to 150°C
Power Input (as a splitter)	1.5W max.
Internal Dissipation	0.375W max.

Permanent damage may occur if any of these limits are exceeded.

Pin Connections

SUM PORT	2
PORT 1	1
PORT 2	8
PORT 3	5
PORT 4	4
GROUND EXTERNAL	3,6,7

Outline Drawing



Features

- wide bandwidth, 1850-3000 MHz
- excellent output VSWR, 1.2:1 typ.
- excellent power handling, 1.5W
- aqueous washable

Applications

- blue tooth
- IEEE 802.11b, g

Electrical Specifications

FREQ. RANGE (MHz) f_L-f_U	ISOLATION (dB) Typ.	Min.	INSERTION LOSS (dB) ABOVE 6 dB Typ.	Max.	PHASE UNBALANCE (Degrees) Max.	AMPLITUDE UNBALANCE (dB) Max.	VSWR (:1) Typ. Port S	Ports 1,2,3,4
1850-3000	23	15*	0.7	1.7	28	1.3	1.5	1.2

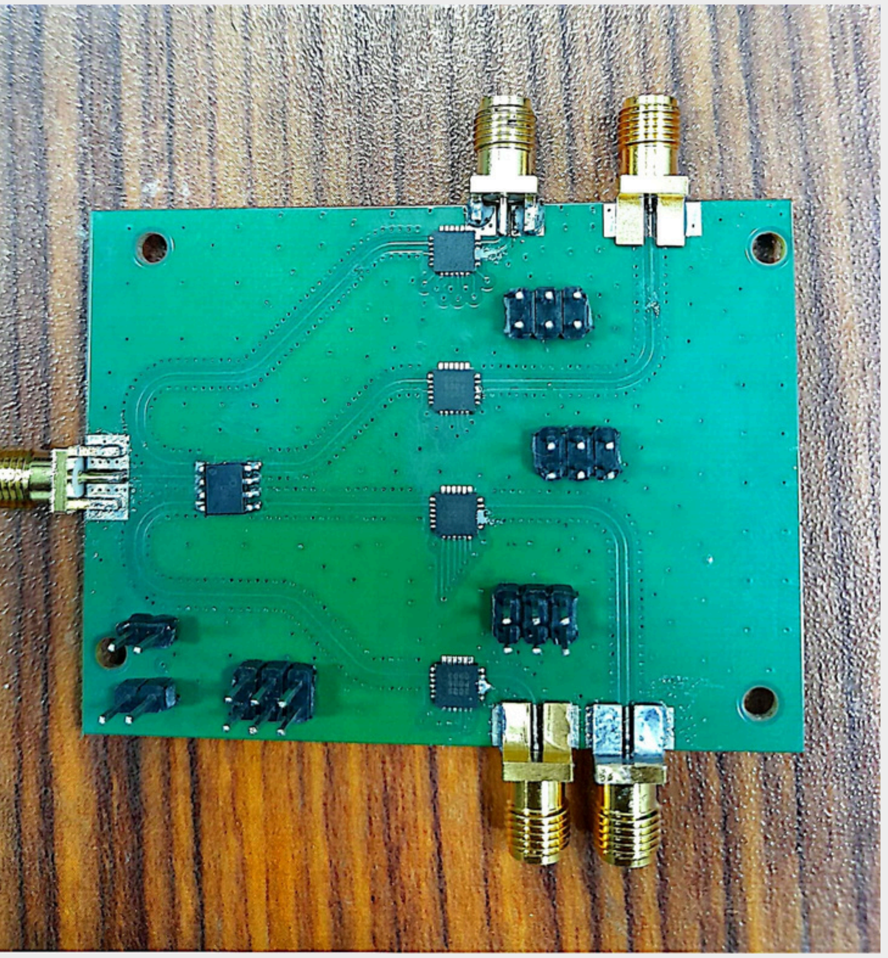
*13 dB above 2600 MHz

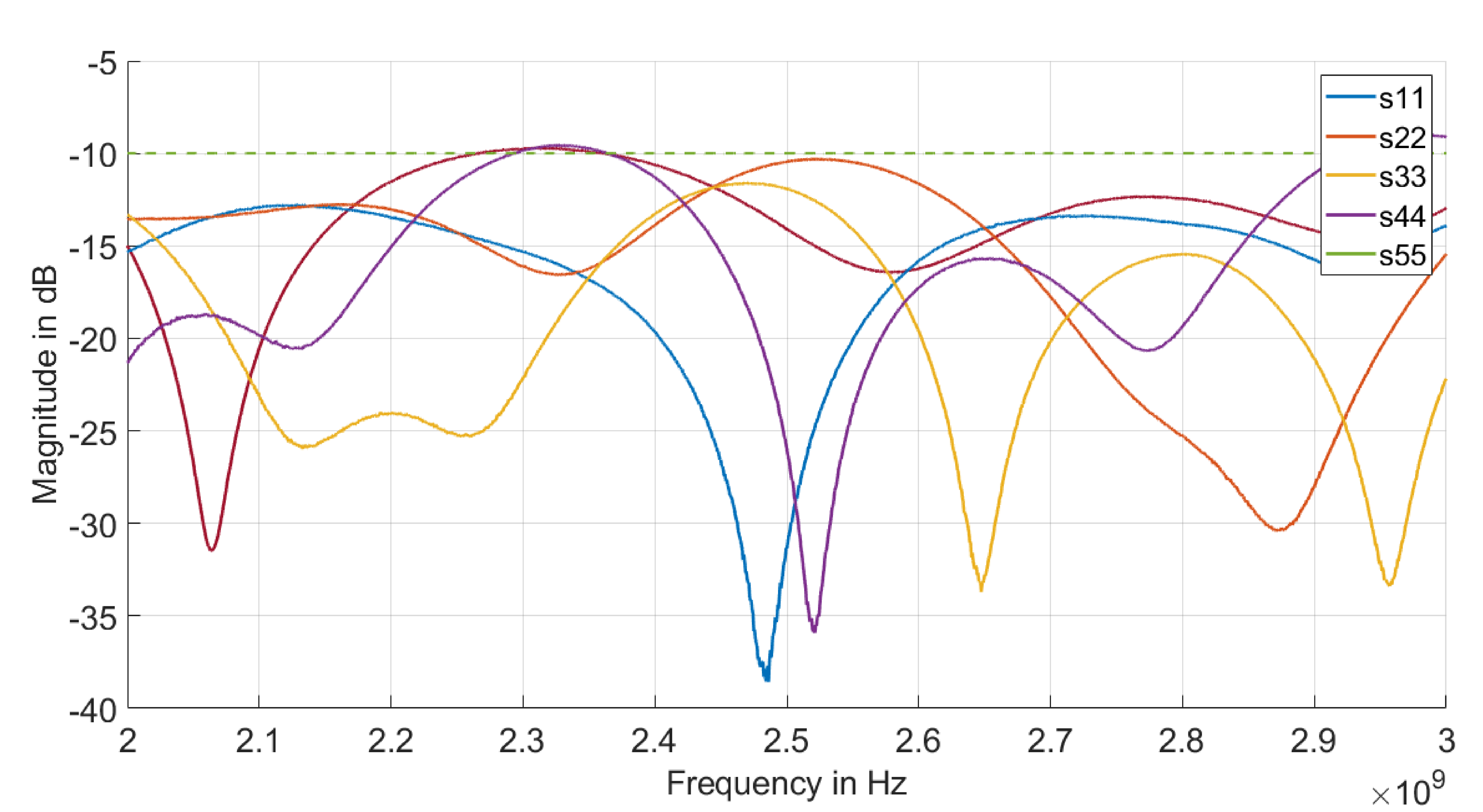
Typical Performance Data

