

S.No	Name	Value(mm)	Description
1	C	1e-12	Varactor Diode
2	Fd-L	5.428	DC Feed Length
3	Fd-W	0.3	DC Feed Width
4	Fd-y	5	DC Feed Position
5	r	5.49	Patch Radius
6	t	0.762	Substrate Thickness
7	Tm	0.01	PEC
8	Tw	1.83	50 ohm line
9	Txl	5.428	Transformer length
10	Txw	0.45	Transformer Width
11	Var X	0.01	Varactor X position
12	Var Y	0.01	Varactor Y position
13	X	25	Substrate X
14	Y	25	Substrate Y

Table I: Component list used in proposed antenna

Since the bias network is attached in the ground side of the patch itself, the biasing network must also be included in the electromagnetic simulations. Varactors are placed such that there is minimum disturbance of currents on the patch. The radiating edges of the patch have minimum current density. This was confirmed by EM simulation. The antenna will not tune if varactor are placed at the non-radiating edge hence varactor are placed in the radiating edge opposite to the feed line.

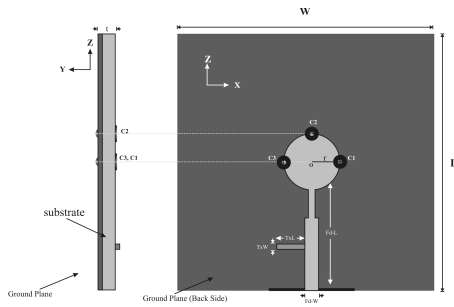


Figure 1: Side View and front View of Proposed Design

III. RESULT

To obtain computational results for the multiband antenna design, CST Microwave Studio (CST MWS) electromagnetic simulations were performed. The MWS method is based upon the explicit solution of Maxwell's equations in differential form in the time domain. The design was optimized using the CST optimizer which was a mat lab script. To optimize the antenna, 1200 iterations were performed altogether and 10 hours were used. From the computational results, optimized dimensions, return loss curve, both 2D and 3D far field radiation characteristics, animation of the Surface current distribution, Electromagnetic and Magnetic field flows of the antenna were obtained

Return loss

An antenna constructed on 0.762mm RT Duroid substrate with dimensions of $\lambda_d/2$ (λ_d is wavelength in the dielectric) had a VSWR of 1.41 when fed at the edge of circular patch by a 50 Ω microstrip line at X band, shown in Fig.1.

The simulated return loss were found -26dB at 8.5GHz with phase of 30 $^\circ$ and measured return loss was -26.6dB at 8.6GHz their graph are shown with simulated plot, measured plot and smith chart in fig. 2,3,4 respectively.

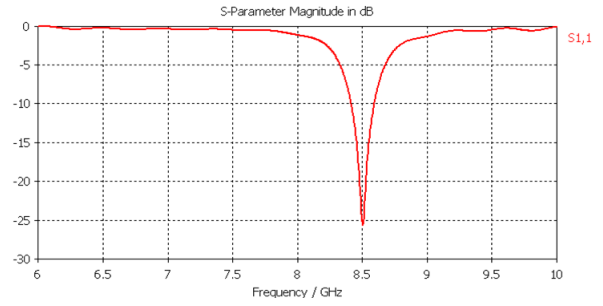


Figure 2: Simulated Tuned Circular antenna using varactor diode at no bias.

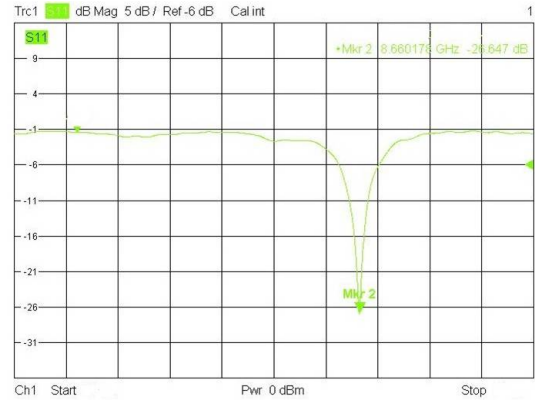


Figure 3: Diagram Showing Measured return loss graph

Where C is the capacitance of various varactors. Above is the S11 for different values of Capacitance.

