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Frequency Reconfigurable CPW Antenna for Various Wireless Applications

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Abstract*— Antennas are necessary and critical components of communication and radar systems. One of the breakthroughs is that a single system could support several applications on different frequency bands or polarizations and the system requires separate antennas in order to support different applications. Sometimes their inability to adjust to new operating scenarios can limit system performance. Making antennas reconfigurable so that their behavior can adjust with changing system requirements or environmental conditions eliminate these restrictions and provide additional levels of functionality for any system. In recent years, many problems like co-site interference, cost, maintainability, reliability, weight etc. arise since the number of systems on individual platforms grows. Therefore, the design of multifunctional antennas for newly developed systems is of practical interest. A coplanar waveguide (CPW) filter using PIN diodes and varactor diodes are introduced. Both filters are based on controlling two stop bands far enough apart so that there is a pass band between them. The filters are small in size and can be incorporated in any CPW antenna design to make it reconfigurable. Using varactor filter antenna we can get a continuous narrow band operation ranging from 2.3 to 4.7 GHz. In the analysis of the designed antenna using FDTD based numerical computation to validate their performance. The simulations were carried out in CST Microwave studio.

Index Terms— **Coplanar waveguide (CPW), filtering antenna, frequency reconfigurability, wideband antenna.**

I. INTRODUCTION

Wireless and mobile communication is one of the fastest growing areas of modern life. In any wireless communication system, the antenna plays a major role in the reliability and performance of the system. Today's small handheld devices challenge antenna designers for ultra-thin, portable and high performance devices that have the ability to meet multi standards.

The reconfigurable antennas [1] are foreseen to be a booster for the future high rate wireless communications, both for the benefits in terms of performance and for the capacity gains. The goal of a reconfigurable antenna is to reduce the complexity of an antenna system operating over a wide frequency band, and to reduce the need of multiple antennas to perform a specific task, providing a relatively large bandwidth and achieving a dynamical reconfiguration within a few microseconds. Available wireless bandwidth is limited and most of it is already allocated to different wireless services. But some of the allocated spectrum remains idle most of the time. Cognitive radio [2] makes use of spectrum when it is idle. It requires a narrowband reconfigurable antenna that changes parameters to work in idle part of the spectrum. There are several methods that rely on geometry reconfiguration for the tuning of the operating frequency of a particular antenna design, including varactor and PIN diodes, and the use of optically activated switches by fiber optic cables [6-8]. The challenge faced by antenna designers is that the reconfiguration of one property, for example, frequency response, will have an impact on radiation characteristics. W.-C. Liu [9] designed a CPW-fed notched planar monopole antenna for multiband operations using a genetic algorithm (GA) in conjunction with the method of moments (MoM). K. Chung et al. [10] presented a Wideband CPW-fed monopole antenna with parasitic elements and slots. The wide bandwidth is achieved by adding two parasitic elements along the length of the monopole and three narrow slots. Reference [3] gave a comprehensive review of various methods used to achieve frequency agility using patch, wire, planar-inverted F antennas, etc. Vivaldi antenna reconfigurability was introduced in [5], providing three narrowband (low, mid, high) and a wideband operation. The main objectives of this paper are to device and analyze compact reconfigurable antenna with simple and efficient tuning mechanisms. The antenna proposed in this work utilizing two tuning schemes involving PIN diodes and varactors [4] in order to achieve frequency reconfiguration.

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II. FILTER DESIGN

A. Switched Filter

The proper selection of slot size modifies the resonant frequency. It can easily tuned by changing the electrical length. This may be readily accomplished by introducing a short circuit at a specific location on the slot. The reliability, compactness, high switching speed, very small resistance and capacitance in the ON and OFF states makes it appropriate for the switching applications. The basic structure for the filter was a coplanar waveguide with a square ring resonator as shown in Fig.1. The lower stop band frequency moves considerably as different switch combinations are used and the higher stop band frequency remains almost constant.

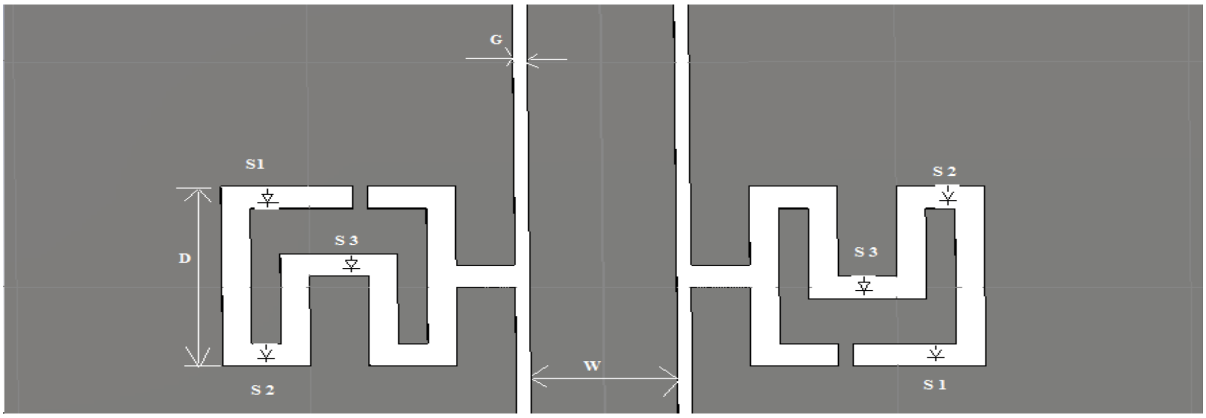

Fig 1 CPW switched Filter G=0.5mm, D=8mm, W=3mm.

B. Varactor Filter

The method consists of placing varactor diode at appropriate location, provide narrow instantaneous bandwidth that is dynamically selectable with high efficiency. Fig. 2 shows the varactor filter along with its dimensions. The varactor was modeled in CST MWS as a capacitor with a forward resistance of 2.5 Ω, which was the forward resistance of the varactor diode obtained from manufacturer's data sheet. This design has several advantages over the switched filter design including simpler structure, less lumped elements, low cost, low power consumption, continuous pass band, and smaller size.

