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SLOT LOADED MICROSTRIP PATCH ANTENNA FOR DUAL FREQUENCY OPERATION IN S AND C- BAND

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ABSTRACT

In recent years, several methods for obtaining dual band, multiband and/or wideband antenna characteristics have been developed for different communication system and often require dual frequency patch antennas in order to avoid the use of two different antennas. A suitable dual frequency antenna should have resembling characteristics in both operating forms (transmitting and receiving) in terms of return loss, radiation properties and impedance matching. In continuation of investigation carried out by different researchers and from various open literature survey, the proposed antenna is intended for dual frequency behavior for practical utility in S and C band communication. The paper presents a slot loaded rectangular patch antenna in S and C-band. The antenna is designed on FR4 substrate material with dielectric constant $\varepsilon_r = 4.8$ with coaxial feeding. Two rectangular shaped slots are loaded on the patch in vertical direction and continuously changing the position of the slots along the X- axis to obtain best Return Loss (dB) value. The dimension of the patch is (18 x 15 x 1.5) mm, which is kept constant during all investigations. Loading the slots on the patch with variation of position and dimension has been carried out using high frequency simulation software CST Microwave Studio. The purpose of loading slots on the basic patch is to investigate frequency variations which result in dual frequency behavior. From the simulated values a maximum Return Loss value of -68.341 dB at frequency 5.705 GHz and – 24.80 dB at frequency 4.045 GHz is observed i.e., the antenna showed dual frequency behavior due to loading of slots on the patch. The measured frequency vs. RL plot also indicates dual frequency behavior which resonates at frequencies 3.99 GHz with RL value of -16.63 dB and 5.775 GHz with RL value of - 23.13dB. Measured and simulated values are in good agreement for the investigation carried out.

Keywords: Microstrip Patch, Slot Loaded, Dual Frequency, S and C-Band

1. INTRODUCTION

In this study microstrip patch antenna with various designs is carried out. Patch antenna with variations in structure by introduction of slots of different shapes on the surface is carried out to investigate the shift in resonant frequency/frequencies for applications such as dual frequency operations. Two vertically placed rectangular slots gave the best results with maximum return loss and also dual frequency responses have been found with acceptable VSWR and directive gain with uniform radiation patterns in both lower and upper frequencies. Also tuning frequency frequencies within the same band is investigated. Simulations of the basic rectangular patch antenna and structural modifications of the basic patch using high frequency software CST microwave studio are carried out. The overall dimension of the patch is kept the same to avoid extra space and modifications are carried out within the dimension of the original patch. The results obtained with these simulated values are summarized in the preceding section.

2. LITERATURE REVIEW

Slit and slot loaded antennas are being used widely, especially to enhance its bandwidth. Different designs have been reported by various researchers. Some of the literature relating to the present investigation is mentioned: Garg et al. (2018) designed a miniaturized circular patch antenna with split triangular slit in the radiating patch. The radius of the patch is 23 mm and the ground plane size is 50 mm X 50 mm. The simulation is carried out using CST Microwave studio software. The results show that the proposed antenna resonates at 5.69 GHz frequency with a high return loss of -67.63 dB, and with a wide bandwidth of 575 MHz. Kalyan et al. (2018) designed a simple rectangular patch with small and narrow X shape slots on patch was used and observed wide bandwidth of -35.48 dB with 2.80 GHz (8.9-11.30 GHz) impedance bandwidth of 28.25% was obtained.

Minhas et al. (2017) proposed an antenna with introduction of C shape slots and results showed the antenna resonates at 3.2 GHz and 5.4 GHz with return loss -46.15dB and -24.31 dB respectively. N. Rajasekhar et. al. (2017) proposed two strip fed pentagonal boundary patch antennas, one with V-shaped slits and another with V-shaped slits and a pentagon slot. Both the antennas exhibit wideband characteristics covering wide range of frequencies from 2-6 GHz. Inclusion of pentagon slot gives more bandwidth and good impedance match with an enhanced gain of 4.66dBi.

Arulmurugan, et al. (2021), reported a compact wearable microstrip patch antenna at ISM 2.4 GHz, printed on semi flexible ROGER 3003 substrate. Loaded slits with shorting pins are proposed to reduce the size of the patch and enhance the bandwidth of the antenna. The proposed antenna size is reduced by 20% (0.376 λo x 0.429 λo x 0.0248 λo) when compared with the conventional patch antenna. This antenna is suitable for wireless body area network (WBAN) applications and ISM Bands.

