ANTENNA COURSE PROJECT REPORT

Design of a Compact Dual-Band MIMO Antenna System & MATLAB plotting for dipole radiation pattern at different lengths

Part 1 MIMO Antenna

1. Introduction

Multiple input multiple output (MIMO) technology enhances wireless communication systems by using multiple antennas to handle multiple signal paths simultaneously; instead of relying on a single antenna, MIMO employs a team of antennas (for Tx and Rx) to divide and conquer data transmission tasks.
This team approach results in faster data transmission and improved signal quality.

MIMO is a key component of modern wireless technologies such as 4G LTE, 5G NR

2. Antenna Design and its Dimensions

in this work a compact 4 element dual-band multiple-input and multiple-output (MIMO) antenna system is proposed to achieve high isolation and low channel capacity loss. The MIMO antenna was designed and optimized to cover the dual-frequency bands; the first frequency band is a wide band, and it covers the frequency range of 1500–2500 MHz, while the other frequency band covers the 3410–3560 MHz range.

The layout of the proposed four-element MIMO antenna system is shown in Figure 1. The antenna was designed and optimized using CST studio suite The antenna system consisted of a plus-sign-shaped ground structure on the bottom side of the FR4 substrate with a dielectric constant of 4.2 and thickness of 1.6 mm. Four patch elements were printed on the top side of the substrate to achieve a four-element MIMO antenna system. The antenna dimensions are given in Table 1

Table 1. Proposed Antenna Dimensions [1]

All Dimensions Are in mm	
Wg = 5	L5 = 9.89
Wt = 2.82	L6 = 12.02
W1 = 2	L7 = 11.58
W2 = W3 = 1.41	L8 = 7.77
W4 = 2	L9 = 5.5
L1 = 17	L10 = 7.07
L2 = 12	L11 = 4.5
L3 = 11	L12 = 1
L4 = 10.59	L13 = 2