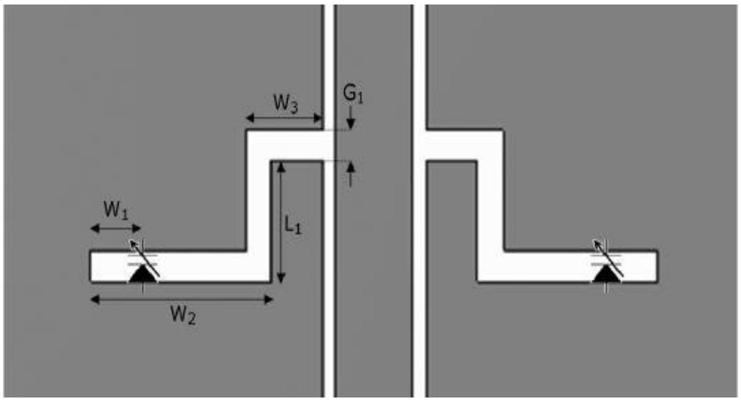

Fig 2 CPW varactor filter: the dimensions are W1=2.1mm, W2= 7mm, W3=3mm, L1=4mm and G1=1mm.

III. ANTENNA DESIGN

The two filters described in the previous section, when combined with any wideband CPW antenna, provide frequency reconfigurable operation.

A. Wideband Antenna

The wide band antenna is shown in Fig.3 along with its dimensions. The antenna was fabricated on a TLC-30 substrate with €r=3 and a thickness of 1.56718 mm.

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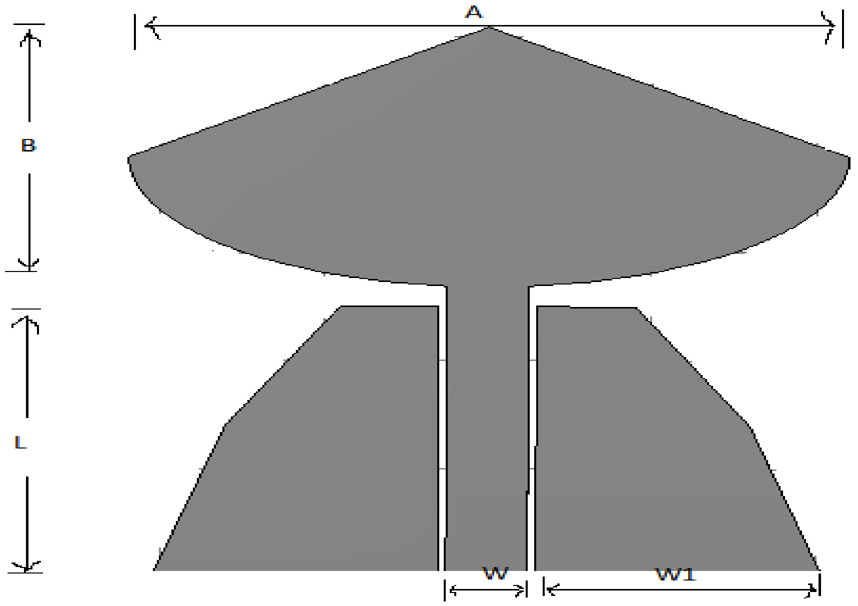

Fig.3. Wide band CPW antenna. A=44mm, B=24mm, W=5mm W1=17.5mm, L=25mm

The return loss characteristic of the CPW monopole antenna is shown in fig 4. From the graph it is clear that the CPW monopole provides a resonance at 2.5 GHz from 2.1 GHz to 3 GHz with a bandwidth of .9 GHz and at 5.7 GHz from 4.4 GHz to 8.5 GHz with a bandwidth of 4.1 GHz.

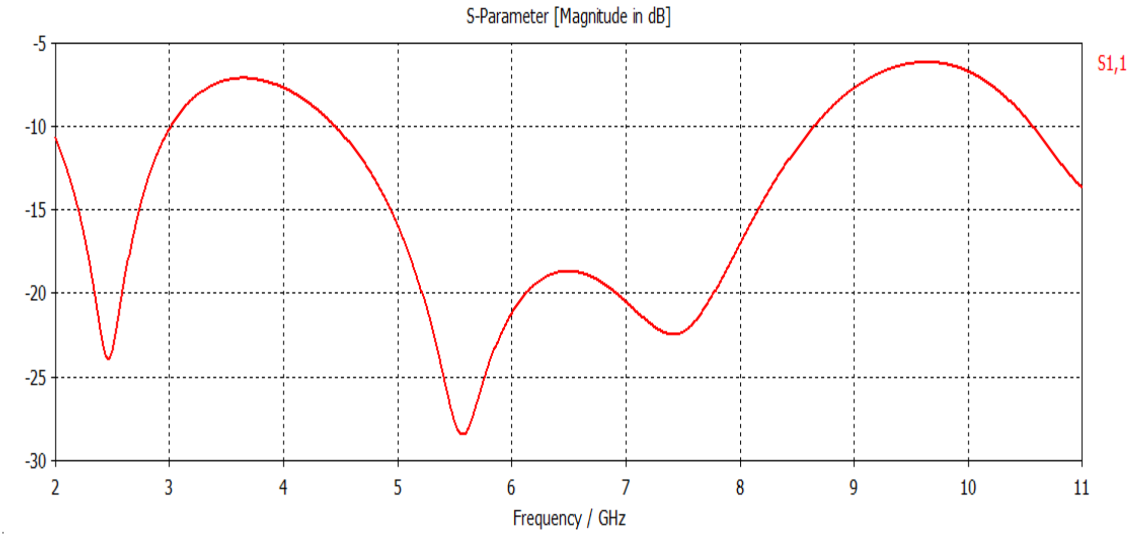

Fig. 4 simulated return loss characteristics of the CPW wideband antenna.