Bordoloi et al. (2019) Investigated a Triangular Cut Modified Rectangular Patch Antenna in S and C-band for Wireless Applications. Dual frequency operation with triangular cut at edges has been reported. Navya and John (2020) proposed rectangular microstrip patch antenna array. The antenna array designed is cost effective and easily available FR4 substrate material of relative permittivity 4.4, thickness 1.6, and impedance 50 ohms. This antenna is simulated using HFSS software. The antenna parameters such as return loss, VSWR, gain, and radiation pattern are studied, which can be used for X- band applications. Bairappaka et al. (2021), A compact microstrip line fed the dual band circularly polarized pentagon shaped microstrip antenna is designed with a pair of rectangular shaped slits and slots. The antenna resonates at 2.5GHz and 3.5GHz with good impedance matching, AR value, gain and radiation pattern. The achieved antenna parameters qualify the structure to be used in WLAN and WiMAX applications.

3. DESIGN OF SIMPLE PATCH

A simple rectangular microstrip patch antenna is designed using high frequency simulation software CST Microwave Studio which resonates at S and C- bands. The dimensions of the simple rectangular patch antenna have been put in Table 1 and Figure 2. shows the geometry of the simple patch.

Table 1: Patch Antenna specification

Antenna parameters	Values in mm
Length of ground plane (Lg)	34 mm
Width of ground plane(Wg)	40 mm
Length of Rectangular Patch (Lp)	15 mm
Width of Rectangular Patch(Wp)	18 mm
Thickness of Substrate	1.5 mm
Dielectric constant of Substrate	4.8

(i) (ii)

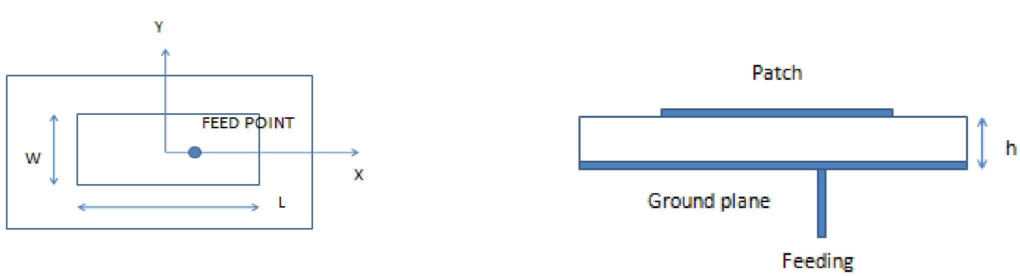


Figure 1: (i) Top and (ii) side view of simple patch antenna with feed point

A simple Microstrip Patch antenna (without modification) is initially designed which covers two bands i.e. S and C band for optimized value i.e. best matching in terms of S11 parameter (Return Loss value). The basic patch is modified, keeping overall dimension of it same, by introducing of double slot to investigate its performance in terms of feed point relocation, Return Loss values.

Two sets of another frequency at 3.48 GHz and 4.19 GHz have also been observed, one below -15 dB and another below -20 dB. This result from the designed structure leads to behave the antenna as a multi frequency antenna. RL plot versus frequency for the feed point moving from center (0 mm) towards edges (+ve, -ve X axis, -6 mm, +6 mm) is shown in figure 2 and tabulated in table 2.

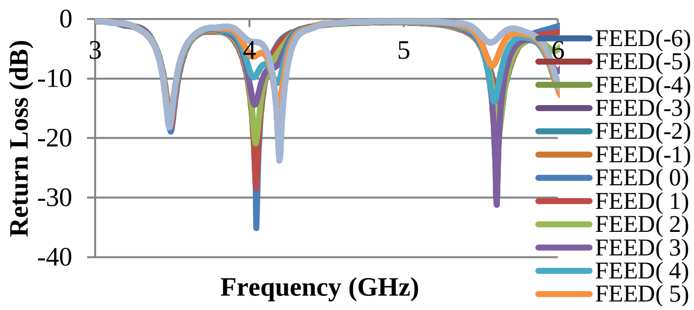


Figure 2: Frequency (GHz) Vs. Return Loss (dB) of simple patch antenna.

Table 2: Return Loss at different feeding points for simple patch antenna and its respective frequency.

