

# POLARIZATION RECONFIGURABLE ANTENNA

Ch. Akhila<sup>1</sup>, S. Goutham Reddy<sup>2</sup>, Nukala Rohit Reddy<sup>3</sup>, Y. Srinivas<sup>4</sup>

<sup>1,2,3</sup>Student, Electronics and Communication Engineering, Vignana Bharathi Institute of Technology

<sup>4</sup>Professor, Electronics and Communication Engineering, Vignana Bharathi Institute of Technology, Telangana, India.

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**Abstract** -The communication system requires the development of low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. Polarization reconfigurable antennas are capable of switching between different polarizations modes. The capability of switching between horizontal, vertical and circular polarizations can be used to reduce polarization mismatch losses in portable devices. Polarization reconfigurability can be provided by changing the balance between the different modes of a multimode structure. The popularity of these antennas is increasing day by day because of ease of analysis and fabrication, and their attractive polarization characteristics. This paper presents a polarization reconfigurable antenna for wireless communication. These antennas are used for communication purposes especially in WLAN. Here antenna is designed in HFSS (high frequency structure simulation) software with probe feeding at a particular resonant frequency. Antenna design and simulation with ANSYS HFSS, the industry leading 3D electromagnetic (EM) simulation tool for high frequency and high speed electronic components to obtain the antenna dimensions and to determine its performance. This antenna is based on a thickness of 1.6mm with a dielectric constant of approximately 4.4. After simulation, the antenna performance characteristics such as antenna input impedance (real and imaginary parts), VSWR, and return loss are obtained.

**Key Words:** polarization, reconfigurable, antenna, wireless communication, substrate. Dimensions.

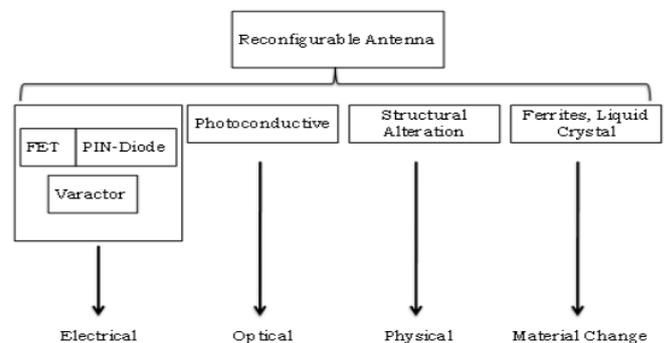
## 1. INTRODUCTION

Here we design the microstrip patch antenna with polarization reconfigurable in which single antenna [1] act as number of antennas by using patch rotation technique. Each antenna radiate different pattern so it increase the number of patterns and increase the diversity gain. In many of application of polarization reconfigurable microstrip antenna is used due to its low profile properties i.e. light weight, small size, ease of installation, conformability etc. Antenna diversity, also known as special diversity or space diversity is wireless diversity scheme that uses number of antennas to improve the reliability and quality of wireless communication. [2] The shape of the patch of microstrip antenna can be any of rectangular, circular, square, triangular, rings etc. Each of them has some theoretical design formula. The design of antenna is inventive where we study the invention of new antenna. By selecting the shape of antenna we can design reconfigurable antenna in terms of

polarization, frequency and pattern. Aim of the work is to study the change of antenna performance with respect to various parameters of microstrip antenna. Simulation has to be done by using HFSS software.

## 2. CLASSIFICATION OF RECONFIGURABLE ANTENNAS AND RECONFIGURATION TECHNIQUES

There are various techniques are there to implement reconfigurable antennas, as indicated in the below figure. Antennas based on electronic switching components to redirect their surface currents are called electrically reconfigurable. [3] Antennas that rely on photoconductive switching elements are called optically reconfigurable antennas. Finally, reconfigurable antennas can be implemented through the use of smart materials such as ferrites and liquid crystals. In this dissertation electrical reconfiguration technique is used to design and implement various reconfigurable antennas.



