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Double slot coupled microstrip antenna

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***Abstract*: To improve the radiation performance a Double slot coupled microstrip antenna has been proposed .The proposed antenna is based on the adjustment of the phase distribution in such a way that the phases should be added in one direction and cancelled out in the other direction. In upper half plane it radiates using stacked patch elements and the radiation of the slots are added and in the lower half plane the back radiation of the slots are cancelled with the front lobe of the side patch plates placed on the same side of feedline. Thus it increases the front radiation and reduces the back radiation .The Front/Back ratio reported ranging from 27 to 33 dB using different stub length of the feedline of proposed antenna.**

Key words: **—Front–back radiation ratio, microstrip antennas, aperture coupling.**

I. INTRODUCTION

Microstrip slot antenna [1] is very small in size and lightweight at microwave and millimeter frequencies but it has the main disadvantage of back radiation which limits its use in the field of communication. This back lobe is undesired because it increases specific absorption ratio (SAR) [2] for the mobile users. It increases the interference to the neighbored cell as well as, increases the power loss. To reduce the back lobe of microstrip slot antenna, Aperture coupled microstrip antenna was introduced in 1985 by D.M.Pozar [3]

Aperture coupled microstrip antenna couples patch to the feedline through a slot. It is an indirect method thus it has many advantages over microstrip slot antenna.

A simple structure of aperture coupled microstrip antenna [4] gives F/B ratio ranging from 10 to 15 dB. A lot of work has been done by different authors to improve the F/B ratio as well as bandwidth.

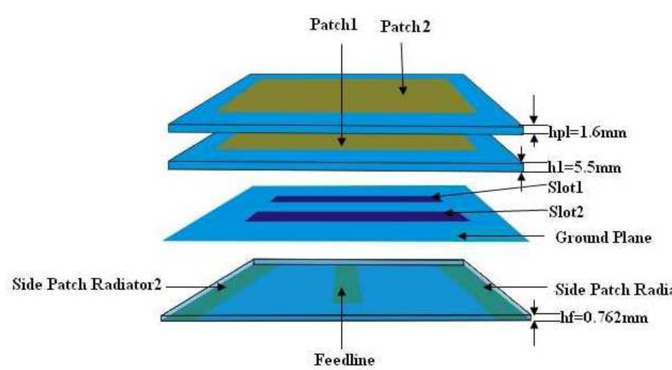
Firstly, reflector plane was used below the antenna to reduce back lobe [5]-[6].It has improved F/B ratio from 13 db to 15dB but it requires a supporting substrate with a minimum thickness of quarter wavelength, which increases the volume and leads to a complex fabrication process. In addition it supports parallel plate modes, which propagate electromagnetic waves bounded by the region between the metal plane and the ground plane and diffracted at the edges of the finite ground plane .As a result; it produces other undesired parasitic radiations.

Secondly, a technique was introduced using cavity at the back of slot to suppress the back radiation [7]-[8] .Although it reduces the back lobe but it excites higher order modes. This degrades the antenna performance and increases the volume.

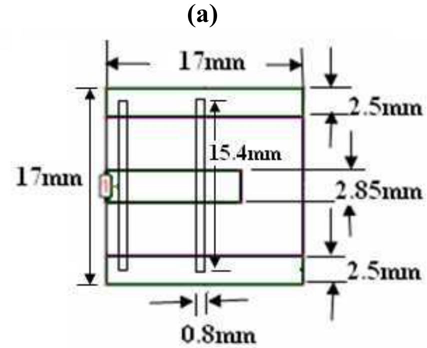
Thirdly, the technique used the movement of the slots on the feedline while the patches are placed at the same side instead of opposite side [9].This technique has only two layers which minimizes its size. It is observed that by the above modifications the F/B ratio can be achieved between 20 to 25 dB.

