DESIGN OF
RECTANGULAR PATCH ANTENNA ARRAY
FOR 5G WIRELESS COMMUNICATION

Semester-V

Antennas and Wave Propagation

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Aim:

We have planned to design a two-element array antenna for 5G wireless communication using HFSS software. The antenna operating frequency is chosen as 28GHz. Our final design must contain two rectangular patches on a Roger RT-5880 LZ, dielectric constant ε_r =1.96.

Process:

1. Implementation of a single patch antenna (was already submitted in update-1 but results are included to illustrate the comparison).
2. Implementation of a two-element antenna array.
3. Implementation of Koch snowflake iteration-1

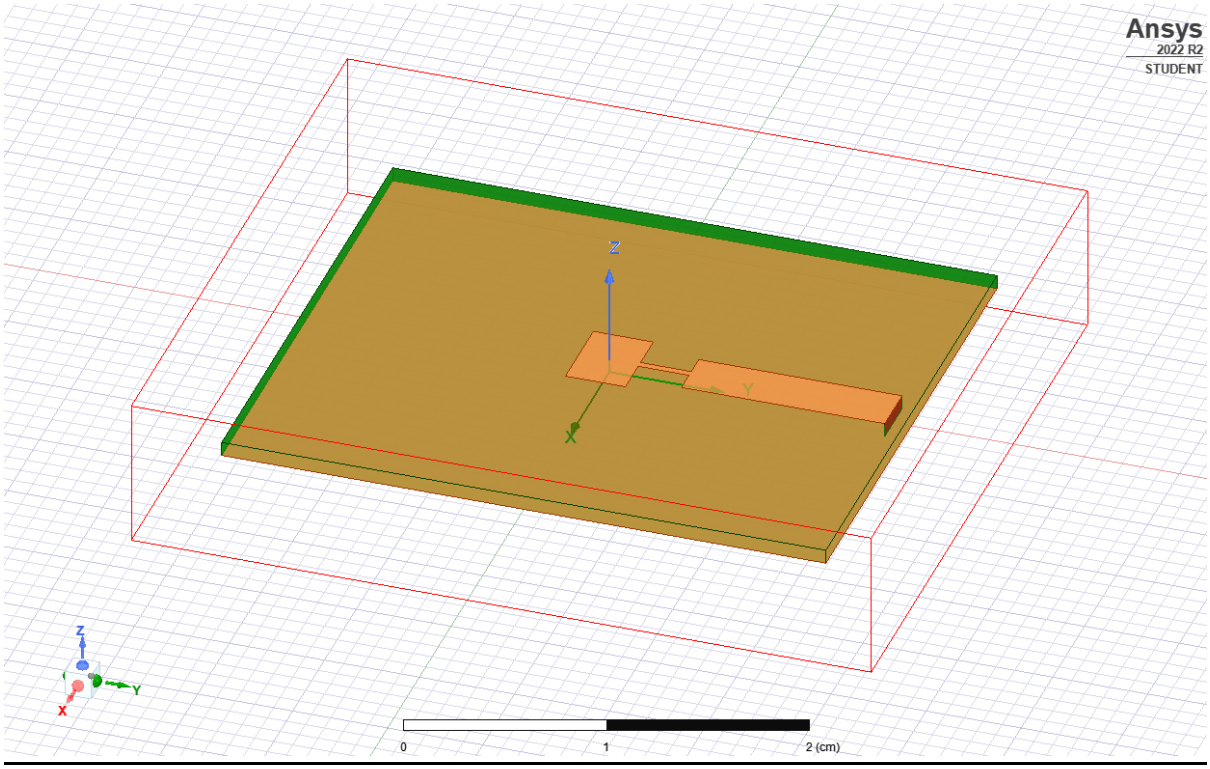
Theory:

- Fractals antennas are widely preferred for wireless communication systems as they are of small size, light weight, low profile, low cost, and are easy to fabricate and assemble.
- The Koch snowflake geometry drew the attention of researchers as it is smaller than other patch geometries.
- The Koch snowflake has many interesting properties. It is an example of a figure that is self-similar, meaning that it looks the same on any scale.
- The resonant frequency increases with increase in the number of iterations.
- The multiband behaviour is obtained as the numbers of iterations are increased.
- The return losses improve as the number of iterations increase.

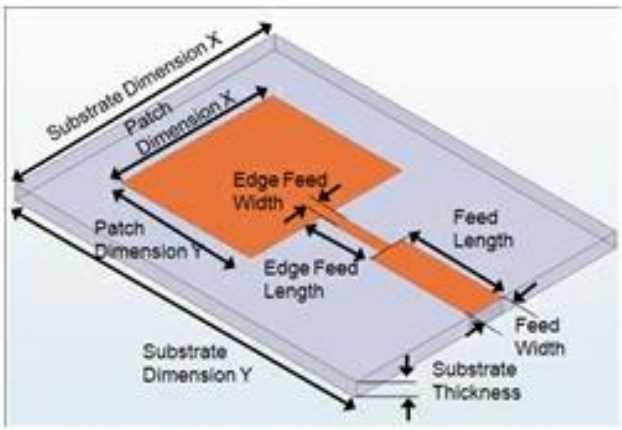
- The bandwidth of the antenna gets increased too with increase in the number of iterations.
- Improvement in VSWR is also observed with increase in iterations.

Fig. 1. Basic Steps construction of a Koch snowflake fractal

1.Implementation of a single patch antenna:



Dimensions:



Patch:

Patch width X= 0.4403 cm

Patch length Y= 0.31535 cm

Substrate:

Substrate material: Rogers RT-5880

Dielectric constant: 1.96

Substrate thickness: 0.0762 cm

Substrate width X: 2.7 cm

Substrate length Y: 3.18 cm

Feed:

Edge feed width: 0.0366 cm

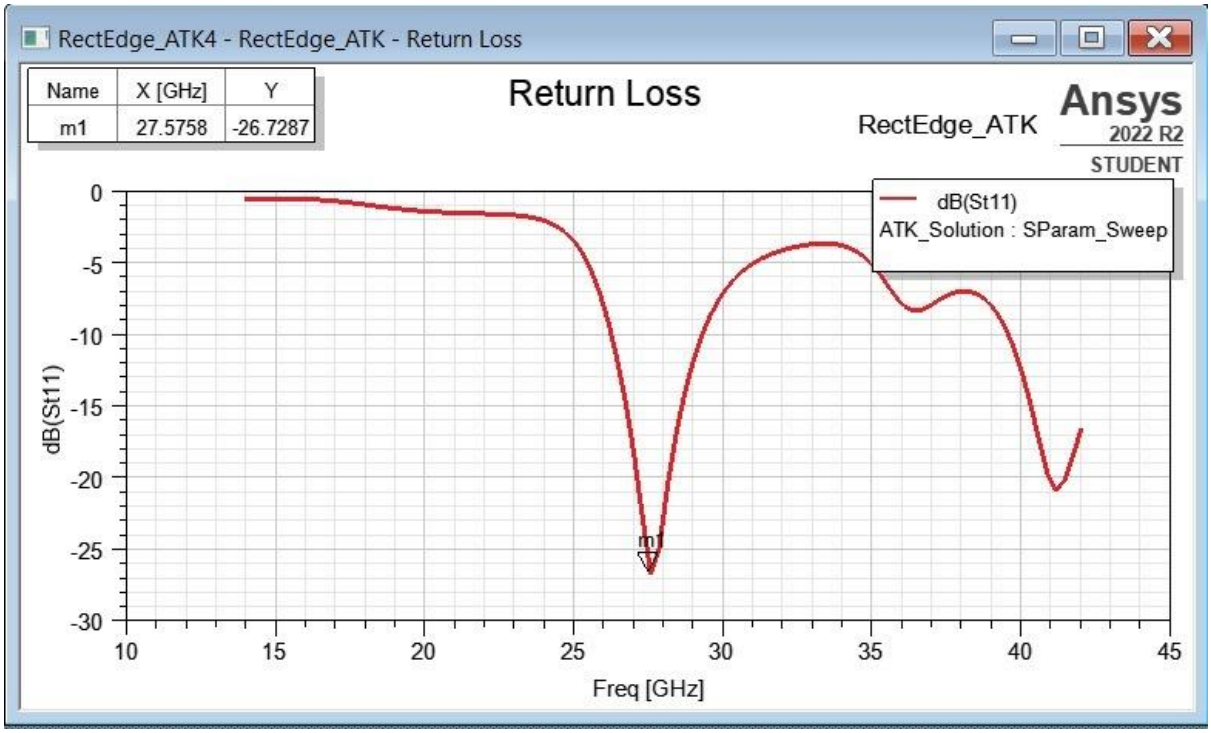
Edge feed length: 0.267 cm

Feed Width: 0.2738 cm

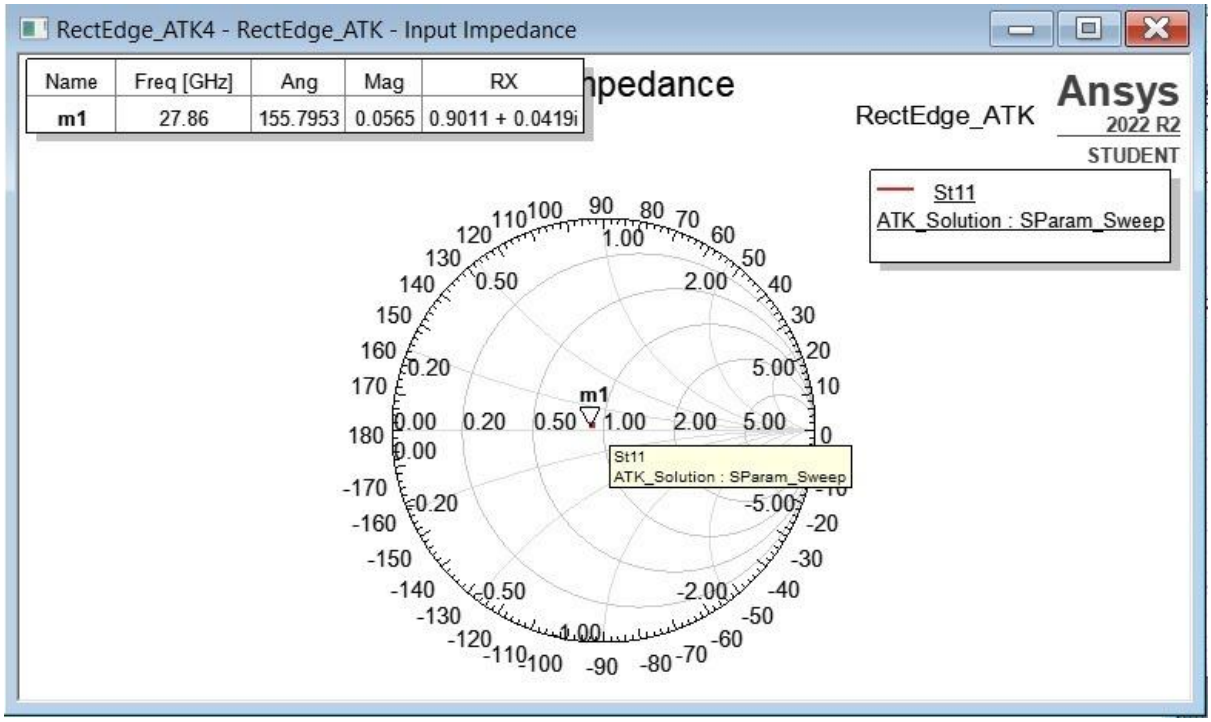
Feed length: 1.07 cm

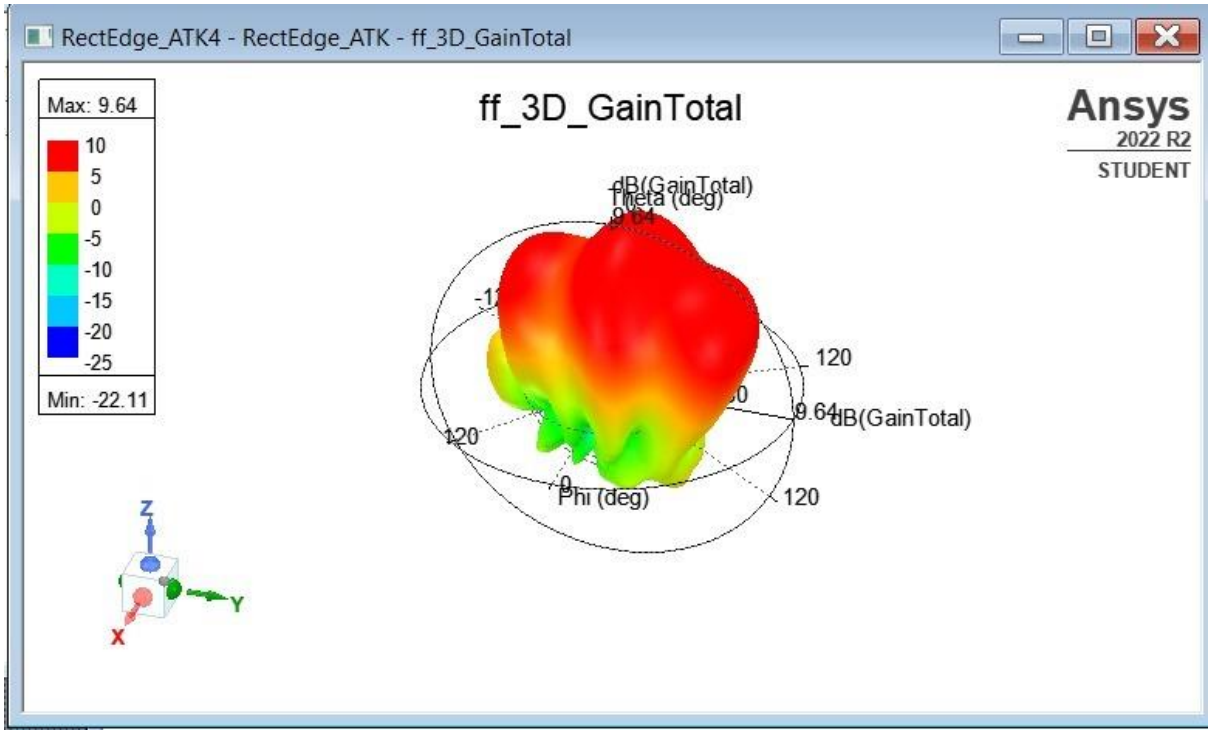
Frequency: 28GHz

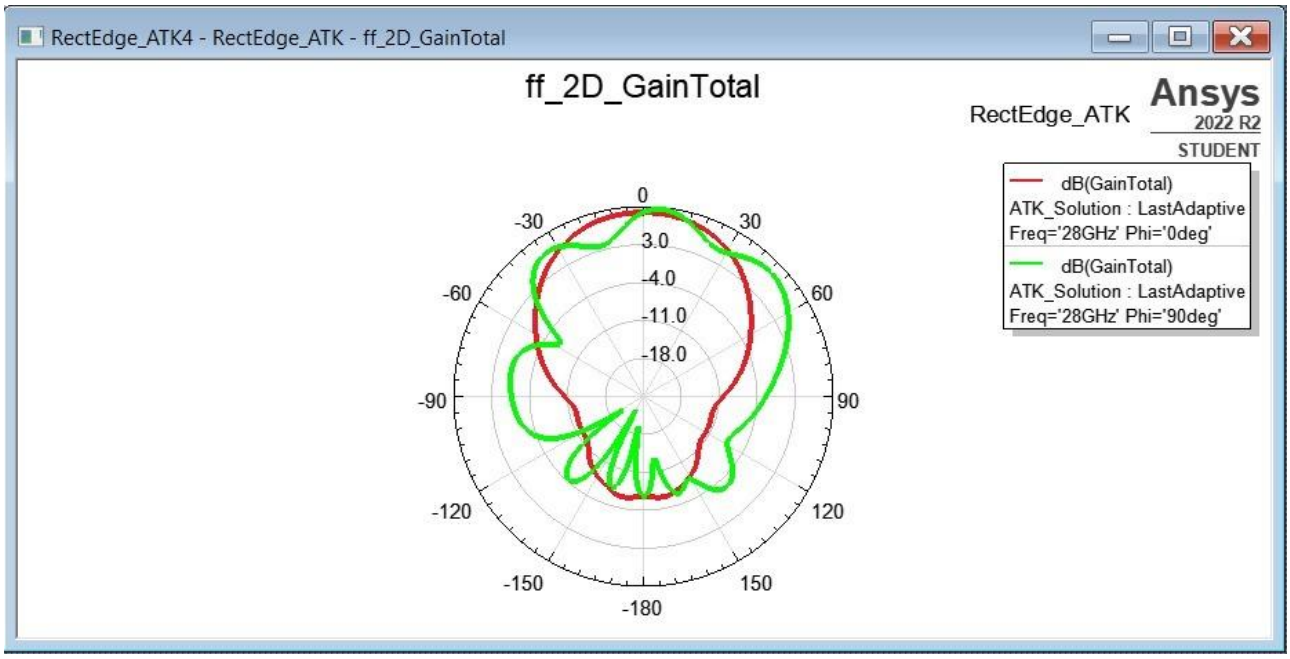
Results:

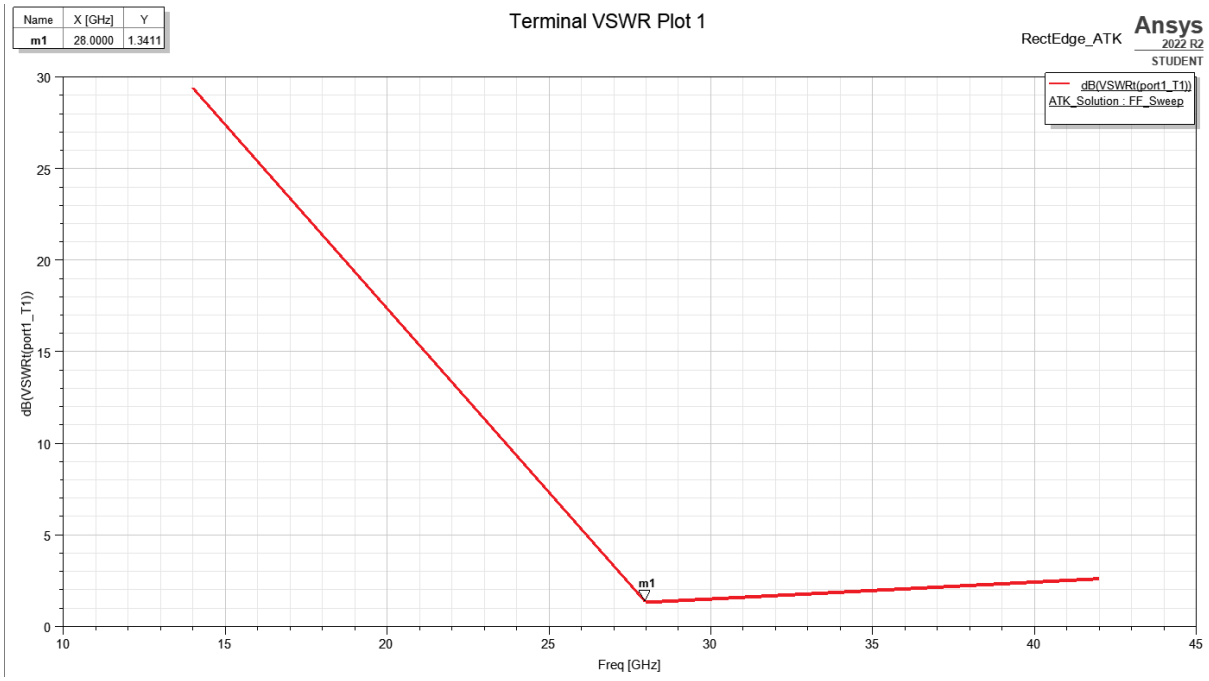


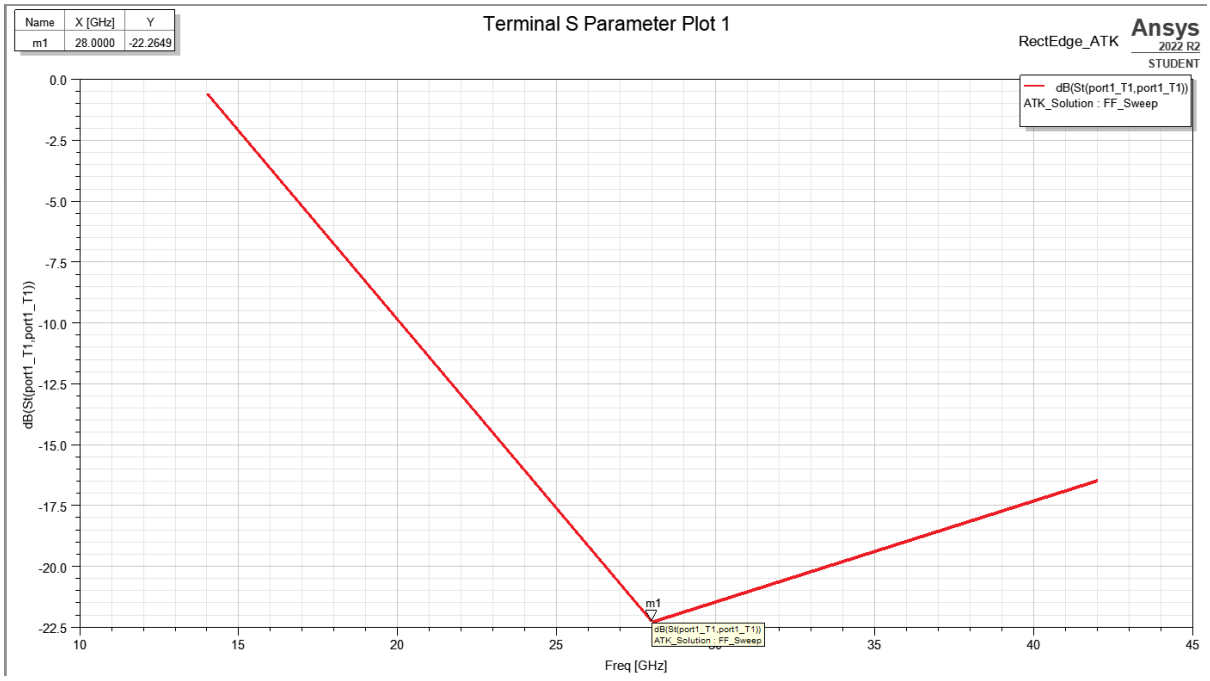
Input impedance:




RectEdge_ATK4 - RectEdge_ATK - ff_3D_GainTotal
Max: 9.64
10
5
0
-5
-10
-15
-20
-25
Min: -22.11
ff_3D_GainTotal
Ansys
2022 R2
STUDENT
dB(GainTotal)
Theta (deg)
120
9.64
dB(GainTotal)
120
0
Phi (deg)
120
Z
Y
X

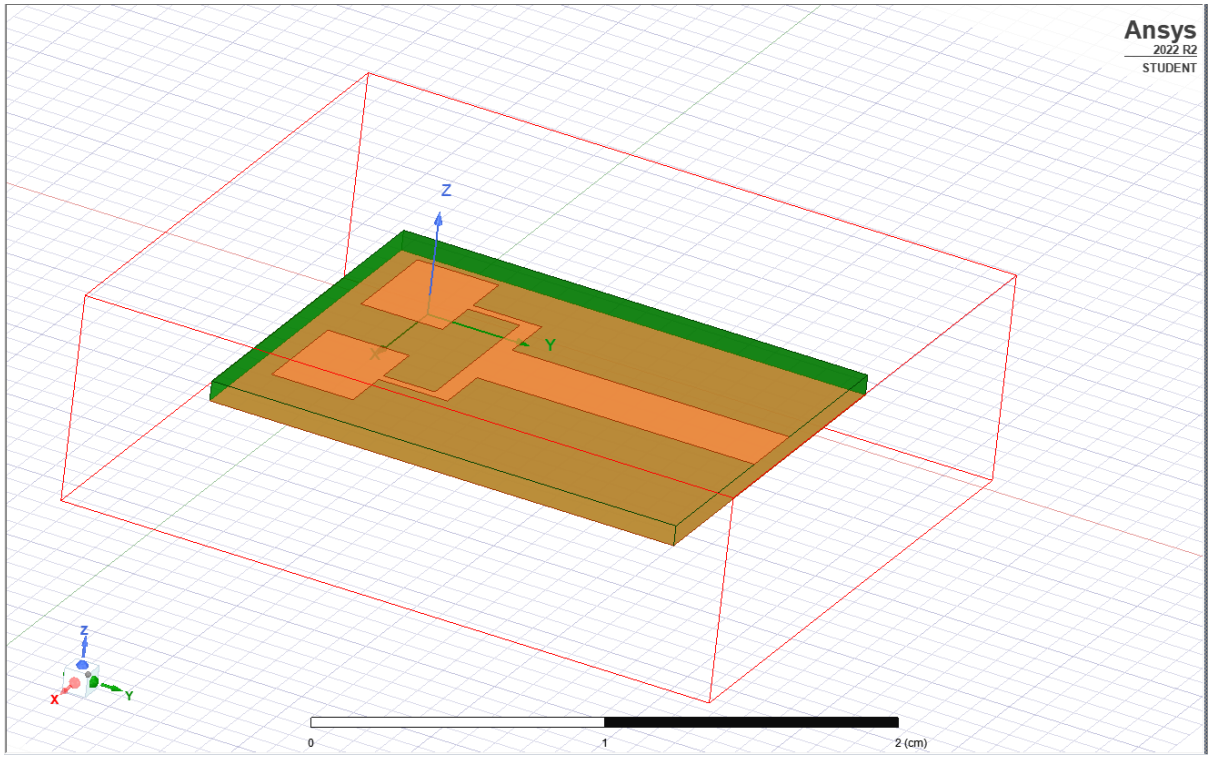

RectEdge_ATK4 - RectEdge_ATK - ff_2D_GainTotal
ff_2D_GainTotal
RectEdge_ATK
Ansys
2022 R2
STUDENT
dB(GainTotal)
ATK_Solution : LastAdaptive
Freq='28GHz' Phi='0deg'
dB(GainTotal)
ATK_Solution : LastAdaptive
Freq='28GHz' Phi='90deg'
0
30
60
90
120
150
-180
-150
-120
-90
-60
-30
3.0
-4.0
-11.0
-18.0