SE.NO.	CAPACITANCE(PF)	FREQUENCY	S11(dB)
1	1	8.4	-13
2	0.9	5.2	-8
3	0.8	5.4	-14
4	0.7	5.2	-7
5	0.6	6.1	-7
6	0.5	6.4	-8
7	0.4	6.8	-10
8	0.3	7.3	-11
9	0.2	7.8	-13

Table II: Simulated Return loss different resonance frequencies at different Capacitance

Three varactor diodes were used at optimized positions only for making the antenna reconfigurable at different resonant frequencies without changing any other parameter and preventing the mode splitting.

The DC biasing feed was designed in such a way to pass the DC only without affecting the performance and different parameters of the previously circular patch antenna designed at 8.5GHz.

From fig. 5, it was found that the designed antenna was reconfigurable at different frequencies without changing other parameters such as impedance, polarization and pattern.

The simulated results were authenticated by measurement process and corresponding correlation is shown in figure 6.

Radiation Pattern

In general, radiation pattern is a graphical description of the relative field strength transmitted from or received by

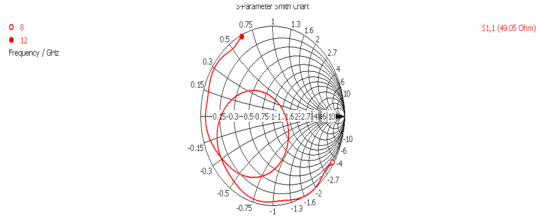


Figure 4: Diagram Showing Smith chart of return loss

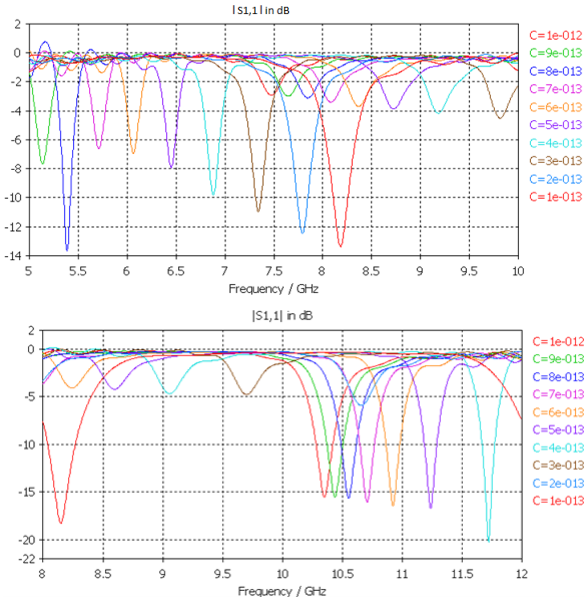


Figure 5: Return loss graph of different resonance frequencies at different capacitances

the antenna. Antenna radiation patterns are taken at one frequency, one plane cut (E-plane or H-plane) and one polarization. The patterns are usually presented in polar form with a dB strength scale. The radiation patterns are normalized to the maximum graph value, 0 dB, and the gain directivity is given for the antenna.

The simulated and measured radiation patterns for all proposed antenna are shown in Figure 7 to Figure 9. Fig.7 and 8 show the E- and H-plane patterns for X- band antenna constructed on an RT Duroid substrate ($\epsilon_r = 3.2$) with dimensions of 0.762 and circular patch radius 5.49 mm.

The E-plane radiation pattern of designed antenna was found 220 offset with maximum power 6.4 dB. The Half Power Beam width was found 106.90. In figure 7 the radiation pattern have two side lobes and one back lobe which was came out 18.8 dB down from the one major lobe.

The H-plane radiation pattern was found 00 offset with maximum power 6.2 dB and the half power beam width for this pattern was found 65.30. There is no significant back lobe in H-plane pattern as shown in figure 8.

Measured HPBW in H plane and E plane was observed 850 and 1100 and side lobes were found 14dB and 10.3 dB down as shown in figure 9.

