IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Variation in the parameters of rectangular microstrip patch antenna on different substrates and its comparison with grooved patch

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1. Introduction

Mobile phones have become integral part of our lives and microstrip antennas are widespread in mobile phone market. Microstrip antennas can be directly printed onto a circuit board. So the fabrication becomes easier and economical.

In this paper the performance of microstrip rectangular patch antenna is recorded for substrates fr4-epoxy, quartz_glass and porcelain. The performance of the patch antenna is also compared with grooved microstrip patch antenna.

2. Literature Survey

The design equations for rectangular microstrip antenna are as follows [1]. Let antenna to be designed for f, ε_r be the dielectric constant of substrate material and let h be the thickness of the dielectric substrate.

a. <u>Designing of patch</u>

The top view of rectangular micro strip antenna is shown in figure (1).

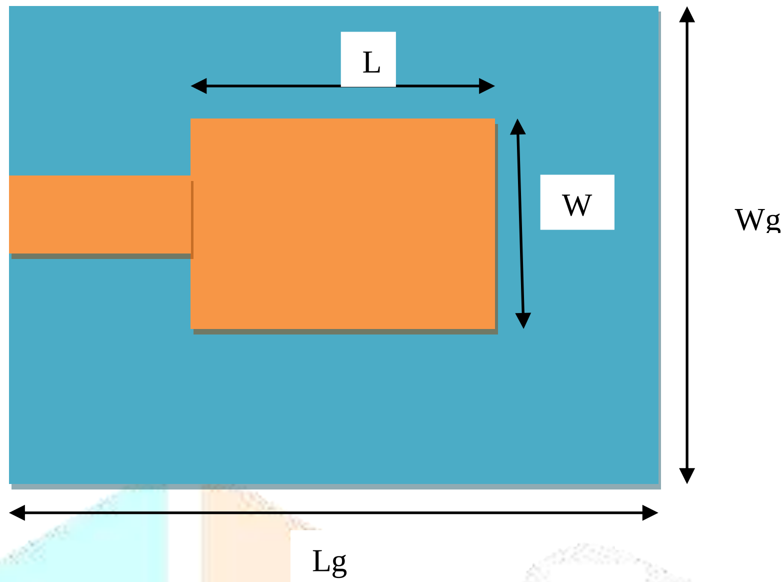

Figure (1) : Top view of rectangular microstrip antenna

The side view of rectangular micro strip antenna is shown in figure (2).

Figure (2) : Side view of microstrip patch antenna

The width W and length L of the patch are given (1) and (2) respectively.

$$W = \frac{c}{2*f}\sqrt{\frac{2}{\epsilon_r+1}} \quad (1)$$

$$L = L_{eff} - 2\Delta L \quad (2)$$

$$L_{eff} = \frac{c}{2*f*\sqrt{\epsilon_{eff}}} \quad (3)$$

$$\Delta L = 0.412h\frac{(\epsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \quad (4)$$

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (5)$$

b. Designing of Substrate

The length Lg and width Wg of substrate are given by (6) and (7) respectively.

$$L_g = 30 + (6 * h) \quad (6)$$

$$W_g = 30 + (6 * h) \quad (7)$$

3. Methodology

HFSS 13.0 is used for the simulation of rectangular microstrip patch antenna.
fr4_epoxy is selected as substrate material, patch and ground plane are of copper.
For $\varepsilon_r = 4.4$; h= 1.5mm; f =2.4GHz the dimensions of patch and substrate are given below

Plane	Length(mm)	Width (mm)
Patch	30	38
Substrate	39	47

The dimensions of the ground plane are same as that of substrate but it is fabricated the layer lies below the substrate.

quartz_glass is selected as substrate material, patch and ground plane are of copper.
For $\varepsilon_r = 3.78$; h= 1.5mm; f =2.4GHz the dimensions of patch and substrate are given below

Plane	Length(mm)	Width (mm)
Patch	32	40
Substrate	41	49

Porcelain is selected as substrate material, patch and ground plane are of copper.
For $\varepsilon_r = 5.7$; h= 1.5mm; f =2.4GHz the dimensions of patch and substrate are given below

Plane	Length(mm)	Width (mm)
Patch	26	34
Substrate	35	43

Length of the feed line depends on the length of the substrate and patch. Width of the patch is kept same for all the cases i.e., 2.8mm.

1. A rectangular copper patch of 0.05mm is constructed on XY plane.
2. Below the patch a rectangular dielectric substrate of 1.5mm is constructed.
3. Below the substrate a rectangular copper ground plane of thickness 0.05mm is constructed.
4. Copper feedline of 0.05mm is constructed on substrate and united with the patch.
5. A rectangle is constructed in YZ plane as a port for excitation to cover all the three above layers.
6. Lumped port excitation is assigned to the rectangle.
7. A rectangular radiation box is constructed around the patch to cover the antenna assembly and radiation is assigned.
8. Analysis setup in the frequency range 1.5GHz to 3GHz.
9. Results are recorded.
10. Grooves are made on patch at every 4mm distance and the results are tabulated.

4. Results and discussions

Antenna is designed to resonate at 2.4GHz. The various parameters of microstrip patch antenna for different substrates are listed in Table 1.

For fr4_epoxy as substrate the following results are obtained:

The return loss v/s frequency is as shown in figure (3)

