ISTANBUL TECHNICAL UNIVERSITY

Electronics and Communication Engineering

ANTENNAS

EHB 456E

TERM PROJECT

2019-2020 Autumn

Microstrip Patch Antenna Design

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1.) Antenna Requirements

a.) Antenna parameters

Gain

The term Antenna Gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source. Antenna gain is more commonly quoted than directivity in an antenna's specification sheet because it takes into account the actual losses that occur.

Directivity

Directivity is a fundamental antenna parameter. It is a measure of how 'directional' an antenna's radiation pattern is. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be 1 (or 0 dB).

Radiation Pattern

Radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far-field.

Bandwidth

Bandwidth describes the range of frequencies over which the antenna can properly radiate or receive energy. Often, the desired bandwidth is one of the determining parameters used to decide upon an antenna. Bandwidth is typically quoted in terms of VSWR.

Polarization

The polarization of an antenna is the polarization of the radiated fields produced by an antenna, evaluated in the far-field

Impedance

Antenna impedance relates the voltage to the current at the input to the antenna

a.) Reference Solution

As a solution the following article is used:

Iqbal, N. and Karamzadeh S. (2017). UWB Microstrip Antenna Design for Microwave Imaging Systems. *International Journal of Electronics, Mechanical and Mechatronics Engineering Vol.7 Num.2 - 2017 (1411-1417)*

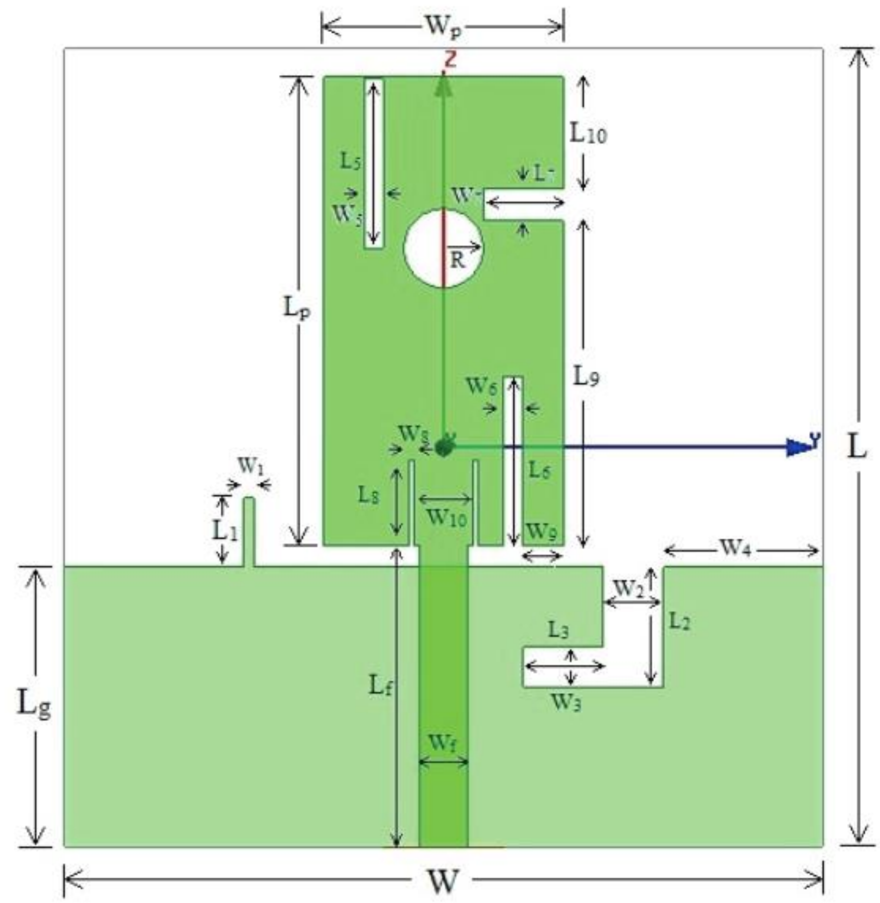

Figure 1. The proposed antenna is reference antenna (Top view – Bottom view)

Parameter	Values (mm)	Parameter	Values (mm)
L	40	W_4	8
W	38	L_5	8.5
Height	1.6	W_5	1
L_g	14	L_6	8.5
L_1	3.5	W_6	1
W_1	0.5	L_7	1.6
L_2	6	W_7	4
W_2	3	L_8	4.3
L_3	2	W_8	0.2
W_3	4	L_9	16.3
L_p	23.5	W_9	2
W_p	12	L_{10}	2.3
L_f	15.1	W_{10}	3
W_f	2.4		

