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Design and Analysis of Staked Multiband Microstrip Antenna

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Abstract: A swastik slot loaded rectangular patch stacked with H-shaped patch antenna for multiband applications is presented in this manuscript. The antenna designing is done by using HFSS simulation tool. Feeding is done by using microstrip feed line (50Ω). The resonating behaviour of antenna depends on notch length and width of H-shaped patch as well as on separation between two patches and dielectric constants of the substrate. Finally, by considering optimum value the return loss (S11<-15dB) of design antenna -21.95 dB,-24.08dB,-17.83dB,-27.48dB,and -25.81dB at frequencies of 3.6GHz, 4.06GHz, 7.7 GHz, 9.76GHz, and 13.87GHz respectively.

Keywords: Swastik Slot, H-shaped patch, Stacked Microstrip antenna, Multi-band.

I. INTRODUCTION

During the last few years wireless technology has gained so much significance and has been quickly and extensively developed in the recent world. For further improvement in future the point of the specialized communication devices is to give image, speech & information correspondence anywhere and anytime all through the world. This demonstrates that for communication reason in future the antennas must have the capacity to cover all the conceivable frequency bands. For this it ought to meet the necessities of wideband or multi-band. With the increment in number of frequency bands the design of antenna turn out to be more complex. For the communication of more information there is requirement of adequate bandwidth. Multiband antennas are necessary to cover several frequency bands with a single radiating element. However, it would be desirable to have antennas that could work simultaneously at multiple frequencies. For this reason multi frequency antennas are required. .Conventionally, as a single frequency band antenna cannot operate at all of frequency bands of mobile communication, multi-band antennas covering these bands individually should be prefer. Therefore, multiband and wideband antennas are necessary to make available multifunctional operations for mobile communication.

In recent times, many multiband antennas have been investigated because of coverage for many mobile and wireless communication services such as GSM, CDMA, DCS and PCS. Many usual techniques such as in the [1], switches and PIN diodes are used for multiband operation. This antenna is composed of two layers; the base layer is a patch with two slots created on each side controlling by switches. In [2] a dual broadband rectangular slot antenna for 2.4 and 5 GHz wireless local area network (WLAN) is presented by using U-shaped strip inset in the centre of the rectangular slot antenna. The obtain impedance bandwidths for two operating bands can achieve about 10.6% for the 2.4 GHz band and 33.8% for the 5 GHz band. A broadband U-slot loaded rectangular patch Stacking with H-shaped patch is designed in [3]. The resonating behaviour of the antenna depends on notch parameters like length and width of H shaped patch and separation between the two patches. Optimization of notch parameters gives impedance Bandwidth of and exhibits broadband resonance with a similar radiation pattern for the entire range [4]. Demonstration of the single-feed planar monopole antenna not only has good impedance matching for triple-band operation, but also performs as a diversity triple-band antenna [5]. A compact microstrip fed dual-band coplanar antenna comprises of a rectangular centre strip and two lateral stripes printed on a substrate. This antenna generates two individual resonant modes to cover up 2.4/5.2/5.8 GHz WLAN bands and suitable to the IEEE 802.11 WLAN standards of 2.4, 5.2 and 5.8 GHz WLAN bands [6]. In [7], a stacked microstrip patch antenna loaded with u-shaped slots on both the driven and parasitic patches with relative comparison of feeding techniques probe and co-planar waveguide feeding has been investigated. In the present work, a swastik-slot loaded rectangular patch staked H-shaped patch antenna is designed and analysed. The main motive of this design is to make antenna suitable for multiband applications. In swastik slot there are three vertical slots which are responsible for three resonant peaks and also in H-shaped patch, two notches are present which also creates two different resonant peaks.

II. MATHEMATICAL FORMULATION

For antenna designing the mathematical description is simply given by the following equations [8].Width of microstrip antenna is simply given as

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$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

Where,
W= Width of Patch
ε_r= Dielectric constant of the substrate

Actual length of microstrip antenna is given as

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

Where,
L_{eff}= Effective length of the patch.
ΔL = Extended electrical length

Effective length of the patch is simply given by

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (3)$$

Where,
ε_{reff} = Effective dielectric constant
Its value is given by,

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (4)$$

Where,
h = thickness of the substrate
Now the extended electric length is given by

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.8)} \quad (5)$$

The width of microstrip line in microstrip antenna is given as follows:

For $\frac{W_{eff}}{h} \geq 2$

$$W_{eff} = \frac{2h}{\pi}\left\{\frac{\varepsilon_r-1}{2\varepsilon_r}\left[\ln(B-1)+0.39-\frac{0.61}{\varepsilon_r}\right]+B-1-\ln(2B-1)\right\} \quad (6)$$

And for
$\frac{W_{eff}}{h} < 2$

$$W_{eff} = \frac{8he^{A}}{(e^{2A}-2)} \quad (7)$$

$$W_f = W_{eff} - \frac{t}{\pi\left[1+\ln\left(\frac{2h}{t}\right)\right]} \quad (8)$$

Where, A and B are given as follows

$$A = \frac{Z_{ol}}{60}\left(\frac{\varepsilon_r+1}{2}\right)^{0.5} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left(0.23+\frac{0.11}{\varepsilon_r}\right)$$

$$B = \frac{377\pi}{2Z_{ol}\sqrt{\varepsilon_r}}$$

III. ANTENNA DESIGN AND STRUCTURE

In this paper, antenna is designed by using ANSOFT HFSS (High Frequency Structural Simulator) [9] [10]. Method of finite element solver is used. Here two patches are used one patch is feeded with microstrip line having characteristic impedance 50Ω and another one is parasitic patch. Feeder patch is rectangular shaped loaded with swastik shaped slot and parasitic patch is H-shaped. Dielectric material of substrate between ground and feeding patch is FR4 and it is 30 mm wide and 30 mm long and height of the substrate is 1.5 mm and the substrate material used between two patches is varying and 30 mm wide and 30 mm long but height of the substrate is varying. Below table 1 shows the dimension of design antenna parameters**.** We take different types of substrate such as glass, FR4 epoxy, mica and Bakelite. And also varies the height of substrate as 0.5mm, 1mm, 1.5mm, and 2 mm. In H-shaped parasitic patch there are two notches

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(Upper notch and lower notch). Length of notch is varied and observes its effect on multiband characteristics of antenna. Figure 1(a), 1(b) and 1(c) shows the configuration of design stacked antenna where as Figure1 (d) shows the front view of design antenna configuration.

Table1. Dimensions of antenna

S.No.	Parameters	Dimensions	Material
1	Substrate1	W_{sub}=30 mm L_{sub}=30 mm H_{sub}= 1.6mm	FR4
2	Feeding patch	L_p= 16 mm W_p= 11.964mm	Copper
3	Ground Plane	W_g= 30mm L_g= 30mm	Copper
4	Swastik Slot	L_{Hs}= 5mm, L_{vs}= 5mm, W_s= 1.5mm	Copper
5	Feed line	W_f= 3.01mm L_f = 8 mm	Copper
6	Substrate2	W_{sub}=30 mm L_{sub}=30 mm H_{sub}= Varying	Varying
7	Parasitic Patch	L_p= 18 mm W_p= 26.5mm Ln=Varying Wn=8mm	Copper