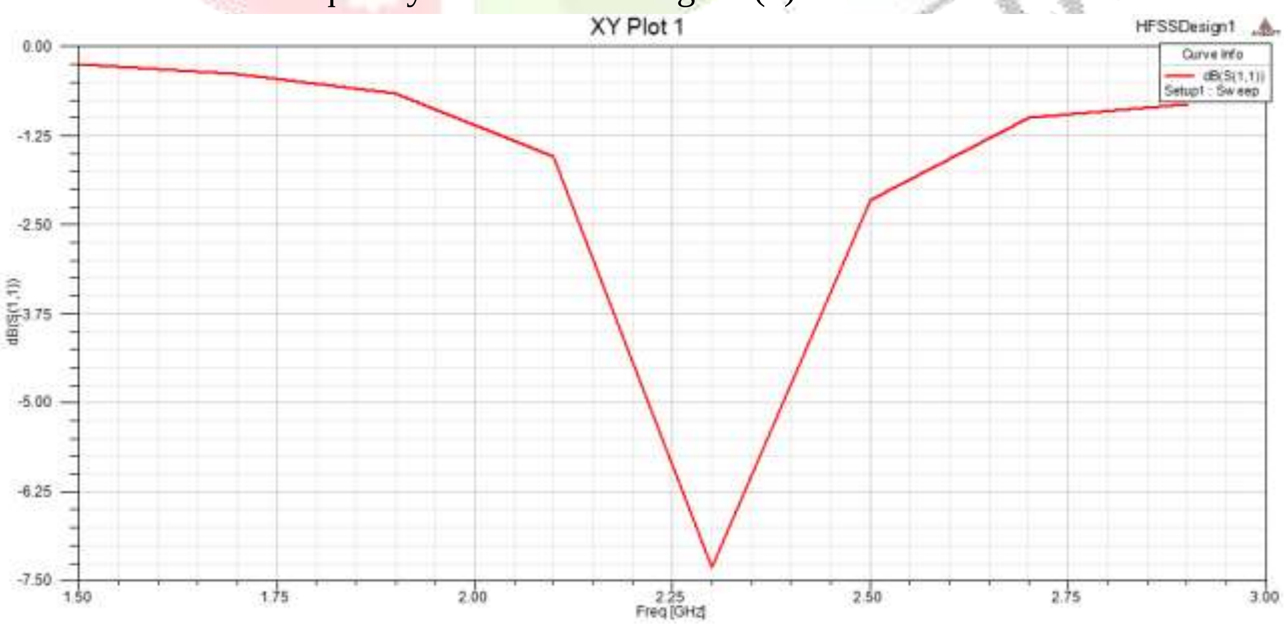

Figure (3): Return loss v/s Freuqncy for fr4-epoxy substrate

It is clear that the antenna is resonating at 2.3GHz against the designed frequency of 2.4GHz and return loss is -6.45db.

The VSWR v/s frequency is as shown in figure (4). It is evident that VSWR at resonating frequency is 12db.

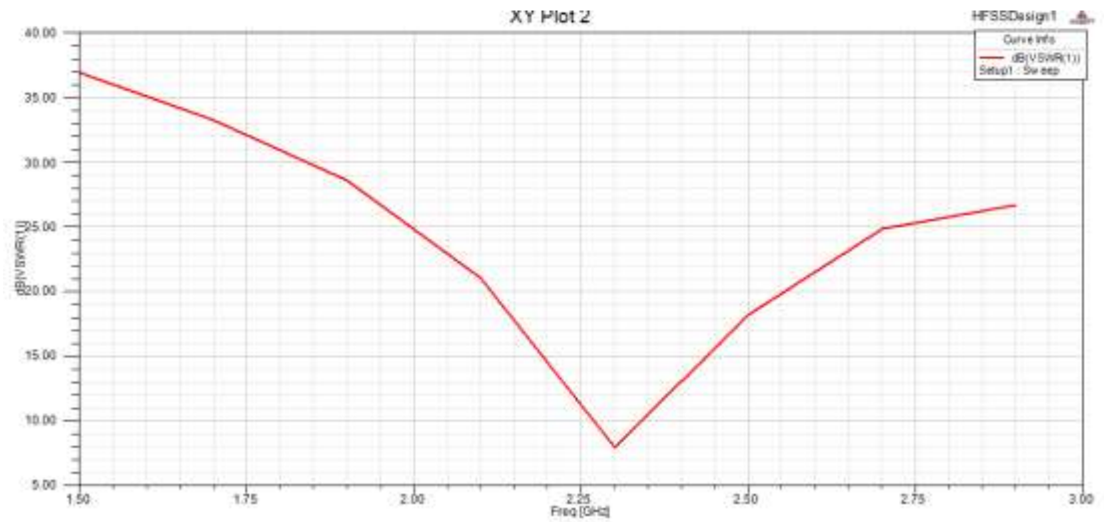

Figure (4): VSWR v/s Frequency for fr4-epoxy substrate

The 3D polar plot of gain is shown figure (5).The maximum gain is 3.08db. It is also clear that the minor lobe characteristics are not ideal.

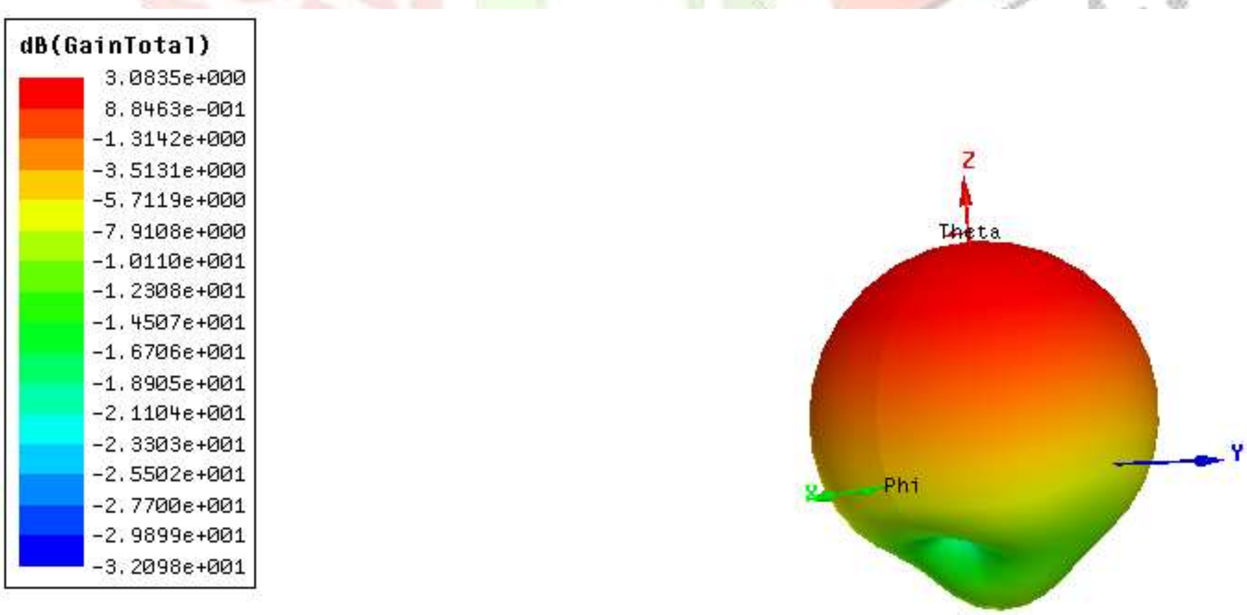

Figure (5):3D polar plot for fr4_epoxy substrate

For quartz_glass as substrate the following results are obtained:

The return loss v/s frequency is as shown in figure (6)