**Fig-3:** various techniques to achieve reconfigurable antennas

When designing reconfigurable antennas, we must address which reconfigurable property (e.g., frequency, radiation pattern, polarization or combination of these) needs to be modified. Based on that Reconfigurable antennas can be classified into four different categories

1. Frequency reconfigurable Antennas
2. Radiation Pattern reconfigurable Antennas
3. Polarization reconfigurable Antennas
4. Compound Reconfigurable Antennas

### 3. Antenna Design and Analysis

A micro strip 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 usually made of copper or gold can be virtually assumed to be of any shape. [4]The radiating elements and the feed lines are usually photo etched on the dielectric substrate. The radiating patch may be square, rectangular, circular, ring, elliptical or any other configuration. Square, rectangular and circular shapes are the most common because of ease of analysis and fabrication. Some of the advantages of the micro strip antennas compared to conventional microwave antennas are

- Low weight, low volume,
- Low fabrication cost,
- Easy mass production,
- Linear and circular polarization are possible with simple feed,
- Easily integrated with MIC,
- Feed lines and matching networks can be fabricated simultaneously with antenna structures.

Patch antennas find a variety of applications starting from military to commercial, because of their ease of design and fabrication. Patch arrays are extensively used in phased array radar applications and in applications requiring high directivity and narrow beam width.[5] One of the first tasks in the printed antenna design is the selection of a suitable substrate material. The major electrical parameters to be considered are the relative dielectric constant and the loss tangent. A higher dielectric constant results in smaller patch antenna but generally reduces bandwidth and results in tighter fabrication tolerances. A high loss tangent reduces the antenna efficiency and increases feed losses. As a rule of thumb, select a substrate with lowest possible dielectric constant. Substrate thickness is chosen as large as possible to maximize bandwidth and efficiency but not so large to allow surface-wave excitation. For a maximum operating frequency of 'f', the substrate height 'h' should satisfy

$$h \leq \frac{0.3 c}{2\pi f \sqrt{\epsilon_r}}$$

Where 'c' is the speed of light and ' $\epsilon_r$ ' is the relative dielectric constant of the substrate material.

[6]A square patch antenna with a loop slots on a ground plane exhibits polarization reconfigurability from LHCP to RHCP by using patch rotation technique. The copper

patch placed on a FR4-Epoxy substrate ( $\epsilon_r= 4.4$ ,  $h=1.6\text{mm}$ ) can change its polarization from LHCP to RHCP by altering the incidence direction of the externally applied electric field to the patch. A four arm sinuous antenna is fed to a four module photonic feed system, by changing the phase shift of the signals that are applied to the module; this sinuous antenna can change its polarization from LHCP to RHCP.

### 4. Antenna Characteristics

An Antenna is a device that is made to efficiently radiate and receive radiated electromagnetic waves. There are several important antenna characteristics that should be considered when choosing an antenna for your application as follows,

- Antenna radiation patterns
- Directivity
- Power Gain
- Polarization

### 5. HFSS (high frequency structure simulation)

Wireless communications have progressed very rapidly in recent years, and many mobile units are becoming smaller and smaller. To meet the miniaturization requirement, the antennas employed in mobile terminals must have their dimensions reduced accordingly. Planar antennas, such as micro strip and printed antennas have the attractive features of low profile, small size, and conformability to mounting hosts and are very promising candidates for satisfying this design consideration. For this reason, compact, broadband and wideband design technique for planar antennas have been attracted much attention from antenna researchers. Very recently, especially after the year 2000, many novel planar antenna designs to satisfy specific bandwidth specifications of present day mobile cellular communication system including the global system for mobile communication (GSM: 890 - 960 MHz), the digital communication system (DCS: 1710 - 1880 MHz), the personal communication system (PCS: 1850 -1990 MHz), and the universal mobile telecommunication system (UMTS: 1920 - 2170 MHz), have been developed and published in the open literature.

Planar antennas are also very attractive for applications in communication devices for wireless local area network (WLAN) systems in the 2.4 GHz and 5.2 GHz bands. The aim of this tutorial is to show how to use HFSS to design planar antennas for wireless communications. Therefore, we have chosen rectangular probe feed patch antenna. At the end we will propose some projects.

HFSS is a high performance full wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft windows graphical user interface. It integrates simulation, visualization, solid modeling and automation in an easy to learn environment where solutions

to our 3D EM problems are quickly and accurately obtained. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency and fields.

The name HFSS stands for High Frequency Structure Simulator. Ansoft pioneered the use of the Finite Element Method (FEM) for EM simulation by developing/implementing technologies such as tangential vector finite elements, adaptive meshing and innovations such as modes to nodes and full wave spice.

Ansoft HFSS has evolved over a period of years with input from many users and industries. In industry, Ansoft HFSS is the tool of choice for high productivity research, development and virtual prototyping.

