# Design and Implementation of Reconfigurable Microstrip Patch Antenna for S-Band Applications

**P.JOTHILAKSHMI[1#], S.SHANGARALAVAKUSARAJA[1*]**
[1#]Assistant professor, Department of ECE
[1]*Student, ME Communication Systems, Department of ECE
Sri Venkateswara College of Engineering, Sriperumbudur, Chennai
Tamilnadu, india.
Email id: jothi@svce.ac.in

*Abstract*: Microstrip patch antennas have become one of the hotspot for researchers because of its various advantages and compatibility. Reconfigurable antennas have recently received much attention in wireless and satellite communication systems due to their selectivity for operating frequency and polarization. The active tuning of such antenna parameters is typically achieved by varying the switch conditions. A single prototype can be used to support multiple functions at multiple frequency bands. Objective is to design a reconfigurable antenna which operates at four different frequencies in S-band. The simulated antenna radiates at four different frequencies of 3.594 GHz, 3.7 GHz, 3.8 GHz, and 3.9 GHz and has a return loss of -29.47 dB, -15.44 dB, -30.38 dB, and -23.015 dB respectively. And then it is fabricated using FR4 as substrate and then it is found to be in good match with the simulated results.

Key-words: Reconfigurable, Fractal, Switches, Resonant frequency, Microstrip

## 1 Introduction

Antenna is a transformer that transforms electrical signals into electromagnetic waves, or vice versa. The receiving and transmitting functionalities of the antenna structure itself are fully characterized by Maxwell’s equations. An antenna system is defined as the combination of the antenna and its feed line. A microstrip antenna in its simplest configuration consists of a radiating patch on one side of a dielectric substrate, which has a ground plane on the other side. The patch conductors, normally of copper or gold, can assume virtually any shape, but regular shapes are generally used to simplify analysis and performance prediction. Ideally, the dielectric constant of the substrate should be low to enhance the fringe fields that account for the radiation. Multiband antenna has been taken more and more attention, because of its small volume, light weight, easy and active circuitry integration. But multiband antenna has a drawback of poor out of band rejection so it was avoided. So reconfigurable antennas came into existence. Reconfigurable antennas have received much attention in design of smart and adaptive systems. It provides multiple services with a single antenna with good out of band rejection and then the cost is also reduced when compared to a multi band antenna. Compared to conventional antennas, reconfigurable antennas provide the ability to dynamically adjust various antenna parameters. The active tuning of such antenna parameters is typically achieved by manipulating a certain switching behavior. Reconfigurable antennas reduce any unfavorable effects resulting from co-site interference and jamming. MEMS switches and PIN diodes switches can be used across the slots. Choice of the substrate materials depends on the application. Conformal antennas require flexible substrates; low frequency antennas require high dielectric constant substrates to reduce the size of the antenna. The first design step is to choose a suitable dielectric substrate of appropriate thickness h and loss tangent. A thicker substrate, besides being mechanically strong, will increase the radiated power, reduce conductor loss, and improve impedance bandwidth. However, it will also increase the weight, dielectric loss, surface wave loss, and extraneous radiations from the probe feed. Fractal complex shapes make antenna size to be reduced when compared to the common antenna size [1].Increase in the demands of antenna for various applications multiband antennas were extensively used. Reconfigurable is made by using RF-MEMS switches which is costlier but consumes less power when compared to other switches [2]. Various fractal shapes like Koch curves, Sierpinski triangle, and Hilbert curve are available for making antennas. Second order Koch curve [3] and then Sierpinski carpet [4] fractals are used for making the antenna. A reconfigurable antenna along with a band pass filter is designed with electronic switches, which is designed for operating at the Ultra Wide Band [5] for Cognitive Radio applications. Here the electronic switch is used to control the band pass frequency of the filter. Resonant frequency can be varied by varying the depth of the slot for varying the size of the antenna [6]. Multiband antennas design was made in such a way that for each band of operation different part of the antenna is active, and it will be larger in size. For using in cognitive radio system a photo conductive switch [7] is made used for incorporating the re-configurability technique. A dual frequency reconfigurable antenna array and a discrete phase shifter is designed which is capable of operation at two independent frequencies [8] the re-configurability is achieved by using the PIN diodes. A new reconfigurable multi-band micrsostrip antenna design was made with slots were cut in a hexagonal patch. The antenna re-configurability and its resonance [9] are changed by the use of switches configuration. The possibility of realizing a frequency reconfigurable patch antenna with the help of reed switches at microwave frequencies has been made here [10]. For activation of reed switches bias circuits are not needed. The space filling property and multiple scale property of fractals geometries leads to the development of fractal antennas which can be used for various mobile communications devices and for other electronic devices. This enables fractals to produce good antenna performance with minimum antenna space.