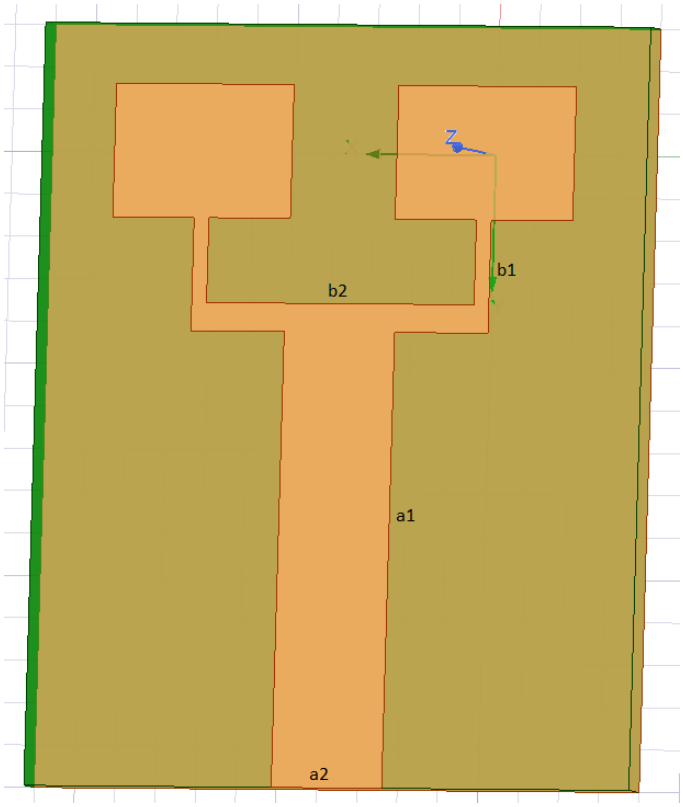


	Freq [GHz]	dB(PeakDirectivity) ATK_Solution : FF_Sweep
1	14.000000	3.484804
2	28.000000	9.596694
3	42.000000	8.757609

2.Implementation of a two-element antenna array:



Dimensions



The width and length of each rectangular patch is similar to the single patch antenna.

Patch:

Patch width= 0.4403 cm

Patch length= 0.31535 cm

Substrate:

Substrate material= Rogers RT-5880

Dielectric constant= 1.96

Substrate thickness= 0.0762 cm

Substrate width X= 1.5 cm

Substrate length Y= 1.8 cm

Feed:

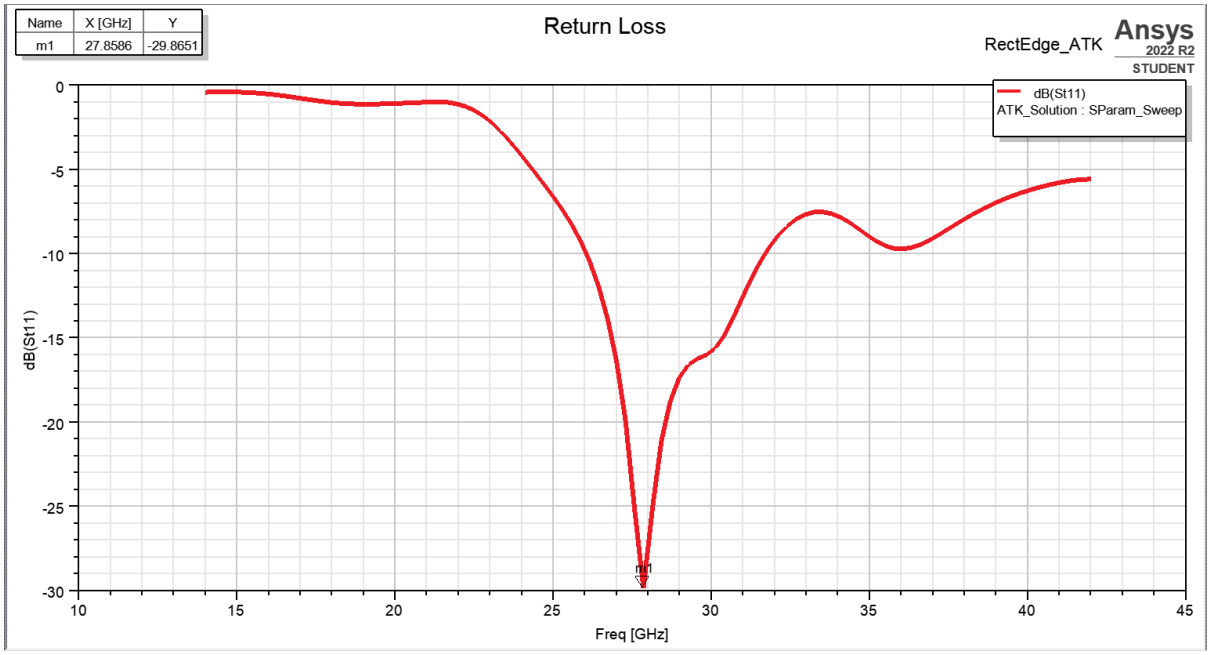
a1= 1.0753 cm

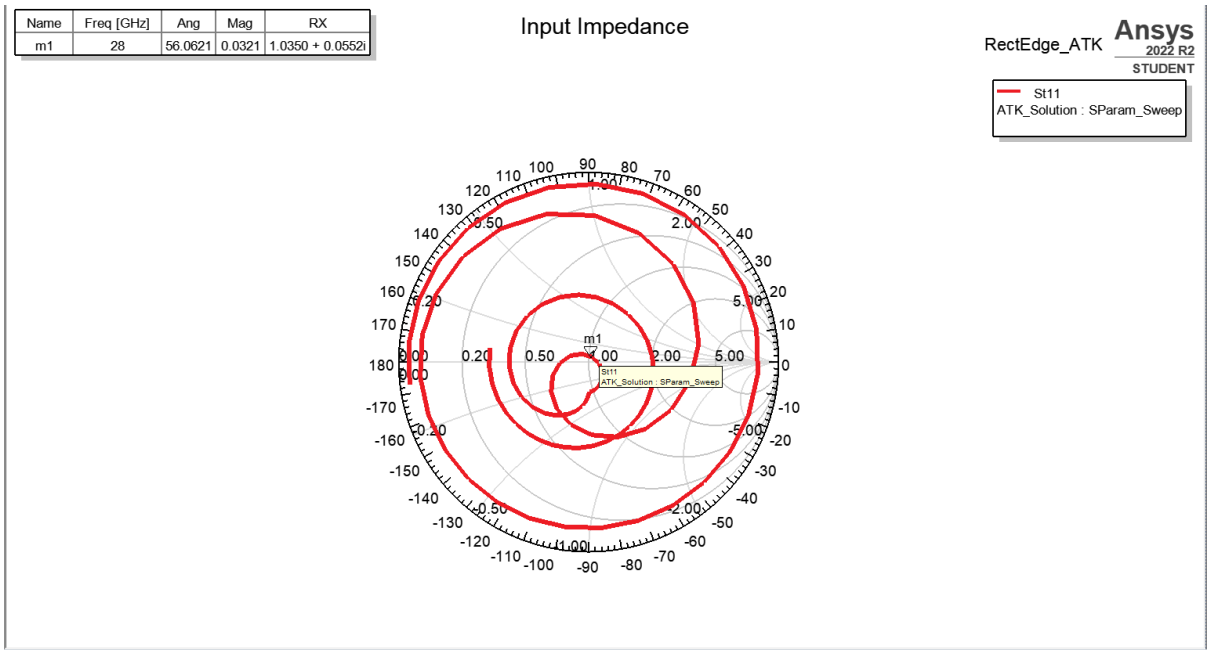
a2= 0.2738 cm

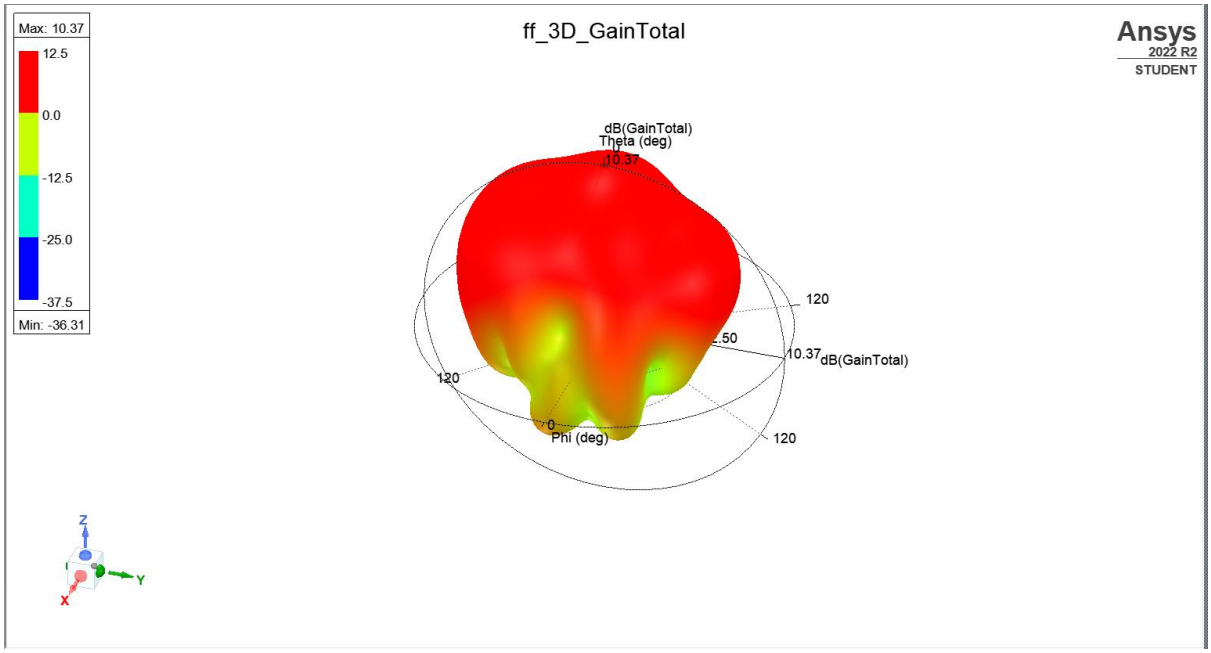
b1= 0.267 cm

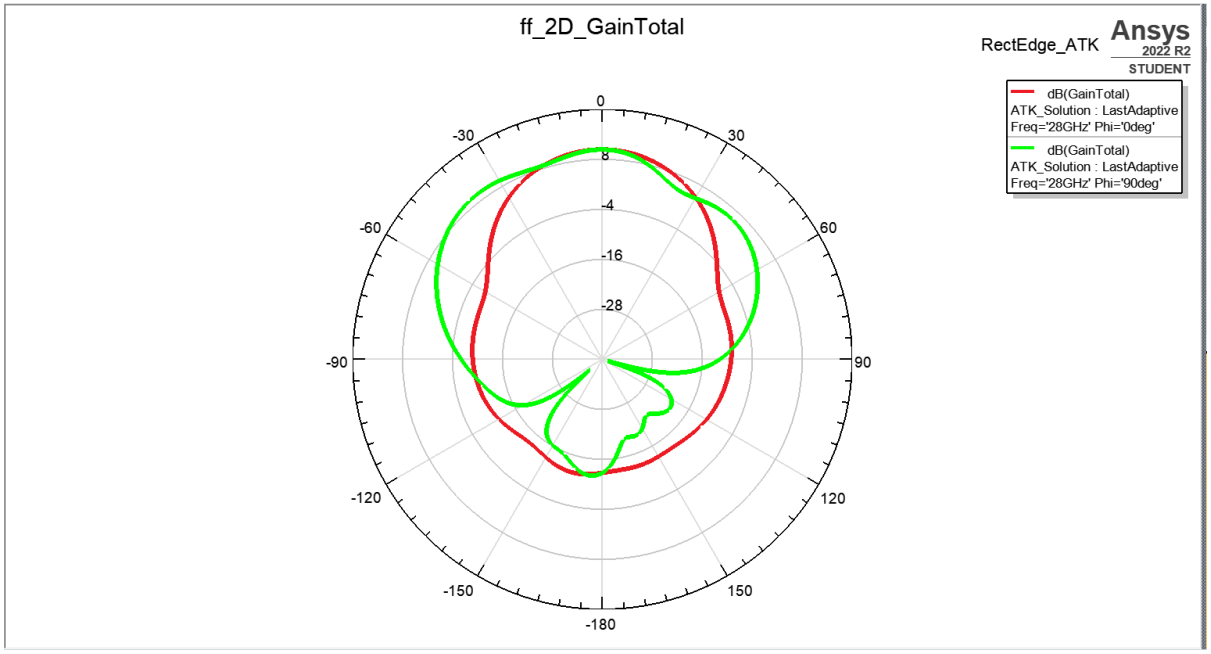
b2= 0.6634 cm

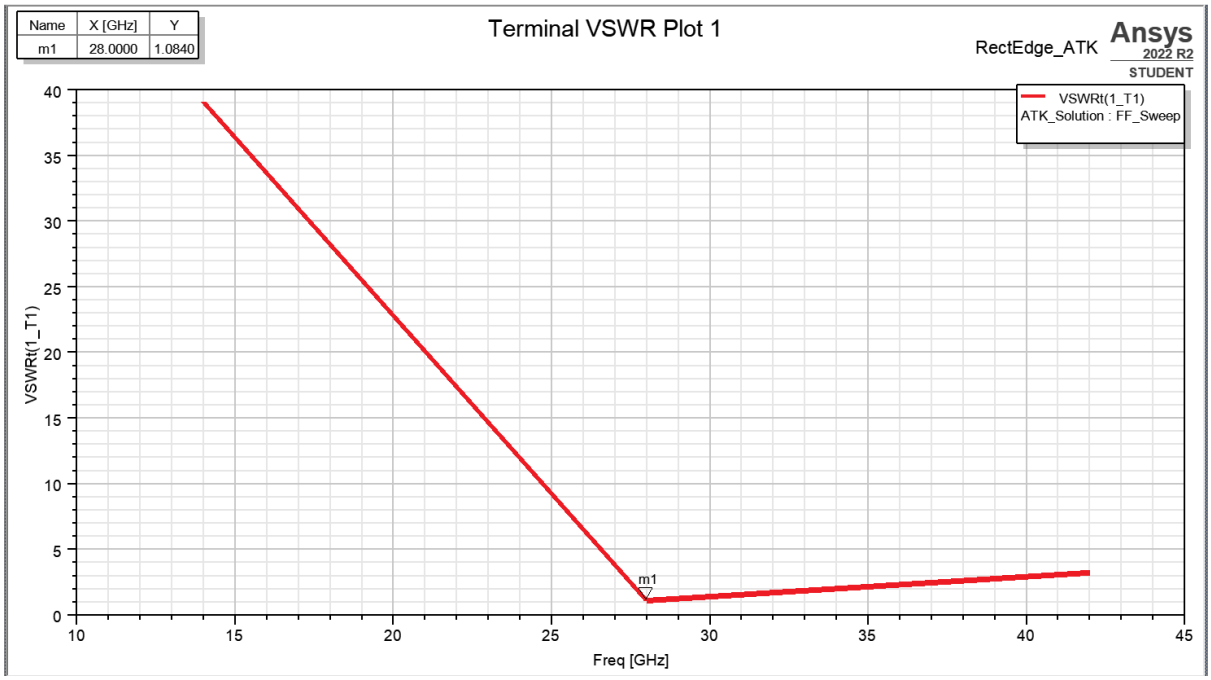
Results:

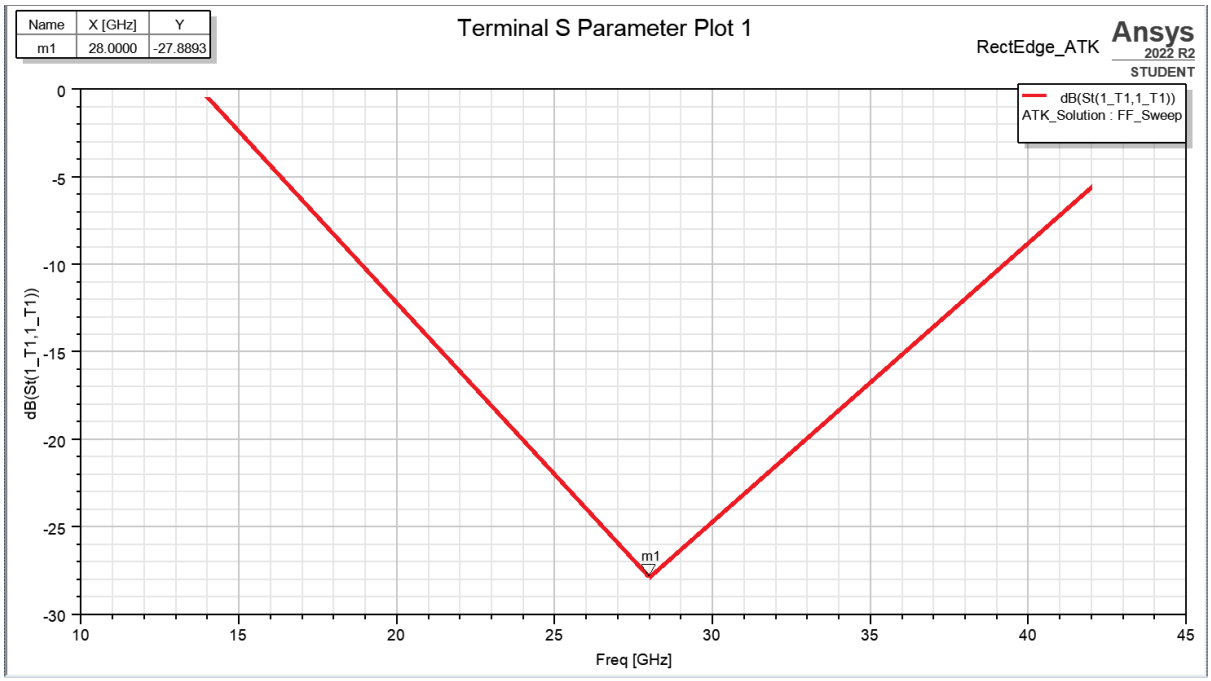

Name | X [GHz] | Y
m1 | 27.8586 | -29.8651
Return Loss
RectEdge_ATK
Ansys
2022 R2
STUDENT
dB(St11)
ATK_Solution : SParam_Sweep
dB(St11)
Freq [GHz]
m1