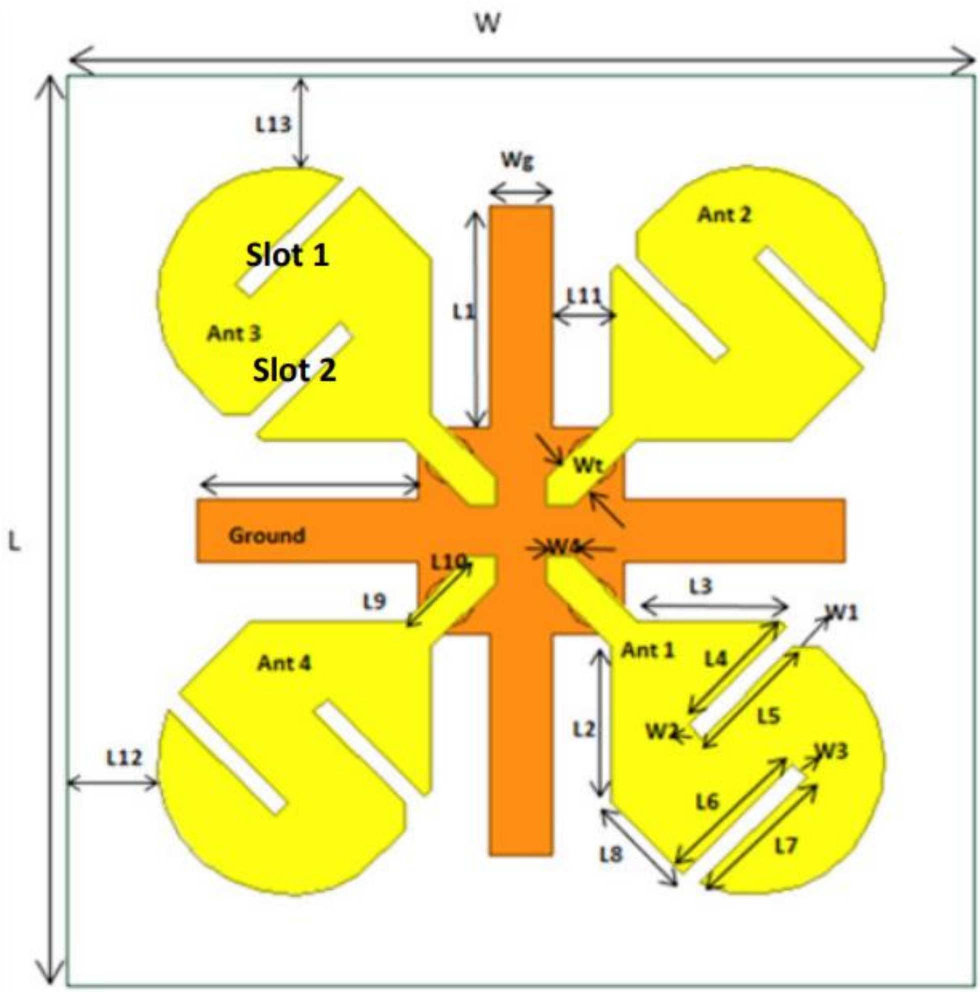

Figure 1. Geometry of the four-element MIMO antenna system

2.1. Development Steps

Firstly, a single rectangular shaped element was designed then two opposite slots were introduced into it reduce the size of the element and transform it into a multi-band antenna element, then three copies were made from the single element; The four elements were arranged in an orthogonal arrangement around a plus-shaped partial ground. t. The sizes of the patch elements, lengths of the slots & the feed cylinders were optimized using parametric sweep in order to achieve a compact multi-band MIMO antenna system with a high diversity gain performance.

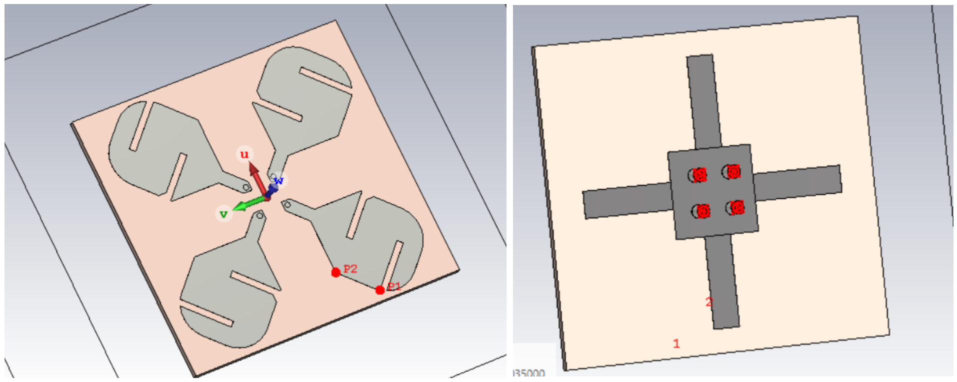

figure 2. Implemented design

3.Results and discussion:

a. S11 (reflection coefficient) :