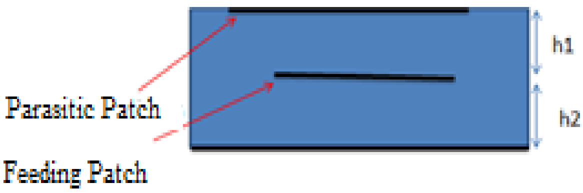

Fig. 1(a) Stacked Patch Antenna

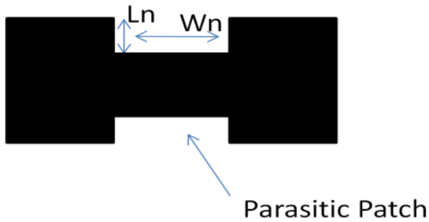

Fig. 1(c) H-shaped parasitic patch

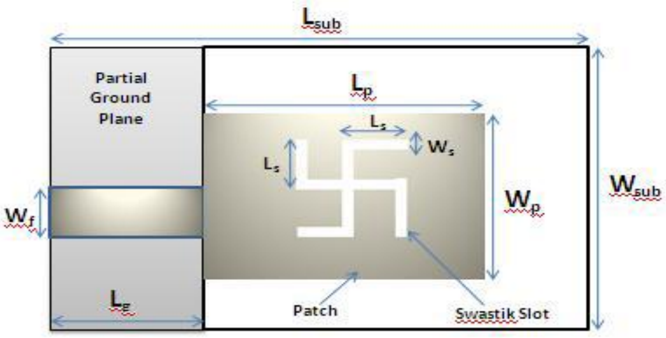

Fig. 1(b) Swastik Slot loaded Feed patch

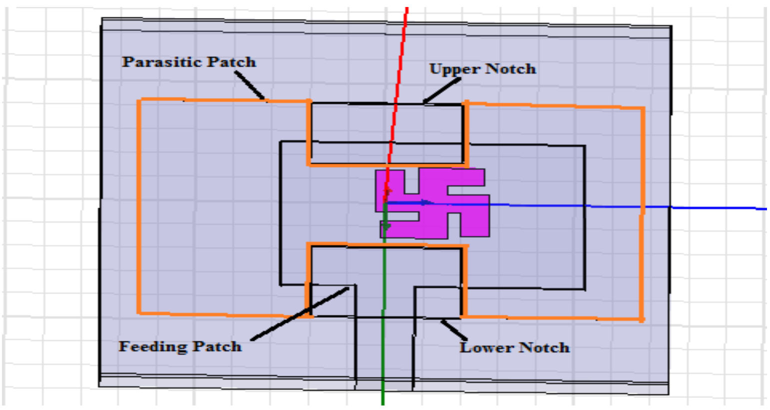

Figure1 (d) the front view of design antenna configuration

IV. RESULTS AND DISCUSSION

In HFSS, rectangular patch and partial ground plane are made up of PEC (Perfect Electrical Conductor) and air or vacuum can be used for the radiation box. Now, consider the analysis effects of varying the separation between two patches on multi-band characteristics of design antenna.

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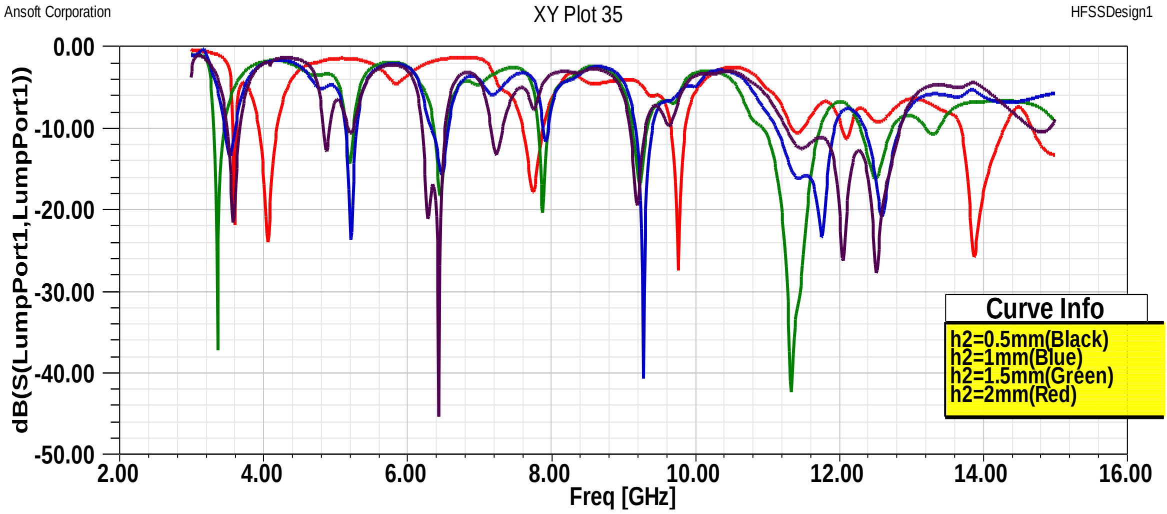

Fig. 2 Return loss v/s frequency curve for varying separation of substrate

Table2. Return loss (S11<-15dB) at different separation of two patches

Separation between two patches	Frequency (GHz)(at S11<-15dB)	Return Loss(dB)	Separation between two patches	Frequency (GHz)(at S11<-15dB)	Return Loss(dB)
0.5mm	3.586	-21.56	1.5mm	3.37	-37.34
	6.2913	-21.11		6.47	-18.32
	6.4474	-45.47		7.88	-20.47
	9.21	-18.83		9.23	-17.15
	12.04	-25.92		11.33	-42.44
	12.51	-27.72		12.52	-16.09
1mm	5.22	-23.64	2mm	3.4	-30.30
	6.48	-15.72		6.4	-19.70
	9.28	-40.70		7.8	-25.90
	11.40	--16.14		11.14	-19.12
	11.75	-23.40		13.11	-17.72
	12.60	-20.54			

From the figure 2 and table 2 it is clear that we get six peaks with good return loss when separation between two patches is 0.5mm.Now, observe the effect of changing dielectric material of substrate2 on multiband characteristics of the antenna design. Figure 3 shows return loss v/s frequency curve at different dielectric material of substrate2.