Freq. (MHz)	Total Loss[1] (dB) S-1	S-2	S-3	S-4	Amp. Unbal. (dB)	Isolation (dB) 1-2	2-3	3-4	Phase Unbal. (deg.)	VSWR S	VSWR 1	VSWR 2	VSWR 3	VSWR 4
1850.00	6.40	7.28	7.36	7.25	0.96	22.67	26.87	32.49	3.18	1.72	1.21	1.37	1.37	1.43
1900.00	6.30	7.13	7.21	7.12	0.91	23.77	29.31	33.79	4.19	1.57	1.19	1.35	1.34	1.40
2000.00	6.17	6.92	6.99	6.93	0.82	25.80	36.26	30.96	6.17	1.33	1.15	1.29	1.28	1.34
2100.00	6.12	6.78	6.84	6.82	0.72	27.06	35.82	27.14	8.09	1.16	1.13	1.24	1.23	1.30
2150.00	6.12	6.73	6.79	6.79	0.68	27.19	32.42	25.65	9.00	1.09	1.11	1.22	1.20	1.28
2200.00	6.13	6.70	6.76	6.77	0.64	27.02	29.67	24.40	9.88	1.07	1.10	1.20	1.18	1.26
2300.00	6.18	6.67	6.72	6.76	0.58	26.00	26.00	22.39	11.73	1.15	1.09	1.16	1.14	1.23
2400.00	6.27	6.67	6.72	6.79	0.53	24.75	23.51	20.86	13.53	1.28	1.07	1.13	1.11	1.20

RESULTS

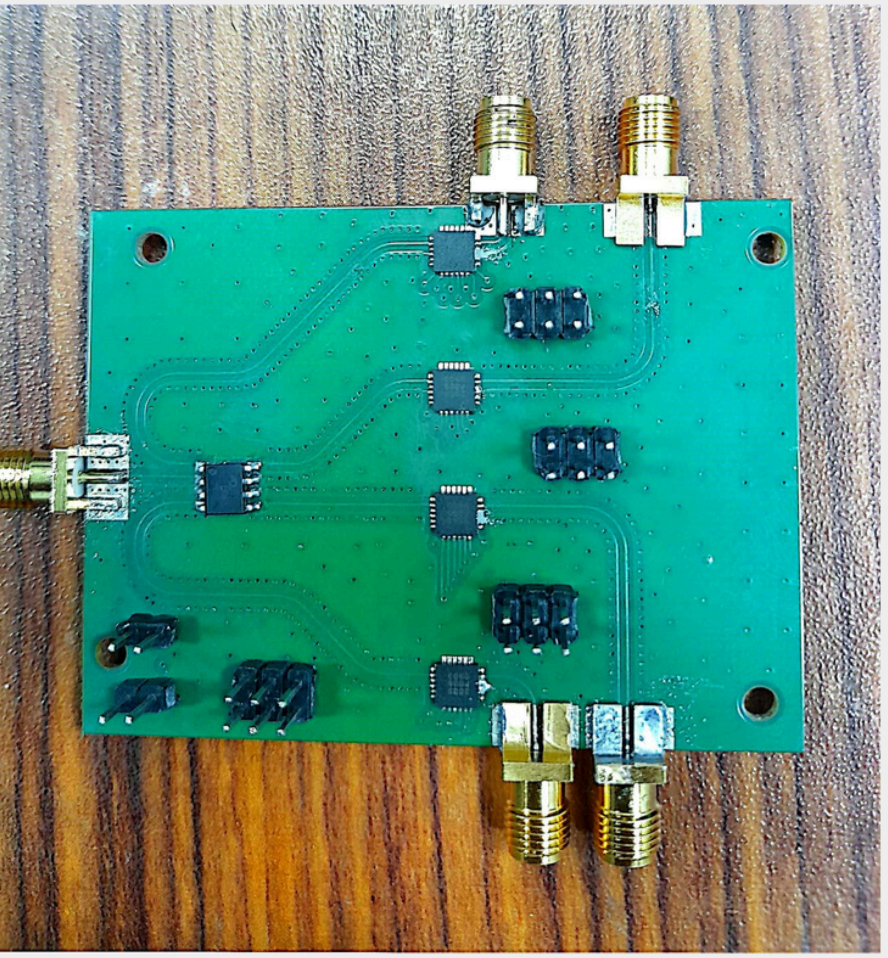
MATCHING (S11)