To solve the mentioned problems and to further increase the F/B ratio a new technique is proposed here which reduces the back lobe without the use of reflector or cavity and also it reduces other parasitic distortions. It is the technique which increases the F/B ratio up to 33 dB. The proposed design is based on the basic aperture coupled microstrip antenna. It is very similar to conventional aperture coupled microstrip antenna the only difference is to cut parallel slots in an infinite ground plane and to place two side patch plates on the same side of feedline. It also allows very easy adjustment of impedance matching.

II. ANTENNA STRUCTURE AND DESIGN



(a)



(b)

Figure1: Double slot coupled microstrip antenna
a) Front view b) Side view

Fig. 1 shows the cell structure of the proposed design, which is in x-y plane. It has three resonators one is slot and the other two are the patches. Two parallel slots are etched on a dielectric substrate of thickness h_f and relative permittivity of εr_f and are fed by only one microstrip feed line. Substrate for microstrip feedline is chosen RT/Duroid 5880[10].Microstrip feedline is printed on the other side of the ground plane and located at the centre of the each slot. Each slot is coupled to patch, which is printed on the opposite side of the feedline. The layer between the slot and the patch is air, which limits the effect of surface waves and enables easy adjustment of the slot-to-patch distance. The air would be replaced by honeycomb or foam to provide the structural rigidity needed for a space borne antenna. The dielectric substrate between the two patches is again RT/Duroid 5880.

Patch length determines the resonant frequency of the patch. Dimension of ground plane must be chosen large enough to replace entirely the infinite ground plane.

To obtain maximum magnetic coupling the position of the patch is placed at the center of the antenna. The feed line is at the right angle to the center of slot. Two slots are etched parallel to each other. Slot length affects the coupling level and back radiation. It should be in the range of 0.2 λ_0 to 0.3 λ_0.

The special designing of the two side patch plates are provided here to reduce the back lobe. In contrast to the combination of a slot and a microstrip patch in conventional aperture coupled microstrip antennas, the patches here are employed to reduce the radiation into the half-space that they occupy and increase the radiation in the other half-space. Therefore, the slot antenna can produce radiation patterns with a high front–back ratio. The above objective is achieved by optimizing standing wave distributions of the aperture electric field in the slot through the adjustment of the position of the patches along the axis of the slot.

The main objective of this proposed design is to increase F/B ratio of the antenna. It is observed that the movement of the two parallel slots on the patch plates and the adjustment of the stub length can reduce the back lobe.

The relative parameters of the proposed design: (for the frequency range 4.91 to 5.3 GHz)

TABLE I
RELATIVE PARAMETERS OF THE PROPOSED DESIGN

Antenna element	*Dimensions/parameters*
Patch 2 (Substrate)	Thickness H_2=1.6mm Relative Dielectric Constant εr_2 = 2.2, Loss Tangent $\tan\delta_2$ = 0.0009
Patch 2	Length L_P =17 mm, Width W_P = 17 mm
Patch 1 (Air)	Thickness H_1 = 5.5.mm. Relative Dielectric Constant εr_1= 1 Loss Tangent $\tan\delta_1$ = 0
Patch1	Length L_P =17 mm, Width W_P = 17 mm
Aperture	Length L_a = 15.4mm, Width W_a = 0.8 mm
Feed Substrate (RT/Duroid 5880	Thickness H_f = 0.762 mm. Relative Dielectric Constant εr_f = 2.2, Loss Tangent $\tan\delta_f$ = 0.0009
Microstrip Feed Line	Width W_f = 2.85 mm, ***Case1:*** Length L_{f1} = 11.95 mm, Stub Length L_{s1} =3.425 mm ***Case2:*** Length L_{f2} = 12.35 mm, Stub Length L_{s2} =3.825 mm ***Case3:*** Length L_{f3} = 12.55 mm, Stub Length L_{s3} =4.025 mm ***Case4:*** Length L_{f4} = 12.75 mm, Stub Length L_{s4} =4.225 mm

III. SIMULATION AND RESULT

The analysis is based on the solution of the integral equations solved in spectral domain using full wave moment method [11]-[13].