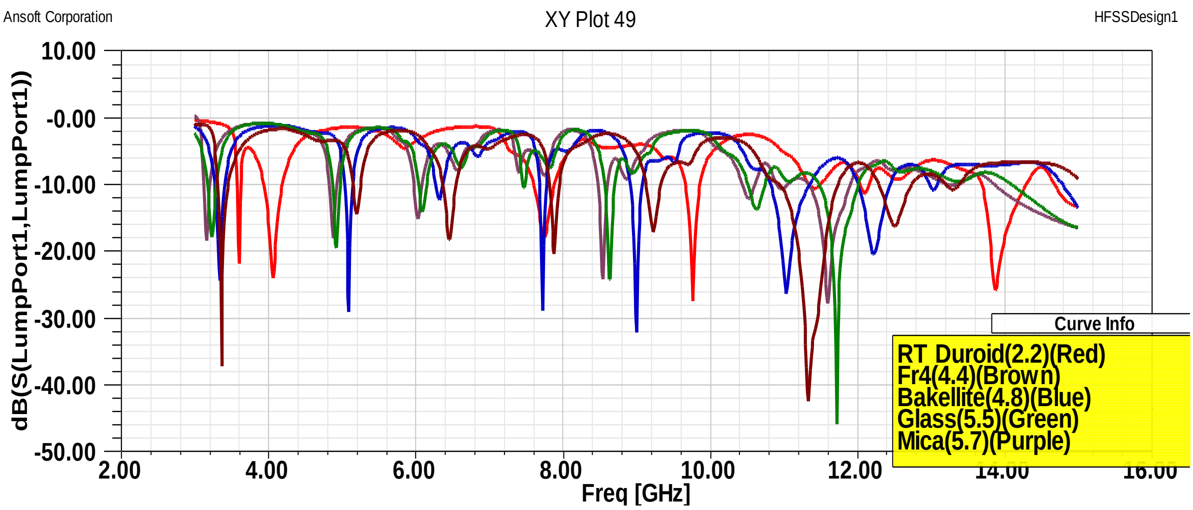

Fig. 3 Return loss v/s frequency curve for different material of substrate2

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Table3. Return loss (S11<-15dB) for different material of substrate2

Dielectric Material for Substrate 2	Frequency (GHz)(at S11<-15dB)	Return Loss(dB)	Dielectric Material for Substrate 2	Frequency (GHz)(at S11<-15dB)	Return Loss(dB)
RT Duroid(2.2)	3.7	-27.94	Bakelite(4.8)	3.3	-24.45
	4.22	-36.54		5.1	-29.08
	7.1	-31.56		7.7	-28.99
	10.53	-15.32		9	-32.28
	11.09	-47.51		11.03	-26.40
	12.08	-26.49		12.22	-20.52
	12.58	-21.57	Glass(5.5)	3.2	-17.90
FR4(4.4)	3.3	-37.34		4.9	-19.59
	6.4	-18.32		8.6	-24.27
	7.88	-20.47		11.7	-45.87
	9.24	-16.72	Mica(5.7)	3.16	-18.38
	11.33	-42.44		4.88	-18.03
	12.50	-16.22		8.54	-24.17
	11.60	-27.77			

From figure 3 and table 3 it is clear that we get seven peaks with good return loss when RT Duroid dielectric material is used. Now, observe the effect of changing length of upper notch for H-shaped patch. Figure 4 shows return loss v/s frequency curve at different length of upper notch.