## 2 Antenna Design

A fractal patch antenna is to be designed which has to operate around 3.9 GHz with reconfigurable ability incorporated into that patch. The antenna design is based on having pairs of symmetrical slots to form branches. Switches can be mounted over these slots to obtain different resonant frequencies. Initially a patch is made and then it is simulated and then its parameters are varied to resonate at a desired frequency. Once it is achieved then the reconfigurability has to be incorporated into the patch, for that switches are inserted into it. For deciding the switch position a narrow study has to be made by placing at different positions and then its desired position is found. And then an optimization has to be made. Substrate used here is FR4 which has a dielectric constant of 4.4 and then a microstrip line feed is used for feeding the patch. The simulated antenna structure is shown in Fig.1.along with its dimensions. Self-similarity of the fractal shape antenna provides the consistency of the radiation pattern.

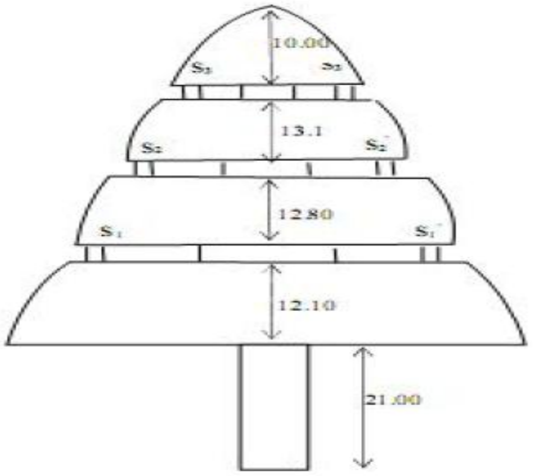


Fig.1. Dimensions of proposed modified CEDAR shaped antenna ( mm)