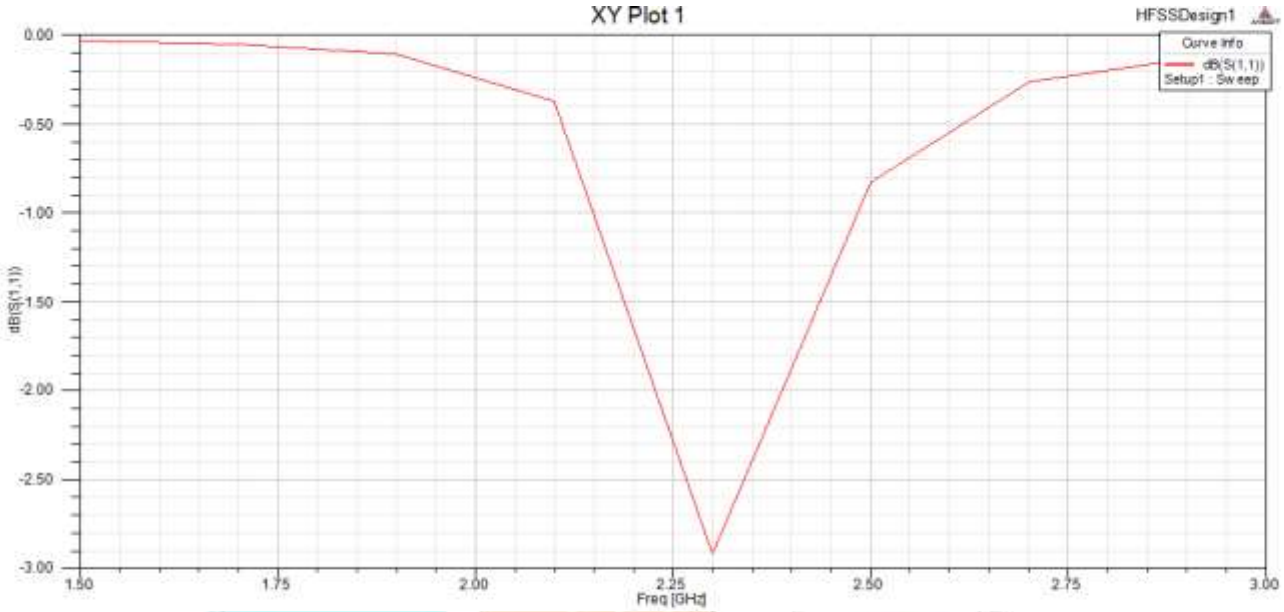

Figure (6): Return loss v/s Freuqncy for quartz_glass substrate

It is clear that the antenna is resonating at 2.3GHz against the designed frequency of 2.4GHz and return loss is -2.9db.

The VSWR v/s frequency is as shown in figure (7). It is evident that VSWR at resonating frequency is 16db.

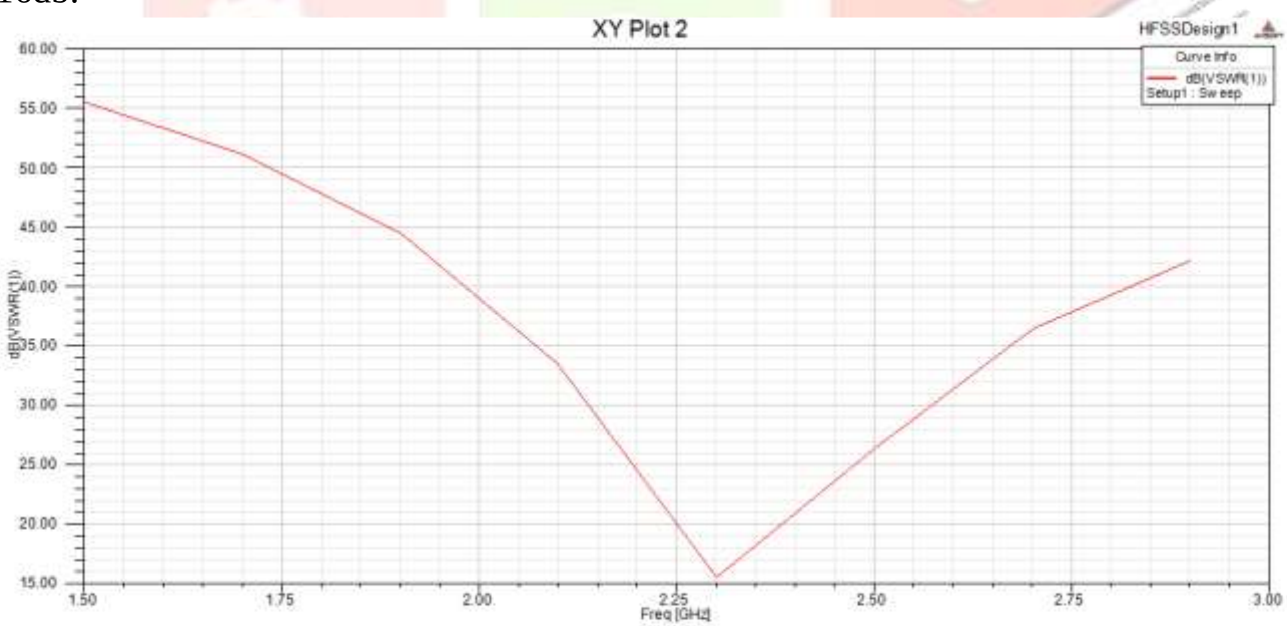

Figure (7): VSWR v/s Frequency for quartz_glass substrate

The 3D polar plot of gain is shown figure (8).The maximum gain is 6.20db. It is also clear that the minor lobe characteristics are good.

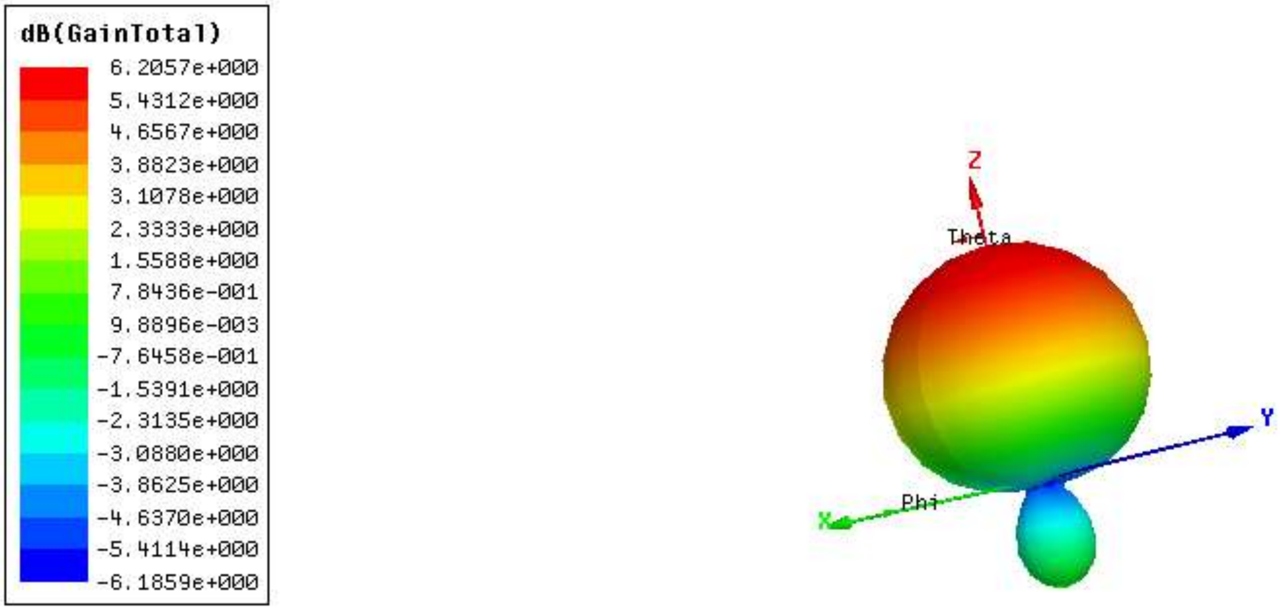

Figure (8): 3D polar plot for quartz_glass substrate

For porcelain as substrate the following results are obtained:

The return loss v/s frequency is as shown in figure (9)

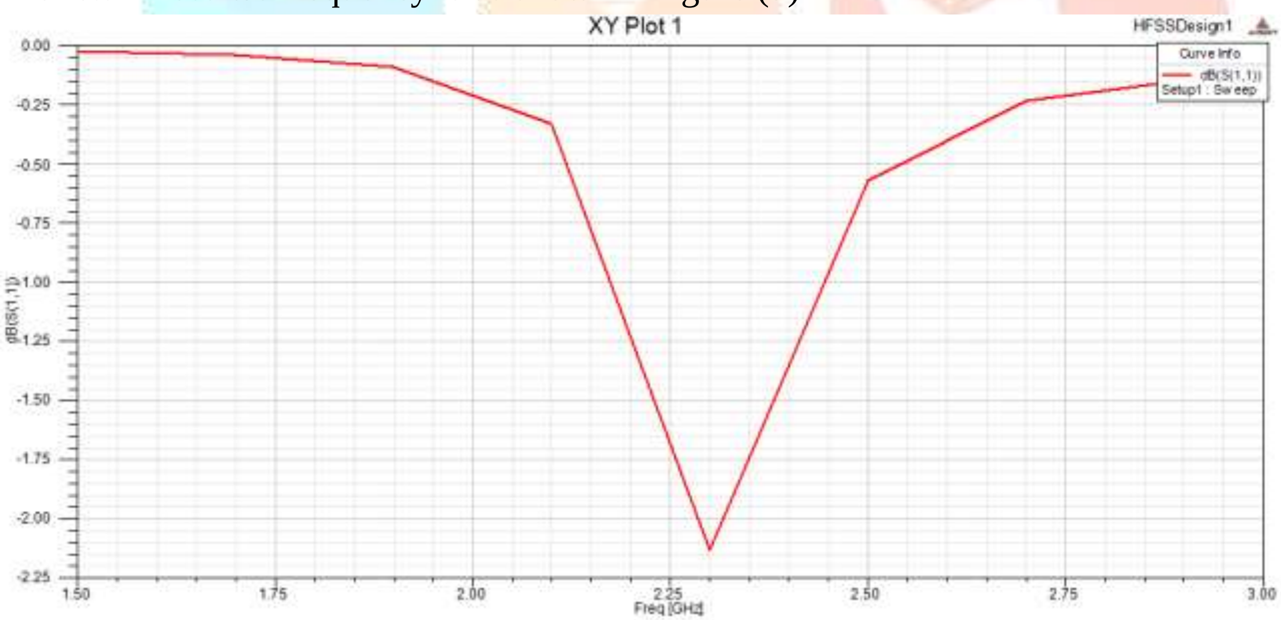

Figure (9): Return loss v/s Freuqncy for porcelain substrate

It is clear that the antenna is resonating at 2.3GHz against the designed frequency of 2.4GHz and return loss is -2.1db.

The VSWR v/s frequency is as shown in figure (10). It is evident that VSWR at resonating frequency is 18db.

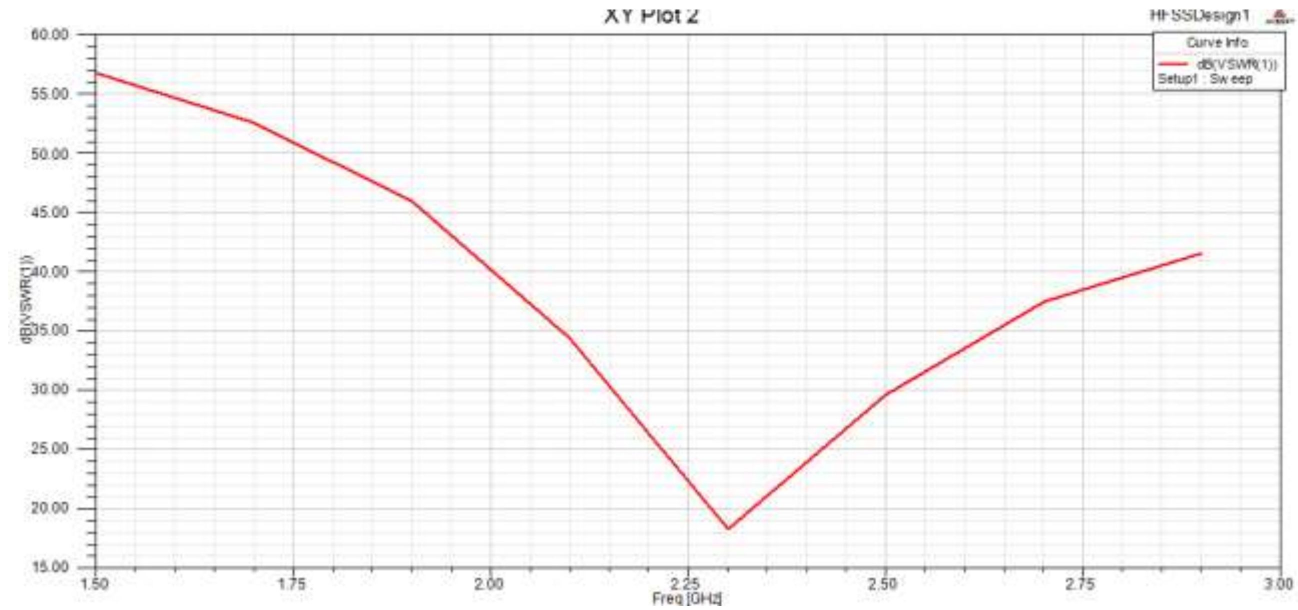

Figure (10): VSWR v/s Frequency for porcelain substrate

The 3D polar plot of gain is shown figure (11).The maximum gain is 5.20db. It is also clear that the minor lobe characteristics are good.