Table 1. Dimensions of the proposed antenna in this reference article

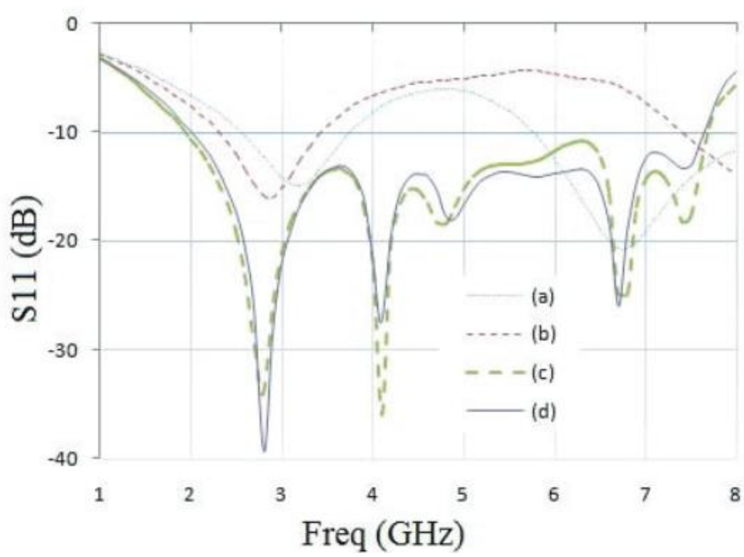

Figure 2. S11 parameter of the proposed antenna (see d)

2.) Modelling and Simulation

Modelling structure which is used in this project:

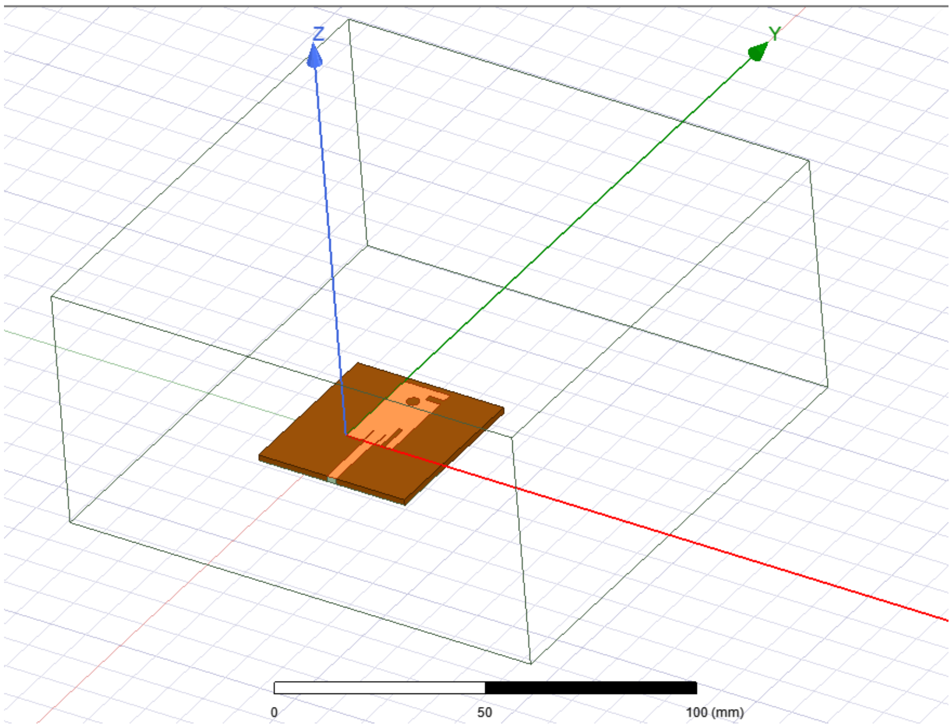

Figure 3: Antenna Model with radiation box

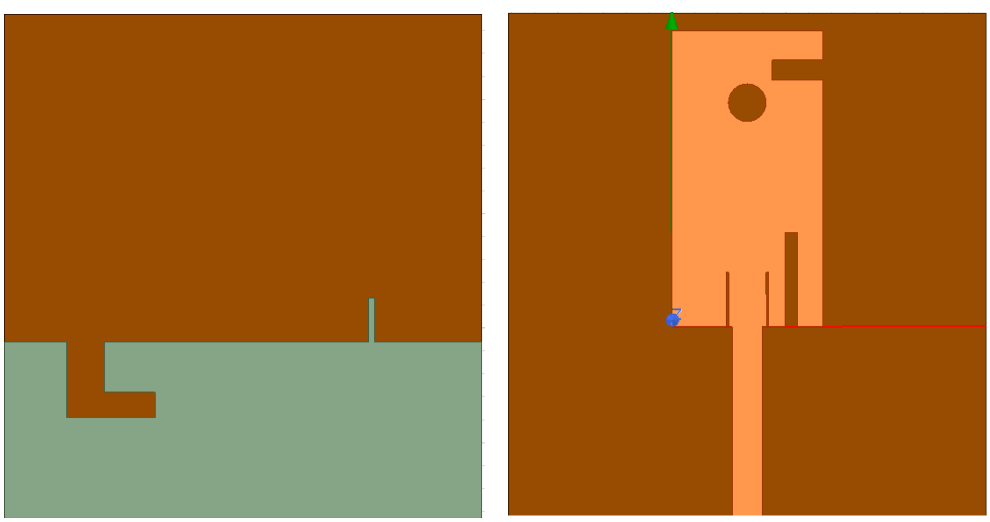

Figure 4: Top and bottom view of the antenna

Dimensions for the proposed antenna in this project:

W5/L5 section of the proposed antenna in the article is added back to satisfy the antenna requirements.

Every parameter of the antenna is multiplied with a coefficient “**scale**” to shift the center frequency.

For substrate, **FR4_epoxy is used, h=1.6mm, εr = 4.4**

For patch and ground, **perfect E** is used.

For radiation box, **air** is used.

Lumped port is used for feeding the antenna. Its width is equal to the width of the transmission line of the antenna.

Name	Value	Unit	Evaluated Value	Type
Wp	12*scale	mm	13.2mm	Design
Lp	23.5*scale	mm	25.85mm	Design
W5	1*scale	mm	1.1mm	Design
L5	8.5*scale	mm	9.35mm	Design
W7	4*scale	mm	4.4mm	Design
L7	1.6*scale	mm	1.76mm	Design
L10	2.3*scale	mm	2.53mm	Design
W6	1*scale	mm	1.1mm	Design
L6	7.5*scale	mm	8.25mm	Design
W9	2*scale	mm	2.2mm	Design
Wf	2.4*scale	mm	2.64mm	Design
Lf	15.1*scale	mm	16.61mm	Design
W8	0.2*scale	mm	0.22mm	Design
L8	4.3*scale	mm	4.73mm	Design
W10	3*scale	mm	3.3mm	Design
L9	16.3*scale	mm	17.93mm	Design
W	38*scale	mm	41.8mm	Design
L	40*scale	mm	44mm	Design
substhickn...	1.6	mm	1.6mm	Design
Lg	14*scale	mm	15.4mm	Design
W1	0.5*scale	mm	0.55mm	Design
L1	3.5*scale	mm	3.85mm	Design
W2	3*scale	mm	3.3mm	Design
L2	6*scale	mm	6.6mm	Design
W3	4*scale	mm	4.4mm	Design
L3	2*scale	mm	2.2mm	Design
W4	8*scale	mm	8.8mm	Design
scale	1.1		1.1	Design

Table 2. Dimensions of the proposed antenna in this project

Simulation:

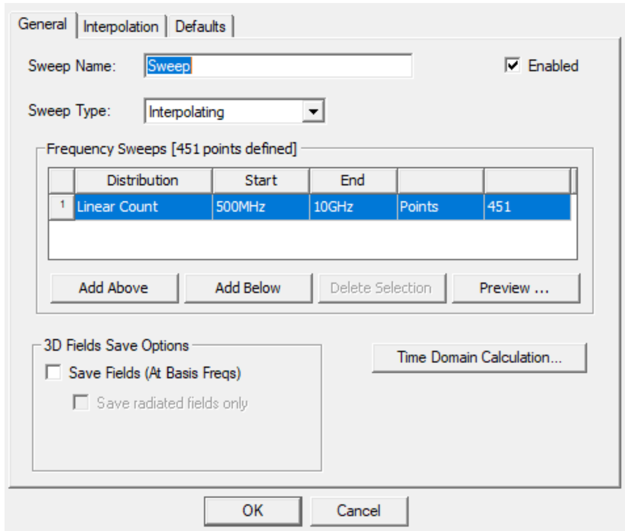

Figure 5. Detailed analysis setup

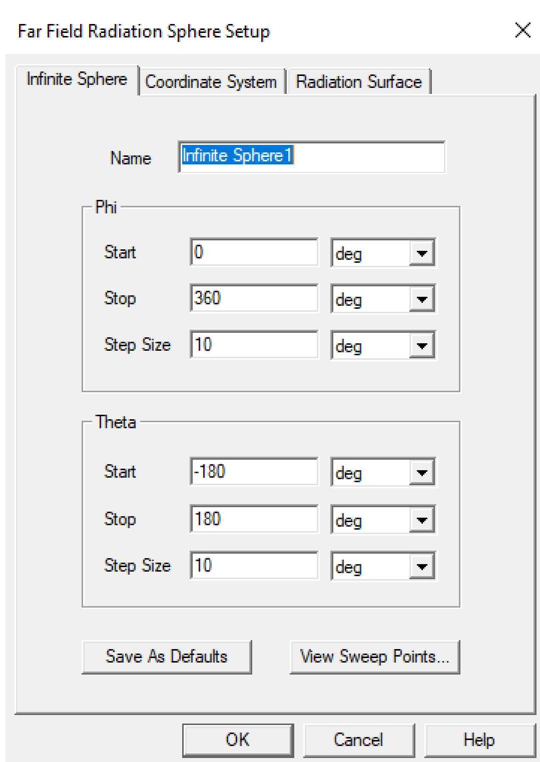

Figure 6. Far-Field Radiation Sphere Setup

Simulation Results

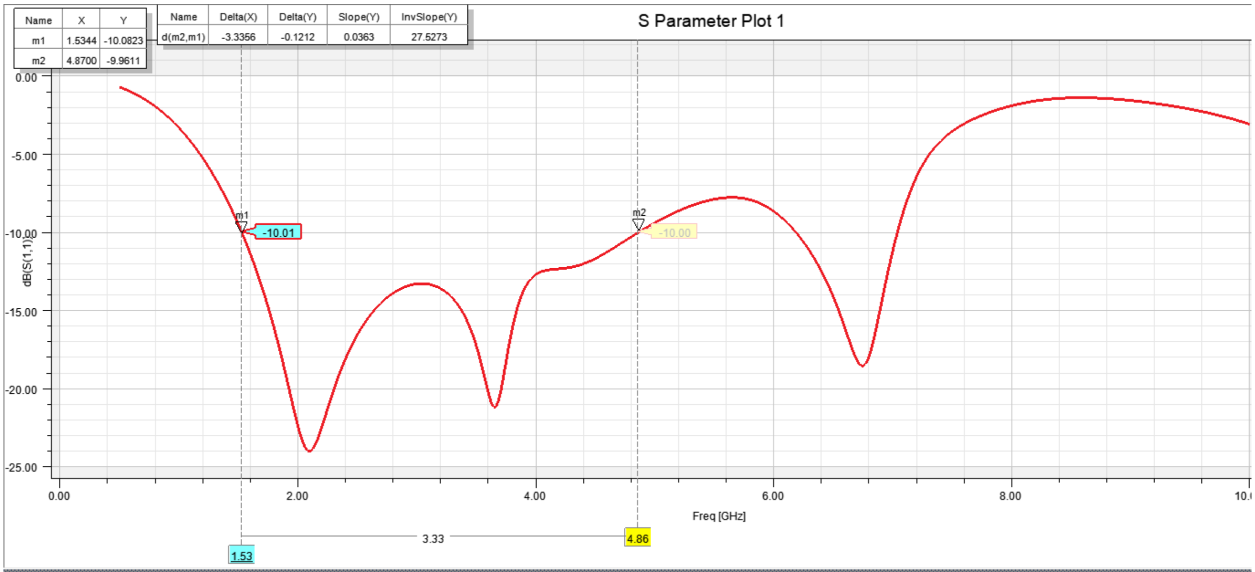

Figure 7. S11 plot

As shown above, the bandwidth of the antenna is 3.33 GHz. However, the center frequency is not exactly 2 GHz, and there are two peak frequencies inside bandwidth, instead of one.

