Middle-East Journal of Scientific Research 24 (9): 2832-2842, 2016
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2016.24.09.23873

Design and Development of Reconfigurable Microstrip Patch Antenna for Secure Communication

T. Yathavi and S. Uma Maheswari

Department of Electronics & Communication Engineering, Coimbatore Institute of Technology, India

Abstract: A 2.4 GHz unlicensed high frequency microstrip patch antenna with switchable polarization is proposed to be designed and analyzed. The proposed antenna further exploits the current overcrowded 2.4 GHz using polarization diversity. The antenna will be able to transmit in Linear Polarization (LP), Right Hand Circular Polarization (RHCP) and Left Hand Circular Polarization (LHCP) methods via slots and PIN diodes. The functionality is realized through incorporating slots of equal slot length in the circular patch and utilizing four PIN diodes to switch the slots ON or OFF. The simulation is carried out in Ansoft HFSS. A circular patch with FR4 substrate is used for simulation. The antenna provides a reflection coefficient of -17.25 dB for linear polarization, -17.78 dB for RHCP and -17.98 dB for LHCP. Axial ratio obtained 41.9 dB for Linear polarization, 3 dB for RHCP and 3 dB for LHCP Small in dimension and with unique features, the proposed antenna is expected to be potentially suitable for secure wireless applications in limited space and multipath rich environments.

Key words: Reconfigurable antenna · 2.4 GHz . microstrip patch antenna · Polarization · Secure communications

INTRODUCTION

Antenna became an essential device in wireless communication system. Need for wireless devices are increasing day by day. The rapid development of wireless communication encourages the need of high throughput or high data rate in almost all communications. United States (U.S) Federal Communication Commission known as FCC allocates frequency bands for commercial use. The frequency bands near 2.4 GHz, 24 GHz and 60 GHz are declared as unlicensed by the FCC. Microstrip antennas presents interesting features like low profile, light weight, low production cost and good aerodynamic profile. The antennas can be integrated with the feeding network on the same substrate, resulting structures are compact and very useful in practical applications. An important drawback of microstrip antennas is their low radiation efficiency mainly caused by high concentration of field in the dielectric substrate which adds both dielectric and ohmic losses. Conventional antenna may face restrictions and limitations to adapt to the new adjustments, due to their characteristics of being fixed and inflexible. One solution to overcome this restriction is the use of reconfigurable antenna. Reconfigurable antennas, or multi-functional antennas, have recently become quite an active and important topic of research all over the globe. This is due to the fact that the characteristics and properties of the reconfigurable antenna [1] such as operating frequency/bandwidth, far-field radiation pattern and polarization - can be altered dynamically using external control, hence providing additional functionality and versatility to the systems. Flexibility and reconfigurability features could result in the adaptability of the antenna to address complex system requirements and new specifications. Furthermore, through this concept, the number of components, sizes and hardware complexities could be reduced [2] hence the cost would be more economically efficient. These benefits would render reconfigurable antennas to become a highly desired feature in modern radio-frequency (RF) systems for wireless and satellite communications. The antenna is analyzed and designed using Ansoft HFSS software. Rectangular plot, radiation pattern and field pattern are measured using the software and hence bandwidth, directivity and total power gain is measured.

Corresponding Author: S. Uma Maheswari, Department of Electronics & Communication Engineering, CIT, India.

Antenna Design Equations: A noval small microstrip antenna for 2.4 GHz applications is proposed in this paper. The antenna dimensions [3] are calculated using design equations.

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi\varepsilon_{\Gamma} F\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]}\right\}^{1/2}} \quad (1)$$

$$F = \frac{8.791\times 10^{9}}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

where ε_r – Relative dielectric constant of substrate

usually $2.2 \leq \varepsilon_r \leq 12$
f_r – Radiation Frequency of Patch

where h – Height of the substrate

$h << \lambda$, usually $0.003\lambda \leq h \leq 0.05\lambda$)

The design equations given by (1) and (2) provides effective radiation from the patch.