The main objective is to find out the best possible radiation field with the parallel slots and the two side patch plates used. The simulation tool used here IE3D software [14]. For obtaining the above goal, the cell structure consists of the two parallel slots on the ground plane, two side patch plates, two stacked patches and single microstrip feedline is considered.

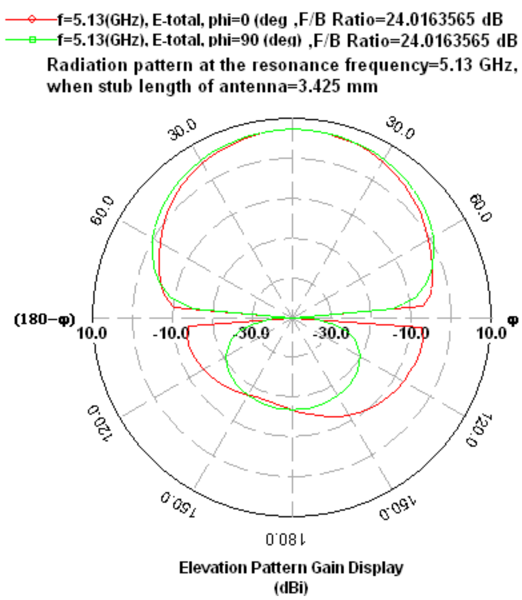
Spacing of the slots and stub length of the feedline are the two parameters which affects the performance. In this paper the stub length is taken as variables to find out best possible F/B ratio. For different values of the stub lengths, the radiation performance plotted and F/B ratio is calculated. It is concluded that F/B ratio can be achieved up to 33 dB.

The antenna operates from 4.91 GHz to 5.3 GHz frequency range. For the proposed design the two parameters affect the F/B ratio very much. First the spacing between the slots and second the stub length of the feed line. The width of the microstrip feed line is set for 50 Ω characteristic impedance, and the tuning length is chosen to be less than 5mm for impedance matching.

The influence of the stub length variation on the radiation pattern:

Four different structures are described, in which the stub length varies from 3.425 mm to 4.225mm. The spacing between the slots is 7 mm. For the four different stub lengths of the feed line F/B ratio of the antenna varies between 27dB to 33db. Figures 2, 3, 4 and 5 shows the radiation patterns for F/B ratio 27 dB, 30 dB, 32 dB and 33 dB. The combination of the two parallel slots and the two parallel side patch plates with the varying stub length are used to increase the radiation in one half space while to reduce in the other half space .The working of the proposed antenna is based on the adjustment of the SWR distribution of the two parallel slots on the two side patch plates.

Case 1: Stub length=3.425mm



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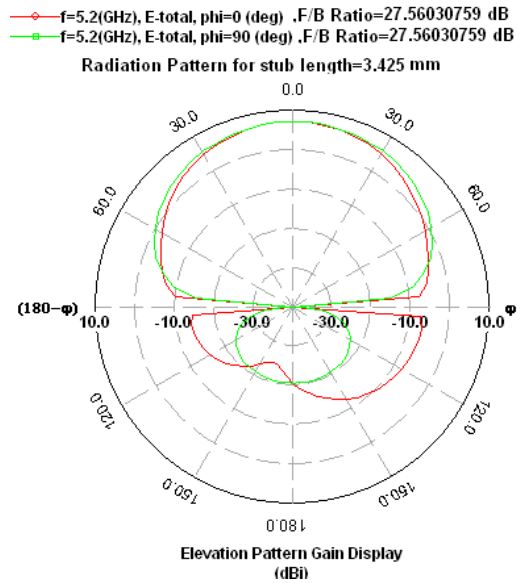