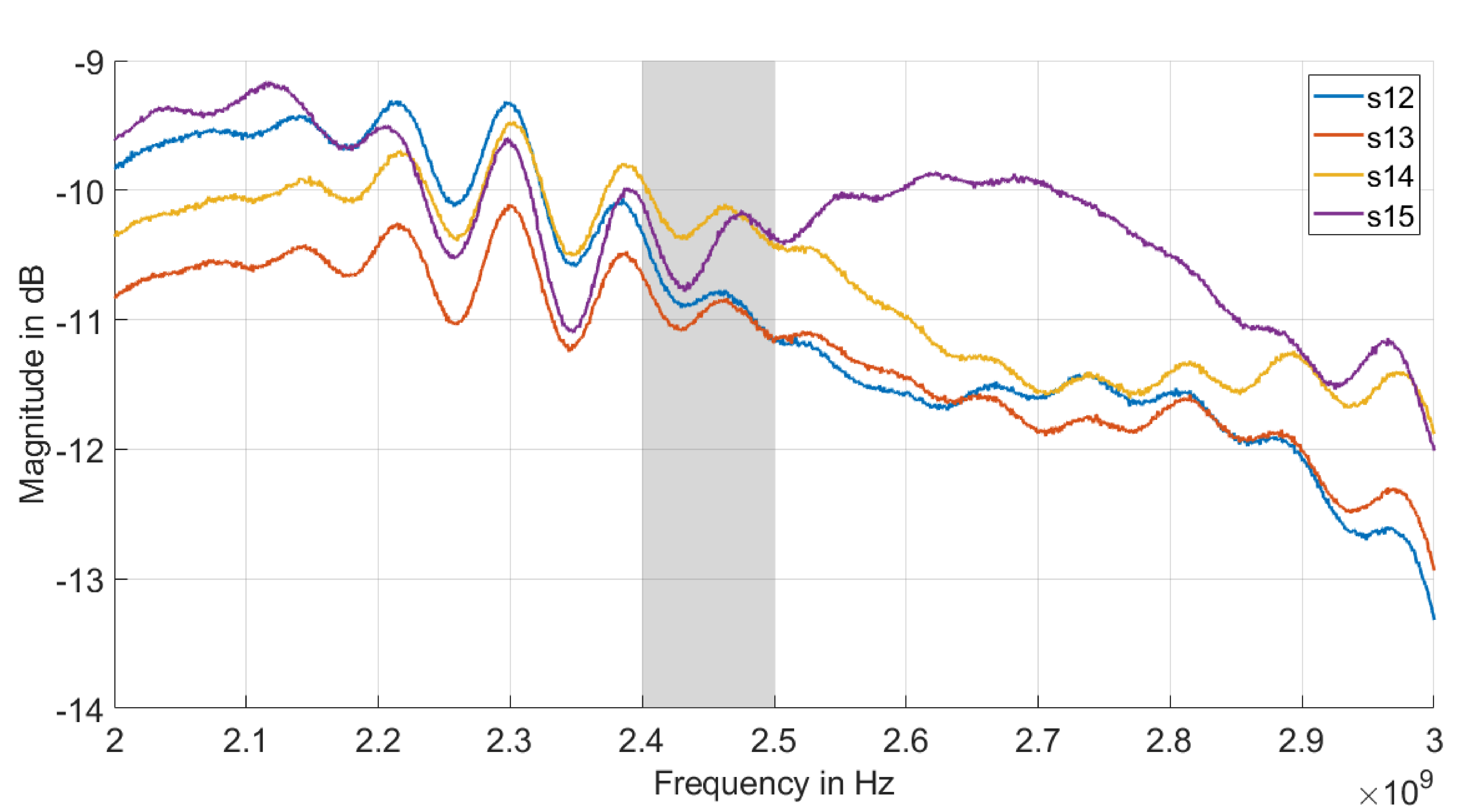




RESULTS

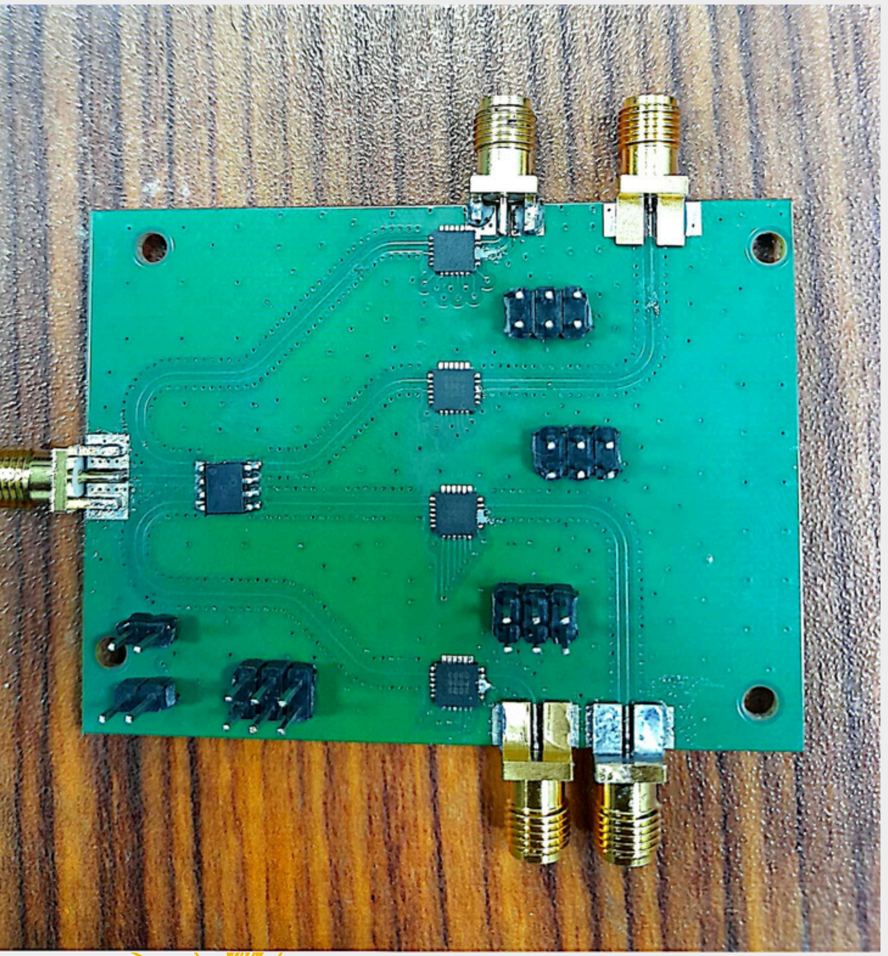