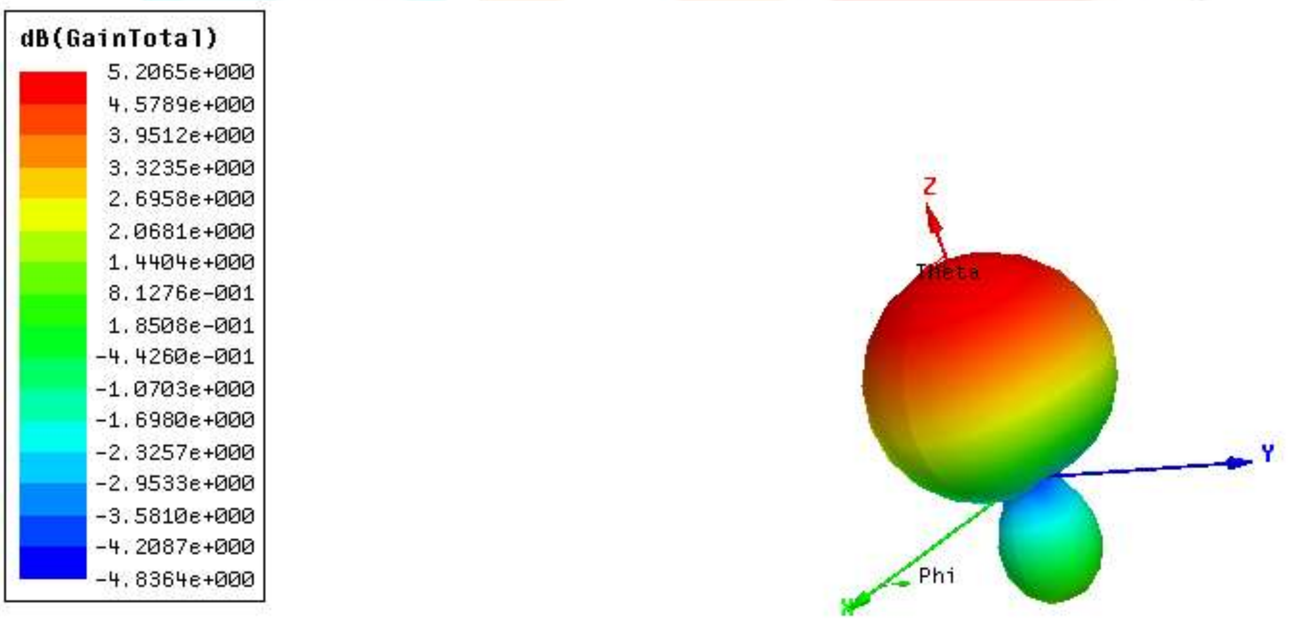

Figure (11): 3D polar plot for porcelain substrate

Substrate	ε_r	Resonating Frequency	Z_{in}	Patch Dimensions	Return loss	VSWR	Gain
Fr4_epoxy	4.4	2.3GHz	243Ω	L=30mm W=38mm	-6.45db	12db	3.08db
Quartz_glass	3.78	2.3GHz	215.1Ω	L=32mm W=40mm	-2.9db	16db	6.20db
Porcelain	5.7	2.3GHz	301.5Ω	L=26mm W=34mm	-2.1db	18db	5.20db

Table 1: Comparison of microstrip antenna parameters for different substrate

From table (1) it is clear that if the relative permittivity of substrate increases, input impedance will also be increases but patch dimensions reduces. Antenna is very good for quartz_glass but its return loss and VSWR are poor compared to fr4_epoxy. Fr4_epoxy exhibits excellent return loss and VSWR but the gain is poor compared to other two materials and also its minor lobe has considerable gain.

Comparison with fr4_epoxy microstrip antenna with its grooved patch

Grooved patch(grooves along x-axis)

Figure 12 shows the grooved structure rectangular microstrip antenna with copper grooves. It is clear from figure 1 that the grooves are made along x-axis.

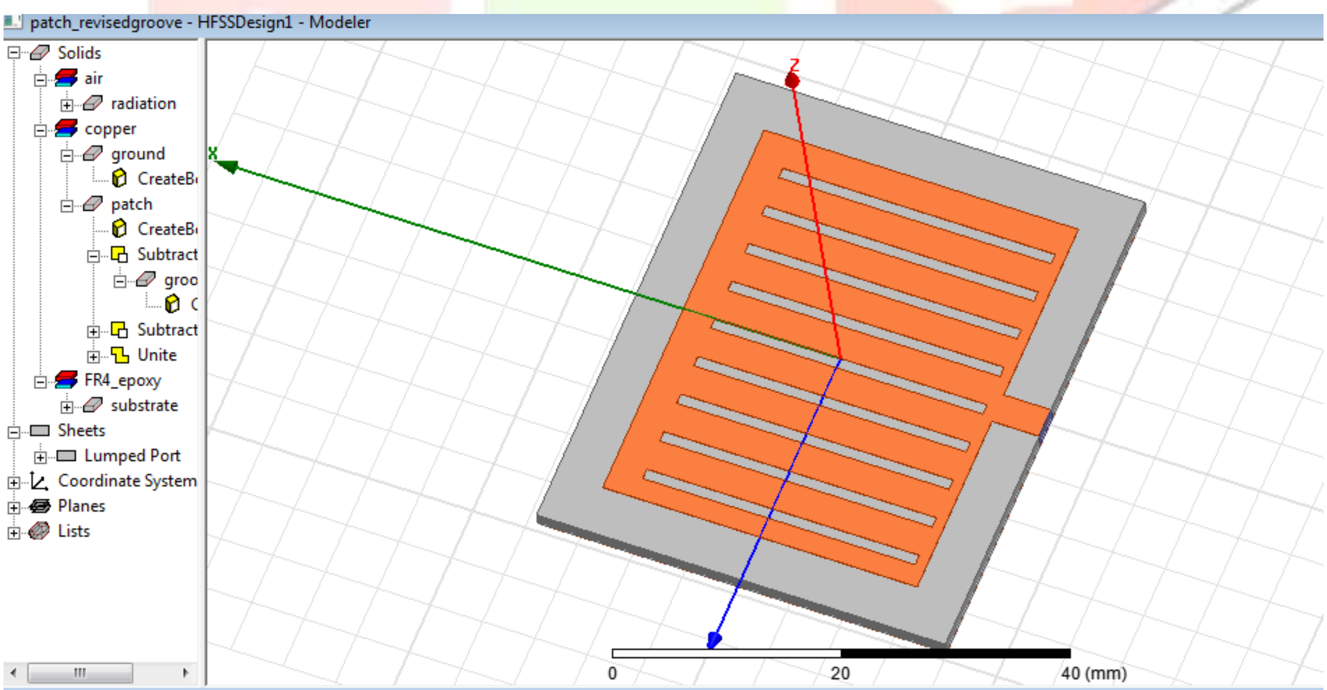

Figure 12: Grooved structure of microstrip patch antenna

For grooved strip microstrip patch antenna with copper substrate the following results are observed (grooves along x-axis):

The return loss v/s frequency is as shown in figure (13)