B. Antenna with Switched Filter

The reconfiguration of an antenna may be achieved through many techniques. Some designers resort to circuit elements while others rely on mechanical alteration of the structure. Yet other approaches bias different antenna parts at different times, reconfigure the feeding networks or appropriately excite the antenna arrays. All such approaches have significantly contributed to the evolution of reconfigurable antennas during the last decade. More recently, antenna designers have used electrically actuated switches such as PIN diodes and RF MEMS and variable capacitors in order to achieve reconfiguration. Structure of the switched monopole antenna is shown in Fig 5.

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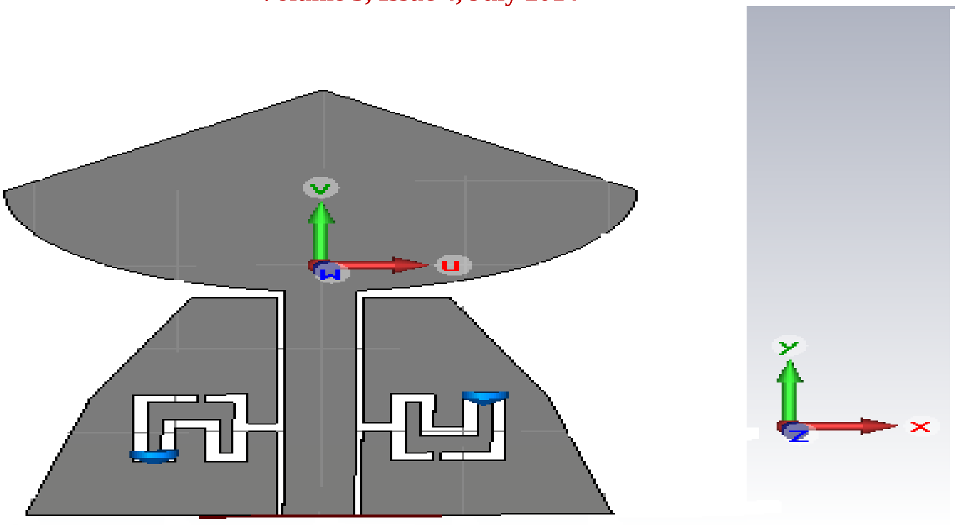

Fig.5 switched monopole antenna.

The proper selection of the slot size modifies the electrical length changes the stop band frequencies, causing a change in the pass band frequency. The antenna exhibits good radiation characteristics for different switch positions. The PIN diodes are inserted along the longer resonator at three different positions S1, S2 and S3.

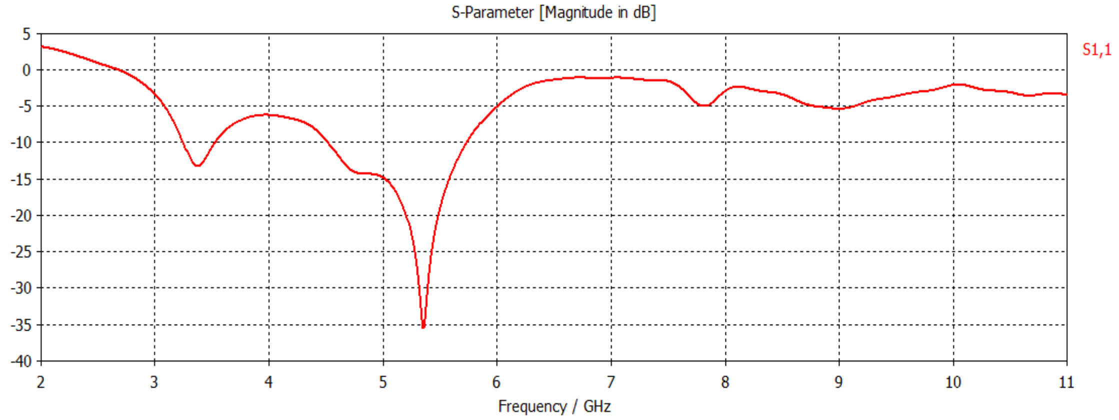

Fig. 6. Simulated reflection characteristic when switch combination S1 is ON

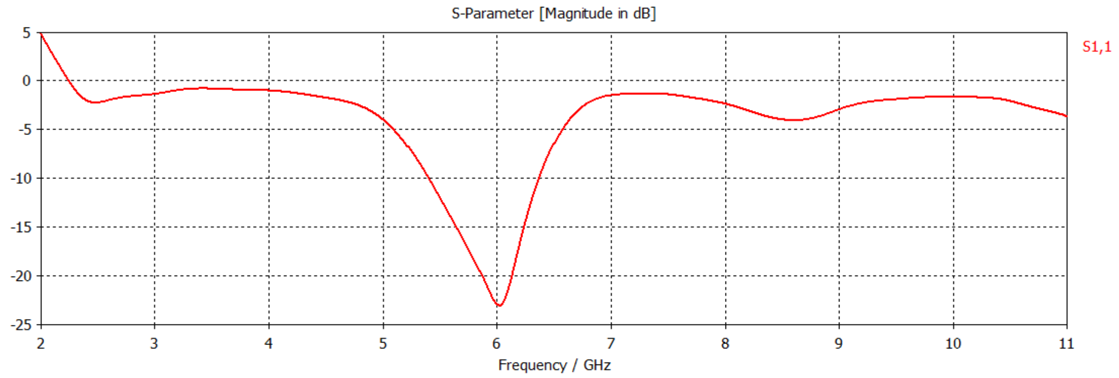

Fig.7. Simulated reflection characteristic when switch combination S2 is ON

When switch combination S1 is ON, the antenna radiates at 4.5 GHz to 5.7 GHz with a bandwidth of 1200 MHz. The return loss shown in Fig.6. When switch combination S2 is ON, the antenna radiates at 5.5 GHz to 6.4 GHz with a bandwidth of 900 MHz. The return loss characteristics are shown in Fig.7.