INSERTION LOSS PER TRACE

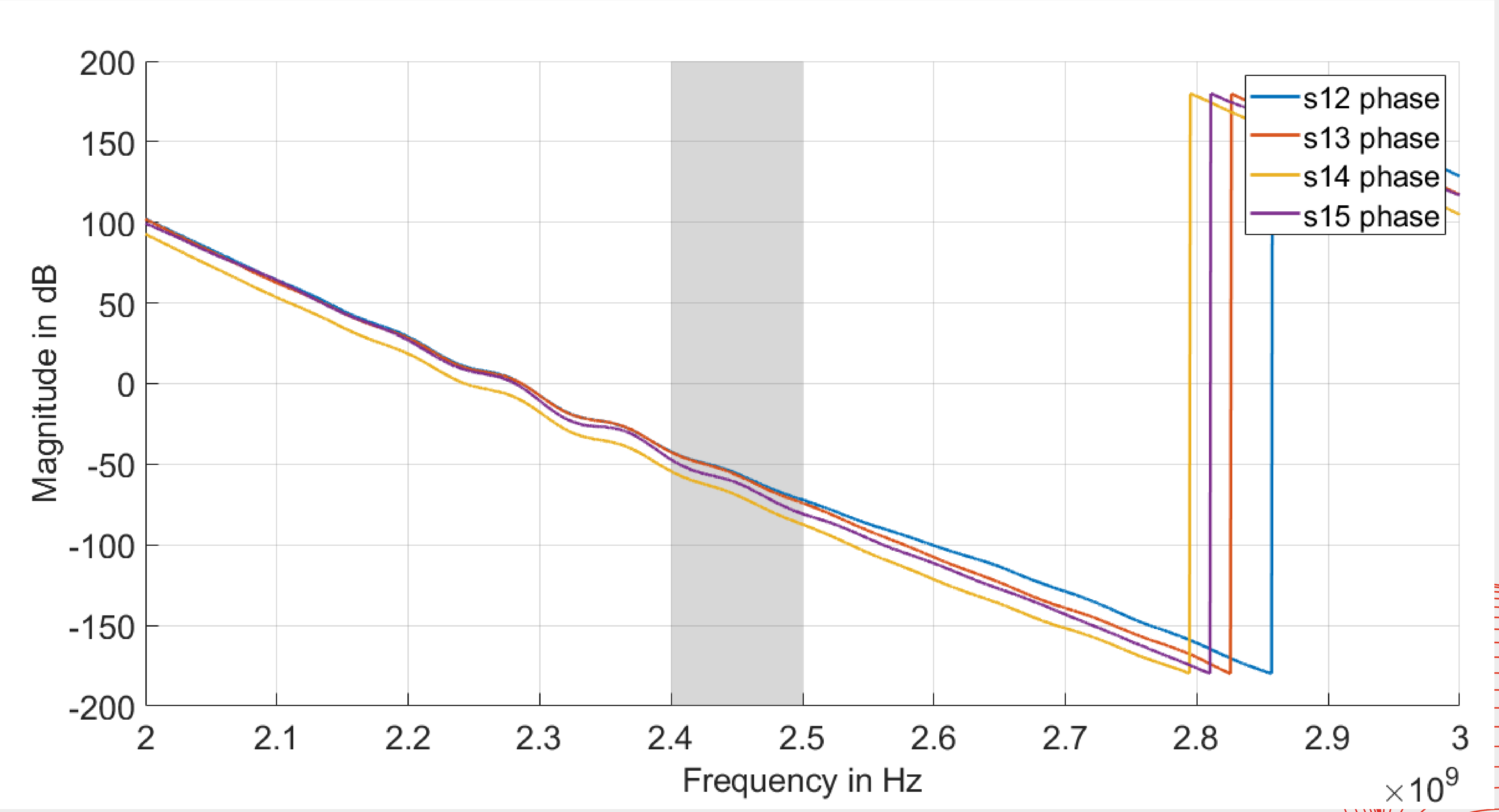




RESULTS

PHASE PLOT (WHEN ALL BIT 0)