Name | Freq [GHz] | Ang | Mag | RX
m1 | 28 | 56.0621 | 0.0321 | 1.0350 + 0.0552i
Input Impedance
RectEdge_ATK
Ansys
2022 R2
STUDENT
St11
ATK_Solution : SParam_Sweep
m1

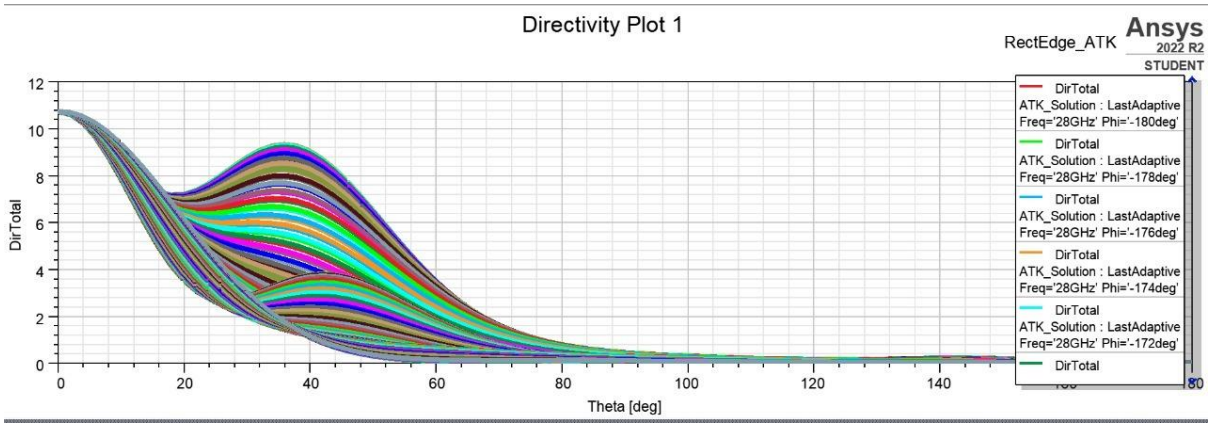

Max: 10.37
12.5
0.0
-12.5
-25.0
-37.5
Min: -36.31
ff_3D_GainTotal
Ansys
2022 R2
STUDENT
dB(GainTotal)
Theta (deg)
10.37
120
10.37
dB(GainTotal)
120
0
Phi (deg)
120
Z
Y
X

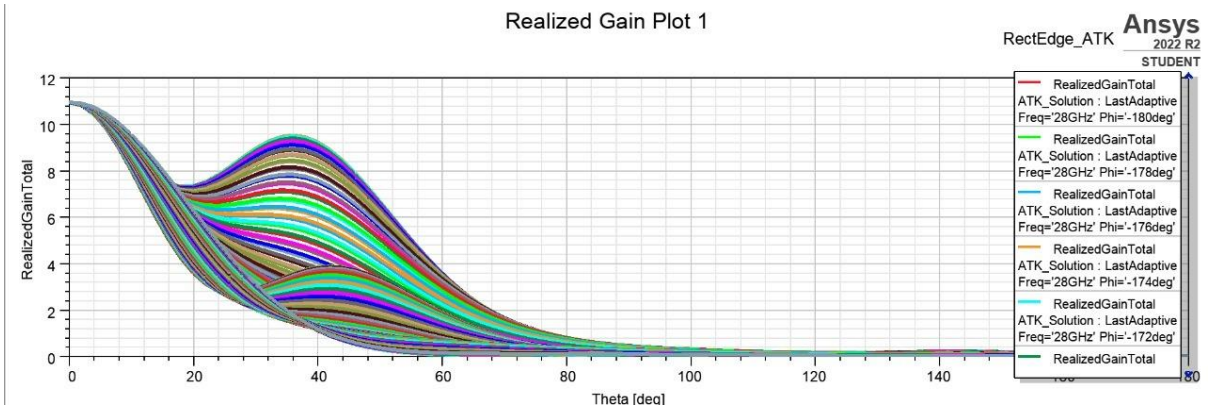

ff_2D_GainTotal
RectEdge_ATK
Ansys
2022 R2
STUDENT
dB(GainTotal)
ATK_Solution : LastAdaptive
Freq='28GHz' Phi='0deg'
dB(GainTotal)
ATK_Solution : LastAdaptive
Freq='28GHz' Phi='90deg'
0
30
60
90
120
150
-180
-150
-120
-90
-60
-30
8
-4
-16
-28



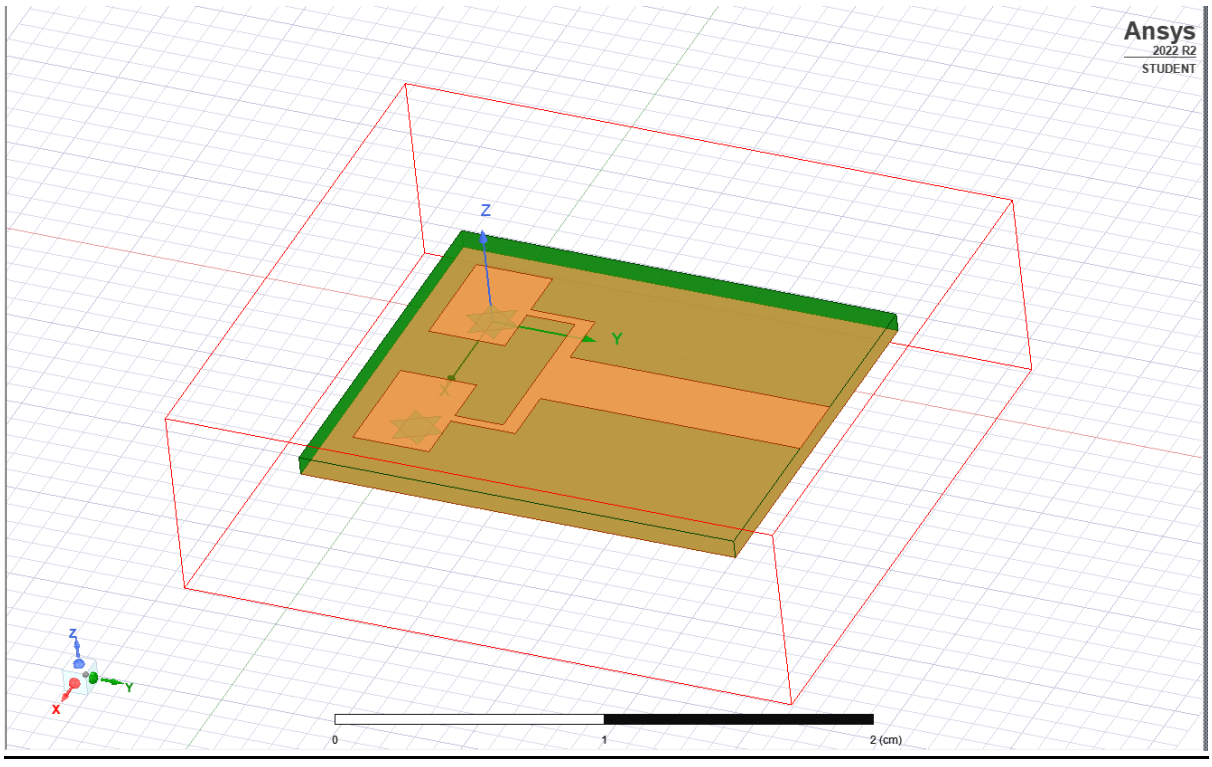


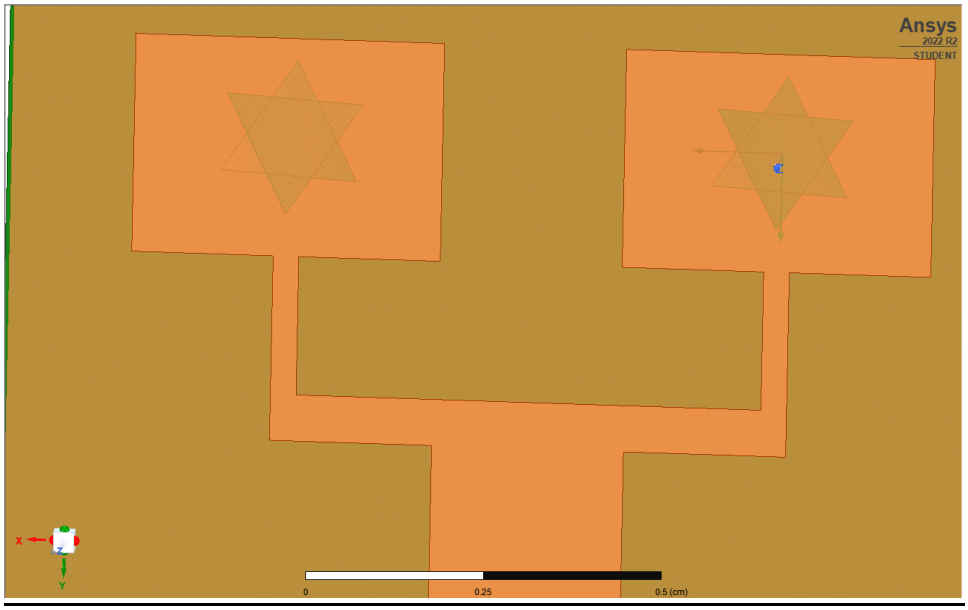
	Freq [GHz]	dB(PeakDirectivity) ATK_Solution : LastAdaptive
1	28.000000	10.300910