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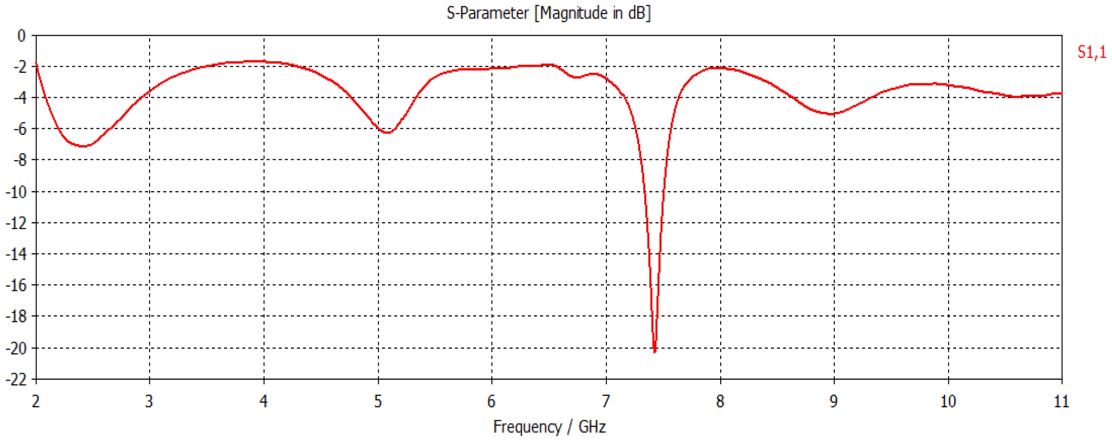

Fig.8. Simulated reflection characteristic when switch combination S3 is ON

When switch combination S3 is ON, the antenna radiates at 7.3 GHz to 7.7 GHz with a bandwidth of 400 MHz. The return loss shown in Fig 8.

C. Varactor Antenna

For the varactor-tuned antenna, the varactor filter design is combined with the wideband monopole antenna. The simulated structure is shown in Fig.9. The varactor monopole antenna has a wideband operation when diodes placed at the entrance of the short-circuit slot are turned on. Besides this, it has a continuous narrowband mode of operation ranging from 2.3to 4.8 GHz when the capacitance is changed from 2.25 to .5pF. The varactor position is optimized and it is placed at a point in the slot. The different capacitive loadings of the varactor correspond to different electrical lengths. Extensive parametric analysis is conducted to optimize the antenna characteristics.

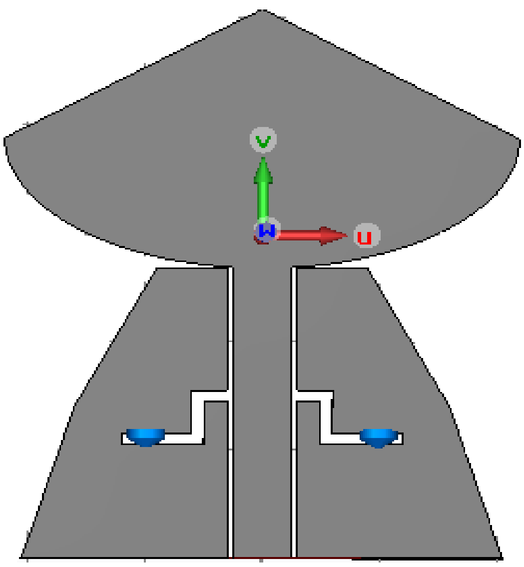

Fig. 9 Simulated structure of varactor tuned antenna

The frequency corresponding to return loss minimum is taken as resonant frequency of the antenna. The range of frequencies for which the return loss value is within the -10dB points is usually treated as the bandwidth of the antenna. The reflection characteristics of the antenna simulated for different capacitance values are shown in Fig.10. As the capacitance value of the varactor increases from 2.25pF to 0.25pF the resonant frequency shifted from 2.3GHz to 4.8GHz.

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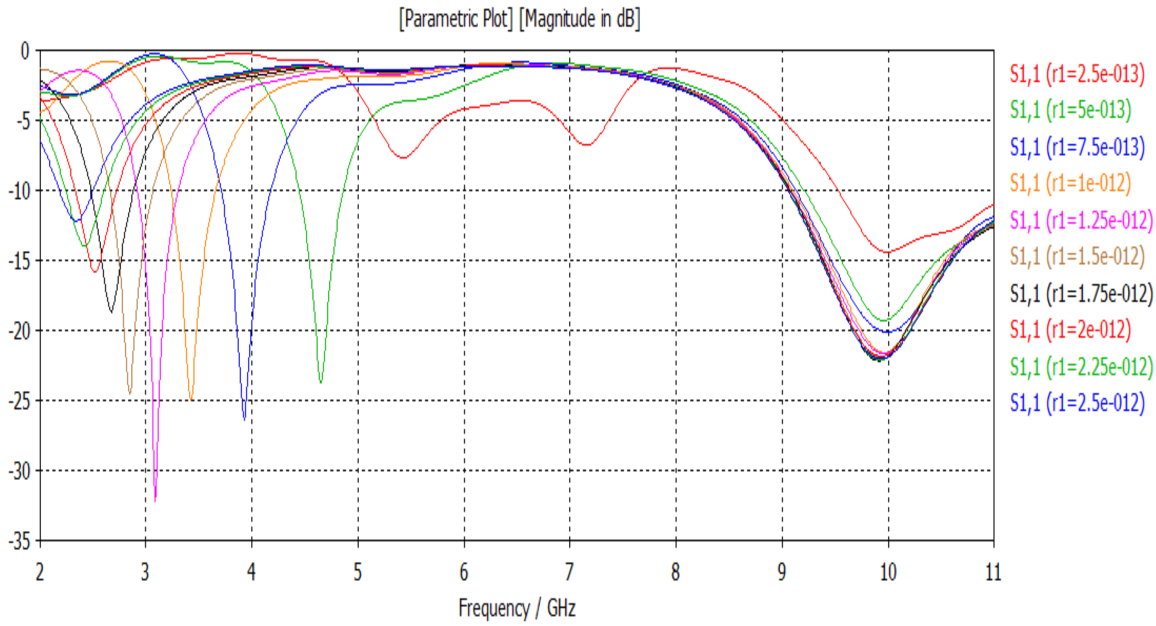

Fig 10 Simulated reflection coefficients of the varactor antenna

D. Radiation Pattern

The detailed EM behavior of the antenna is revealed by examining the radiation patterns. The 3D radiation patterns show similar broadside radiation characteristics for the different PIN diode states. Fig.11and Fig.13 shows the simulated 3D radiation patterns at 5.7GHz and 7.3GHz.