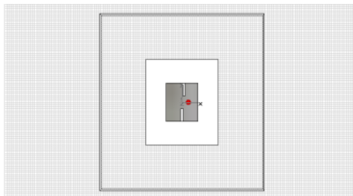
Port Location (in mm)	Frequency 1 (GHz)	Return Loss (dB)	Frequency 2 (GHz)	Return Loss (dB)
0	**4.045**	**-35.104**	5.625	-13.52
1	4.045	-28.43	5.62	-14.59
2	4.04	-20.90	5.625	-19.08
3	**4.035**	**-14.43**	**5.605**	**-31.21**
4	4.18	-10.78	5.59	-13.90
5	4.19	-15.25	6.00	-12.92
6	4.195	-3.80	6.00	-11.80
-1	4.045	-28.43	5.62	-14.59
-2	4.04	-20.90	5.615	-19.08
-3	4.04	-14.43	5.605	-31.21
-4	4.18	-10.78	5.59	-13.90
-5	4.19	-15.22	6.00	-12.90
-6	4.195	-23.78	6.00	-11.80

From figure 2 and table 2 it is found that maximum return loss (RL) is of -35.104 dB at 4.045 GHz with feed point location at the center **(0, 0 mm)** and another return loss is equal to -31.21 dB at frequency 5.605 GHz is obtained with the feed point location at **3 mm** from the center toward radiating edge, (+ve direction from center)

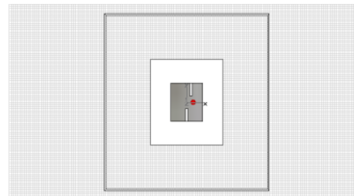
4. Modification of Patch

Modification of this basic structure has been done by introducing slots on the patch in such a way that overall dimension and feed point locations are unaltered (feed point at 3mm)., and it has been carried out by introducing two slots with slot length of 6 mm and width 1 mm placing vertically from both the radiating edges opposite to each other. One slot is above the other slot as shown in the structures as given below (Figure3 and figure 9).

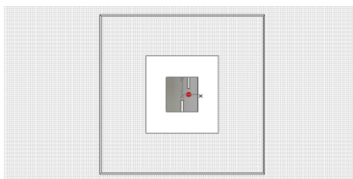
Shifting the position of the upper and lower slot in left and right along the X axis towards the radiating edge, variation of Return Loss (dB) with Frequency (GHz) has been observed. First, the position of the upper slot changes by 1 mm in step toward the left and then right keeping the lower slot fixed at the center. Further shifting the slot is done by along X axis (+ve, -ve direction) keeping the position of upper slot at the center and the performance of the return loss has been observed. From the simulation, it has been found that the slots position one at center and the other at 6 mm away from center, the maximum return loss with dual frequency responses have been found and shown in figure 4, figure 5 and table 3. Table 4 as shown below.



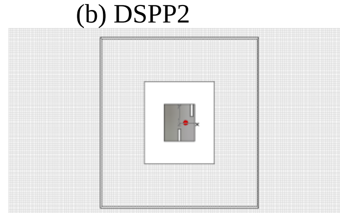
(a) DSPP1



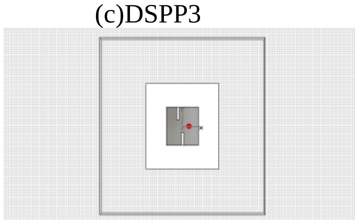
(b) DSPP2



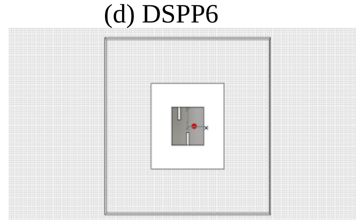
(c)DSPP3



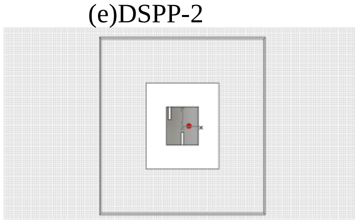
(d) DSPP6



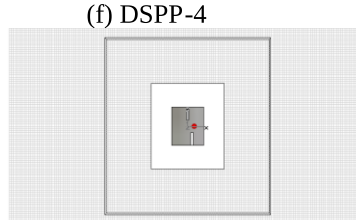
(e)DSPP-2



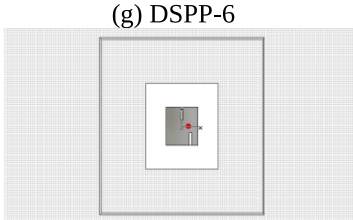
(f) DSPP-4



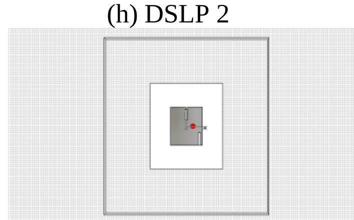
(g) DSPP-6



(h) DSLP 2



(i) DSLP 4



(j) DSLP6

Figure 3: Structure of slit loaded Patch with different slot position (a)-(j)

