Design & Simulation of Circular Patch Antenna for Multiband application of X Band Using Varactor Diodes

Pawan Pujari
Student, Arya Institute of Technology & Research,

Kirti Vyas,
Asst.Prof, Arya Institute of Technology & Research

Bhoopendra Kumar Sharma
Assoicate Professor, Techno India NJR Institute of Technology, Udaipur

***Abstract*—**Wireless communication systems are evolving to- ward multi functionality. This multi functionality provides users with options of connecting to different kinds of wire- less services for different purposes at different times.It is highly desirable to develop single radiating element having capabilities of performing different functions and/or multi- band operation in order to minimize the antennae's weight and area to enhance portability.

The proposed recon gurable Circular Patch antenna is a good candidate for X band communication. Circular Patch Antenna designed, simulated at 8.5 GHz successfully. The same antenna was made capable for frequency tuning by using varactor diode at optimized position and achieved from 6.5 GHz to 8.2 GHz in simulation and 7.6 GHz to 8.6 GHz and 10.4 to 11.6 GHz in practical. Three varactor diodes were used at optimized positions only for making the antenna tunable at different resonant frequencies without changing any other parameter and preventing the mode splitting.

I. INTRODUCTION

The evolution of wireless communication and mobile phone devices not only revolutionized our life styles but given various technological breakthrough. One technologi- cal battle front is antenna design for highly portable devices invented for above mention services. Through gradual de- velopment today we are depend upon microstrip antennas for above mention services because microstrip antennas are lightweight, compact, conformable to planar and non- planar surfaces, simple and inexpensive [1]. But microstrip antennas have major challenge in terms of operating band- width which very narrow. After invention of microstrip antenna researchers are putting lot of effort to increase the impedance bandwidth and since then technology have passed through various phases like development of broad- band [2], wideband[3] and ultra wideband antennas [4]. Recently researchers are developing small multiband anten- nas for applications where high instantaneous bandwidth is not required such as cellular communication but with the changing time the requirement of new small and multiband antennas are becoming even more challenging. Recon g- urable antenna has the ability to modify its operating frequency and radiation pattern dynamically. Recon gurable antennae offers great degrees of freedom reduce the number of antenna required by intended system function and can play more complex roles. They can be more cost effective as compare to adaptive or they can be incorporated into adaptive arrays to improve their performance by provid- ing additional degrees of freedom. Recon gurability in antennae allows us for spectrum reallocation in multiband communication systems, dynamic spectrum management, it reduces the number and size of antennae in a system. Generally Recon gurability can be obtained using follow- ing techniques: Tunable elements in the feeding networks, adaptive matching networks, phase shifters and tunable lters, tunable elements embedded such as PIN diodes, MEMS (switches, varactors, moveable parts) and optical switching in the radiating elements, mechanically moveable radiating elements.

Several types of tunable antennas are being proposed by researchers and process is still going on for example, using RF-MEMS switches, Weedon et al.[5] developed a frequency-reconfigurable patch antenna that could dynamically support both L band and X band, though approach provides great flexibility in reconfiguring the patch antenna's operating frequency and polarization, but complex design, the cost and complex biasing circuitry make the im- plementation of such a structure very challenging. Yang and Rahmat-Samii presented a more practical way to construct a frequency-reconfigurable patch antenna by introducing a switchable slot using pin diode [6]. Although design was simple with effective dc biasing yet size of patch is large and only two band is available.

II. VARACTOR TUNED MICROSTRIP CIRCULAR PATCH ANTENNA

Here a circular patch has been proposed with microstrip fed and quarter wave transformer as shown in figure 1 and geometric details have been presented in TableI. The RT Duroid substrate of dielectric 3.2 was used with thickness 0.762 mm and resonant frequency of circular patch is 8.5 GHz without tuning. A quarter wave transformer is added for impedance matching In this approach three varactor diodes connected between the radiating edge of a microstrip circular patch and the ground plane behaves as an additional variable susceptance, making the patch operate as if it had additional variable electrical length, and therefore variable frequency than an unloaded patch. When a reverse bias voltage is applied to the varactors, the capacitance offered by them reactively loads the patch and changes its effective electrical length and hence its resonant frequency. As the re- verse bias voltage of the varactor increases, the capacitance offered by the varactor decreases and hence the resonant frequency increases. If varactor diode is operated at zero bias or a small forward bias, it effectively become a short circuit, and therefore can be used, when required to suppress a radiating mode. A bias decoupling network was designed to bias the varactor diodes. The purpose of the bias dc- coupling network is to provide isolation between the RF signals and DC power supply.