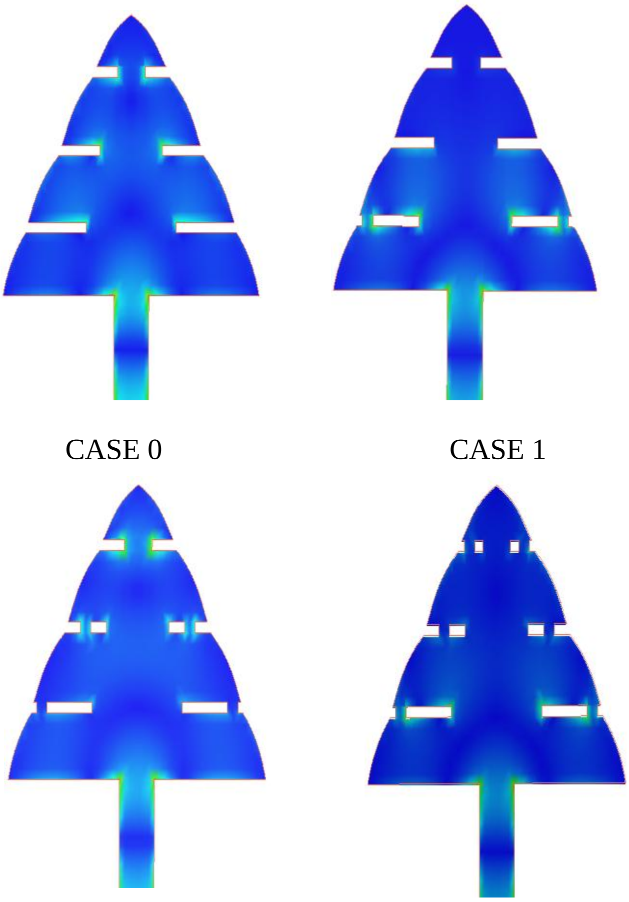
## 3 Simulated Results and Analysis

The design and parameter optimization is done using the Advanced Design System (ADS). Antenna radiates with respect to their discontinuations, so the position of switches varies the resonant frequency of the antenna. Totally three pairs of switches are mounted across the trims to control the current flow on the patch. A parametric study is made to decide the position of the switch for the proper resonance of the antenna. Initially switches $(s_1, s_1')$ is made and then its resonance is studied for various positions and then the effective resonance point is selected and then further switches are incorporated into the patch. After that next pair of switches $(s_2, s_2')$ is made and its resonant frequency is studied for various positions. And then the same is made for switches $(s_3, s_3')$. The positions of the switches affect the current flow path, varying these positions certainly tune the obtained resonance frequency. The positions of the switches are denoted $d_1$, $d_2$, and $d_3$.The locations of the switches are chosen such as $d_1 = 0.8$ mm, $d_2 = 3.5$ mm and $d_3 = 0.7$ mm. Initially first pair of switches $(s_1, s_1')$ is alone activated (i.e.) ON it is said to be case 1 and then it is proceeded for switches $(s_2, s_2')$ here both pairs of switches are made ON it is case 2 and then $(s_3, s_3')$ is made ON along with that. ON condition says the presence of switch OFF condition says that the switch is removed. Each switch has a dimension of

2.0 mm * 3.0 mm. They are made up of copper strips. The successive activation of each pair of switches, from bottom to top, results in altering the flow of current and as a result in shifting the resonance frequency. Four switching cases are chosen. In the OFF state, the copper strips were removed .When a switch is OFF, the current flows around the corresponding trim, thus its path is longer, and the resonance frequency is lower.

TABLE 1
SWITCH CONDITIONS

| **Case** | **$(s_1,s_1')$** | **$(s_2,s_2')$** | **$(s_3,s_3')$** | | |
|---|---|---|---|---|---|
| 0 | OFF | OFF | OFF | | |
| 1 | ON | | OFF | OFF | |
| 2 | ON | | | ON | OFF |
| 3 | ON | | | ON | ON |



CASE 0 CASE 1

CASE 2 CASE 3

Fig.2. Representation of current distribution in modified cedar antenna

Here switches will be of copper strips which are used in spite of electronic switches to avoid the biasing networks. Switches in their ON state were replaced by 3 mm * 2 mm copper strips. In the OFF state, the copper strips were removed. Using switches, such as PIN diodes, RF MEMS, requires the design of their biasing networks. These biasing networks will have their effect on the antenna's characteristics, especially the radiation patterns. However, copper switches other types of switches do not need such biasing lines. They are actuated from below the ground plane, without affecting the radiation patterns. To make the antenna to operate at different resonant frequency, switch conditions has to be varied. Table 1 shows the switch conditions for four cases. Once the antenna has been simulated its performance has to be measured, for measuring that their character has to measured and analyzed. Here its return loss and radiation pattern is measured and analyzed. Both the characteristic features are measured for all the conditions individually and it is plotted.