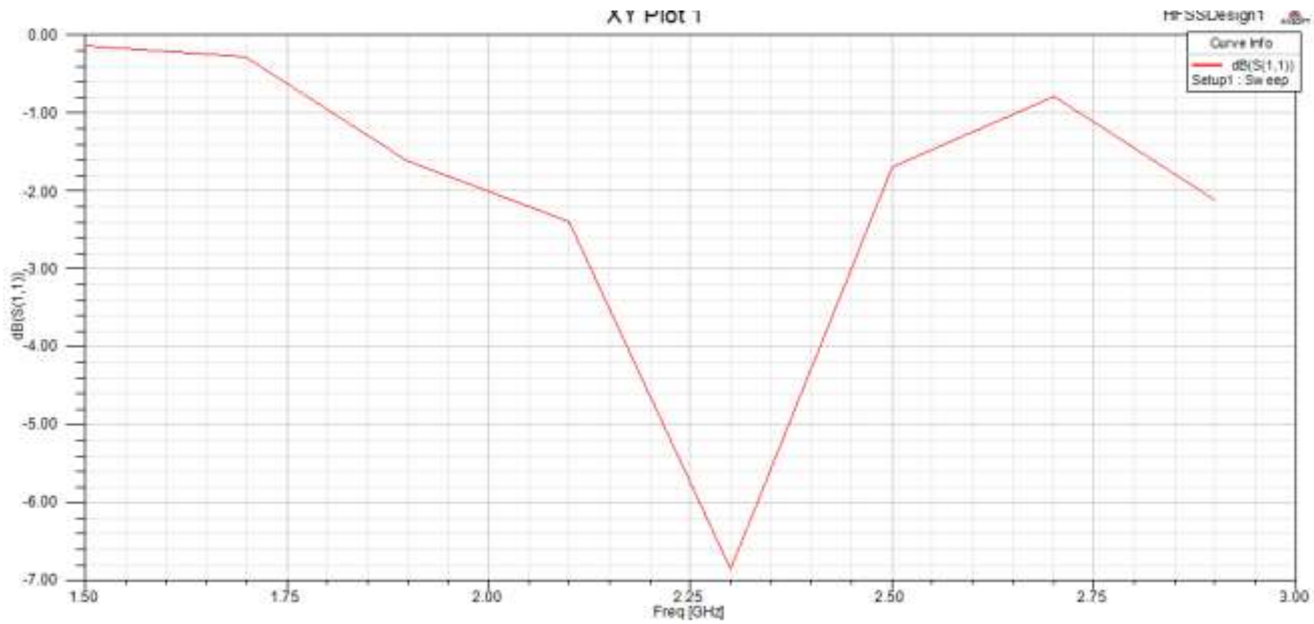

Figure (13): Return loss v/s Freuqncy for grooved patch

It is clear that the antenna is resonating at 2.3GHz against the designed frequency of 2.4GHz and return loss is -6.8db.

The VSWR v/s frequency is as shown in figure (14). It is evident that VSWR at resonating frequency is 7db.

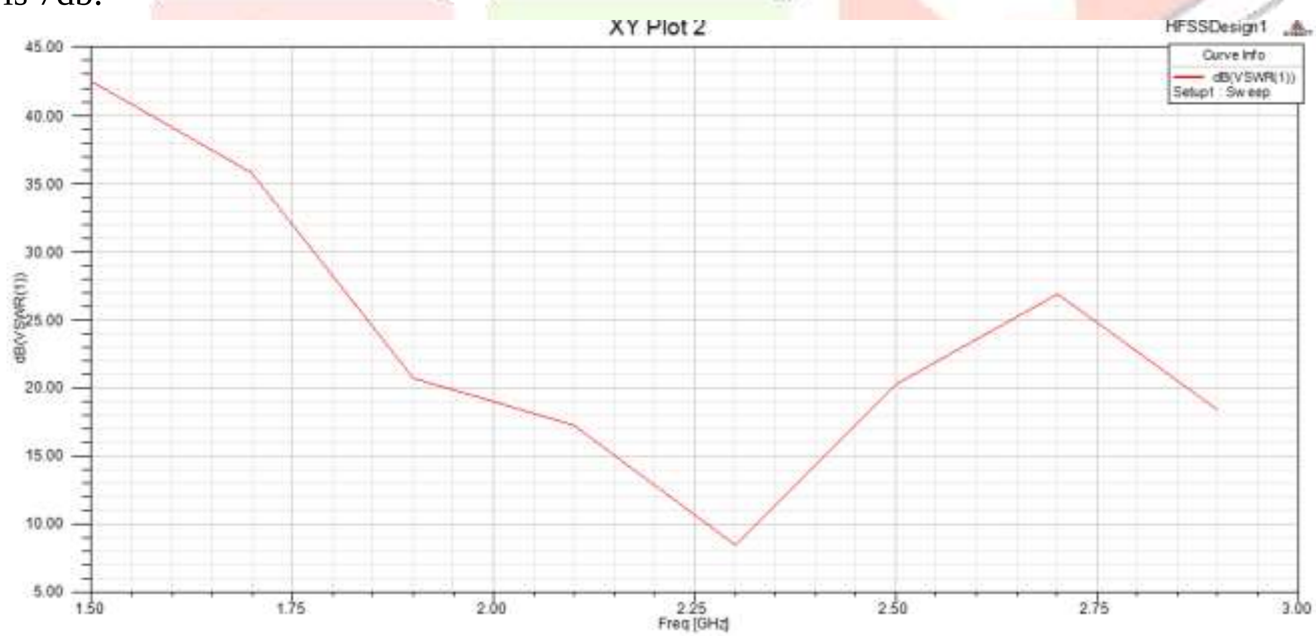

Figure (14): VSWR v/s Frequency for grooved patch

The 3D polar plot of gain is shown figure (15).The maximum gain is 1.77db. It is also clear that the minor lobe characteristics are good.