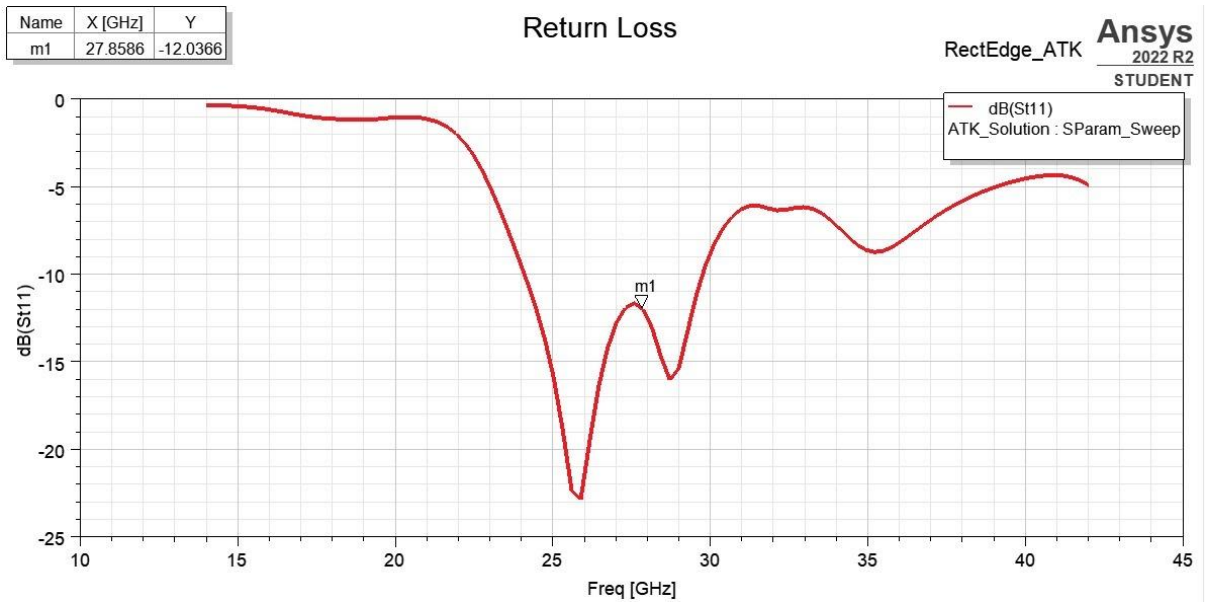


3.Implementation of Koch snowflake iteration-1:

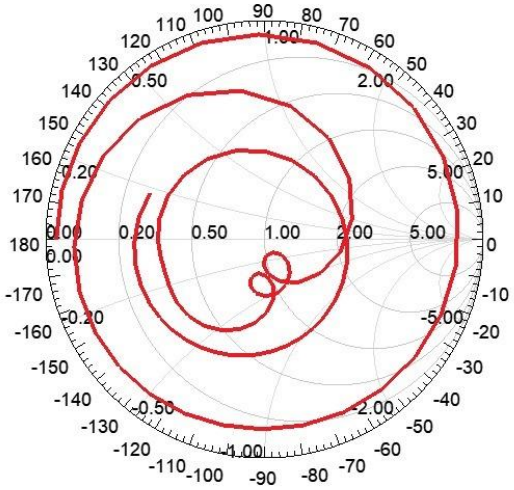



Ansys
2022 R2
STUDENT
0
0.25
0.5 (cm)

Results:


Name
X [GHz]
Y
m1
27.8586
-12.0366
Return Loss
RectEdge_ATK
Ansys
2022 R2
STUDENT
dB(St11)
ATK_Solution : SParam_Sweep
m1
dB(St11)
Freq [GHz]
0
-5
-10
-15
-20
-25
10
15
20
25
30
35
40
45