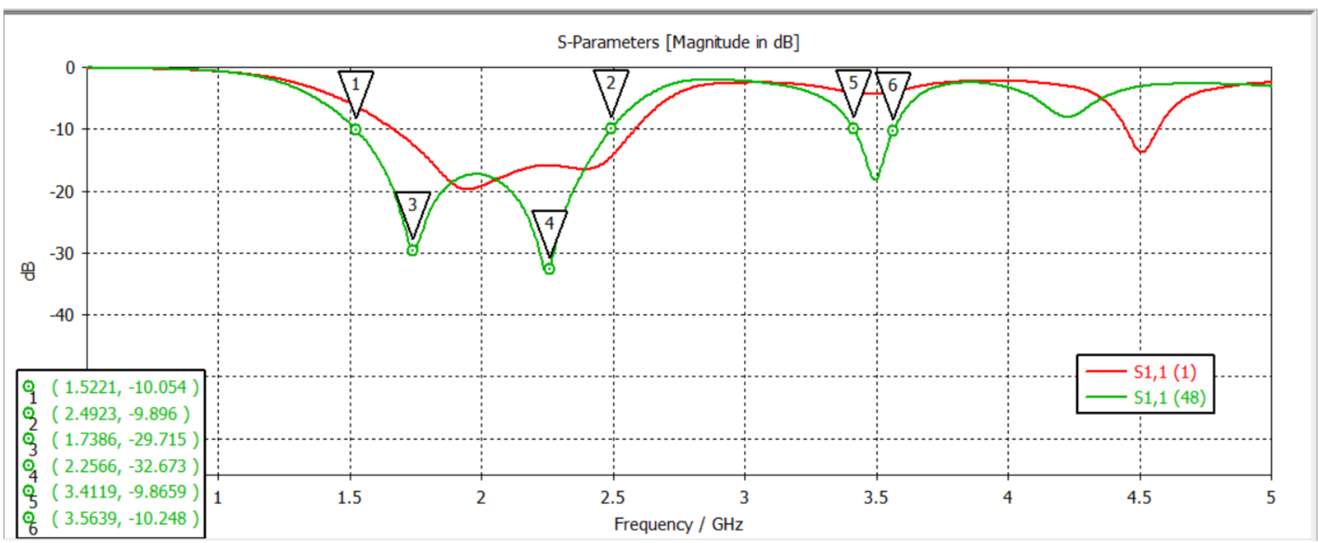

Figure 3. S11 obtained before (1) and after optimization and parametric sweeps (47)

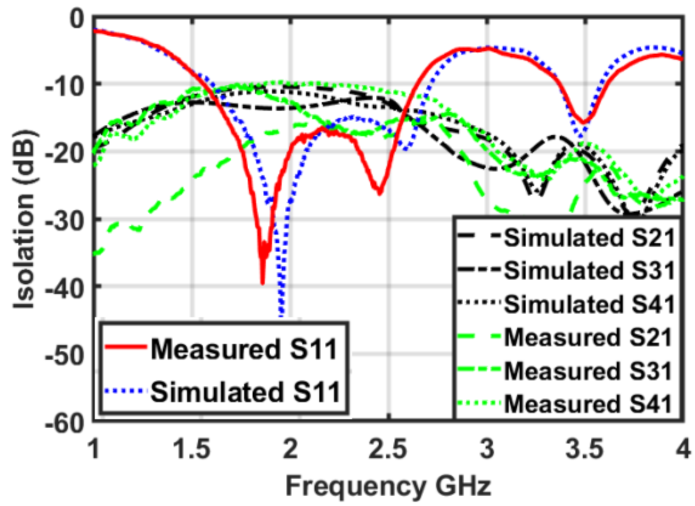

Figure 7. Simulated and measured S-parameters of the dual-band MIMO antenna system.

Figure 4. S11 from the reference paper after optimization

by comparing the obtained and reference S11 curve we can see that the wide band frequencies bandwidth is similar (1.5 – 2.5 GHz obtained vs 1.5 – 2.6 GHz reference) with slight differences in resonant frequencies, the narrow band resonant frequency is the same with a slightly reduced bandwidth

b. envelope correlation coefficient:

Envelope Correlation Coefficient is an important MIMO antenna performance parameter; it tells us how independent two antenna element's radiation patterns are. ρ shows the influence of diverse signals that reach the antenna elements by following distinct propagation paths. The value of "ρ" is calculated using the S-parameters, using the formula:

$$\rho_{ij} = \frac{\left|S_{ii}{}^{*}S_{ij} + S_{ji}{}^{*}S_{jj}\right|^2}{\left(1 - |S_{ii}|^2 - |S_{ji}|^2\right)\left(1 - |S_{jj}|^2 - |S_{ij}|^2\right)},$$

It could be measured directly using CST or plotted using MATLAB, in this work I calculated it using CST studio suite.
for a MIMO antenna system to be considered practical; |ρ| should be ≤ 0.3.