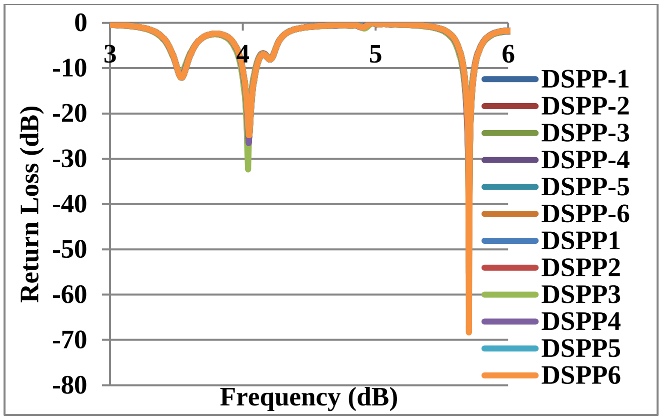


Figure 4: Frequency (GHz) Versus Return Loss (dB) for different position of upper slot

Notation DSPP1 to DSPP6 (for shifting upper slot towards +ve, -ve direction) and DSLP (for lower slot position)is used to represent new slot position and number 0 to 6 represents slot position from center (0,0) to 6 mm towards the radiating edge along +ve and –ve X axis direction. While shifting one slot another slot is being fixed at center. Values are summarized in table 3 (upper slot position) and table 4 (lower slot position)

Table 3: Frequency (GHz) Versus Return Loss (dB) value for different position of the upper slot

Upper Slot Position along X axis	Frequency-1 (GHz)	Return Loss (dB)	Frequency-2 (GHz)	Return Loss (dB)
At center	4.045	-24.69	5.7	-55.726
1 mm	4.04	-26.13	5.7	-31.116
2 mm	4.04	-28.693	5.7	-25.366
3mm	4.04	-32.386	5.7	-21.957
4 mm	4.045	-26.548	5.7	-31.876
5 mm	4.045	-24.753	5.7	-55.346
6 mm	**4.045**	**-24.80**	**5.7**	**-68.341**
-1 mm	4.045	-25.122	5.705	-50.00
-2 mm	4.045	**-24.650**	5.705	**-37.056**
-3mm	4.045	**-25.126**	5.705	**-54.105**
-4 mm	4.045	-24.492	5.705	-38.657
-5 mm	4.045	-24.572	5.705	-52.767
-6 mm	4.045	24.629	5.705	-55.261