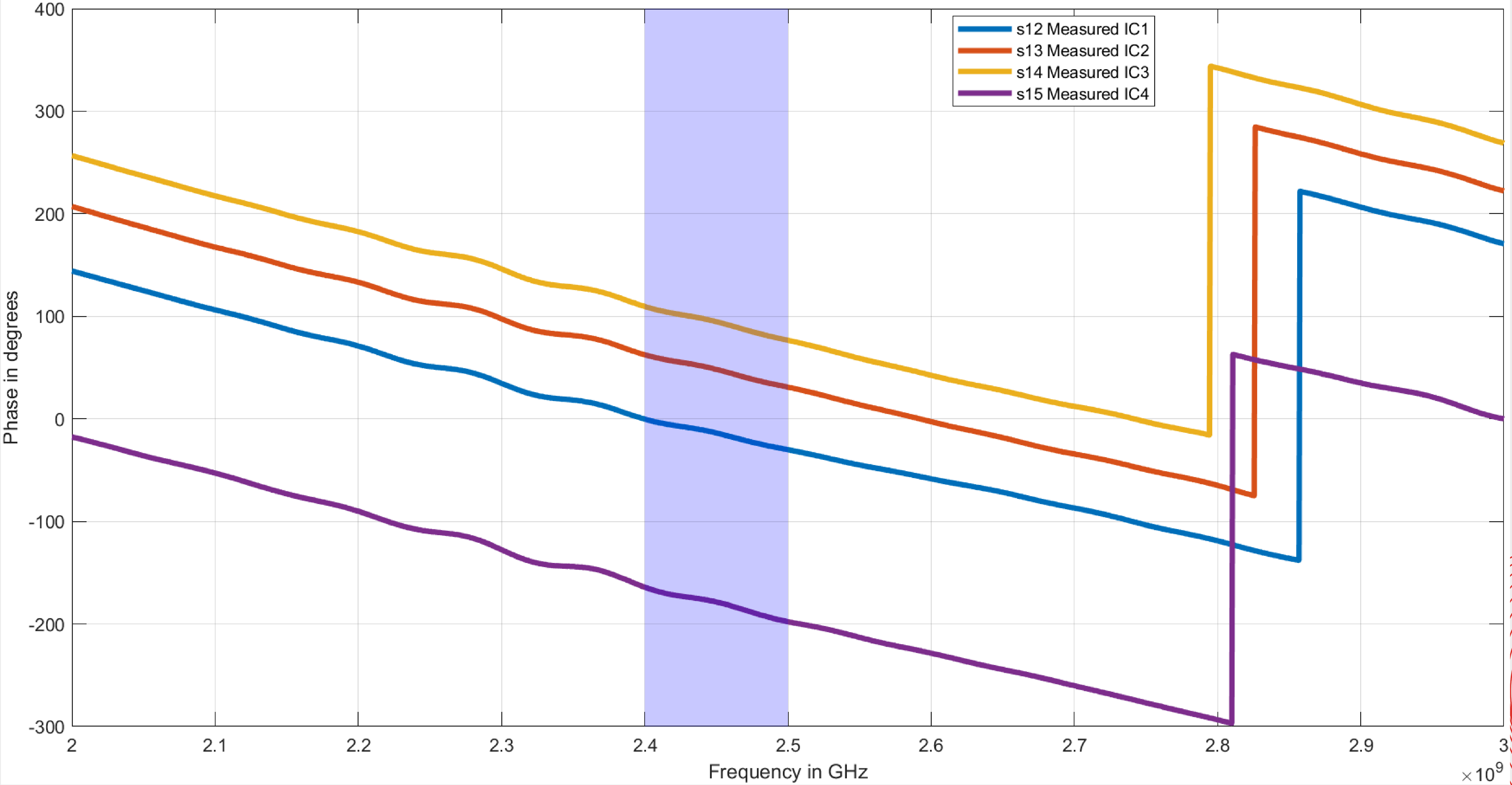
PHASE SHIFT CHARACTERISTIC TABLE

AT THETA=30

IC	BIT STREAM	PHASE SHIFT
1	111011	0
2	101101	63.5
3	111110	127
4	001111	203.5

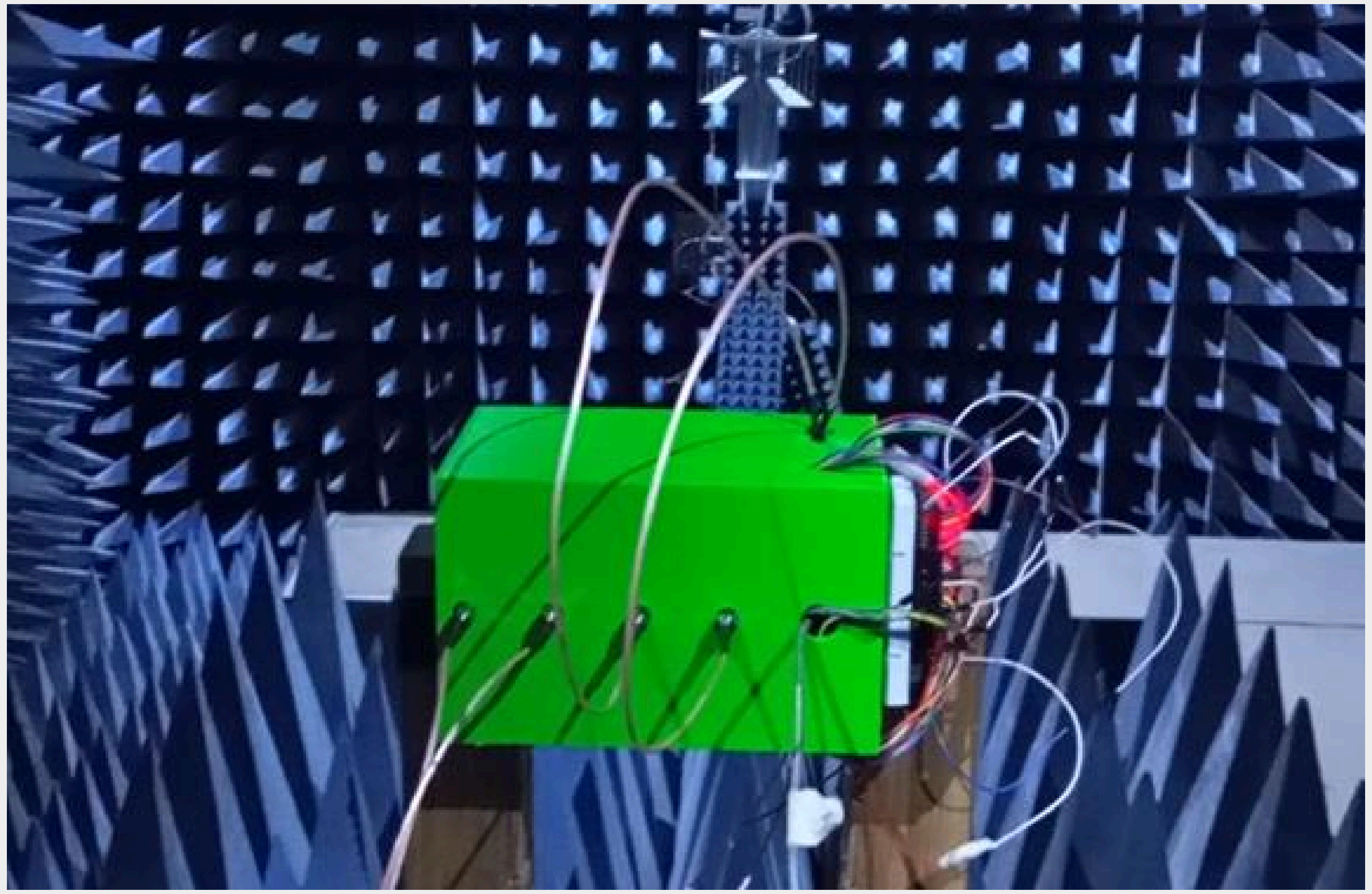
RESULTS

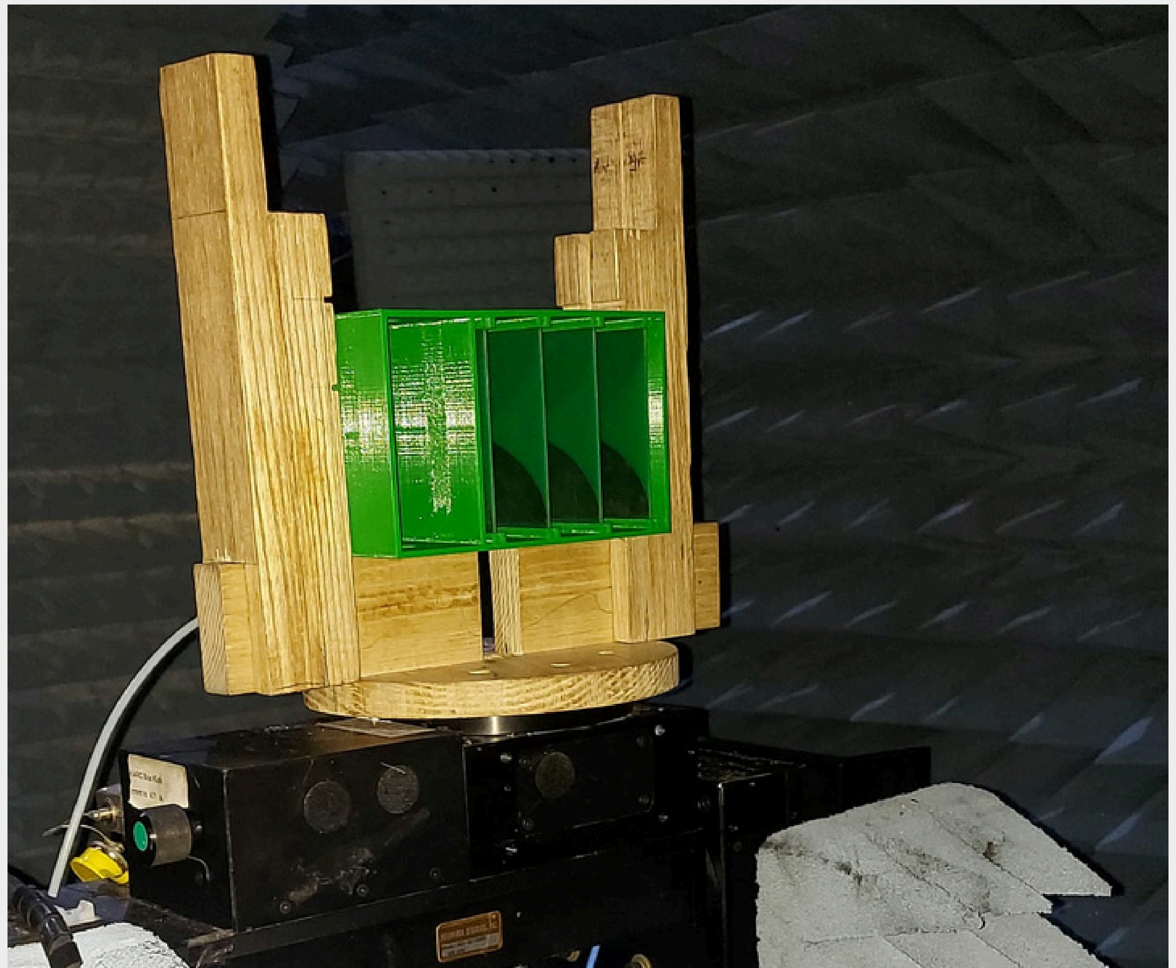