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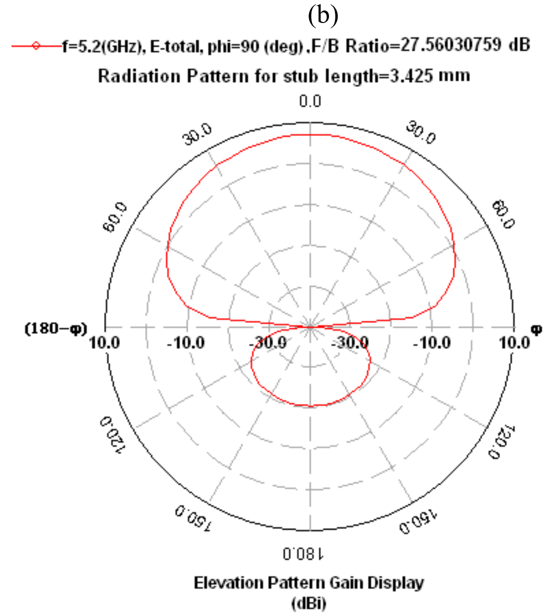
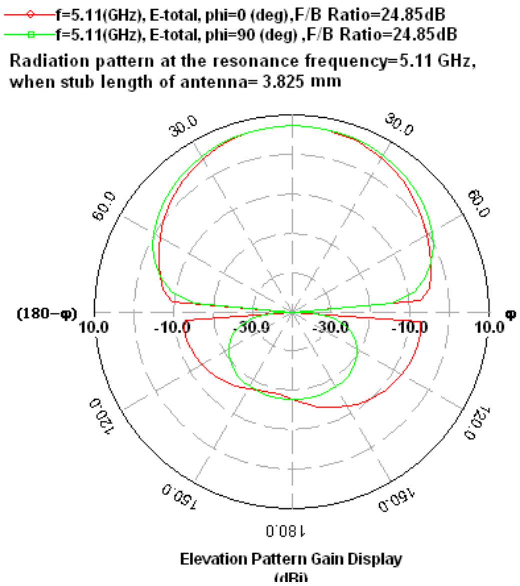


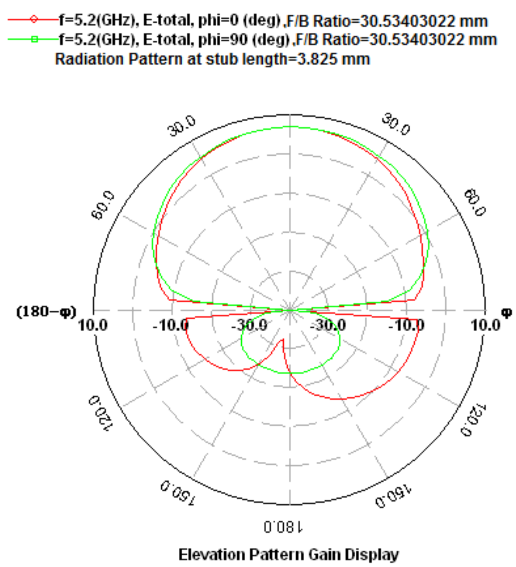
(c)

Figure2: Radiation patterns for Ls=3.425mm
(a)At resonance frequency=5.13 GHz and stub length=3.425 mm, for phi=0 and phi=90 (b) At frequency=5.2 GHz and stub length=3.425 mm, for phi=0 and phi=90(c) At frequency=5.2 GHz and stub length=3.425 mm, for phi-0 (deg).