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 in 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.

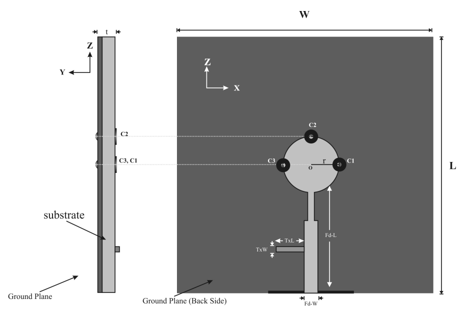


Figure 1: Side View and front View of Proposed Design

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 $\lambda_d/2$ ($\lambda_d$is wavelength in the dielectric) had a VSWR of 1.41 when fed at the edge of circular patch by a 50Ω microstrip line at X band, shown in Fig.1.

The simulatedvreturn loss were found -26dB at 8.5GHz with phase of 30^0 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.

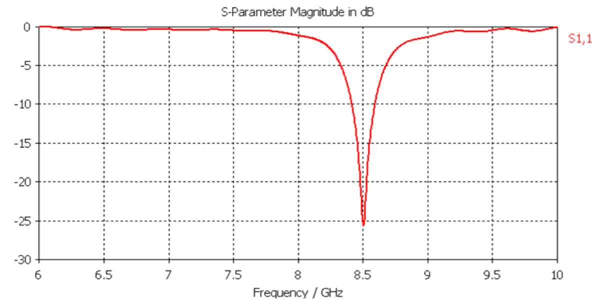


Figure 2: Simulated Tuned Circular antenna using varactor diode at no bias.

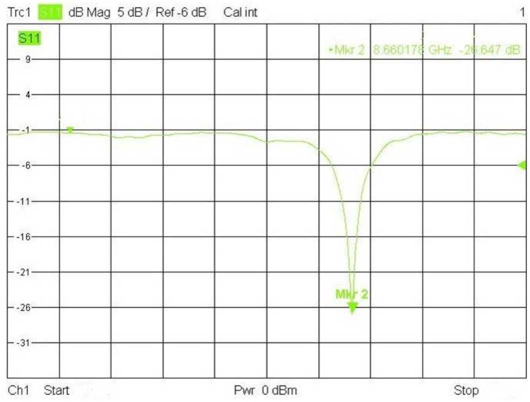


Figure 3: Diagram Showing Measured return loss graph

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

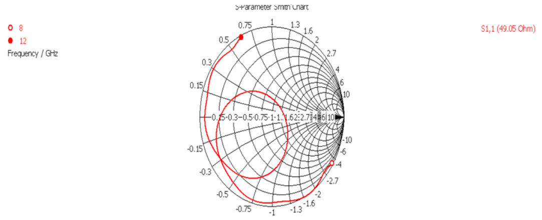


Figure 4: Diagram Showing Smith chart of return loss

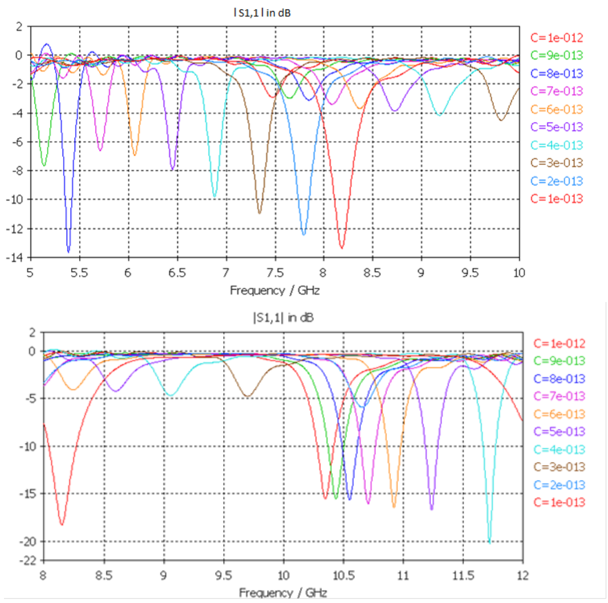


Figure 5: Return loss graph of different resonance frequencies at different capacitances

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 ($\varepsilon_r = 3.2$) 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