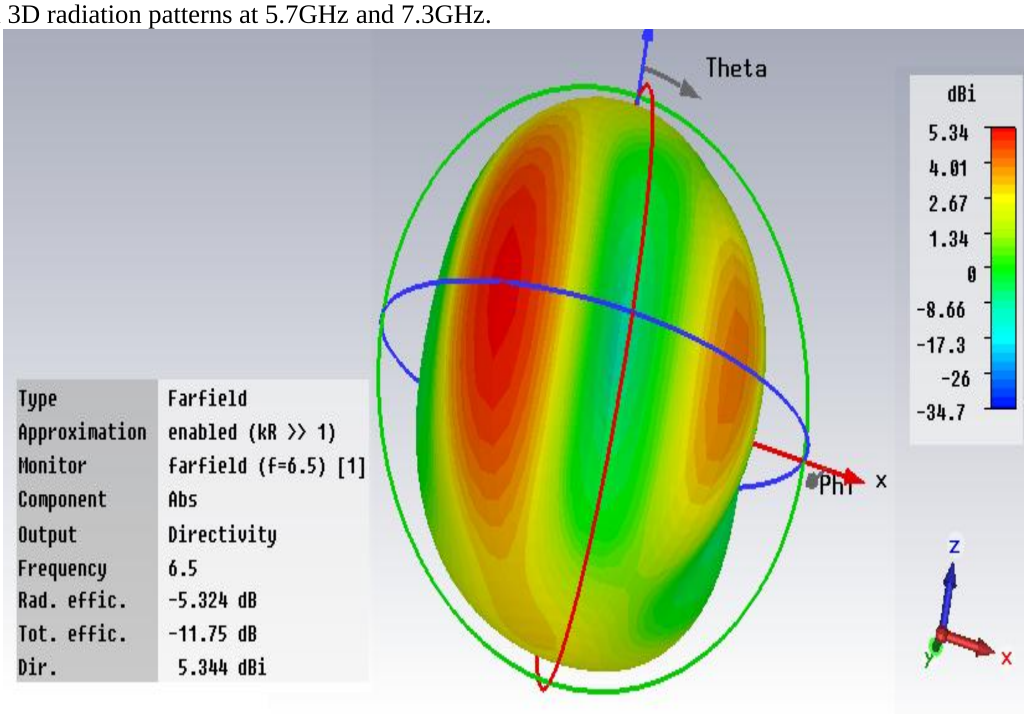

Fig 11 simulated 3D radiation patterns at 5.7GHz

The polar plot of the 3D radiation pattern at 5.7 GHz with phi=90^0 and theta = $90^0$is shown in figure12 (a) and 12(b)

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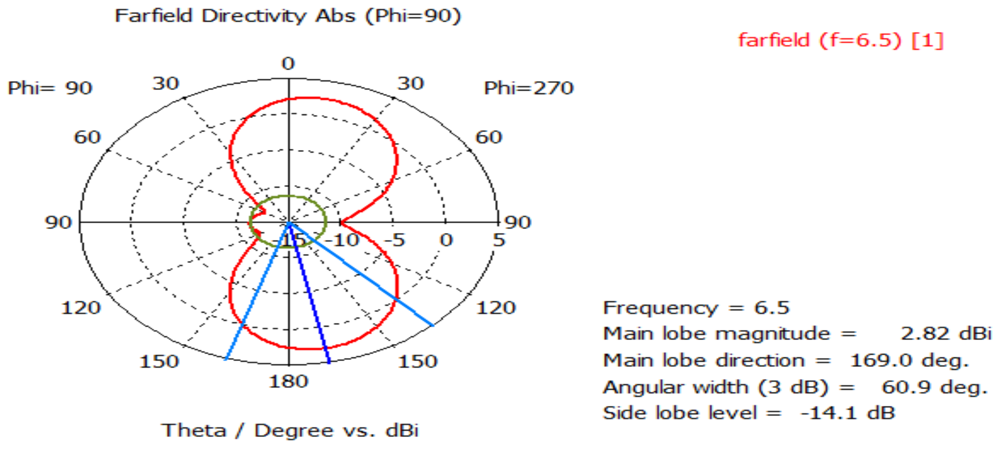

Fig 12(a) The polar plot of the 3D radiation pattern at phi=90^0

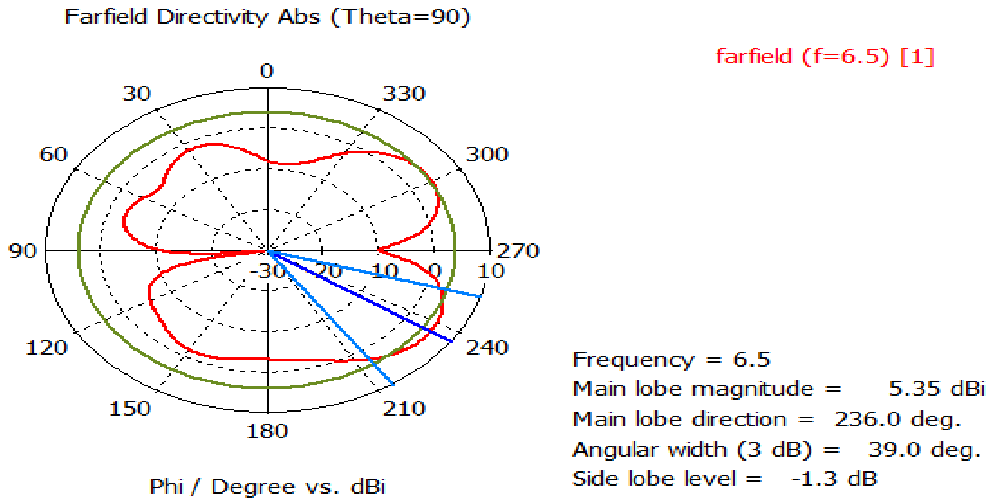

Fig 12(b) The polar plot of the 3D radiation pattern at theta=90^0.