FOR 30 DEGREE BEAM STEERING



AUTOMATION AND TESTING

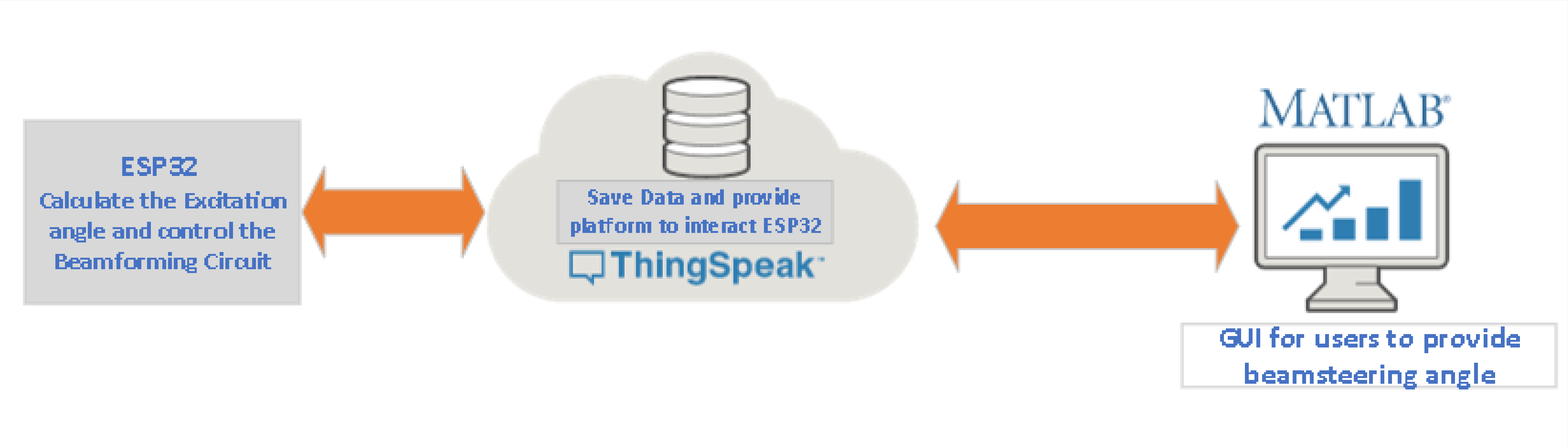
- Automation of testing process
- Accurate and repeatable measurement of antenna performance
- Testing setup to cover a range of WiFi environments