### 6. Coaxial Feed/Probe Coupling

Coupling of power through a probe is one of the basic mechanisms for the transfer of microwave power. The probe can be an inner conductor of a coaxial line in the case of a coaxial line feeding or it can be used to transfer power from a triplet line (strip line) to a microstrip antenna through a slot in the common ground plane. A typical microstrip antenna using a coaxial connector is shown in the figure. The coaxial connector is attached to the back side of the PCB, and the center conductor after passing through the substrate is soldered to the patch metallization.

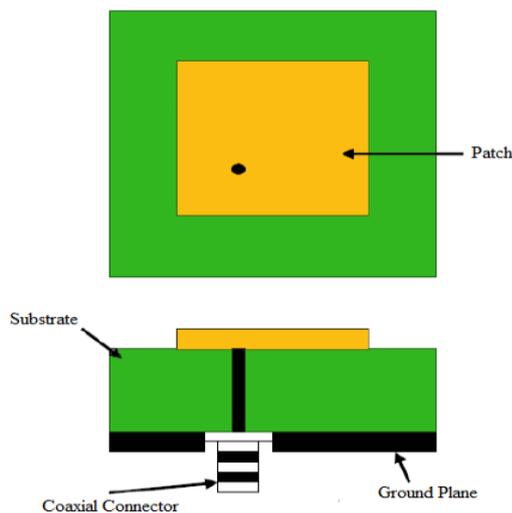


Fig-4: Coaxial probe feeding of a microstrip antenna

### 7. Design Procedure of Reconfigurable Antenna

The reconfigurable patch antenna is simplest form of patch antenna as shown in Fig. 3.1 and usually designed to operate near the resonance. The length 'L' of the patch radiator is then selected such that it satisfies the condition of resonance. It is usually chosen close to  $\lambda/2$  such that the

input impedance of the patch is pure real at the desired frequency. Since the two ends of the patch are open, an open-end correction is usually taken into account while calculating the physical length 'L' of the patch.

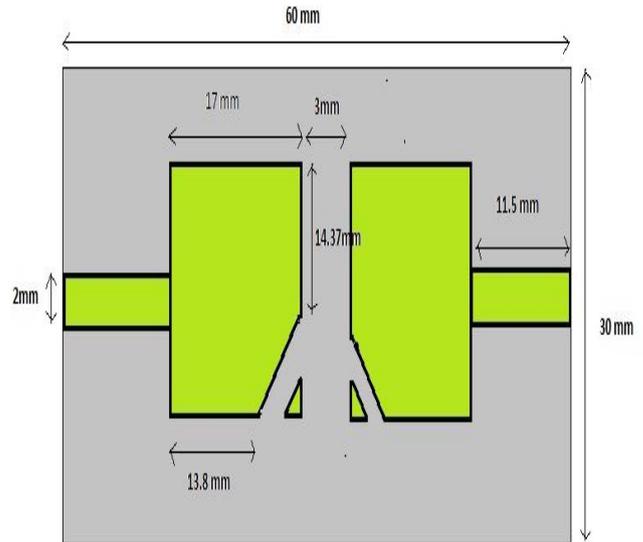


Fig-5: Geometry of proposed antenna

The patch width 'W' generally lies between 0.5 to 2 times 'L'. The width can be used to vary the input impedance of the patch. As we have to ultimately match the patch input impedance to 50 ohms, we can control input impedance to some extent by changing the patch width 'W'. If 'W' is chosen very small, the antenna radiation efficiency will be reduced. So there is tradeoff between the input impedance and radiation efficiency. Once W and L are selected, we can calculate the input impedance of the patch and then use impedance transformer to match this impedance to the 50 ohm feed line. The design of a rectangular micro strip patch antenna begins with,

- (a) Choice of a substrate
- (b) Selecting feed mechanism,
- (c) Determining patch width w and
- (d) Selecting the feed location.

The micro strip rectangular structure as shown in figure has been used to implement a polarization reconfigurable rectangular patch antenna.

In the following steps rectangular patch antenna design procedure is given after choosing its essential parameters such as frequency of operation ( $f_r$ ), dielectric constant of the substrate ( $\epsilon_r$ ), height of dielectric substrate (h).

### 8. Fabricated Patch Antennas



**Fig-6:** Fabricated Patch Antennas (without slots, right slots, left slots)

The proposed antenna was fabricated on a substrate with a dielectric constant of 4.4 and a thickness of 1.6 mm. The reconfigurable antenna is tuned at 4.1 GHz. All of the geometrical parameters are  $L= 30$  mm,  $W= 60$ mm,  $h= 1.6$ mm,  $S= 0.1$ mm,  $d= 11.5$  mm and  $l= 2$  mm. Fig. 4.1 shows the pictures of the fabricated antennas. The anodes of the probe connector are connected to the ground, and the cathodes are connected to the corresponding little square patches with two leads being soldered on each one.