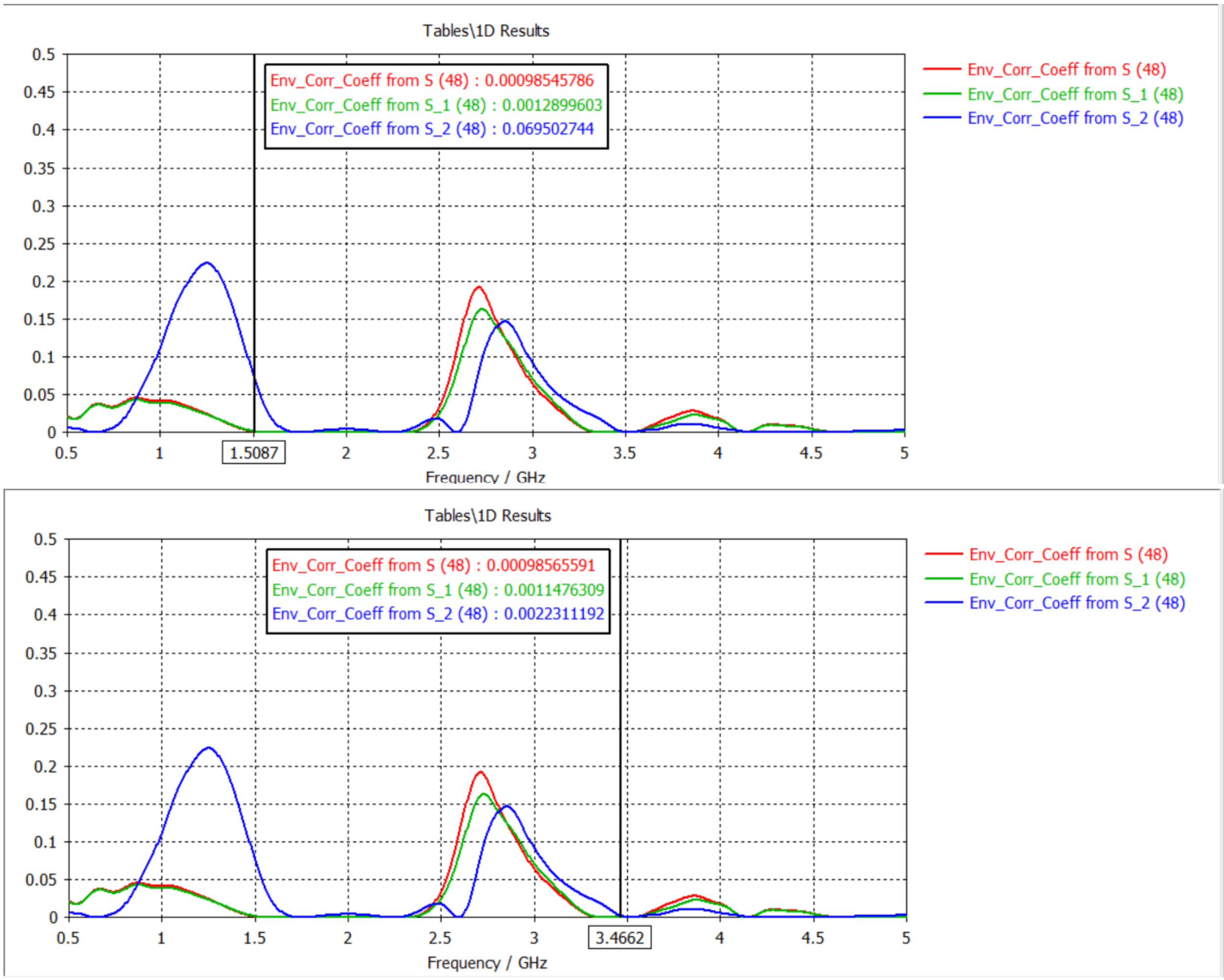

Figure 5. envelope correlation coefficient plot for implemented design

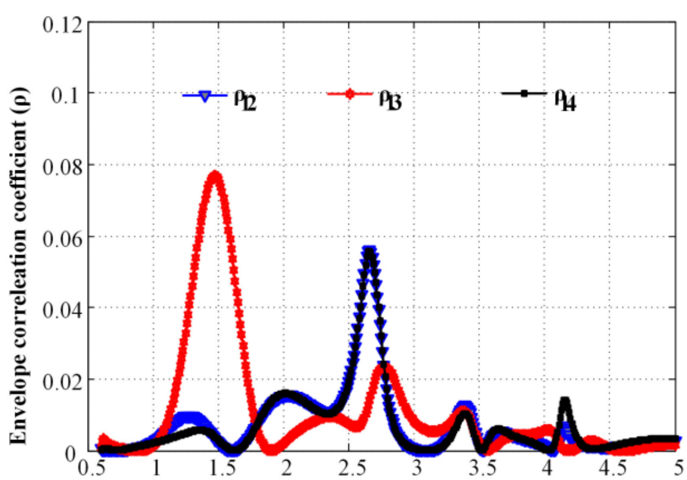

Figure 6. Ecc from paper

As shown in the plots for both the wide and narrow band; the highest value for the ecc is 0.069 & 0.002 respectively and the values are even better from the paper reference results; which indicates that our MIMO antenna has high diversity gain and good performance.