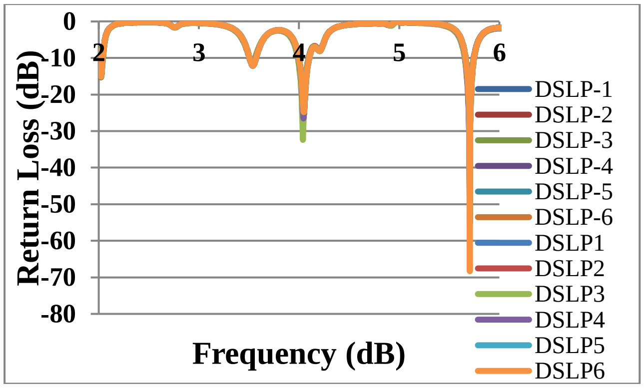


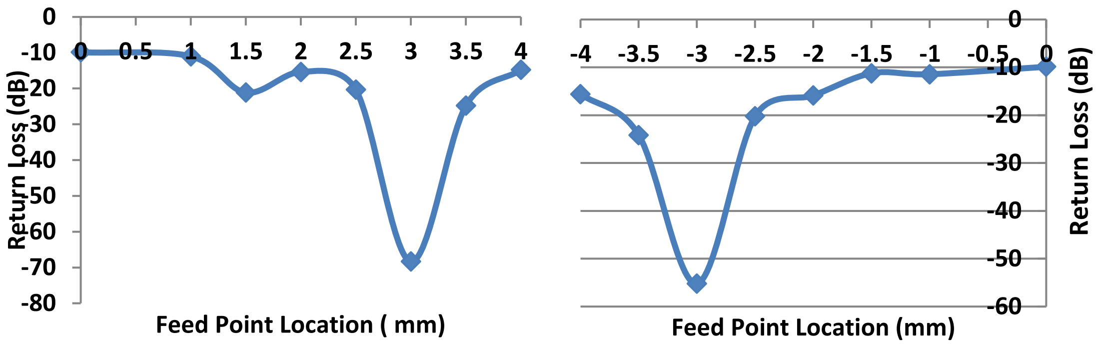
Figure 5: Frequency (GHz) Versus Return Loss (dB) for different position of lower slot

Similarly, in figure 5, DSLP1, DSLP2, DLSP3 etc. indicates the changing the position of the lower slot by 1mm in step, along the X axis, keeping the upper slot at the center (0,0). The geomatrical diagram of the propose antenna is shown iin figure 9 (Structure DSPP6).

Table 4: Frequency (GHz) Vs. Return Loss for various position of the lower slot				
Lower Slot Position along X axis	Frequency-1 (GHz)	Return Loss-1 (dB)	Frequency-2 (GHz)	Return Loss-2 (dB)
At center	4.04	-25.07	5.7	-42.98
1 mm	4.04	-26.44	5.7	-31.116
2 mm	4.04	-27.68	5.7	-25.366
3mm	4.04	-30.15	5.7	-21.957
4 mm	4.04	-28.63	5.705	-31.876
5 mm	4.04	-25.74	5.705	-55.347
6 mm	**4.04**	**-25.81**	**5.705**	**-68.341**
-1 mm	4.045	-25.122	5.7	-50
-2 mm	4.045	**-24.650**	5.7	**-37.058**
-3mm	4.045	**-25.126**	5.7	**-54.105**
-4 mm	4.045	-24.492	5.7	-38.647
-5 mm	4.045	-24.964	5.7	-52.767
-6 mm	4.045	-24.629	5.7	-55.260

From the above graphs 4, and 5 and tables 3 and 4 it is clear that slot position at 6 mm from center towards the radiating edge along the X axis, showed best result with maximum return loss (-68.341 dB) at the higher frequency (at 5.705 GHz) with dual frequency response for these slots loaded structures shown in above table 3and table 4). In continuation, another experiment has been carried out by changing the feed point location along the X axis by 0.5 mm in step to investigate any changes of frequency response and result has been observed and tabulated in table 5.

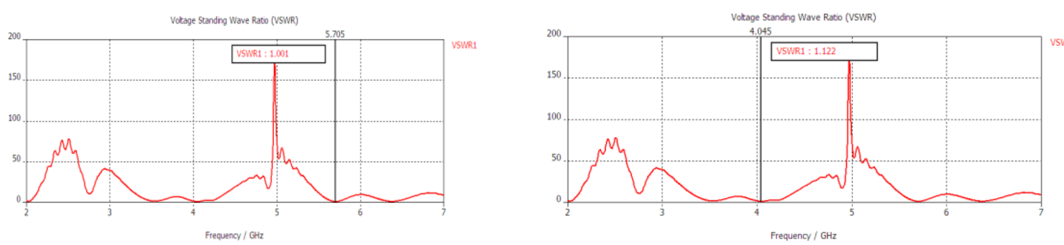
Table 5: Different feeding point location for the structures (DSPP6)				
Feed point location (in mm)	Frequency 1 (GHz)	Return Loss 1 (dB)	Frequency 2 (GHz)	Return Loss 2 (dB)
0	4.04	-16.91	5.705	-9.879
1	4.04	-18.61	5.7	-11.00
1.5	4.045	-21.14	5.705	-13
2	4.045	-25.58	5.705	-15.36
2.5	4.045	-35.88	5.705	-20.36
3	**4.045**	**-24.80**	**5.705**	**-68.341**
3.5	4.035	-18.86	5.695	-24.754
4	4.03	-14.04	5.68	-14.82
-1	4.045	-18.80	5.705	-11.44
-1.5	4.045	-18.79	5.705	-11.238
-2	4.045	-25.50	5.705	-15.88
-2.5	4.045	-36.01	5.705	-20.21
-3	4.045	-24.631	5.705	-55.198
-3.5	4.04	-19.238	5.695	-24.155
-4	4.04	-14.63	5.685	-15.58



(i) (ii)

Figure 6: Return Loss (dB) at different Feeding point Location.