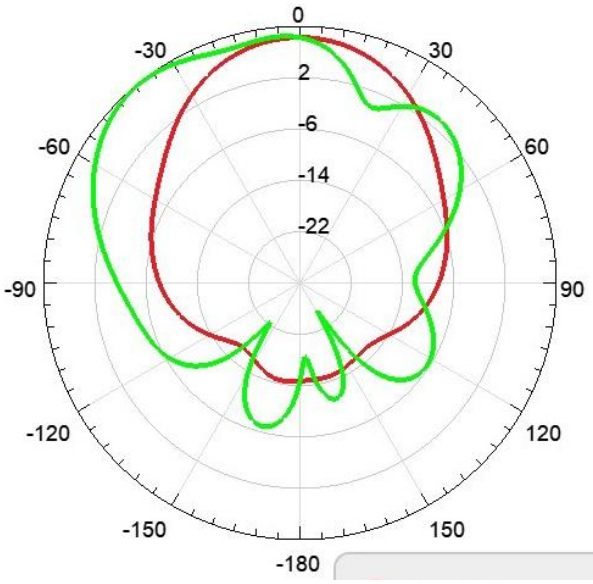
Input Impedance



RectEdge_ATK Ansys 2022 R2 STUDENT

St11
ATK_Solution : SParam_Sweep

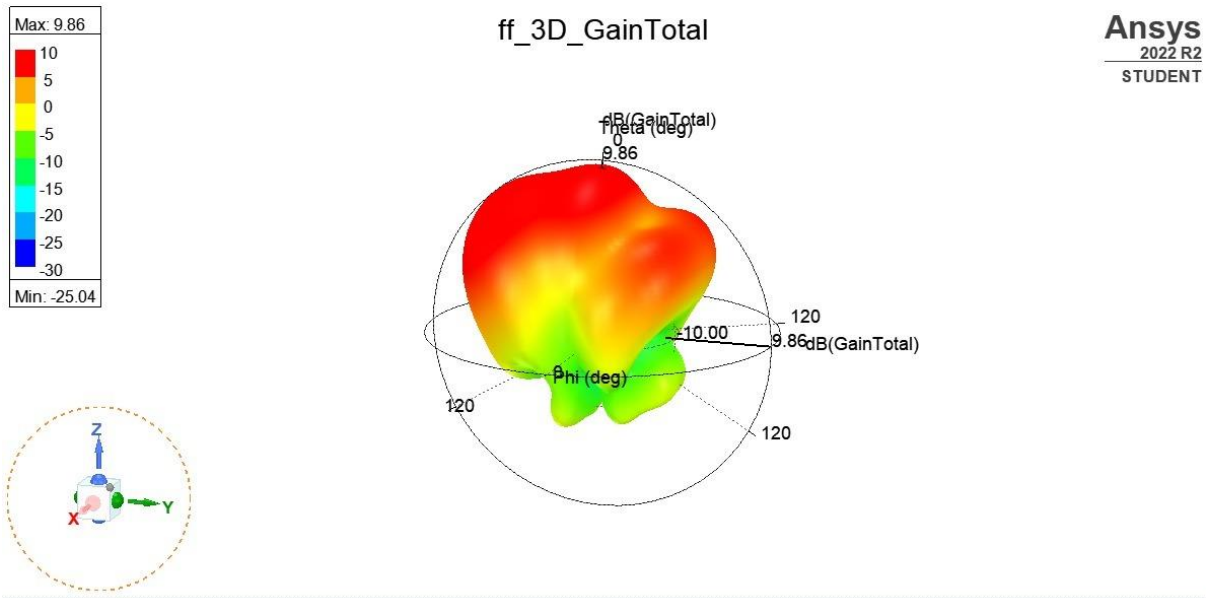
ff_2D_GainTotal

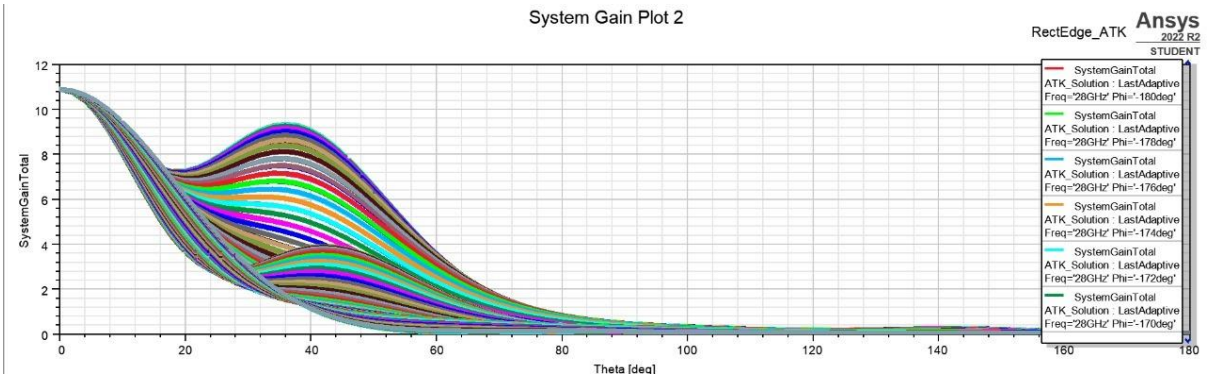


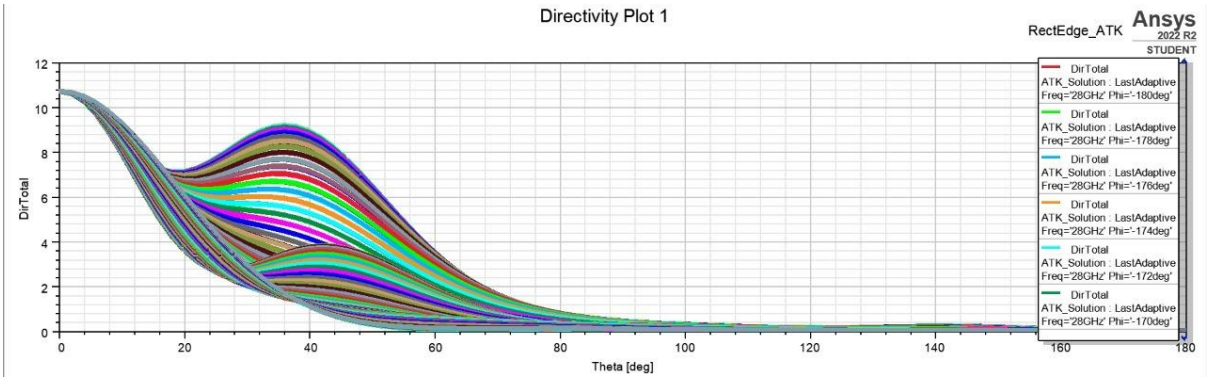
RectEdge_ATK Ansys 2022 R2 STUDENT

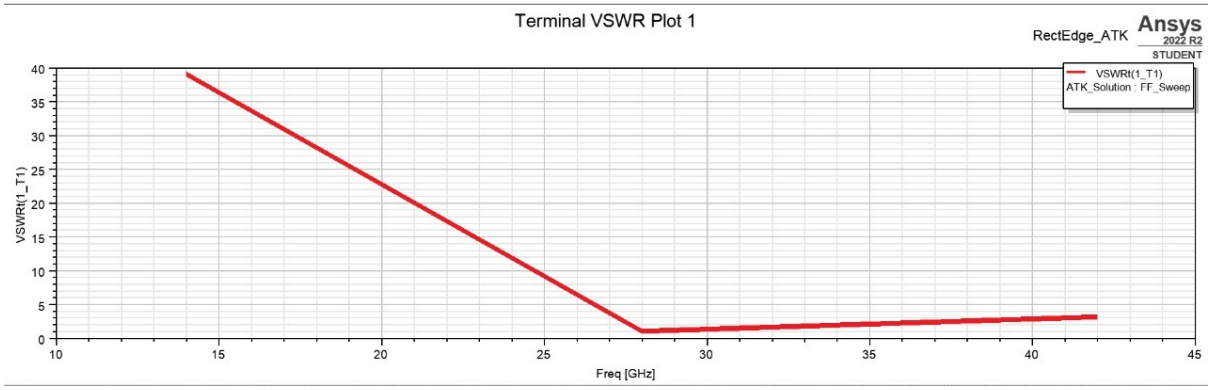
dB(GainTotal)
ATK_Solution : LastAdaptive
Freq='28GHz' Phi='0deg'

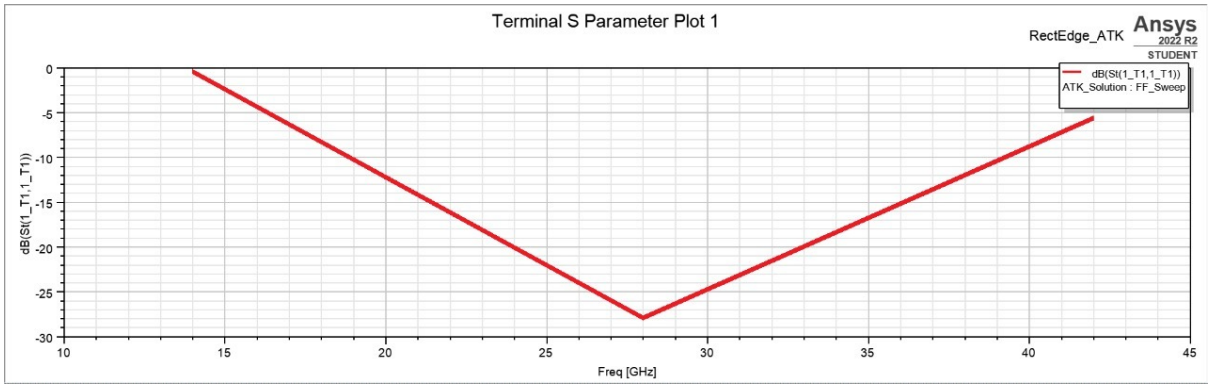
dB(GainTotal)
ATK_Solution : LastAdaptive
Freq='28GHz' Phi='90deg'


Max: 9.86
10
5
0
-5
-10
-15
-20
-25
-30
Min: -25.04
ff_3D_GainTotal
Ansys
2022 R2
STUDENT
dB(GainTotal)
Theta (deg)
0
9.86
120
-10.00
9.86
dB(GainTotal)
Phi (deg)
120
120
Z
Y
X


System Gain Plot 2
RectEdge_ATK
Ansys
2022 R2
STUDENT
SystemGainTotal
Theta [deg]
SystemGainTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-180deg'
SystemGainTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-178deg'
SystemGainTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-176deg'
SystemGainTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-174deg'
SystemGainTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-172deg'
SystemGainTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-170deg'


Directivity Plot 1
RectEdge_ATK
Ansys
2022 R2
STUDENT
DirTotal
Theta [deg]
DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-180deg'
DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-178deg'
DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-176deg'
DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-174deg'
DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-172deg'
DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-170deg'





Directivity Table 1

RectEdge_ATK Ansys 2022 R2 STUDENT

	Theta [deg]	DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-180deg'	DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-178deg'	DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-176deg'	DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-174deg'	DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-172deg'	DirTotal ATK_Solution : LastAdaptive Freq='28GHz' Phi='-170deg'	DirTotal ATK_Sol... Freq='28...
1	0.000000	10.721718	10.721718	10.721718	10.721718	10.721718	10.721718	10.721718
2	2.000000	10.670990	10.670985	10.670825	10.670511	10.670044	10.669429	10.668668
3	4.000000	10.500972	10.500984	10.500411	10.499263	10.497561	10.495289	10.492496
4	6.000000	10.217053	10.217223	10.216146	10.213847	10.210359	10.205720	10.199974
5	8.000000	9.828357	9.828921	9.827401	9.823848	9.818328	9.810918	9.801706
6	10.000000	9.347260	9.348508	9.346729	9.342014	9.334476	9.324246	9.311474
7	12.000000	8.788738	8.790963	8.789193	8.783568	8.774262	8.761475	8.745437
8	14.000000	8.169588	8.173033	8.171572	8.165401	8.154760	8.139935	8.121248
9	16.000000	7.507590	7.512402	7.511528	7.505222	7.493801	7.477637	7.457157
10	18.000000	6.820657	6.826845	6.826766	6.820733	6.809132	6.792428	6.771154
11	20.000000	6.126036	6.133450	6.134269	6.128855	6.117662	6.101236	6.080211
12	22.000000	5.439618	5.447943	5.449631	5.445085	5.434813	5.419432	5.399660
13	24.000000	4.775378	4.784143	4.786535	4.782982	4.774034	4.760356	4.742732
14	26.000000	4.144986	4.153594	4.156392	4.153826	4.146465	4.135003	4.120260

Observation:

Comparison between single patch antenna and antenna array:

In the 2-element antenna array,

- the directivity and the gain has been increased
- the minor lobes are reduced
- the signal strength is increased
- better performance is obtained

Comparison between antenna array and Koch fractal antenna array:

The Koch fractal antenna array has,

- larger bandwidth
- improved VSWR
- increased efficiency

Future design:

We are planning to increase the iterations in the Koch snowflake.

Then we are going to include a partial ground.

Application:

- We have used Roger RT-5880 which is a flexible material. Hence our antenna can be used in wearable devices.
- We can also implement point to point digital radio antennas because radio system uses antenna array to allow bi-directional data flow.
- The antenna can be used in Commercial airline telephones.
- Due to isotropic property and uniformity of Roger material it can be used for satellite application.
- The Koch fractal has the advantage of multiband application.