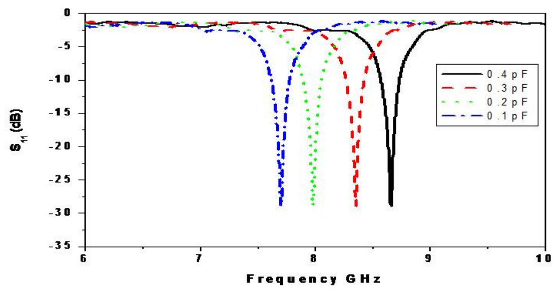


Figure 6: Measured Return loss at different resonance frequencies with variable Capacitance

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 370Ω. 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.

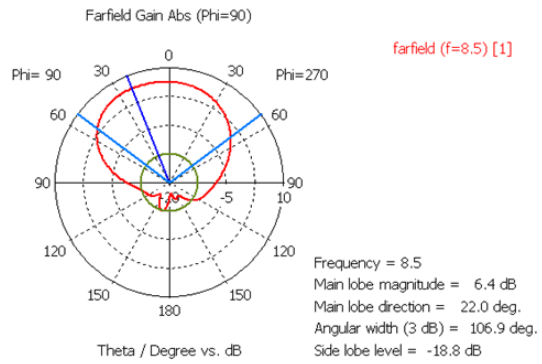


Figure 7: Simulation E-plane pattern for circular antenna at 8.5 GHz

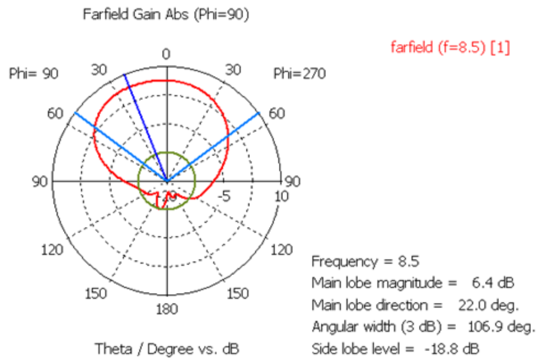


Figure 8: Simulation H-plane pattern for circular antenna at 8.5 GHz

The optimum transformer width was used 0.45mm.This antenna can also be driven by either microstrip or strip line circuits from behind the ground plane if a suitable feed-through is utilized to connect to the antenna.

Current Distribution

Current surface distribution determines how the current flows in the patch geometry. The current flow of the antenna design is investigated by using the CST Microwave Studio. It is most significant part of the patch. It is observed that current follows the boundary line. The current flow of circular patch antenna is presented in Figure 12

The high strength of current is more radiating along the outer path of the antenna and the microstrip transmission line. Apart from that, the upper boundary of the partial ground plane also took a very significantly radiating area, where it is contribute to greater bandwidth and as a monopole antenna characteristic. By careful examination, it is found that corner of main radiator exhibit high current flow at lower corners side of circular patch as shown in Figure 12.

IV. CONCLUSION

Circular Patch Antenna designed, simulated at 8.5 GHz successfully. The same antenna was made capable for frequency tuning by using varactor diode at optimized position. Due to the well known property of varactor diode that the capacitance of varactor diode is varied with the change in applied reverse bias voltage, applying proper reverse biasing to the varactor provide the different resonance frequencies of

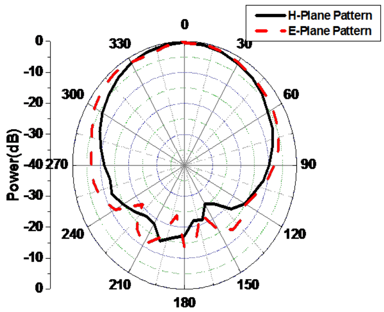
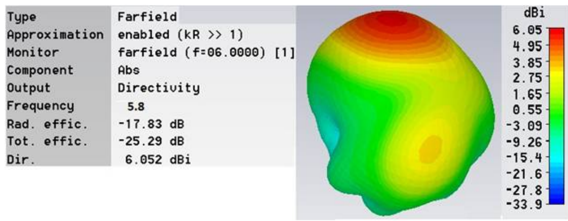
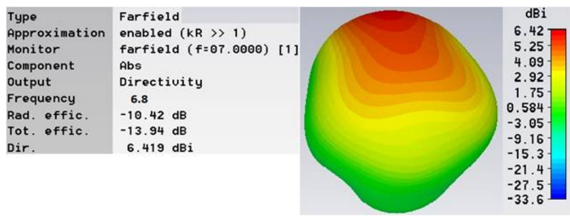