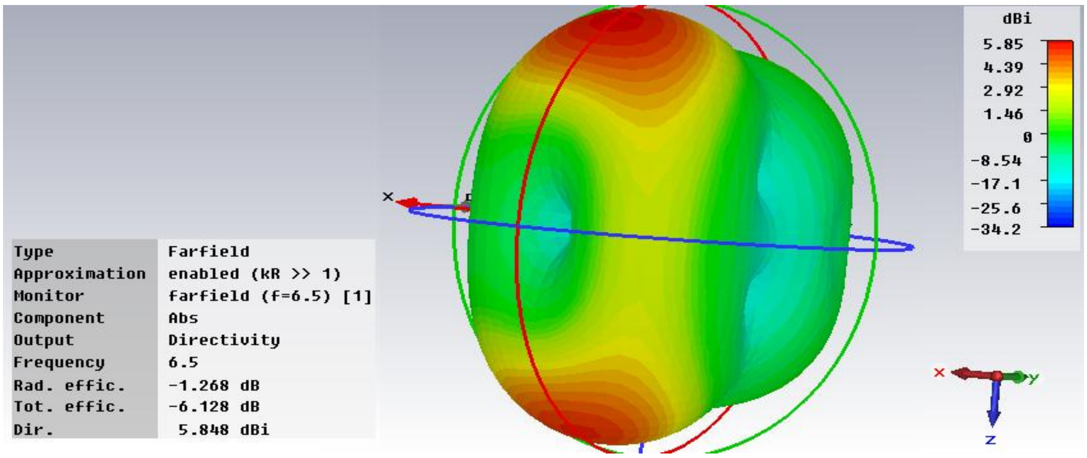

Fig 13. Simulated 3D radiation patterns at 7.3 GHz

The polar plot of the 3D radiation pattern at 7.3 GHz with phi=90^0 and theta = 90^{0}is shown in figure 14 (a) and 14(b)

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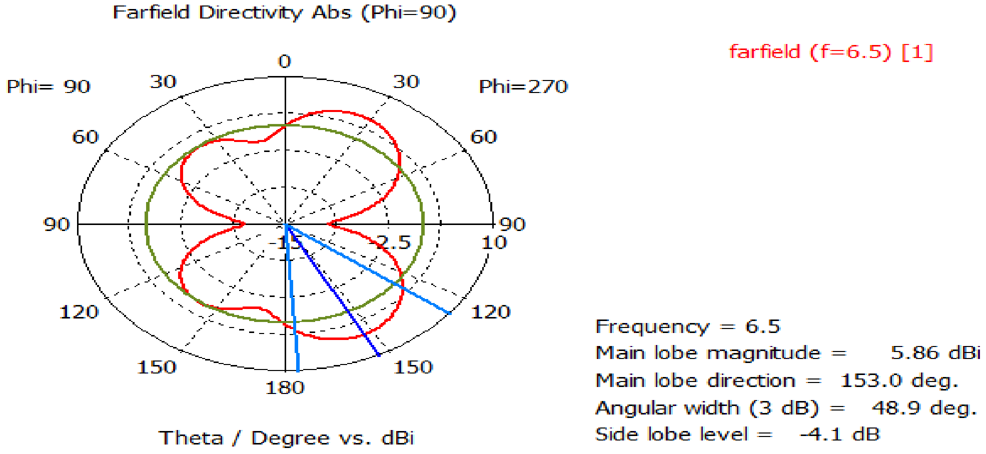

Fig 14(a) The polar plot of the 3D radiation pattern at phi=90^0

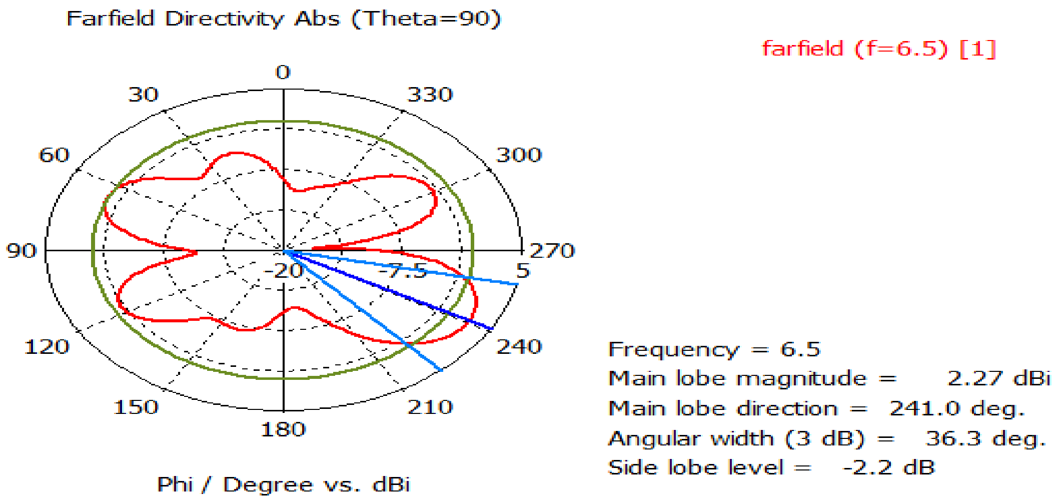

Fig 14 (b) The polar plot of the 3D radiation pattern at theta=90^0.

The radiation pattern of the varactor-tuned antenna was simulated, it was discovered that there was very little difference between the radiation patterns of the antenna with different capacitance values. The reason is that the slots are weakly excited in the pass band. Only the maximum and minimum pass band frequency radiation patterns of antenna will be presented here because the results in other frequency bands are similar. Fig.15and Fig.17 shows the 3D radiation pattern of varactor antenna at 4.6 GHz and 2.43GHz. E plane and H plane plots of the varactor antenna at 4.6 GHz and 2.43 GHz is shown in Fig.16 and Fig.18.