GHZ Microstrip Circular Patch Antenna Design: Based on design equations various dimensions of 2.4 GHz microstrip patch antenna is calculated. The following are the initial specifications that are analyzed and fixed. Substrate material is FR4_epoxy with height 1.524 mm with relative dielectric constant of substrate of 4.4. Length of the slot=Radius/4 and Width of the slot=Ls/4. Table 1: shows the design parameters of the antenna.

Details of the design, development of the polarization reconfigurable circular patch antenna with switchable slit length are presented. Two pairs of slits [4] were located at the edge of the patch, positioned on the *x*-axis and *y* axis. The polarization reconfigurability feature of the antenna was executed by placing four switches at specific positions across the slits. The change of the state of the switches consequently alters the length of the slit, hence creating a length difference between the slit in the *x*-axis and the *y*-axis. This will determine the types of polarization excited by the antenna either LHCP, RHCP or LP. Due to the diagonal feeding on the structure and perturbation segments, the two near degenerated orthogonal resonant modes [5] TM01 and TM10 are excited simultaneously. When the pair of slits is cut on the *x*-axis of the patch, only TM01 mode will be affected without giving much effect on the TM10 mode and vice versa.

The length difference between the slit on the *x*-axis and on the *y*-axis will provide the phase delay between both orthogonal resonant modes. At a specific length difference, the two orthogonal degenerated resonant modes will have the same amplitude and in-phase quadrature, which the CP is excited. LP is excited when two switches on the *x*-axis and *y*-axis are ON, which means no phase difference between both orthogonal resonant modes. This proposed antenna works in three polarization modes, namely LHCP, RHCP and LP. The type of excited polarization [6] depends on the configurations of four switches. The switching conditions of all switches, with the respected modes, are tabulated in Table 2. The nature of polarization can be found [7] by the parameter axial ratio (AR). AR=the ratio of the major axis to the minor axis. Fig. 5 (a), (b), (c) shows the axial ratio for linear polarization, elliptical polarization, circular polarization.

Experimental Results: The proposed microstrip antenna was designed and simulated using Ansoft HFSS 13.0 and antenna parameters resonant frequency, E- field strength, Radiation Pattern, Directivity and axial ratio are obtained. The rectangular plot shown in Fig. 6. shows return loss, S11(dB) is -17.98dB is very minimum at 2.4GHz which is the frequency designed for LHCP. The radiation pattern shown in Fig. 7. provides direction of maximum radiation and maximum radiated power of 4.4 dB for LHCP. Fig. 8. shows the simulated results for axial ratio which is 3 dB for LHCP.

The rectangular plot shown in Fig. 9 shows return loss, S11(dB) is -17.78dB is very minimum at 2.4GHz which is the frequency designed for RHCP. The radiation pattern shown in Fig. 10 provides direction of maximum radiation and maximum radiated power of 4dB. Fig. 11. shows the simulated results for axial ratio which is 3 dB for RHCP.

The rectangular plot shown in Fig. 12. shows return loss, S11(dB) is -17.25 dB is very minimum at 2.4GHz which is the frequency designed for LP. The radiation pattern shown in Fig. 13. provides direction of maximum radiation and maximum radiated power of 4.12dB for LP. Fig. 14. shows the simulated results for axial ratio which is 41.9 dB for LP.

Table 1: Design Parameters

S.No	Parameters	Values
1	L(length of the substrate)	55 mm
2	W(Width of the substrate)	55 mm
3	h(height of the substrate)	1.524 mm
4	t(thickness of the patch)	0.035 mm
5	a(radius of the antenna)	16. 8 mm
6	Ls(length of the slot)	4.25 mm
7	Ws(width of the slot)	1.06 mm

Table 2: Switching configurations of the proposed antenna

	State of switch		Polarization mode		
Configuration	SW1	SW2	SW3	SW4	
LHCP	ON	OFF	ON	OFF	LHCP
RHCP	OFF	ON	OFF	ON	RHCP
LP	OFF	OFF	OFF	OFF	LP