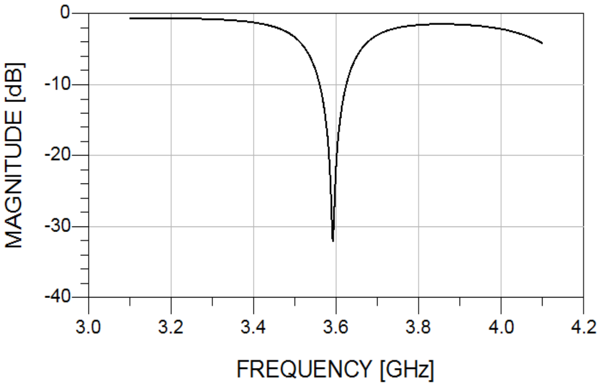


Fig.3. Return loss plot of antenna without switches

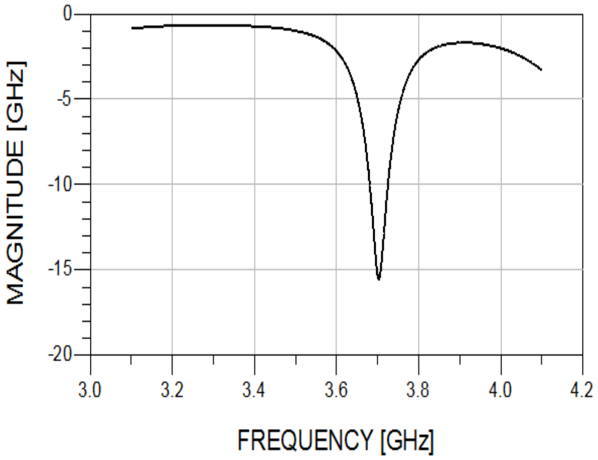


Fig.4. Return loss plot of antenna with a pair of switch connected

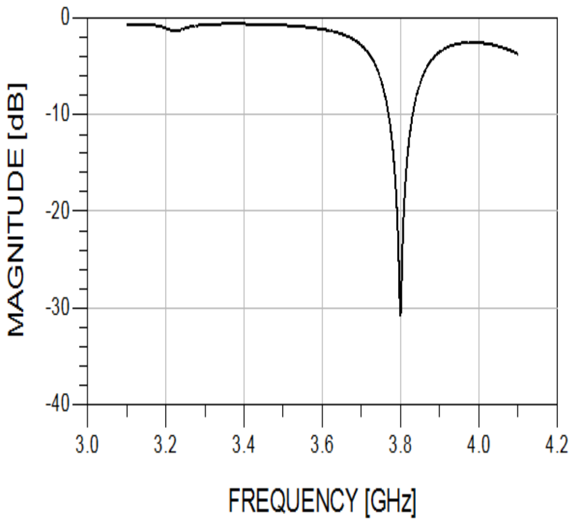


Fig.5. Return loss plot of antenna with two pairs of switch connected

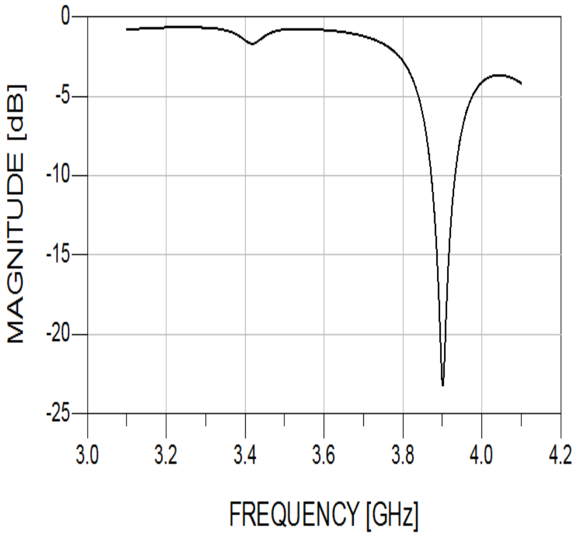


Fig.6. Return loss plot of antenna with three pairs of switch connected

Return loss is the loss of signal power resulting from the reflection caused at a discontinuity in a transmission line. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. It is usually expressed as a ratio in decibels (dB). Return loss is used in modern practice because it has better resolution for small values of reflected wave. Return loss is plotted for four cases individually(i.e.) case 0, case 1, case 2, and case 3 and then it is compared and shown in Fig.8.

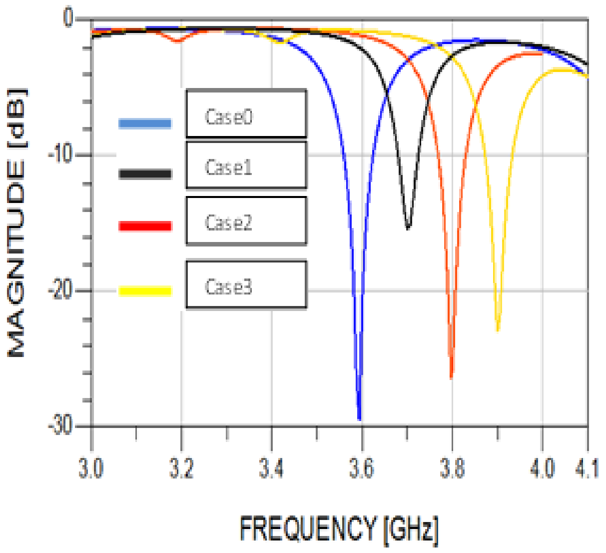


Fig.7. Simulated Return loss comparison

Radiation pattern is defined as a graphical representation of the radiation properties of the antenna as a function of space coordinates. Radiation properties include power flux density, radiation intensity, field strength, and directivity." Radiation pattern refers to the directional dependence of the strength of the radio waves from the antenna. Radiation pattern for all the four cases (i.e.) case 0, case 1, case 2, case 3 is plotted in 2-D and 3-D and shown in Fig.8, Fig.9., Fig.10., Fig.11., respectively.