No asymmetries were seen that, could be consistently attributed to the feed line and matching transformer. The antenna described has the advantage that other circuitry can easily be mounted on the substrate with the antenna if desired. The impedance at the center of the structure is

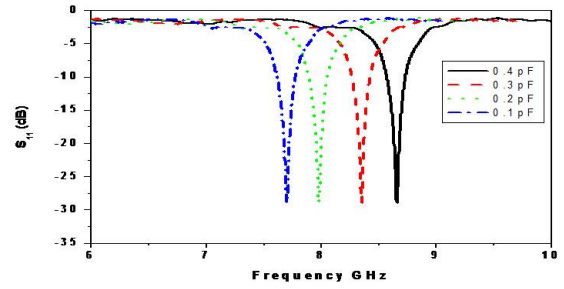


Figure 6: Measured Return loss at different resonance frequencies with variable Capacitance

S.NO.	CAPACITANCE(PF)	FREQUENCY(GHz)	S11(dB)
1	0.1	7.7	-28
2	0.2	8.0	-28
3	0.3	8.4	-28
4	0.4	8.6	-28

Table III: Measured Return loss at different resonance frequencies with variable Capacitance

zero while at the outer edge it is very high (hundreds of ohms) so consequently there will always be a point that provides a good 50 Ω match.

3D Radiation Pattern for Proposed Antenna

3D radiation pattern is exactly reassembling 2D radiation pattern and showing good radiation efficiency in Z-direction where maximum where lobe is created and having minimum side lobes at 8.5 GHz is as shown in figure 10.

Polarizations

The polarization is such that, if the antenna is oriented parallel to the ground the energy radiated would be vertically polarized. The resonant frequencies can be predicted to within a few percent, but the location of the feed point must be determined experimentally. However, once a resonance is found that yields the desired radiation patterns, the same techniques as described earlier may be utilized to match the antenna to the feed line.

Input Impedance

The calculated input impedance of the designed circular patch antenna is 370 Ω . Microstrip feeding technique was used, so to match the input impedance of designed antenna with the feed line a Quarter Wave Transformer was used. At 8.5GHz the length of the transformer was calculated 5.428 mm.

Impedance Matching

In this type of design an impedance transformation to 50 Ohm for this feed was used. This is accomplished by using a quarter wave impedance transformers between the radiating edge impedance and a 50 Ohm microstrip feed line. The width of matching transformer is optimized by simulation. The width of transformer was varied from 0.45mm to 1.45mm and observed that as width of transformer shrinks the return loss improves impedance bandwidth decrease and resonant frequency decrease as shown in the figure 11.

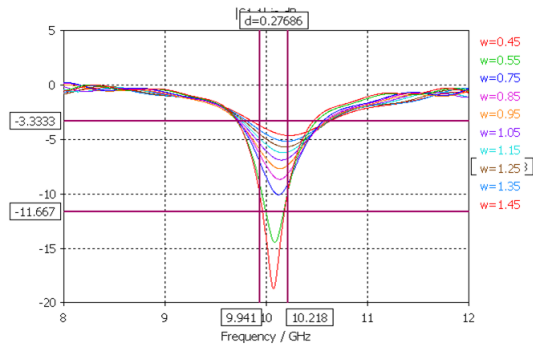


Figure 11: Diagram Showing Quarter length transformer width variation

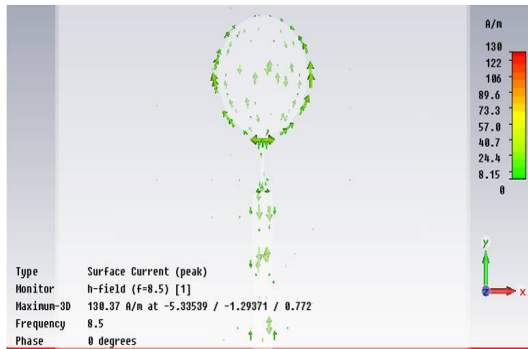


Figure 12: Diagram Showing Surface Current on circular patch (Simulated)

Power Beam width was found 1060. In this radiation pattern there were two side lobes and one back lobe which was came out 18.8 dB down from the one major lobe. The H-plane radiation pattern was found 00 offset with maximum power -6.2 dB and the half power beam width for this pattern was found 65.30.

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