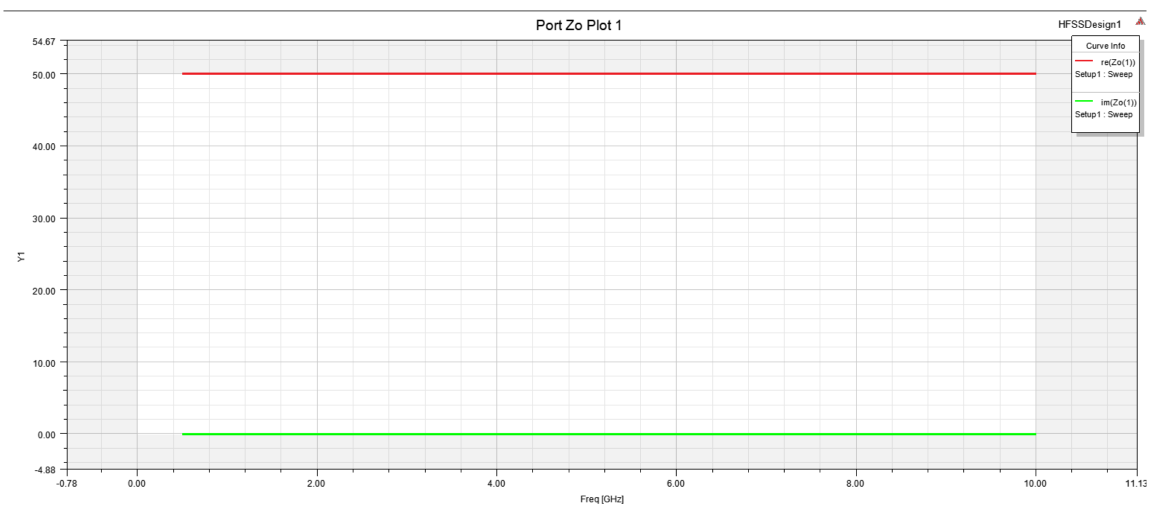

Figure 8. Port Z0 plot

As shown in the graph, the real part of the impedance is 50Ω, while the imaginary part of it 0Ω. Which means impedance is matched with the transmission line.

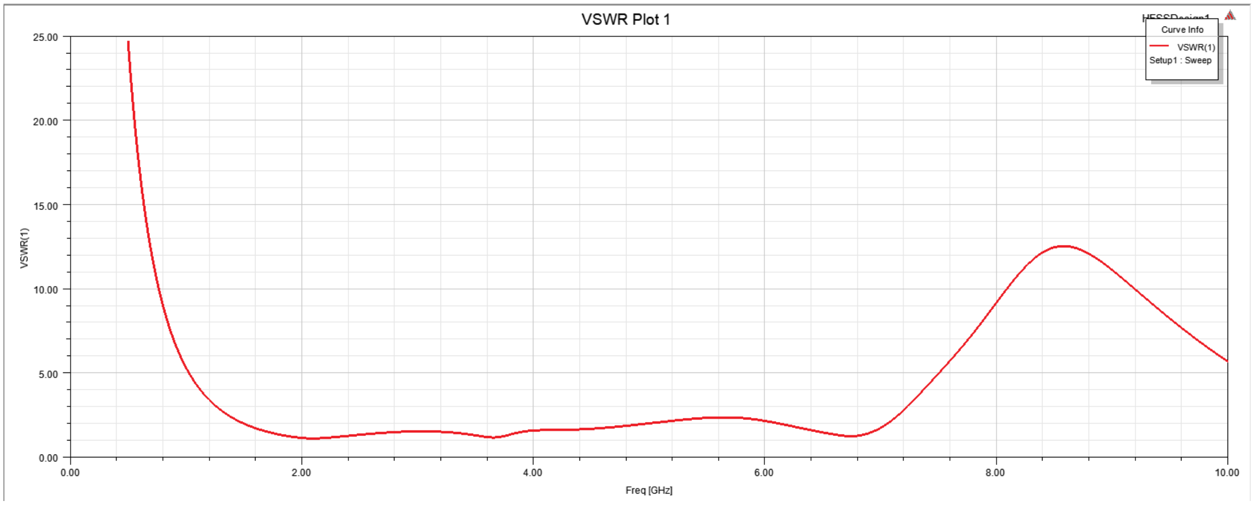

Figure 9. VSWR Plot

VSWR is a plot for how well the antenna is impedance matched to the transmission line. As VSWR decreases, better the antenna radiates. For 2 GHz, VSWR is 1.16, which means most of the power is radiated.