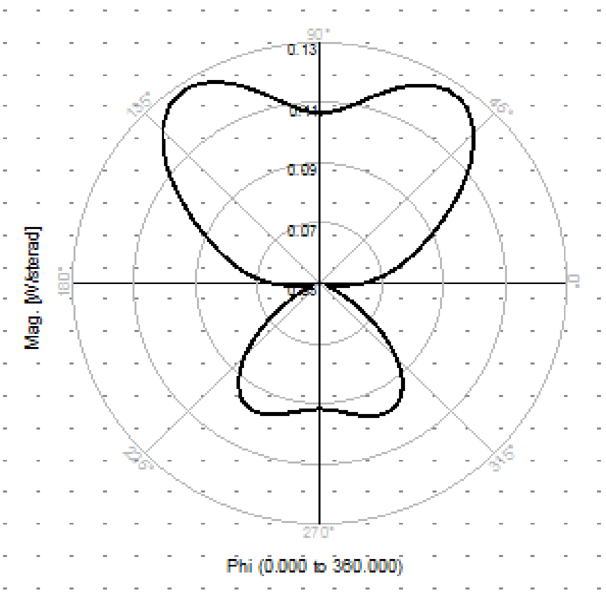


Fig.8(a). 2-D Radiation pattern of antenna at 3.594GHz

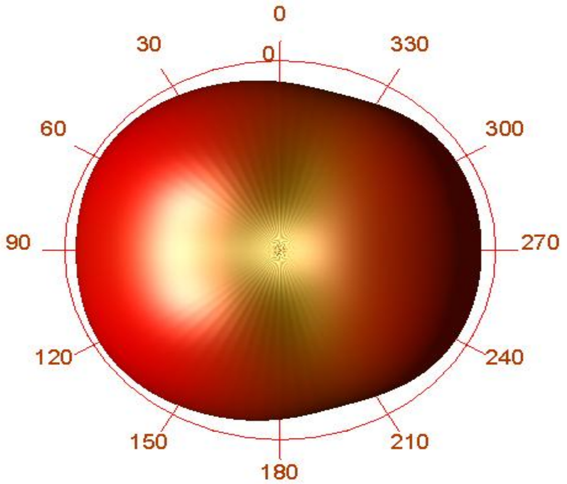


Fig.8(b). 3-D Radiation pattern of antenna at 3.594 GHz

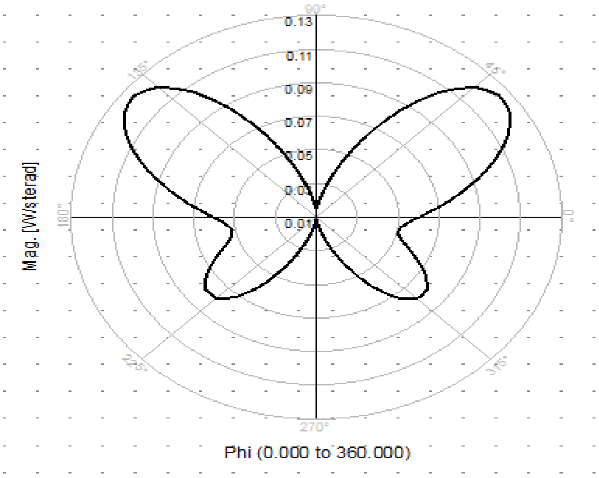


Fig.9(a). 2-D Radiation pattern of antenna at 3.7 GHz

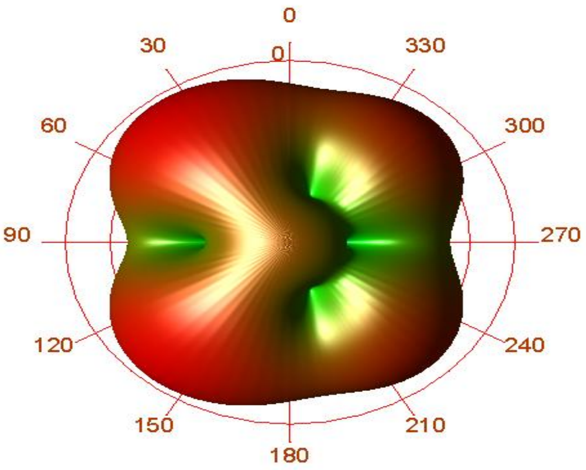


Fig.9(b). 3-D Radiation pattern of antenna at 3.7 GHz

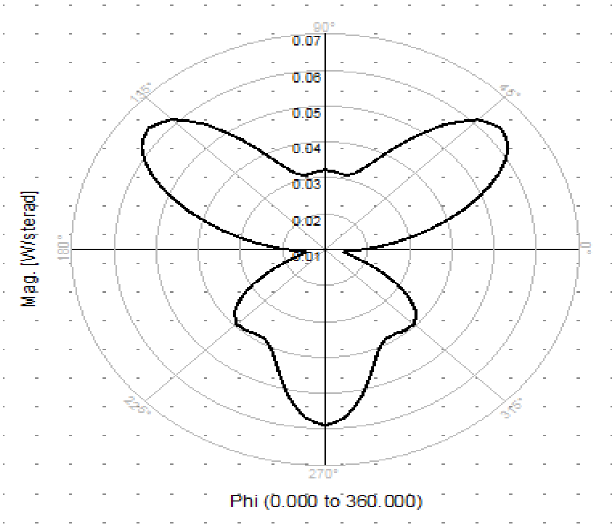


Fig.10(a). 2-D Radiation pattern of antenna at 3.8 GHz

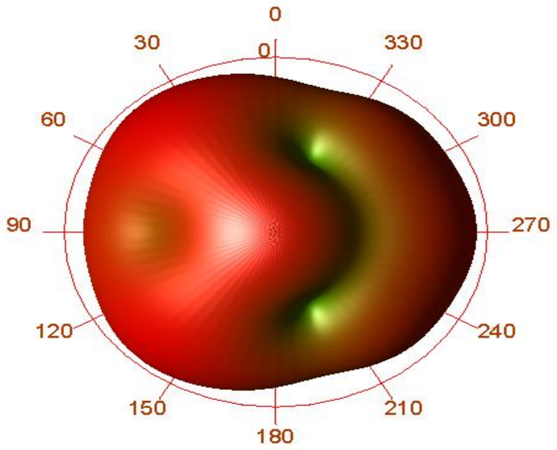


Fig.10(b). 3-D Radiation pattern of antenna at 3.8 GHz

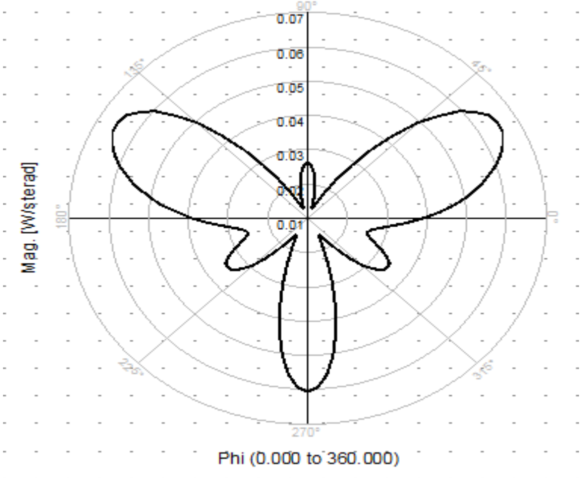


Fig.11(a). 2-D Radiation pattern of antenna at 3.9 GHz