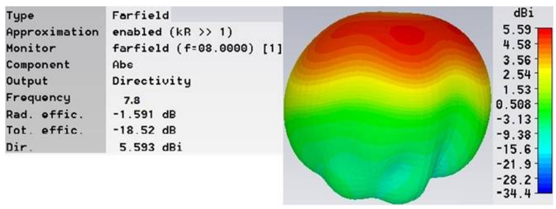
Figure 9: Measured E & H-plane pattern for circular antenna at 8.5 GHz



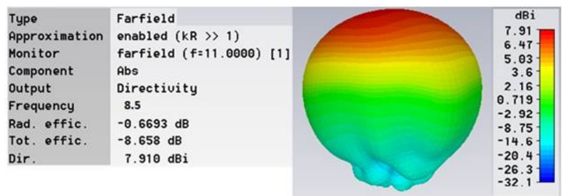
(a) 5.8 GHz



(b) 6.8 GHz



(c) 7.8 GHz



(d) 8.5 GHz

Figure 10: Diagram showing simulated 3D Radiation Pattern of circular Patch antenna at different frequency

antenna achieved from 6.5GHz to 8.2GHz in simulation and 7.6GHz to 8.6GHz and 10.4 to 11.6 GHz in practical. Three varactor diodes were used at optimized positions only for making the antenna tunable 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.

The E-plane radiation pattern of designed antenna was found 220 offset with maximum power 6.4 dB. The Half

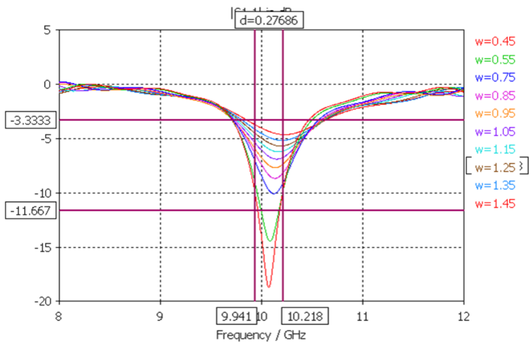


Figure 11: Diagram Showing Quarter length transformer width variation

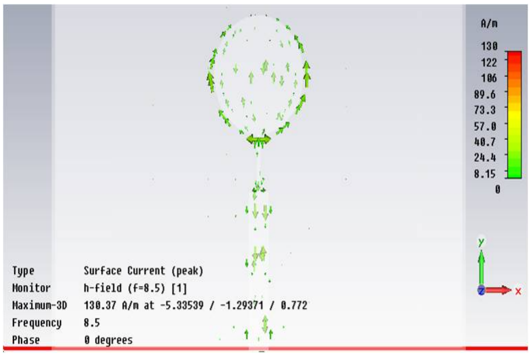


Figure 12: Diagram Showing Surface Current on circular patch (Simulated)

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.

REFERENCES

[1] C. Balanis, *Antenna theory: analysis and design*, ser. Harper & Row series in electrical engineering. Wiley, 1982.

[2] G. Kumar and K. Ray, *Broadband Microstrip Antennas*, ser. Artech House Antennas and Propagation Library. Artech House, 2003.

[3] H. Wang, X. Huang, and D. Fang, "A single layer wideband u-slot microstrip patch antenna array," *Antennas and Wireless Propagation Letters, IEEE*, vol. 7, pp. 9 –12, 2008.

[4] J.-Y. Sze and J.-Y. Shiu, "Design of band-notched ultrawideband square aperture antenna with a hat-shaped back-patch," *Antennas and Propagation, IEEE Transactions on*, vol. 56, no. 10, pp. 3311 –3314, oct. 2008.

[5] W. Weedon, W. Payne, and G. Rebeiz, "Mems-switched reconfigurable antennas," in *Antennas and Propagation Society International Symposium, 2001. IEEE*, vol. 3, 2001, pp. 654 –657 vol.3.

[6] F. Yang and Y. Rahmat-Samii, "Patch antennas with switchable slots (pass) in wireless communications: concepts, designs, and applications," *Antennas and Propagation Magazine, IEEE*, vol. 47, no. 2, pp. 13 – 29, april 2005.