In the figure 6 (i) and 6 (ii) have shown the return loss for different feeding point location, it is found that feeding point location at 3 mm from center towards the radiating edge along the X axis gave maximum return loss (-68.341 dB) at the frequency is equal to 5.705 GHz. The values of VSWR are equal to 1.001 is observed at frequency 5.705 GHz and 1.122 is found at frequency 4.045 GHz. The plot of VSWR at frequencies 5.705 GHz and 4.045 GHz are plotted in figure 7(i) and figure 7 (ii) as shown below. VSWR for the antenna along with radiation plot have also been measured for confirmation of the matching of feed location and variation of pattern (XZ and YZ plane, H- and E- field pattern).



(i) (ii)

Figure 7: Plot of VSWR at frequency 4.045 GHz and 5.705 GHz respectively

Radiation Pattern: The radiation pattern at frequency 5.705 GHz and 4.045 GHz are shown below in figure 8 (i) and figure 8 (ii) respectively. This plot shows a uniform pattern with directive gain 7.77 dBi and 7.82 dBi. respectively as shown below-

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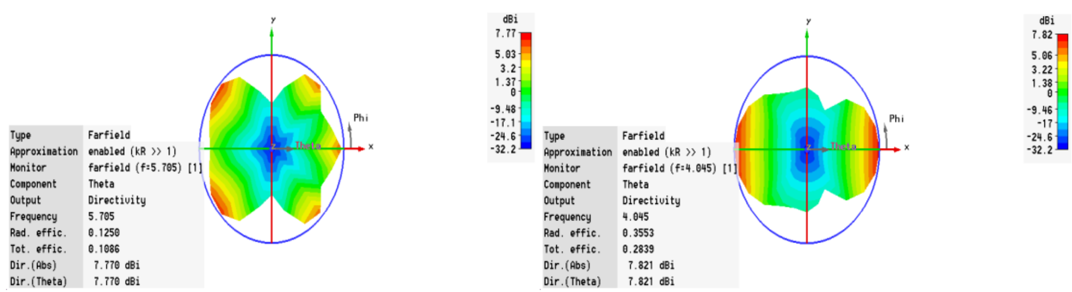

(i) (ii)

Figure 8: Radiation pattern (i), (ii) at frequency 5.705 GHz and 4.045 GHz respectively

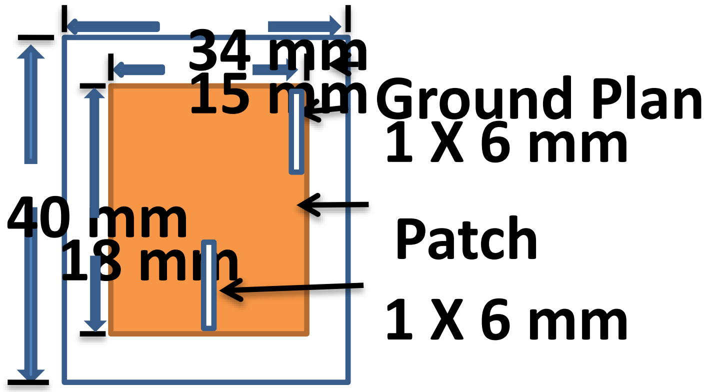

Figure 9: Geometrical diagram of the proposed antenna (structure DSPP 6)

Comparison of Slot Loaded Patch Antenna, Simulated versus Measured (fabricated) Results:
The modified patch (of structure DSPP 6) has been fabricated based on simulation results and measurement is carried out using Vector Network Analyzer (VNA). The performance of the antenna is studied and noted. The fabricated antenna is shown below in Figure 10 and measured value of Return Loss performance is depicted in Figure 12