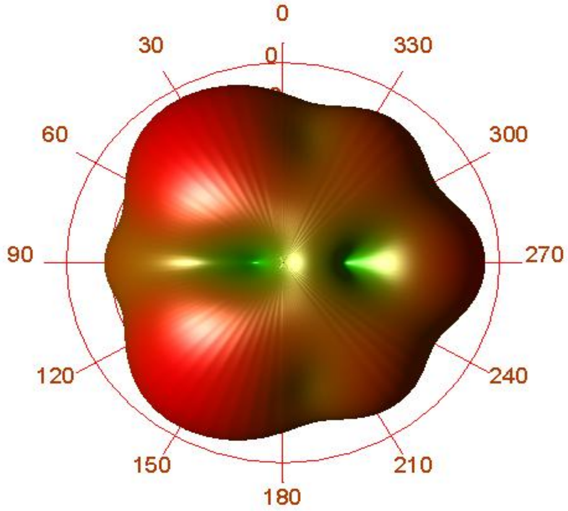


Fig.11(b). 3-D Radiation pattern of antenna at 3.9 GHz.

## 4 Measured Results Analysis

The patch antenna which is tested using Network Analyzer, and then its S1P file is created for making the comparisons along with the simulated results using Advanced Design System. Compared results can be used for analysis purposes. Figure 12 to Figure 16 shows the fabricated proposed microstrip patch antenna for the specified satellite S-Band applications for individual swich conditions and all switch conditions.Compared results of CASE 0, CASE 1, CASE 2, CASE 3 are shown in Figure 17 to Figure 21 respectively.