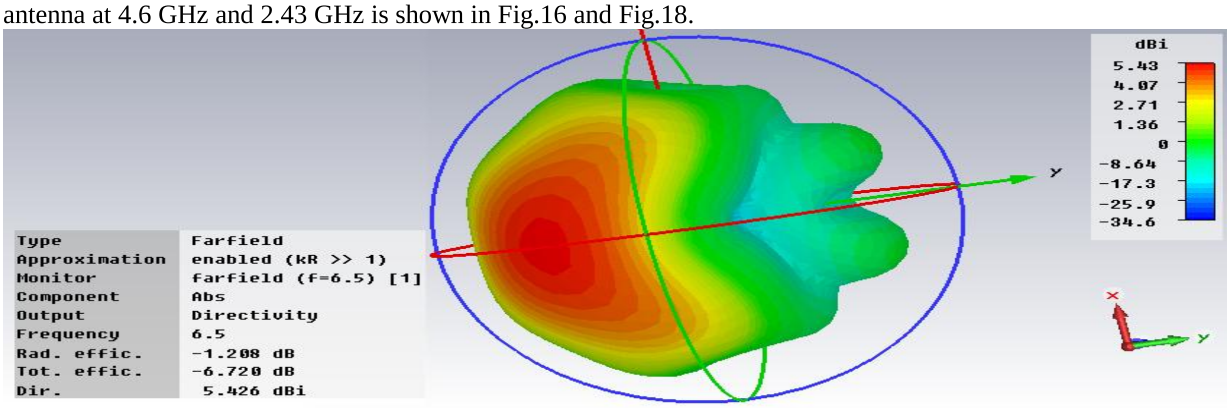

Fig.15 The 3D radiation pattern of varactor antenna at 4.6 GHz

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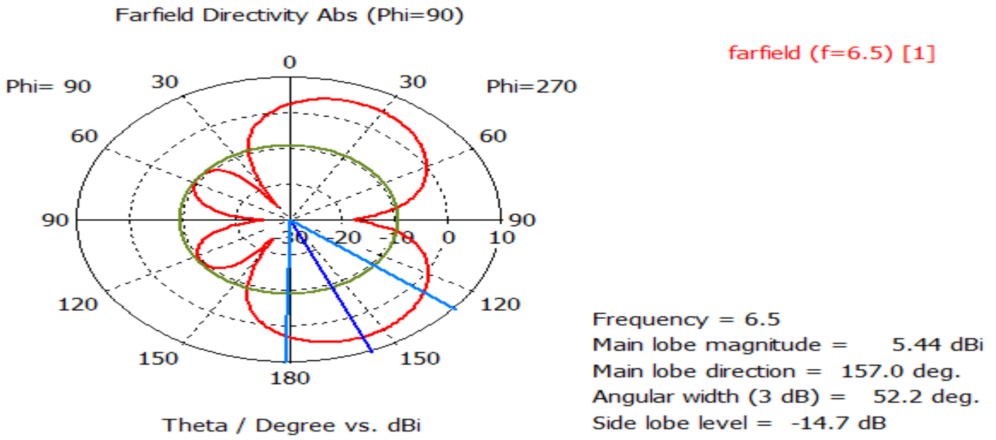