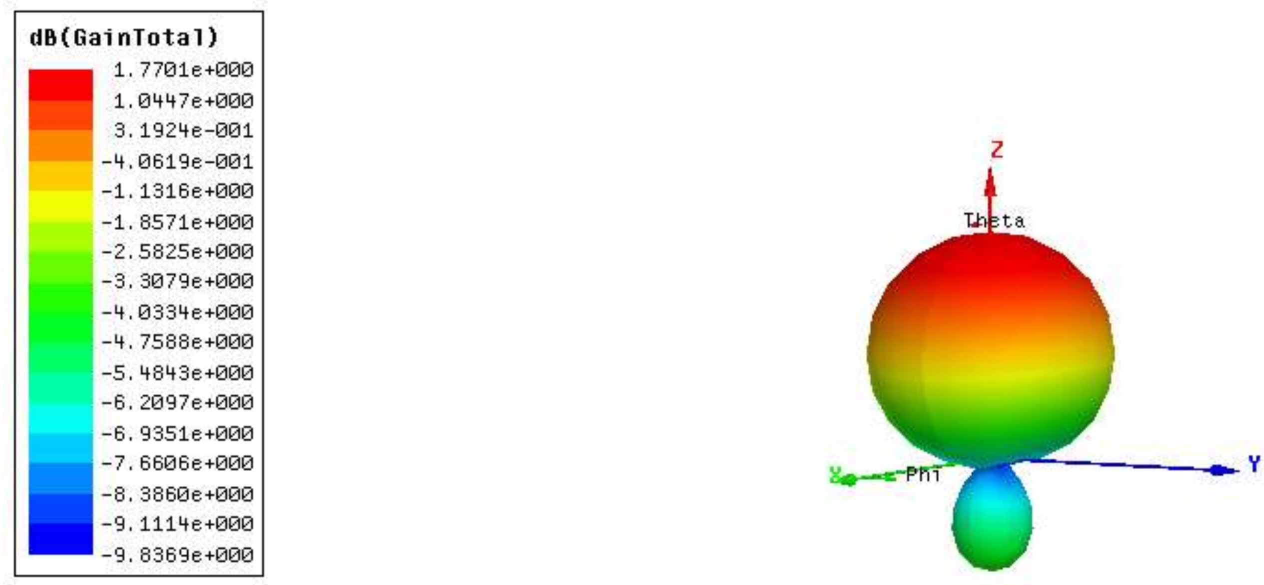

Figure (15): 3D polar plot for grooved patch

Grooved patch (grooves along y-axis)

Figure 13 shows the grooved structure rectangular microstrip antenna with copper grooves. It is clear from figure 1 that the grooves are made along x-axis.

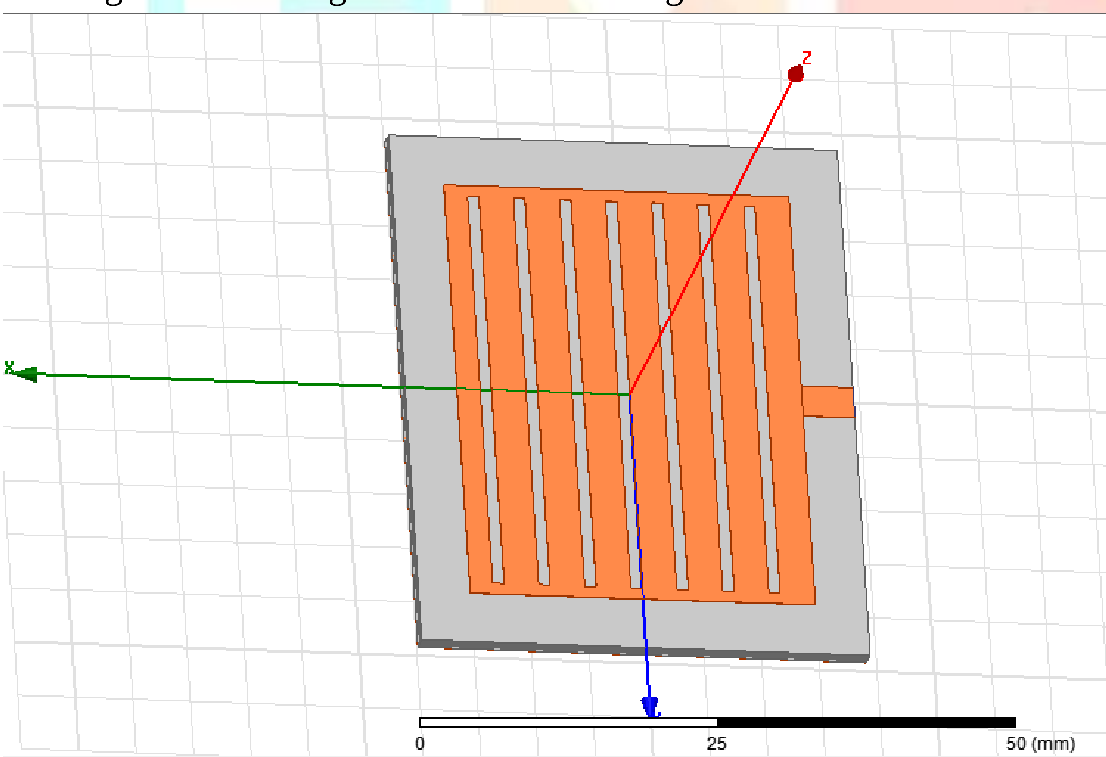

Figure 13: Grooved structure of microstrip patch antenna

For grooved strip microstrip patch antenna with copper substrate the following results are observed (grooves along y-axis):

The return loss v/s frequency is as shown in figure (14)

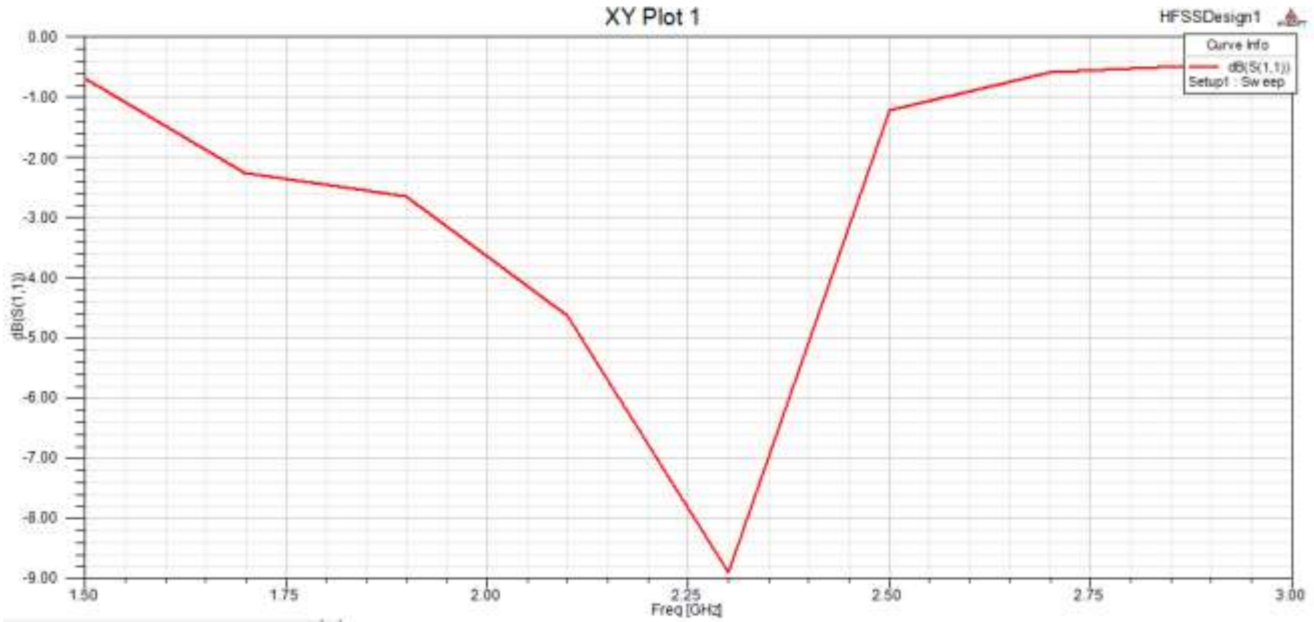

Figure (14): Return loss v/s Frequency for grooved patch

It is clear that the antenna is resonating at 2.3GHz against the designed frequency of 2.4GHz and return loss is -8.8db.