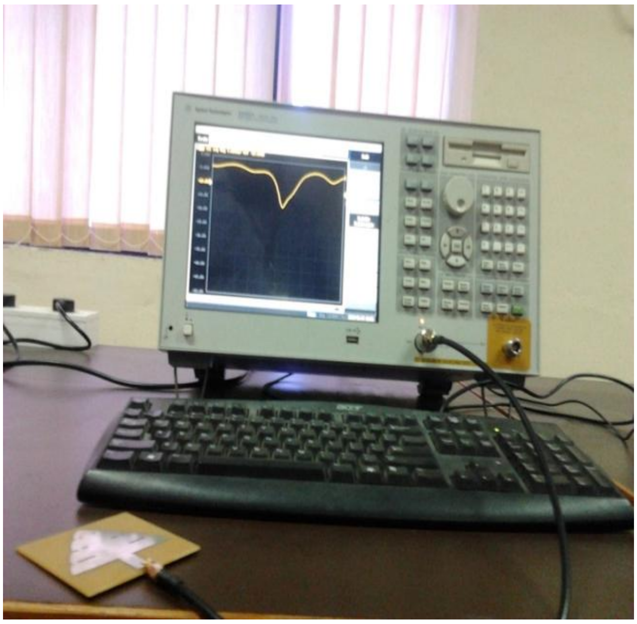


Fig.12.Mesurement setup of proposed microstrip patch antenna.