The geometrical sizes of the perturbation elements on the CP characteristics are investigated. The effects of the square slot side length and the position on the return loss for linear and circular polarization are shown in Fig.4.2 and 4.4 respectively. The side length of the square slot influences the axial ratio, as shown in Fig.3.9, Fig. 3.10 and Fig 3.11. It is found that the size of the perturbation element is greatly influencing the CP characteristic similar to the truncation effects on a square patch. The slot position has a little effect on the axial ratio as shown in Fig. 3.10 and Fig. 3.11. However, the operation frequency of the lowest axial ratio (AR) increases slightly with the decreasing of  $l$ . A narrower slot width would exhibit a better CP characteristic from the simulation, but it should meet the fabrication tolerance. The measured 10-dB bandwidths of  $S_{11}$  for LHCP and RHCP were about 4.0 to 4.2 GHz. Good impedance match was obtained.

### 9. NETWORK ANALYZER

A network analyzer is an instrument that measures the network parameters of electrical networks. Today, network analyzers commonly measure s-parameters because reflection and transmission of electrical networks are easy to measure at high frequencies, but there are other network parameter sets such as y-parameters, z-parameters, and h-parameters. Network analyzers are often used to characterize two-port networks such as amplifiers and filters, but they can be used on networks with an arbitrary number of ports.

Network analyzers are used mostly at high frequencies; operating frequencies can range from 5 Hz to 1.05 THz. Special types of network analyzers can also cover lower frequency ranges down to 1 Hz. These network analyzers can be used for example for the stability analysis of open loops or for the measurement of audio and ultrasonic components.

The two basic types of network analyzers are

- scalar network analyzer (SNA)—measures amplitude properties only
- vector network analyzer (VNA)—measures both amplitude and phase properties

A VNA is a form of RF network analyzer widely used for RF design applications. A VNA may also be called a gain-phase meter or an automatic network analyzer. An SNA is functionally identical to a spectrum analyzer in combination with a tracking generator. As of 2007, VNAs are the most common type of network analyzers, and so references to an unqualified "network analyzer" most often mean a VNA. Three prominent VNA manufacturers are Keysight, Anritsu, and Rohde & Schwarz.

Another category of network analyzer is the microwave transition analyzer (MTA) or large signal network analyzer (LSNA), which measure both amplitude and phase of the fundamental and harmonics. The MTA was commercialized before the LSNA, but was lacking some of the user-friendly calibration features now available with the LSNA.

### 10. Testing results of fabricated antenna

With the processed RF signal available from the receiver / detector section it is necessary to display the signal in a format that can be interpreted. With the levels of processing that are available today, some very sophisticated solutions are available in RF network analyzers. Here the reflection and transmission data is formatted to enable the information to be interpreted as easily as possible. Most RF network analyzers incorporate features including linear and logarithmic sweeps, linear and log formats, polar plots, Smith charts, etc. Trace markers, limit lines and also pass / fail criteria may also be added in many instances.