The VSWR v/s frequency is as shown in figure (15). It is evident that VSWR at resonating frequency is 6.5db.

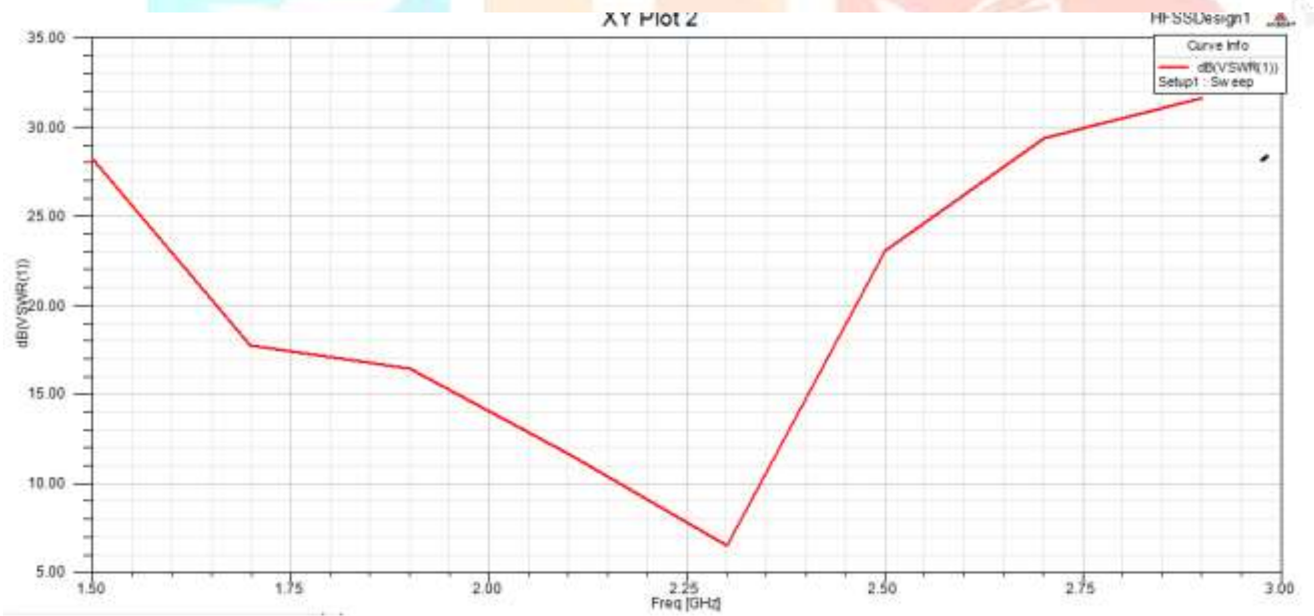

Figure (15): VSWR v/s Frequency for grooved patch

The 3D polar plot of gain is shown figure (16).It radiation pattern is non directional with attenuation.

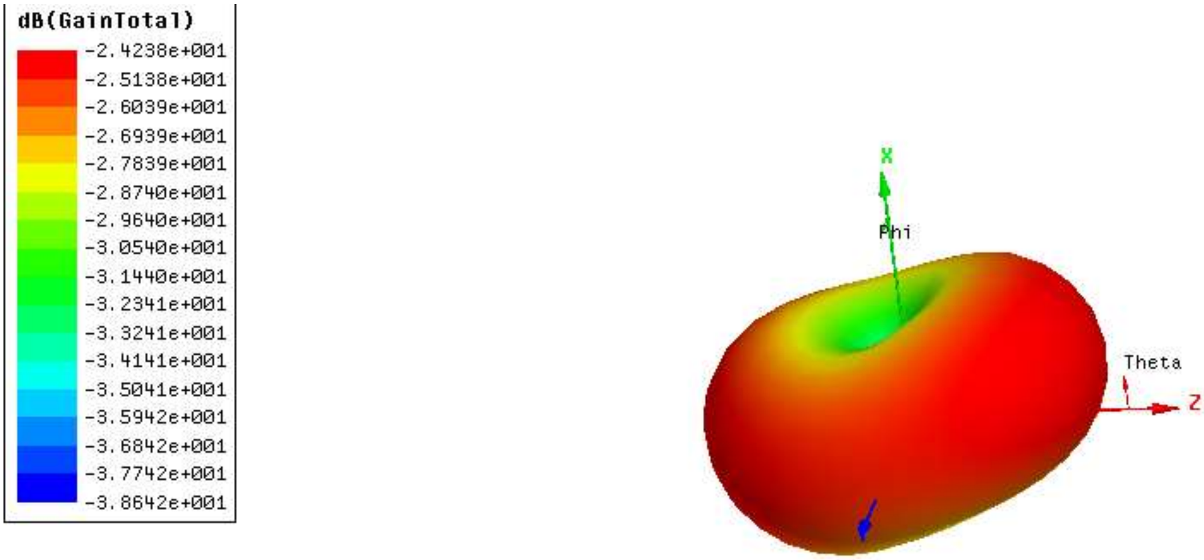

Figure (16): 3D polar plot for grooved patch

	Resonating frequency	Return loss	VSWR	Gain
Microstrip patch	2.3GHz	-6.45db	12db	3.08db
Grooved patch (along x)	2.3GHz	-6.8db	7db	1.77db
Grooved patch (along y)	2.3GHz	-8.8db	6.5db	-2.4db

Table 2: Comparison of microstrip antenna parameters with grooved patch antenna

From table 2 it is clear that in grooved patch (along x-axis) the return loss and VWSR characteristics are more ideal compared to without grooved microstrip patch antenna but the gain is lesser. Grooved antenna has more ideal minor lobe compared to non grooved microstrip patch antenna. Grooves along y-axis exhibit excellent return loss and VSWR performance but at the cost of gain (attenuation).

5. CONCLUSION

In this paper the performance analysis of various parameters of rectangular microstrip antenna is performed for different substrates. In the second part the performance analysis is done between rectangular microstrip antenna and its grooved version. Results are tabulated and discussed.

References

[1] "Microstrip Antenna Design Handbook" by Ramesh Garg**,** Prakash Bhartia**,** Apisak Ittipiboon**.**

[2] http://anlage.umd.edu/HFSSv10UserGuide.pdf

[3] www.emtalk.com