C. Far field plots:

Firstly, we view the radiation pattern and maximum directivity at each resonant frequency

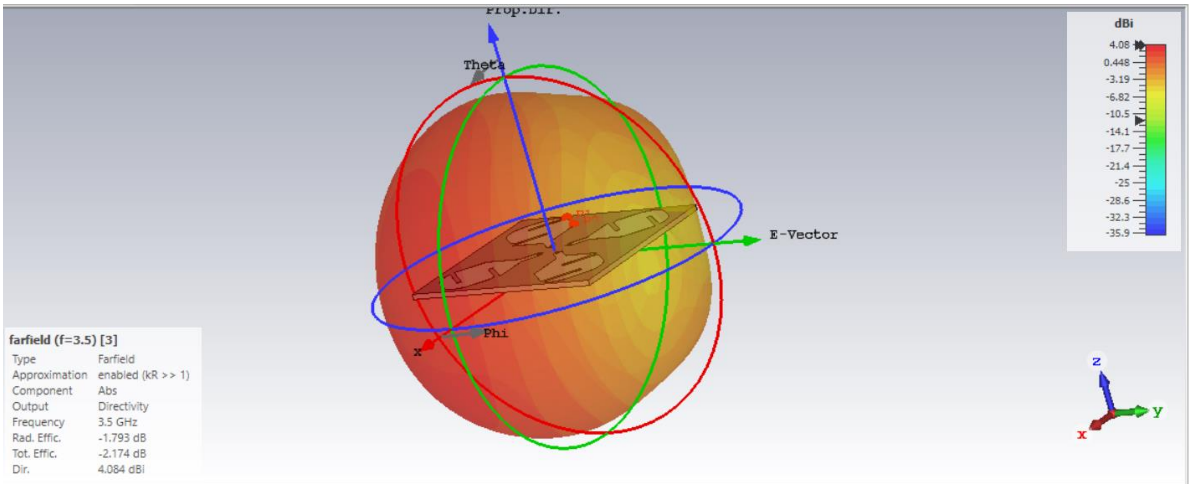

Figure 7. radiation and directivity at 3.5 GHz

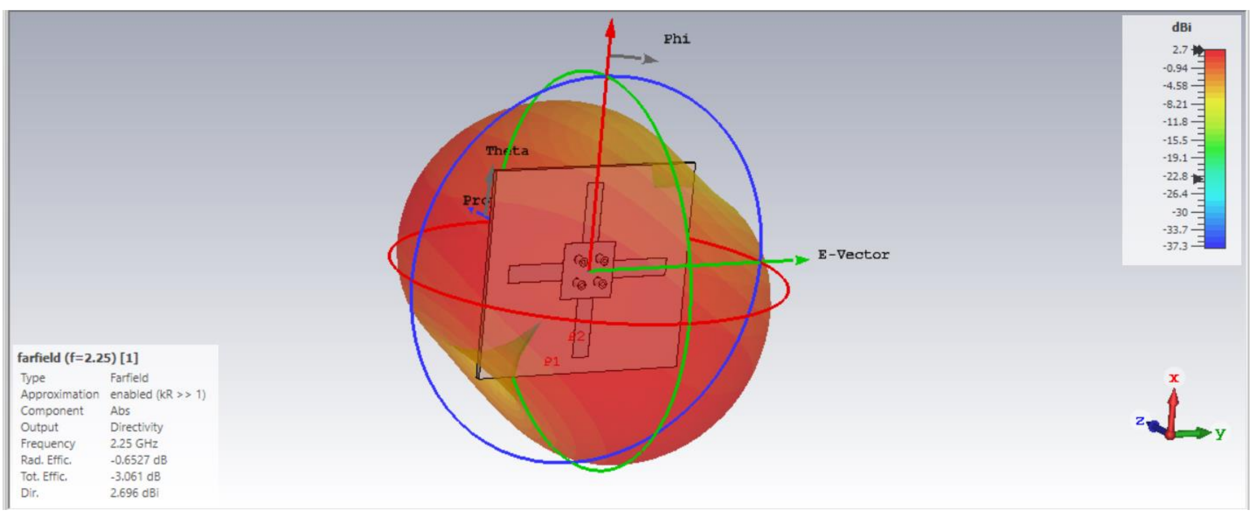

Figure 8. radiation and directivity at 2.25 GHz

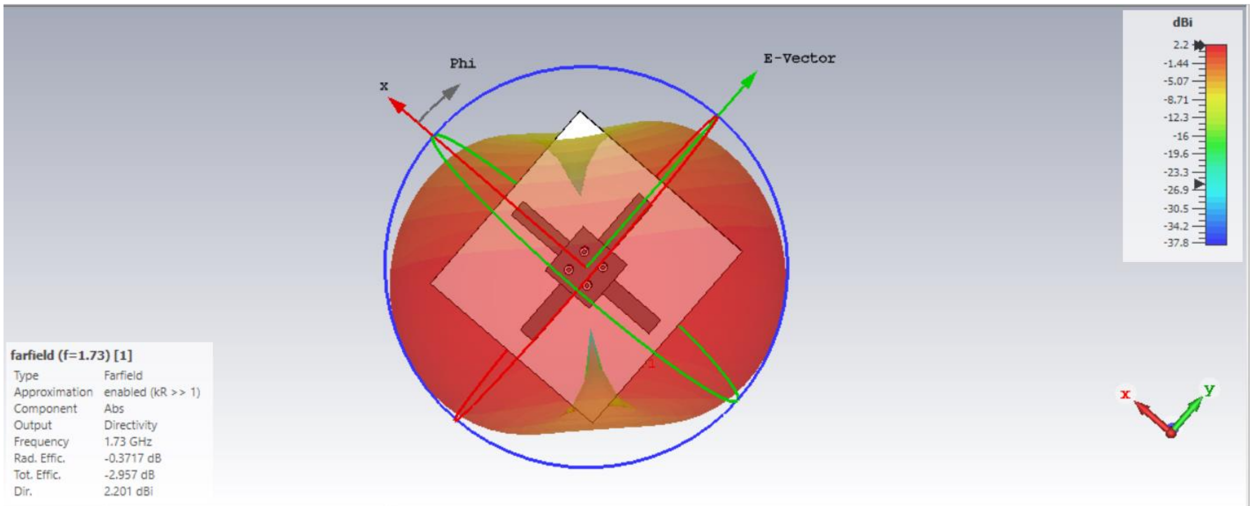

Figure 9. radiation and directivity at 1.73 GHz

And for similarly we obtain the gain results:

farfield (f=3.5) [3]

Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Gain
Frequency	3.5 GHz
Rad. Effic.	-1.793 dB
Tot. Effic.	-2.174 dB
Gain	2.292 dBi

farfield (f=2.25) [4]

Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Gain
Frequency	2.25 GHz
Rad. Effic.	-0.6527 dB
Tot. Effic.	-3.061 dB
Gain	2.043 dBi

farfield (f=1.73) [4]

Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Gain
Frequency	1.73 GHz
Rad. Effic.	-0.3718 dB
Tot. Effic.	-2.957 dB
Gain	1.830 dBi

Figure 10 max gain values at 3.5, 2.25 & 1.73 GHz

And for the **HPBW calculation** we have to view the polar plots of the far field; from the figure 11 below we can see that we obtained wide **HPBW** angles ranging from 172 to 276 degrees