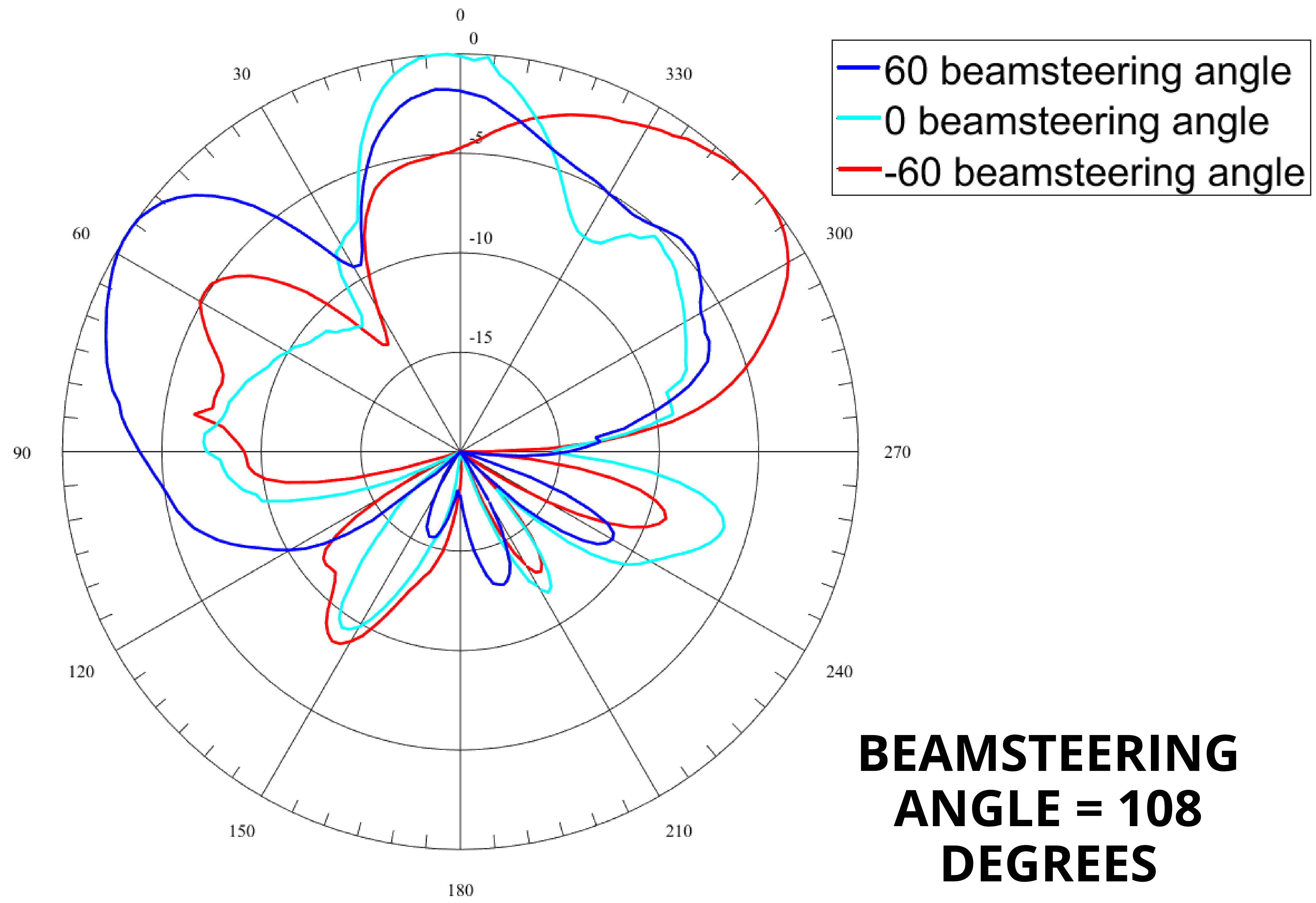


AUTOMATION AND TESTING

- Control the Beamforming circuit
- Save the previous Data in a server
- Provide visual representation of Steered Beam
- Easy to use