**Fig-7:** Antenna testing using Network analyzer



Fig-8: Return loss for linear polarization

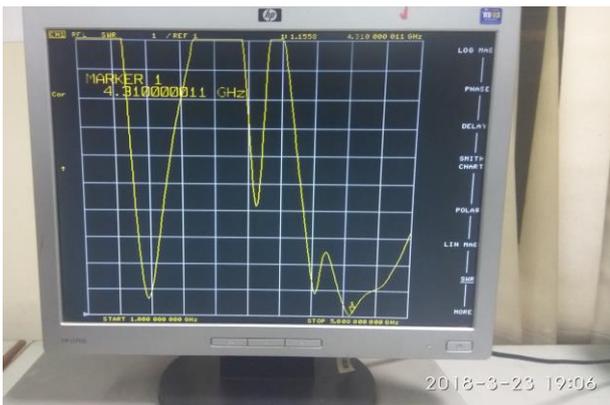


Fig-9: VSWR for Linear Polarization

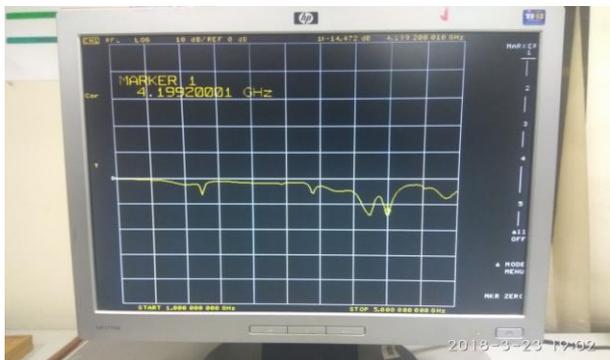


Fig-10: Return loss for RHCP and LHCP

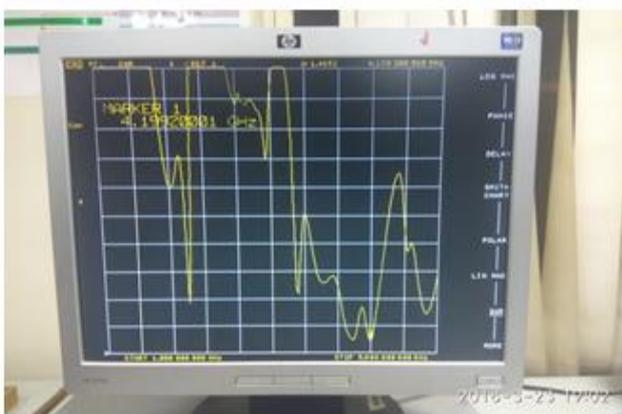


Fig-11 : VSWR for LHCP and RHCP

The measured patterns of the reconfigurable patch for linear polarization at 4.31 GHz is shown in Fig. 4.2 and for LHCP and RHCP at 4.19 GHz is shown in Fig. 4.4. Good radiation performances are achieved for every polarization status. For linear polarization, the cross polarization in the broadside direction is about 40 dB and the obtained gain is 3.3 where as for RHCP and LHCP is 4.9 dB and 4.7 dB respectively.

**Comparison between Simulated and Testing Results**

The table below shows the comparison of simulated and testing results for the proposed antenna designs.

**Table 1:** Comparison of simulated and testing Results

parameter	theoretical		practical	
	linear	circular	linear	circular
Return lo in db	6.6	-17	6.8	-17.7
Operating frequency in GHz	4.1	4.1	4.3	4.19

The above table shows the comparison of simulated results and testing results using network analyzer after fabrication of proposed antenna. Simulation results of return loss for linear polarization is 6.6 dB and circular polarization is -17 dB whereas testing results are 6.8 dB and -17.7 dB respectively. Simulation results of operating frequency for RHCP and LHCP are 4.1 GHz whereas testing results for RHCP and LHCP are 4.3 GHz and 4.19 GHz respectively.

**11. CONCLUSIONS**

In this paper, a detailed study about the different types of reconfigurable antennas was presented. The study was based on the different reconfiguration techniques used to obtain the required reconfigurability. Reconfigurable antennas were mainly divided into electrically, optically, physically, and smart-material-based tunable structures. A comparison between the different techniques used to implement such type of antennas was presented. The use of reconfigurable antennas in satellite communication was also discussed.

Polarization reconfigurable antenna operation is successfully designed at 4.1GHz frequency. The polarization diversity can be achieved by using patch rotation technique with the return loss of -17.5dB for LHCP and -29dB for RHCP respectively. This antenna is used to improve the signal performance in the multipath fading environment.

## 12. REFERENCES

- [1] C. A. Balanis, "Antenna Theory, analysis and design", JOHN WILEY & SONS, INC, New York, 1997.
- [2] CG.Christodoulou.Y.Tawk,S.A.Lane, and S.R.Erwin, Reconfigurable antenna for wireless & space applications, Proc. IEEE, 100(7) ,pp 2250-2261,July 2012.
- [3] R. Garg, P.Bhatia, I. Bhal, A. Ittipibbon, " Microstrip Antenna Design and Handbook", Artech House, Boston, 2001.
- [4] Jingjing Huang; Kin-Fai Tong; Baker, C., "A new polarization reconfigurable microstrip antenna for diversity array," Radar Conference, 2008. RADAR '08. IEEE , vol., no., pp.1,4, 26- 30 May 2008.
- [5] R.L.Haupt and M.Lanagan, Reconfigurable antennas, IEEE Antennas & Prop.Mag., 55(1), pp 49– 61, Feb 2013.
- [6] Reconfigurable patch antennas for wireless and space applications, by Christos G. Christodoulou, Fellow IEEE in July 2012.