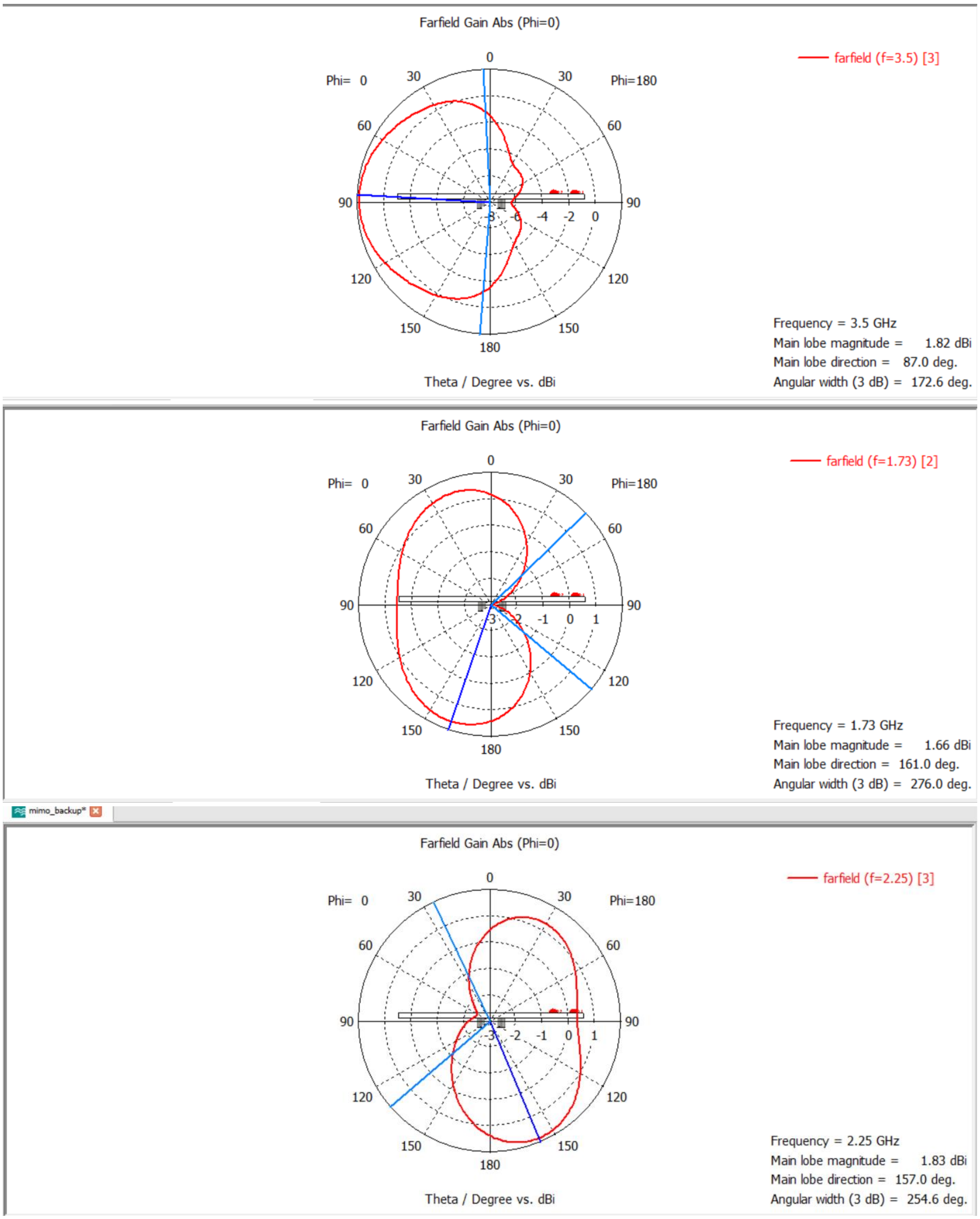

Figure 11 far field polar results (E-field; phi = 0)

Part 2 MATLAB:

MATLAB code for plotting dipole radiation pattern for different lengths relative to wavelength

Editor - C:\Users\Dell\Desktop\lab antena\finalcode.m

delete.m | finalcode.m | dipole.m | horn.m

```
% Angle in degrees
theta = (1:.01:360);
% lambda is arbitrary in this calculation any value will do
lambda = 1;
% d is entire dipole length, both halves
% loop to plot multiple dipole cases; hlaf wave, quarter wave, etc
for d = [lambda/2,lambda/4,lambda,lambda,2*lambda,4*lambda]

k = 2*pi/lambda;
kd2 = k*d/2;
% my field equation is in log scale
y = 20*log10(abs((cos(kd2.*cosd(theta))-cos(kd2))./sind(theta)));
y = y-max(y);
% normalize y to obtain directivity; new max is 0 dB
y(y<-40) = -40;
figure(1)
p = polarpattern(theta,y,'AngleDirection','cw','AngleAtTop',0);
hold on
end
hold off
legend('d = lambda/2','d=lambda/4','d=lambda','d=2*lambda','d=4*lambda');
```