Fig 16(a) E plane pattern of the varactor antenna at 4.6 GHz

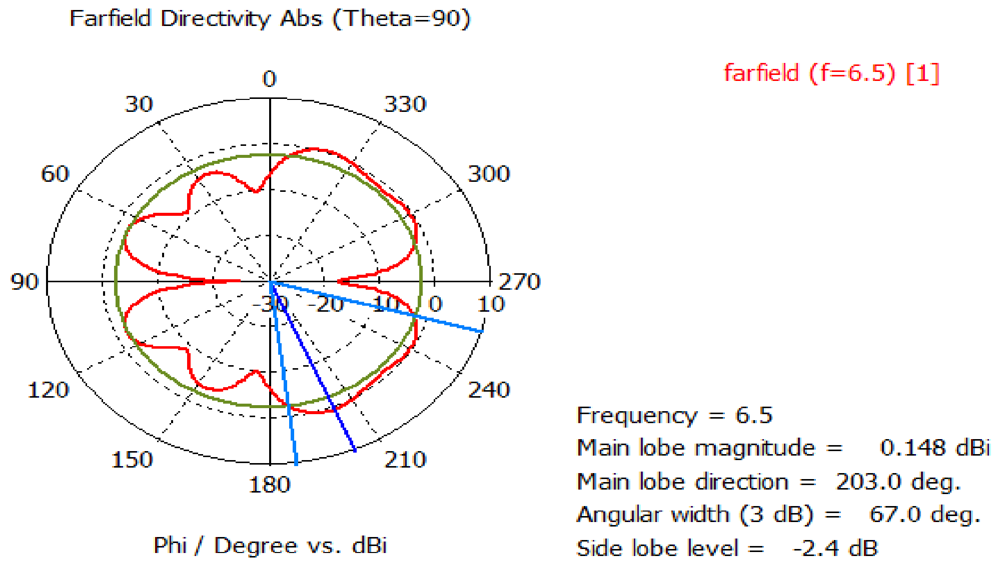

Fig 16(b) H plane pattern of the varactor antenna at 4.6 GHz

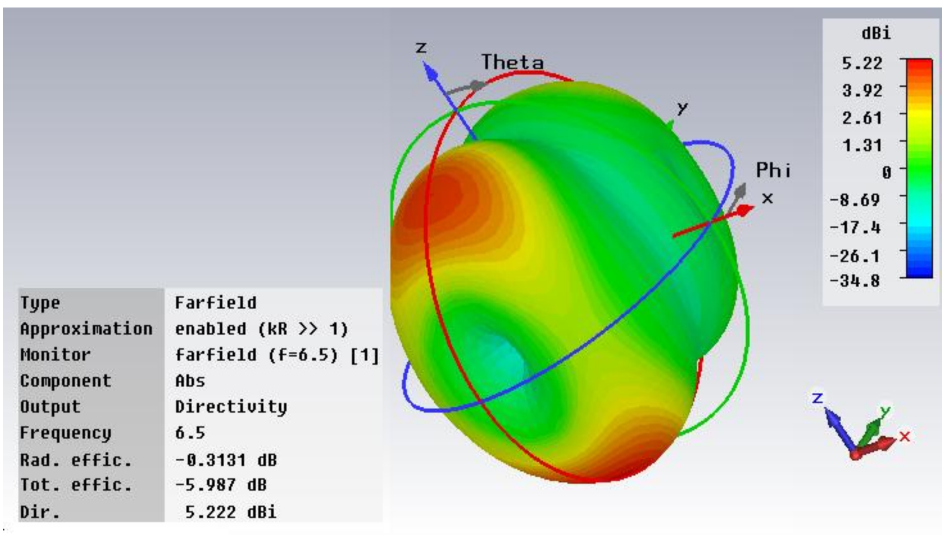

Fig.17 The 3D radiation pattern of varactor antenna at 2.45 GHz

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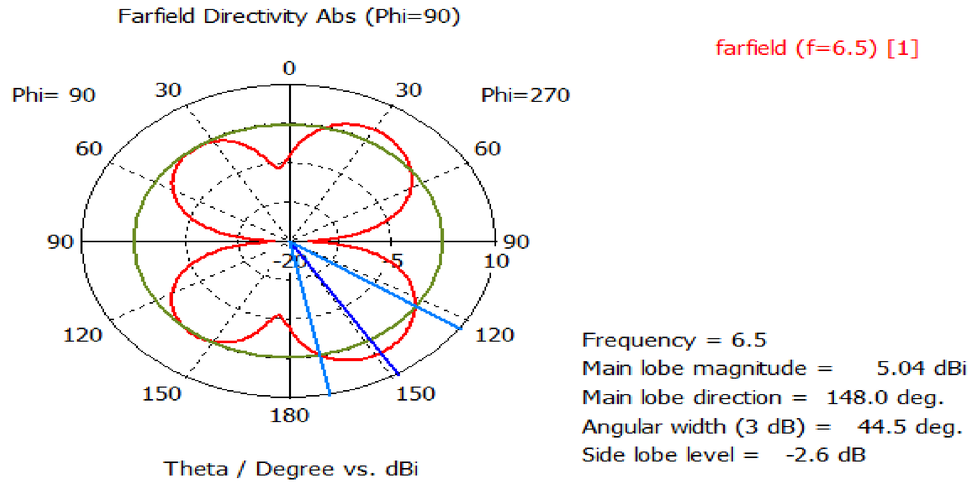

Fig 18(a) E plane pattern of the varactor antenna at 2.45 GHz

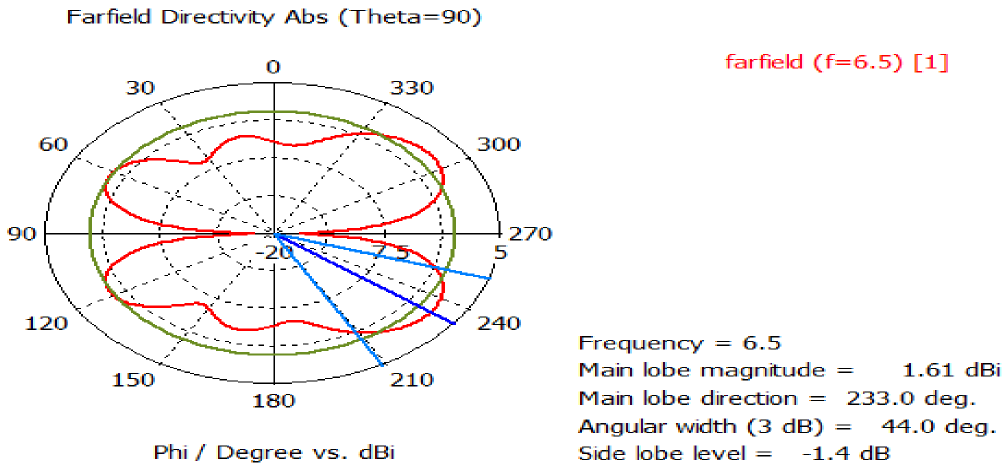

Fig 18(b) H plane pattern of the varactor antenna at 2.45 GHz

IV. CONCLUSION

The aim of the thesis is to develop and optimize compact CPW antenna that would facilitate frequency reconfigurable without the use of any matching circuits and complicated biasing circuits. PIN diodes and varactors are used for switching or tuning mechanism. The rapid growth of modern communication systems demands the ability to design frequency agile RF front ends for operation in various frequency bands. Frequency Reconfigurable antennas can be used to cover these multiple functions with a single antenna aperture. The goal of a reconfigurable antenna is to reduce the complexity of an antenna system operating over a wide frequency band, and to reduce the need of multiple antennas to perform a specific task, providing a relatively large bandwidth and achieving a dynamical reconfiguration within a few microseconds.

The important design considerations throughout the study are compactness of the CPW filters that can be integrated with in the structure of antenna without taking any extra space. The proper selection of the slot size modifies the electrical length that changes the resonant frequency. The PIN diodes are inserted along the longer resonator at three different positions S1, S2 and S3. The antenna offers three narrow bands ranging from 4GHz to 8 GHz. WiFi and WiMax are occupied in the frequency range of 5.15-5.85GHZ. The varactor-tuned antenna has a continuous narrowband mode of operation ranging from 2.3to 4.8 GHz when the capacitance is changed from 2.25 to .5pF. Bluetooth and WiFi are operated in the 2.4-2.48 GHz. The working principles of both filters are validated by simulations. Since wideband and narrowband operation are obtained, these CPW wideband antennas with integrated filters are excellent for cognitive radio applications.

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Jibu George was born in Kerala, India. He received the B.Tech. degree in Electronics and communications from Kerala University, in 2010 and M Tech degree from the University of Kerala in Communication systems Engineering, in 2014. His research interest includes Frequency and pattern reconfigurable antenna design, digital signal processing.