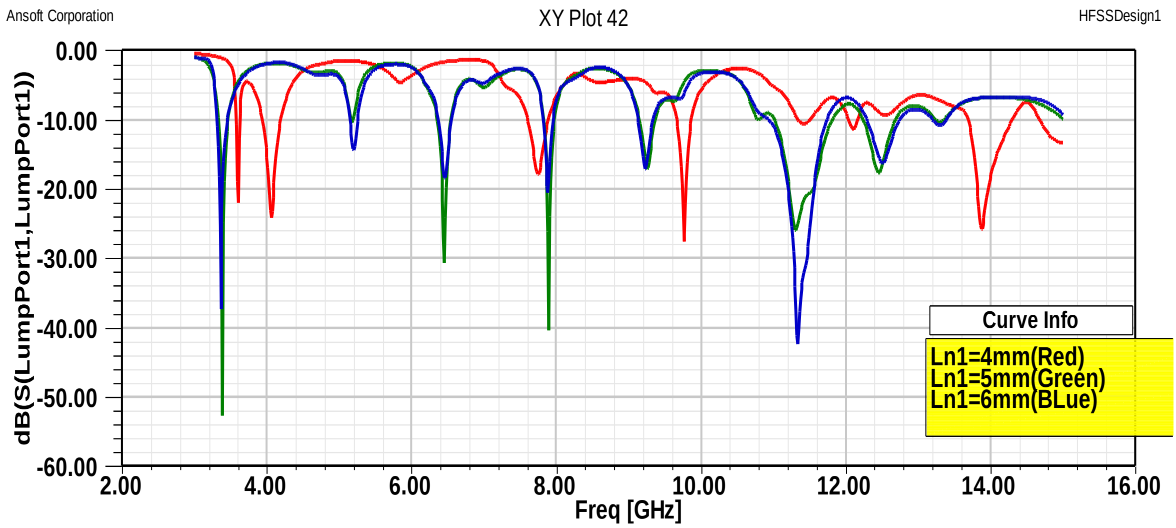

Figure 4 Return loss v/s frequency curve for different length of upper notch

Table 4 Return loss (S11<-15dB) at different frequencies for different length of upper notch

Length of Upper Notch	Frequency (GHz)(at S11<-15dB)	Return Loss(dB)
4mm	3.38	-19.74
	6.45	-28.63
	7.91	-30.58
	11.32	-27.54
	12.44	-17.07
5mm	3.39	-52.61
	6.45	-30.58
	7.90	-40.34
	11.31	-25.84
	12.46	-17.56
	9.25	-17.16

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6mm	3.37	-37.34
	6.45	-18.34
	7.88	-20.47
	9.23	-17.15
	11.33	-42.44
	12.52	-16.09

From the figure 4 and table 4 it is clear that we get six peaks with good return loss when length of upper notch is 5mm.Now, observe the effect of changing length of lower notch on multiband characteristics of this antenna design. Figure5 shows return loss v/s frequency curve at different length of lower notch.