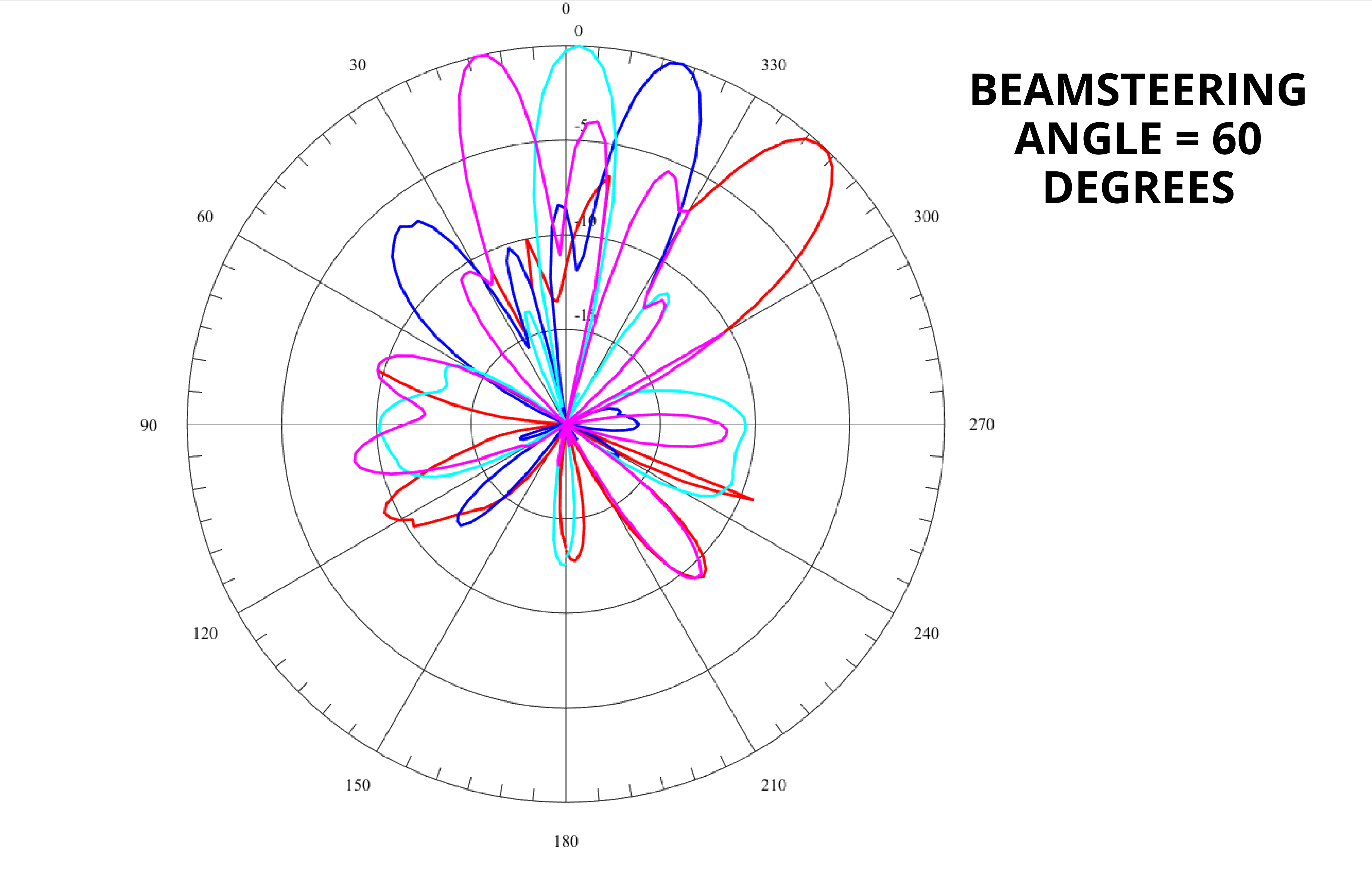


BEAMSTEERING WITH VERTICAL ARRAY



BEAMSTEERING ANGLE = 108 DEGREES

BEAMSTEERING WITH HORIZONTAL ARRAY



BEAMSTEERING ANGLE = 60 DEGREES

MEASURED RESULTS

Vertical configuration

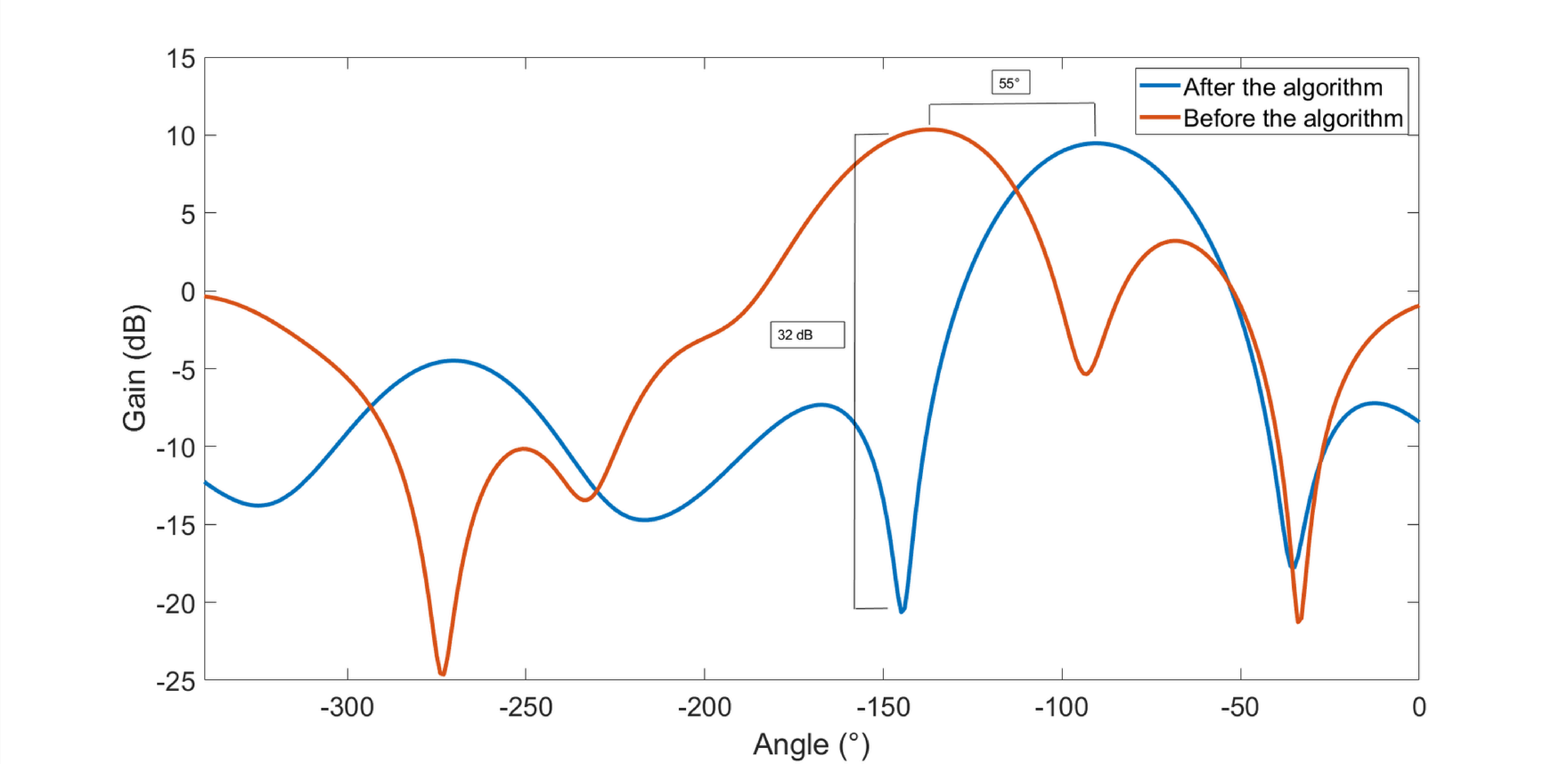
Frequency Band	S-band
Gain	10.4 dBi
Bandwidth	861MHz
Insertion Loss	-3.94dB
Half Power Beamwidth	45-55°
Beam Steering Angle	±60°
Polarization	Linear

Horizontal configuration

Frequency Band	S-band
Gain	16.1dBi
Bandwidth	952MHz
System Gain	3.61 dB
Half Power Beamwidth	17-20°
Beam Steering Angle	±30°
Polarization	Linear

FINAL RESULTS WITH ALGORITHM

- The mobile is placed at -150°
- A gain difference of 32 dB is achieved with beamsteering
- Steered the beam to 55°.



CONCLUSION

WI-FI connectivity improvement

Directional gain and wider bandwidth- Vivaldi antenna array

Precise phase adjustment - Phase Shifter network

Control over beam precise Phase-Beamforming CIrcuit

Efficient and accurate testing

Improved coverage

THANK YOU!