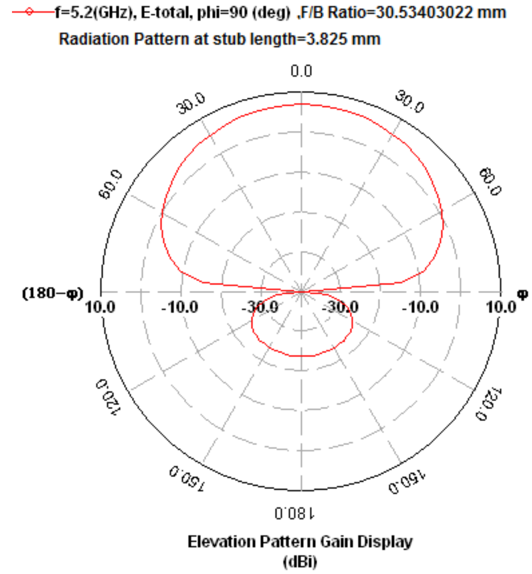
Case 2: Stub length=3.825mm



(d)



(e)



(f)

Figure 3: Radiation pattern for Ls=3.825mm
(d)At resonance frequency=5.11 GHz and stub length=3.825 mm, for phi=0 and phi=90 (e) At frequency=5.2 GHz and stub length=3.825 mm, for phi=0 and phi=90(f) At frequency=5.2 GHz and stub length=3.825 mm, for phi-0 (deg).

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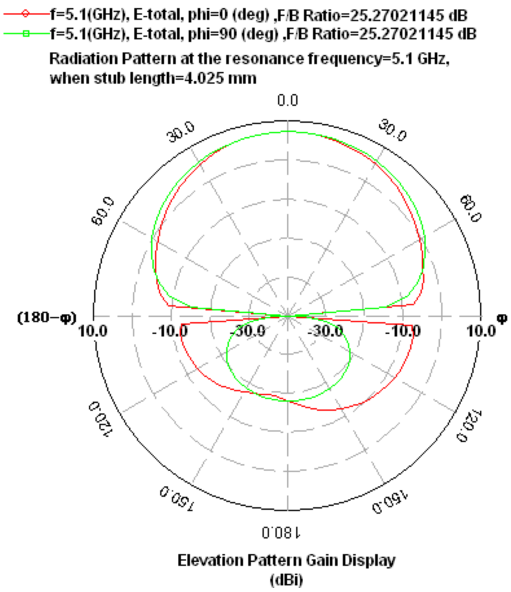
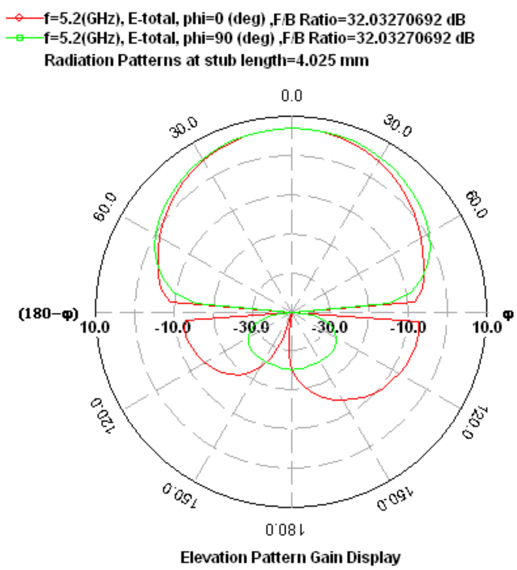
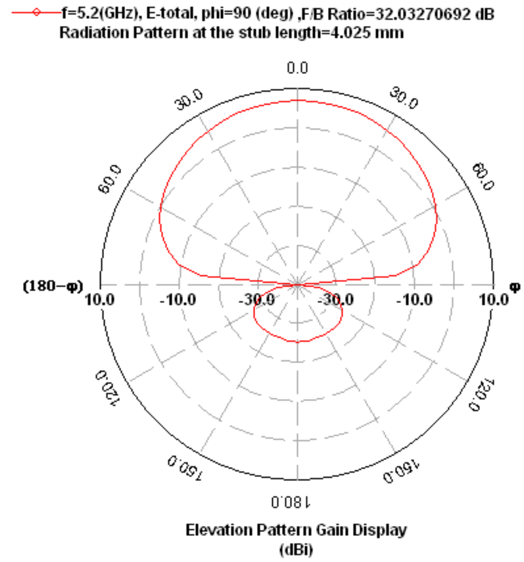
Case 3: Stub length=4.025 mm