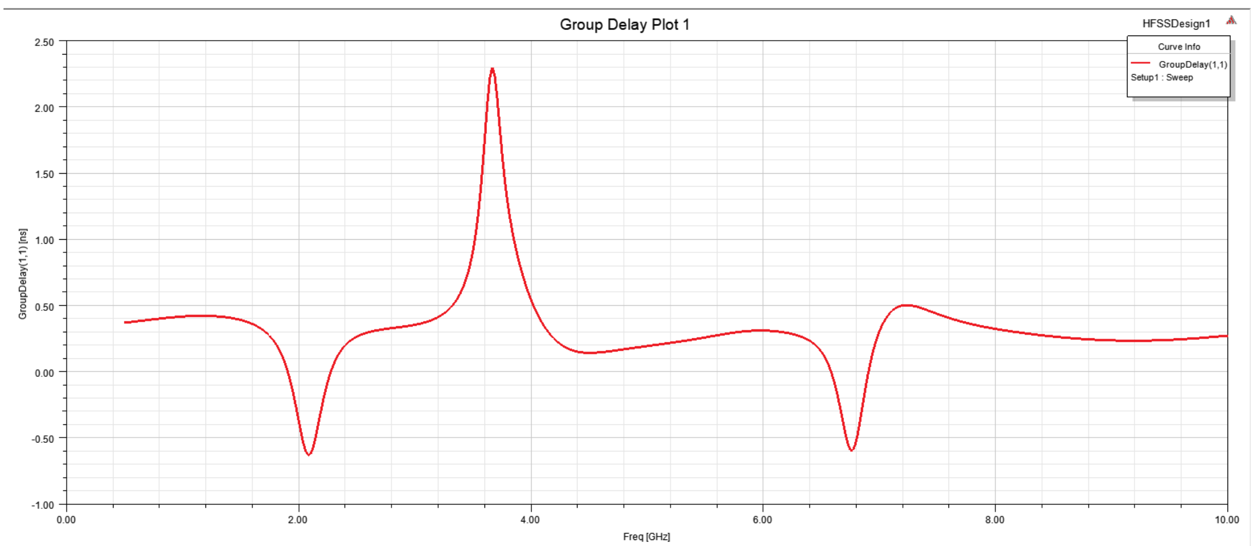

Figure 10. Group Delay

Group delay should be below 1ns to avoid phase distortions on far-field. Unfortunately, the condition is not met for the project.

Antenna Parameters:

Quantity	Freq	Value
Peak Gain		1.7004
Peak Realized Gain		1.4581
Peak System Gain		1.4581
Radiated Power		744.52 mW
Accepted Power		857.51 mW
Incident Power		1 W
System Power		1 W
Radiation Efficiency		0.86824
Front to Back Ratio		5.113
Decay Factor		0

Maximum Field Data:

rE Field	Freq	Value	At(Theta,Phi)
Total	5.25GHz	9.3535 V	-40deg,310deg
X		8.1629 V	60deg,110deg
Y		7.1808 V	90deg,160deg
Z		3.1256 V	50deg,220deg
Phi		9.3317 V	-40deg,310deg
Theta		6.5039 V	0deg,210deg
LHCP		6.9212 V	-40deg,310deg
RHCP		7.546 V	120deg,110deg
Ludwig3/X dominant		8.238 V	110deg,110deg
Ludwig3/Y dominant		7.1452 V	110deg,150deg

Various antenna parameters can be calculated using HFSS. As shown on left:

Radiated power: 744.52 mW
Accepted power: 857.51 mW
Radiation Efficiency: 0.86824

Figure 11. Antenna parameters

Gain plots:

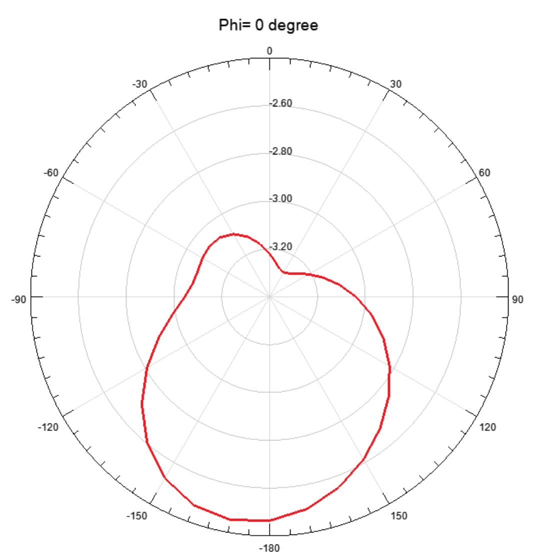

Figure 12. Gain a Phi=0

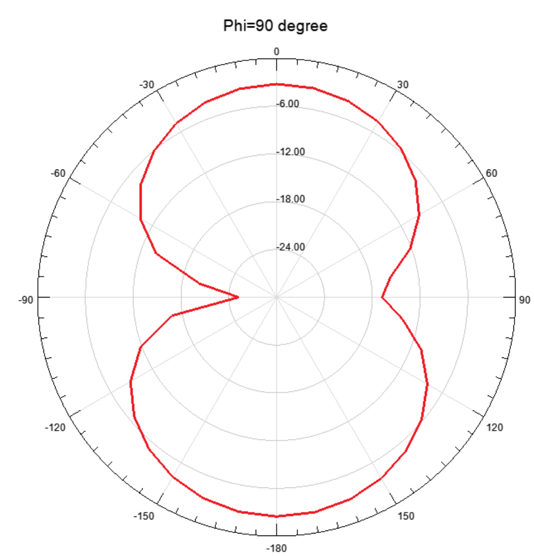

Figure 13. Gain at Phi=90

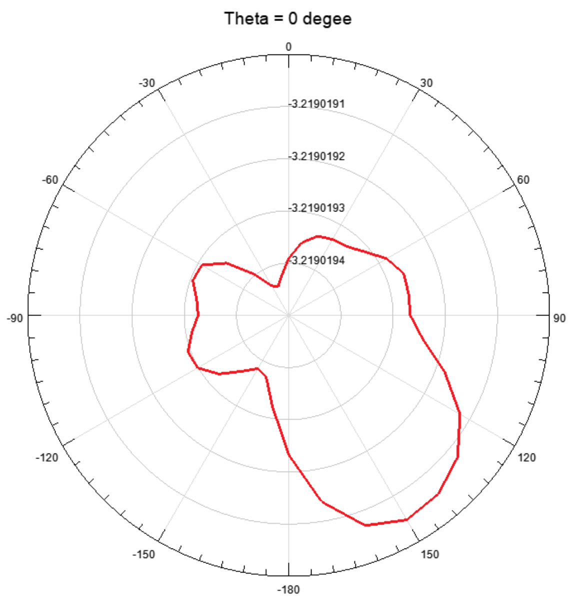

Figure 14. Gain at Theta=0

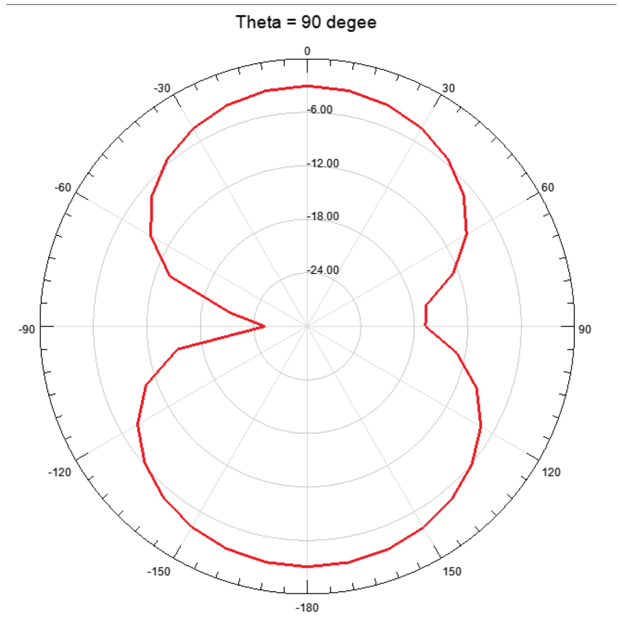

Figure 15. Gain at Theta=90

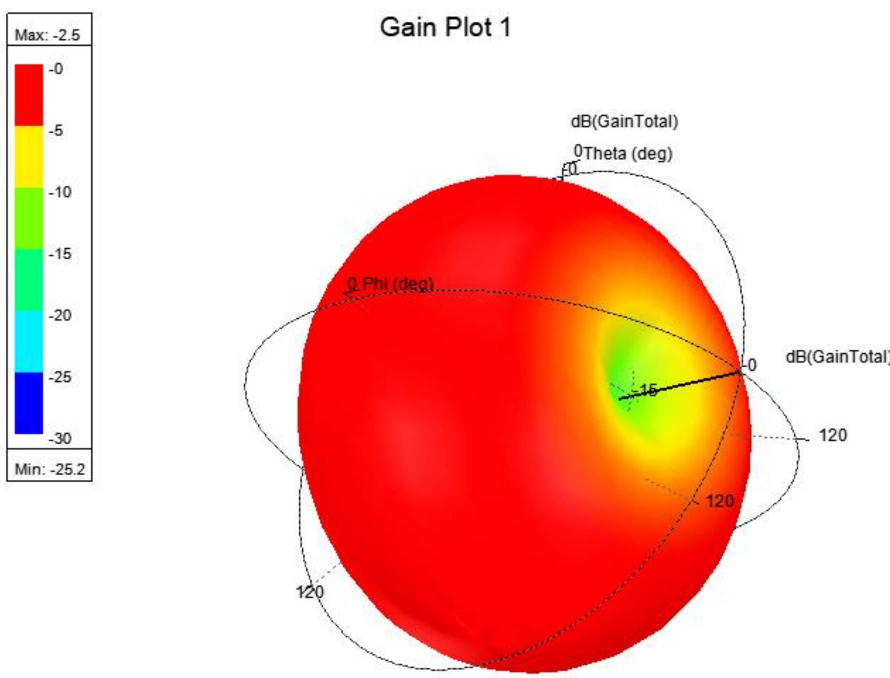

Figure 16. 3D Plot of Gain

Polarization:

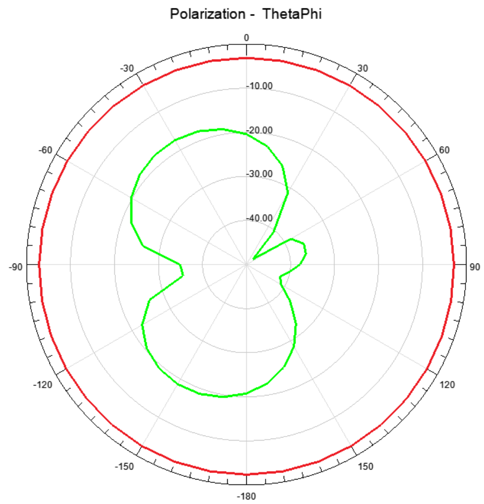

Figure 17. Directivity for circular co.

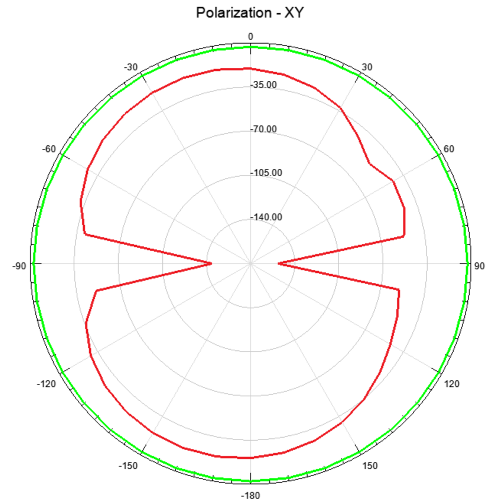

Figure 18. Directivity for Cartesian co.

Compared with DirTheta&DirPhi, DirX and DirY are more close to each other. The huge difference between DirTheta & DirPhi indicates that the antenna is linear polarized.

Note: All polar plots are constituted on 2 GHz frequency.

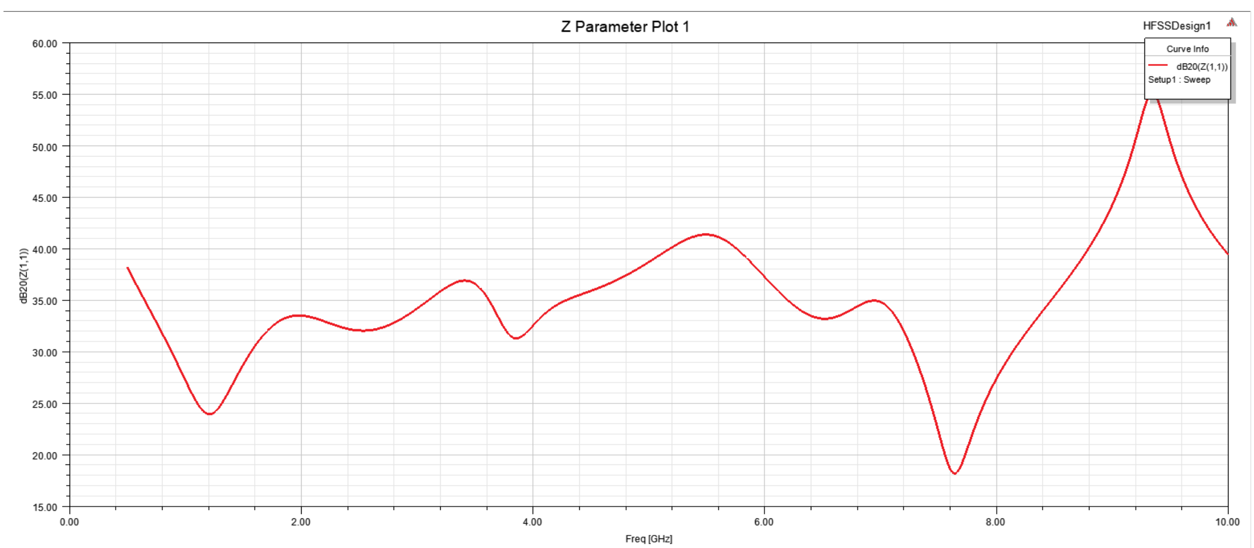

Figure 19. Z parameter plot

References

1- http://www.antenna-theory.com/basics/main.php
2- Antenna Theory: Analysis and Design, Balanis
3- Iqbal, N. and Karamzadeh S. (2017). UWB Microstrip Antenna Design for Microwave Imaging Systems. *International Journal of Electronics, Mechanical and Mechatronics Engineering Vol.7 Num.2 - 2017 (1411-1417)*