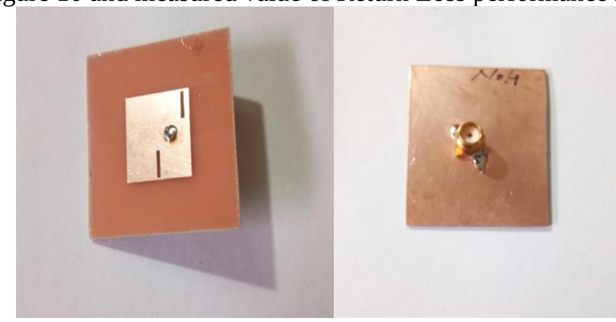

Figure 10: Front view and Back view of the fabricated Patch

Figure 11: Measurements carried out in VNA

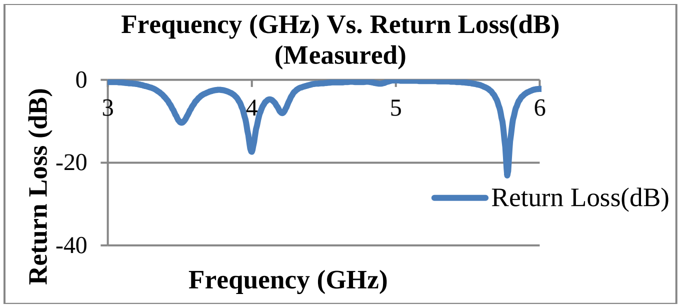

Figure 12: Frequency (GHz) versus Return Loss (dB) of measured antenna (in VNA)

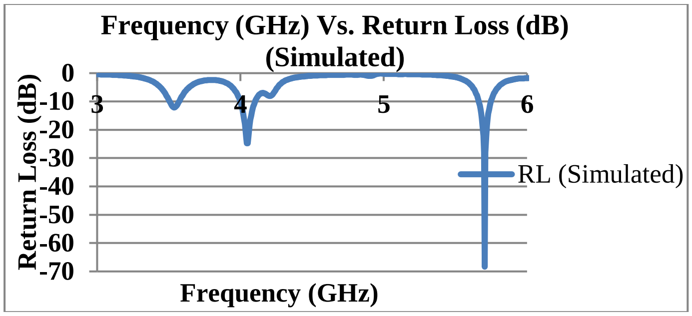

Figure 13: Frequency (GHz) versus Return loss (dB), simulated result

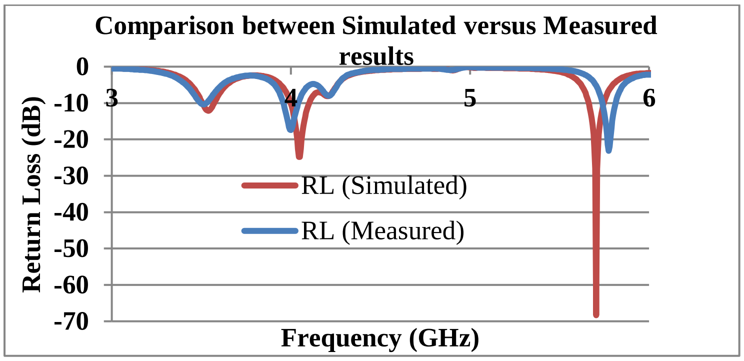

Figure 14: Comparison of Frequency (GHz) Vs. Return loss (dB) of fabricated antenna with simulated result

Figure 12 and Figure 13 show the frequency versus return loss of the fabricated antenna and simulated results for the antenna structure (DSPP 6) respectively, these results are compared and plotted in Figure 14

The measured frequency vs. RL plot indicates that the antenna resonates at two frequencies 3.99 GHz with RL value of -16.63 dB and 5.775 GHz with RL value of - 23.13dB. There is slight shift in resonant frequency in both the frequencies as compared to simulated values (Table 6)

Table 6: Comparison of the Simulated versus Measured results

Sloted Antenna	Simulated Result		Measured Result	
Operated frequency (GHz)	4.045	5.705	3.99	5.775
Return Loss (dB)	-24.80	-68.341	-16.63	-23.13

5. CONCLUSION

From the results, it has been observed that the feeding point location at 3 mm with matching VSWR; the antenna behaves as dual frequency antenna. Measured value and simulation are in good agreement for the fabricated antenna (Figure 10) although there is slight shift in resonate frequencies (both lower and upper frequencies, Table 6). The radiation plots also indicate a broadside radiation pattern having directivity of 7.77 dBi and 7.82 dBi respectively as shown in Figure 8(i) and Figure 8(ii). The position of the double slots has a significant role in controlling the tuning range of frequencies within the band (S- and C- band). The fabricated antenna with more controlling of the slot position, dimension, if placed according to need of applications, can be a good choice for applications within S- and C- band.

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