(g)



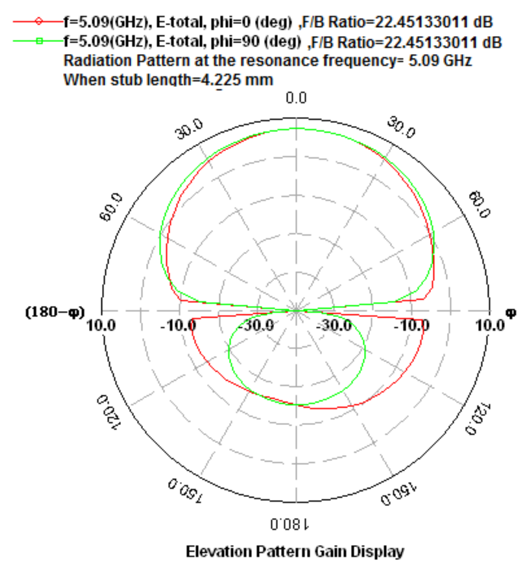
(h)



(i)

Figure 4: Radiation pattern for Ls=4.025mm
(g)At resonance frequency=5.1 GHz and stub length=4.025 mm, for phi=0 and phi=90 (h) At frequency=5.2 GHz and stub length=4.025 mm, for phi=0 and phi=90(i) At frequency=5.2 GHz and stub length=4.025 mm, for phi-0 (deg).

Case 4: Stub length=4.225 mm



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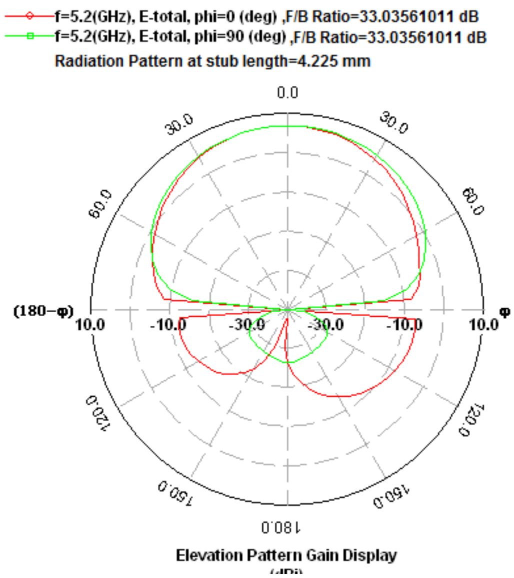
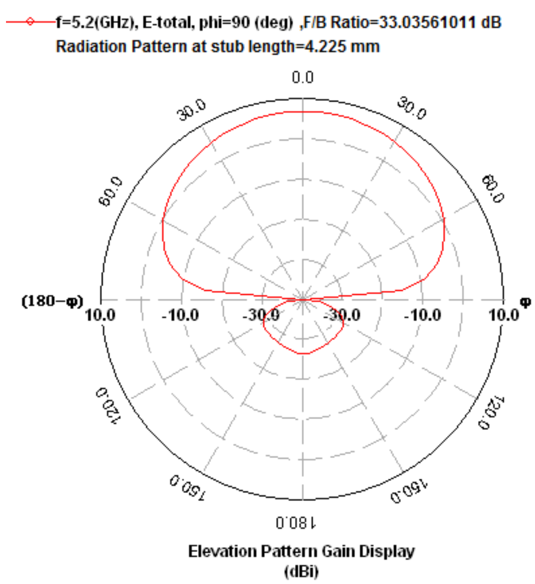


(k)



(l)

Figure 5: Radiation pattern for Ls=4.225mm

(j)At resonance frequency=5.09 GHz and stub length=4.225 mm, for phi=0 and phi=90 (k) At frequency=5.2 GHz and stub length=4.225 mm, for phi=0 and phi=90(l) At frequency=5.2 GHz and stub length=4.225 mm, for phi-0 (deg).