Fig.13. Fabricated microstrip patch antenna for CASE 0

Fig.14. Fabricated microstrip patch antenna for CASE 1

Fig.15. Fabricated microstrip patch antenna for CASE 2

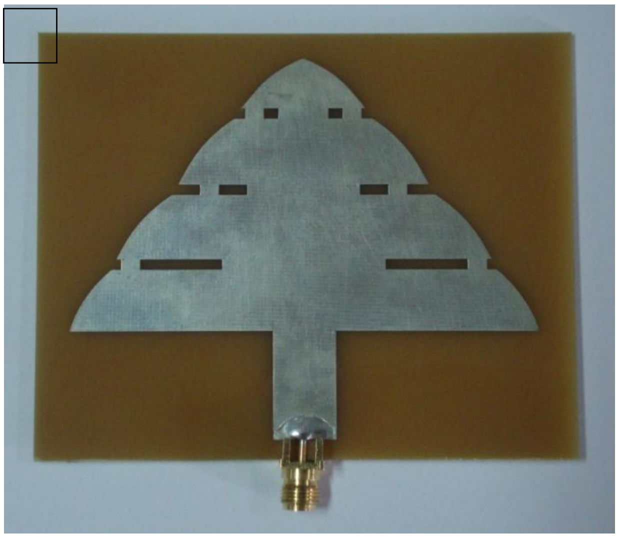


Fig.16. Fabricated microstrip patch antenna for CASE 3

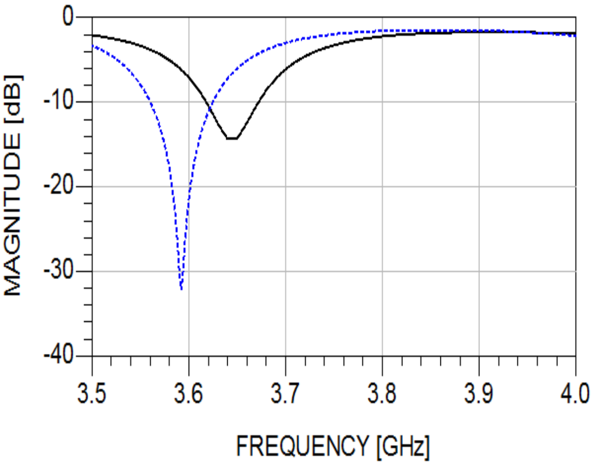


Fig.17. Comparison of Measured and Simulated results for CASE 0

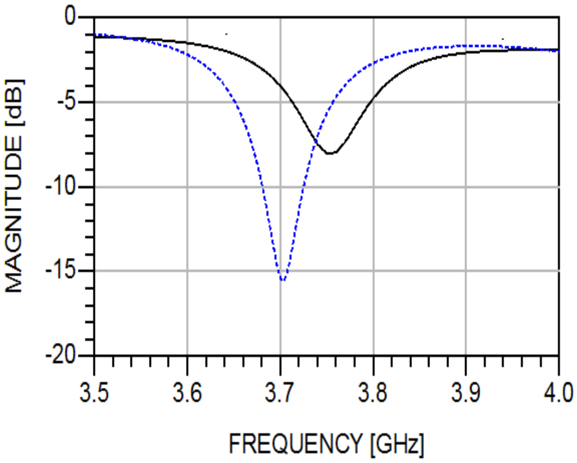


Fig.18. Comparison of Measured and Simulated results for CASE 1

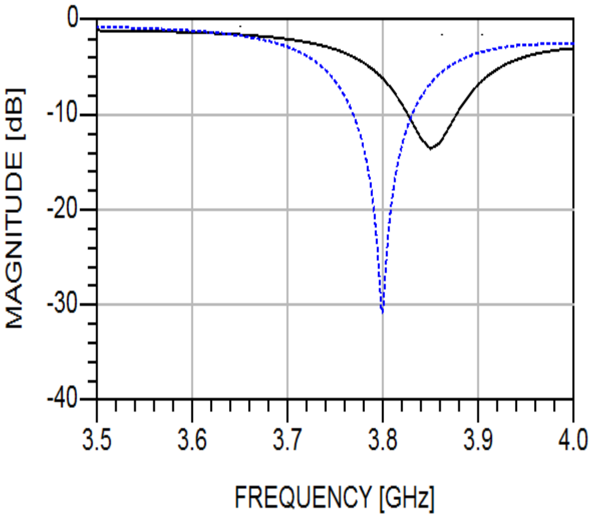


Fig.19.Comparison of Measured and Simulated results for CASE 2

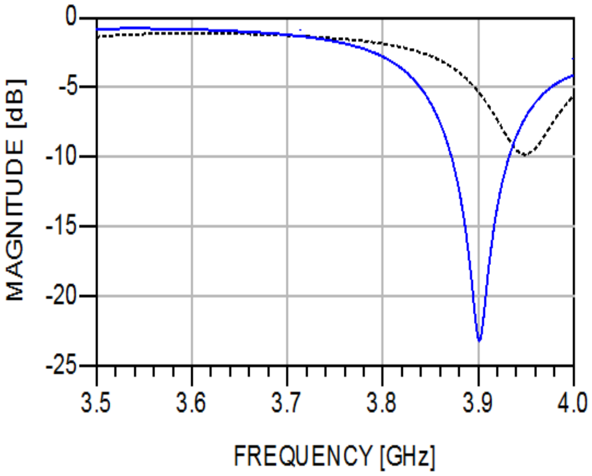


Fig.20.Comparison of Measured and Simulated results for CASE 3

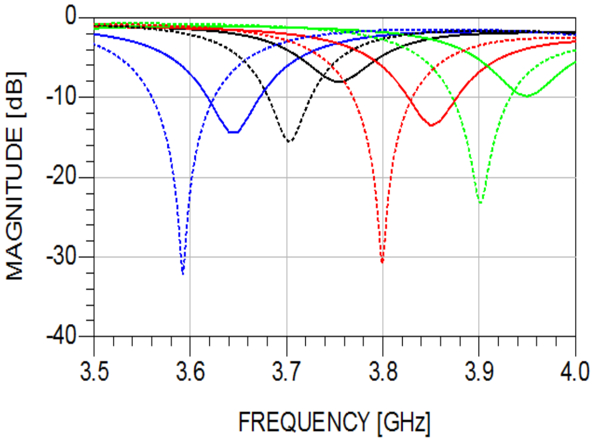


Fig.21. Comparison of Measured and Simulated results for all CASES

## 5 Conclusion

This paper provides the design of reconfigurable microstrip antenna for making an antenna to operate at different frequencies by varying the switch condition. The antenna is designed and synthesised using Advanced Design System. Its return loss, radiation pattern is obtained. It is made to operate at four different frequencies. Then the designed antenna is fabricated using FR4 material and then its return loss is measured using Network Analyzer. Then it is analysed, both simulated and fabricated results are presented and it is found that simulated and fabricated results are matched. The work can be further enhanced by making it operate at more number of frequencies by increasing the number of switch pairs.

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Mrs.P.Jothilakshmi has received her B.E. degree in Electronics and Communication Engineering from Thanthai Periyar Govt. Institute of Technology,Vellore, India in 1996 and M.E degree from Mepco Schlenk Engineering College, Sivakasi, India in 2000. Currently working as an Assistant Professor in Electronics and Communication Engineering Department at Sri Venkateswara College of Engineering, Chennai, India. She has been a teacher for the past 15 years and has guided more than thirty B.E and M.E Students projects. She has published more than thirty three conference and Journal papers both National and International level. Pursuing Ph.D in the area wireless antenna under the supervision of Dr.Mrs (S).Raju, Professor and Head of the Department, Electronics and Communication Engineering, Thiagarajar College of Engineering, Madurai, India. She is a member in professional societies ISTE , IETE and IAENG.