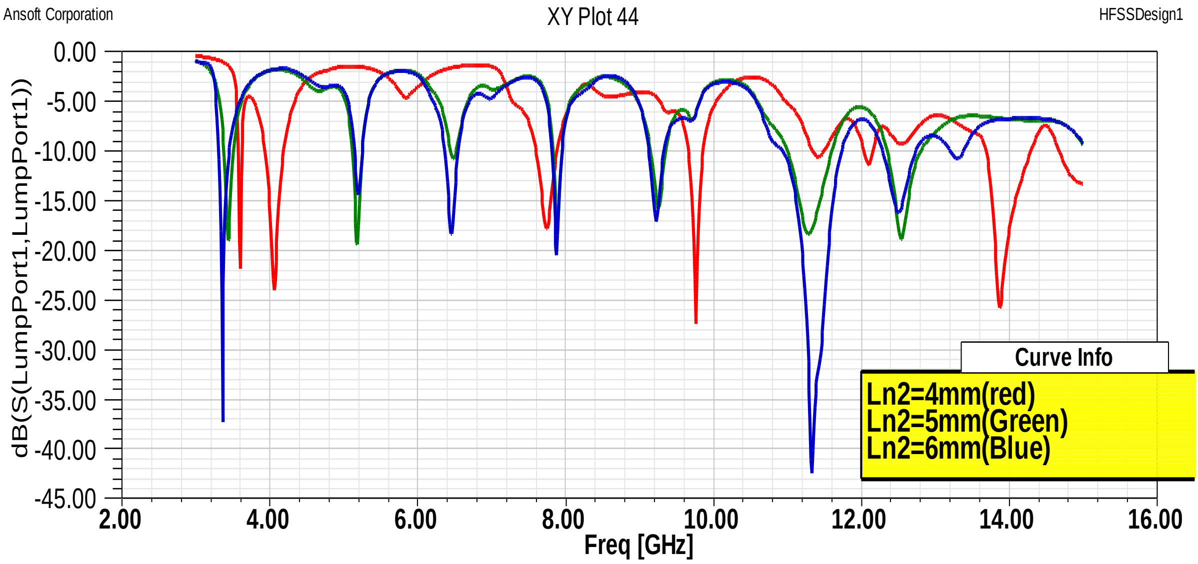

Figure 5 Return loss v/s frequency curve at different length of Lower notch

Table 5 Return loss (S11<-15dB) at different length of Lower notch

Length of Lower Notch	Frequency (GHz)(at S11<-15dB)	Return Loss (dB)
4mm	5.1	-25.68
	7.88	-19.50
	12.80	-18.93
5mm	3.44	-19.01
	5.19	-19.44
	7.90	-18.09
	9.25	-15.79
	11.28	-18.42
	12.56	-18.72
6mm	3.37	-37.34
	6.45	-18.34
	7.88	-20.47
	9.23	-17.15
	11.33	-42.44
	12.52	-16.09

From the figure 5 and table 5 it is clear that we get six peaks with good return loss when length of lower notch is 6 mm. Finally, by considering above analysis it is clear that the optimum results occurs when separation between two patches is 0.5mm, dielectric material used in substrate2 is RT Duroid, length of upper notch is 6mm and lower notch is 5mm.Now using above data design the optimum stacked antenna and get the following results. From the below figure it is clear that above stacked antenna design gives the resonant peaks at 3.6126 GHz (-21.95 dB), 4.0619GHz (-24.08dB), 7.7447 GHz (-17.83dB), 9.7628 GHz (-27.48dB), 13.8709 GHz (-25.81dB) so it works as a multiband antenna. Figure 6 shows return loss v/s frequency curve of optimum antenna design.

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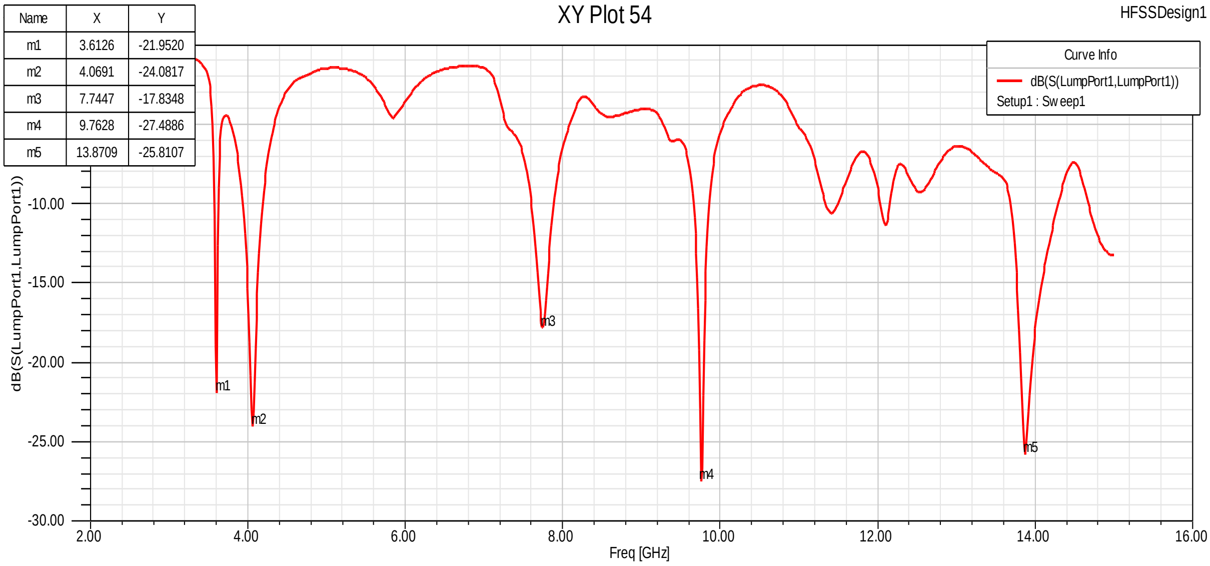

Fig. 6 Return loss v/s frequency curve for optimum stacked antenna

V. CONCLUSION

Detailed simulation analysis of a double layer single feed microstrip stacked antenna have been carried out using Finite element based software HFSS and get return loss (S11<-15dB) at frequencies 3.6126 GHz, 4.0691 GHz, 7.7447 GHz, 9.7626 GHz and 13.8709 GHz. Thus this antenna can be used as a multiband antenna and it can be used for mobile communication.

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