Comparison of F/B Ratios at different stub lengths:

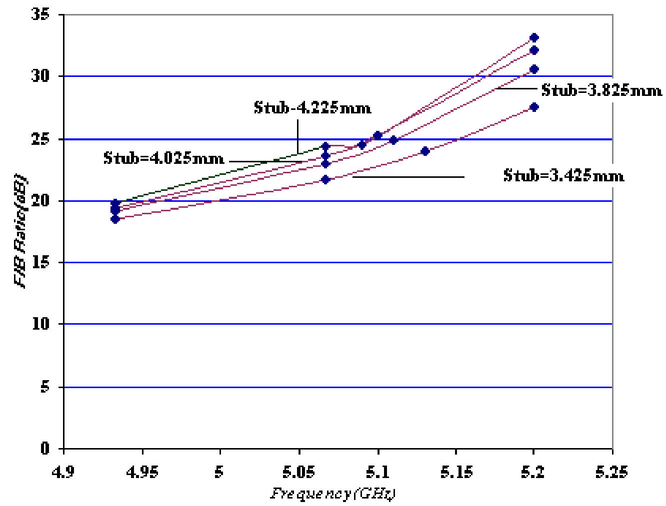


Figure 6: Plot between F/B ratios at different stub lengths versus frequency

The influence of the stub length variation on the return loss:

Sr.no.	Frequency(GHz)	Stub length(mm)	Return loss(dB)
1	5.09	4.225	-27.15
2	5.1	4.025	-42.74
3	5.11	3.825	-28.67
4	5.13	3.425	-18.67

The influence of variation of the stub lengths on the return loss is shown in Fig.7.When the stub length is 4.025mm, the antenna resonates at 5.1 GHz and corresponding return loss is -42.74 dB. This is the minimum return loss. Bandwidth achieved for the proposed structure is between 6-7%.

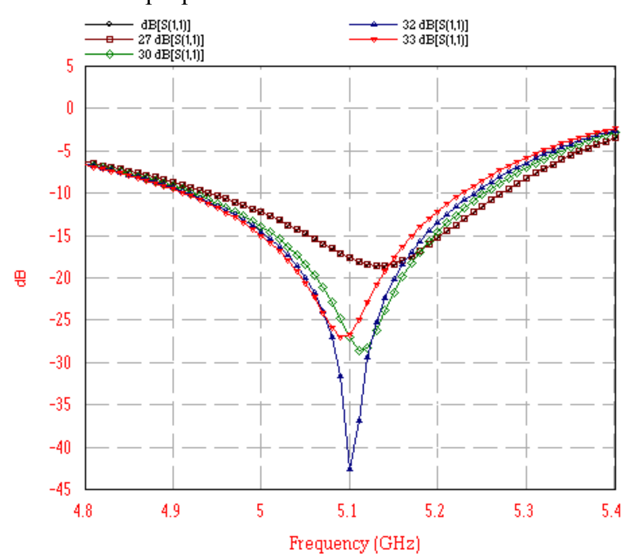


Figure7: Return loss of the proposed antenna.

Brown –Return loss at stub length=3.425 mm
Green- Return loss at stub length=3.825 mm
Blue- Return loss at stub length=4.025 mm.
Red- Return loss at stub length=4.225 mm

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CONCLUSION

It is concluded that if two parallel slots are cut in infinite ground plane and two side patch plates are placed at the same side of feedline in an aperture coupled microstrip antenna, F/B ratio achieved between the frequencies 4.91 to 5.3 GHz is nearly 33 dB. The recorded bandwidth 6-7%.Further work may be done to improve the bandwidth.

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