Table 3: Comparison of Simulated and Measured Results for LP, LHCP, RHCP

Configuration	Polarization	Simulated S11(dB)	Measured S11(dB)
LHCP	LHCP	- 17.98	- 26.37
RHCP	RHCP	- 17.78	- 26.22
LP	LP	- 17.25	- 30.47

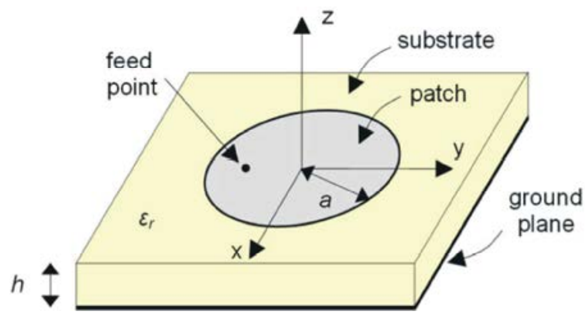

Fig. 1: Circular microstrip patch geometry

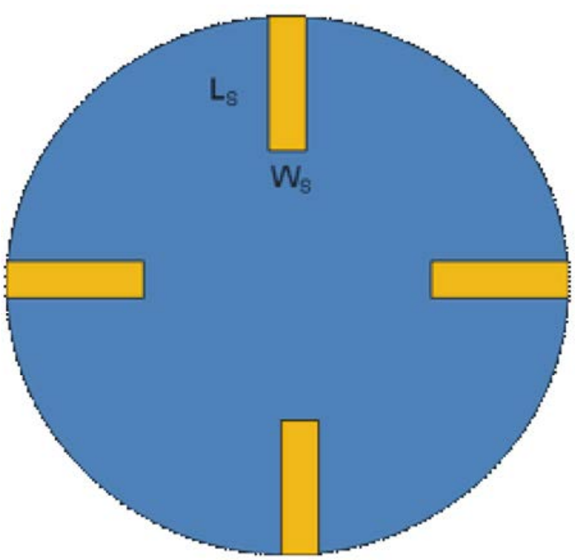

Fig. 2: Circular microstrip patch shows the length and width of the slot

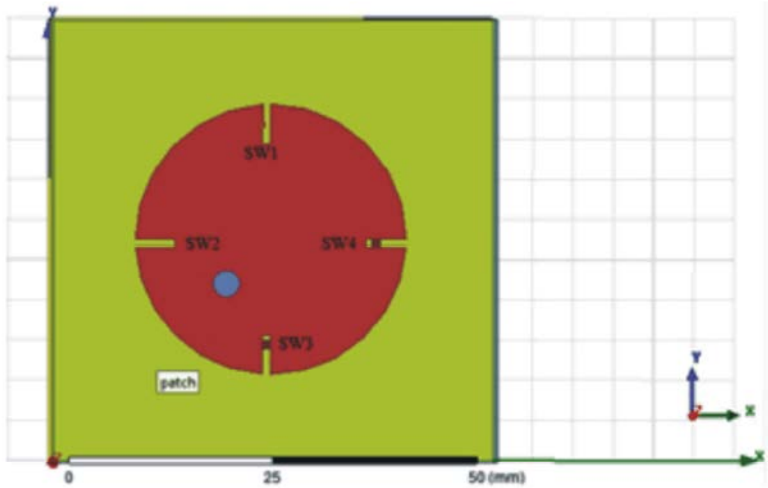

Fig. 3: Geometry of the proposed antenna (Top view) using Ansoft HFSS

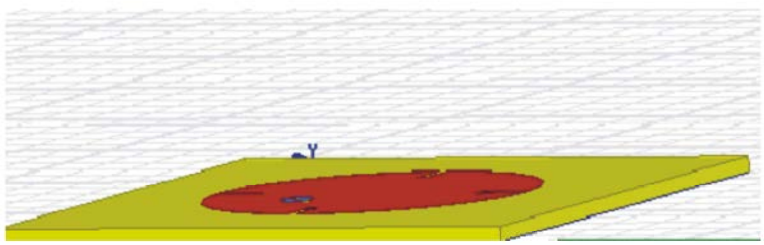

Fig. 4: Geometry of the proposed antenna (Side view) using Ansoft HFSS

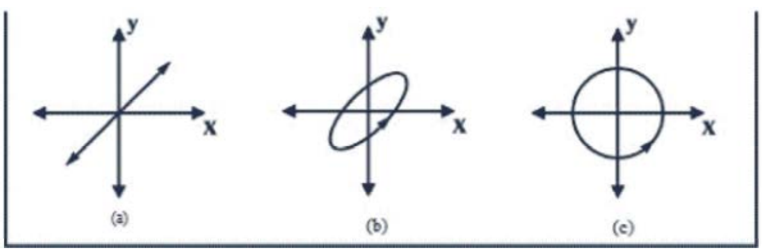

Fig. 5: (a) linear polarization (b) elliptical polarization(c) circular polarization

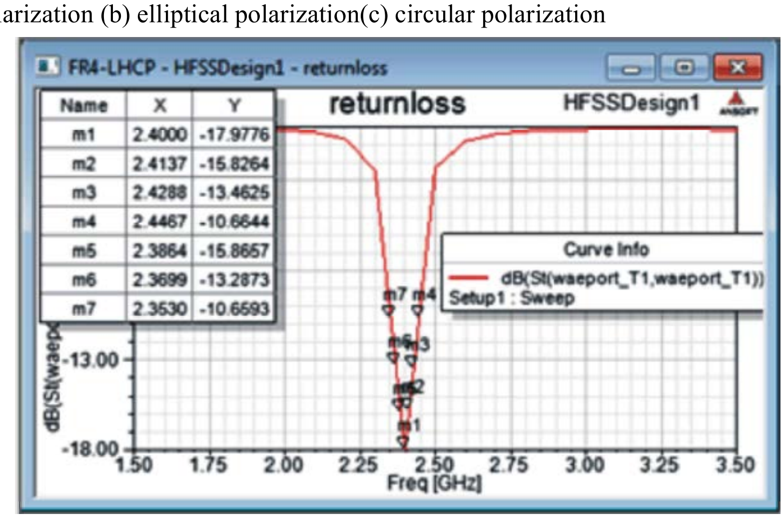

Fig. 6: Rectangular plot (Frequency Vs S_{11}(dB)) of 2.4 GHz microstrip circular patch-LHCP using Ansoft HFSS

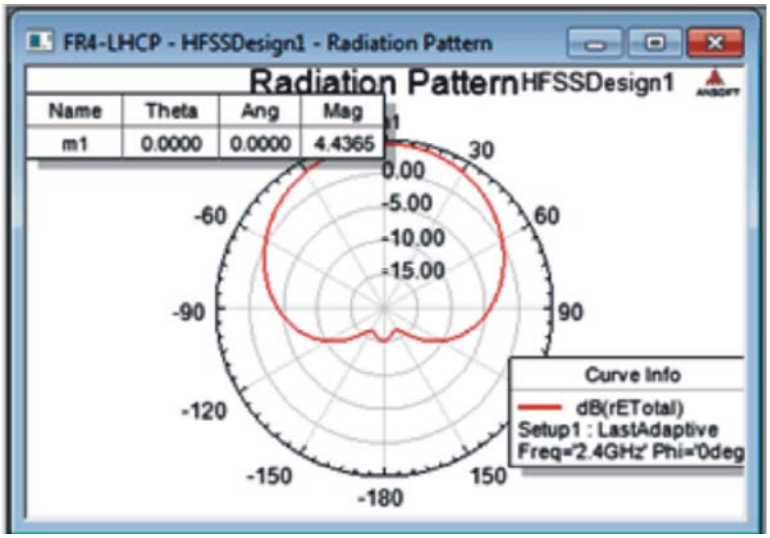

Fig. 7: Radiation pattern of 2.4 GHz microstrip circular patch-LHCP using Ansoft HFSS

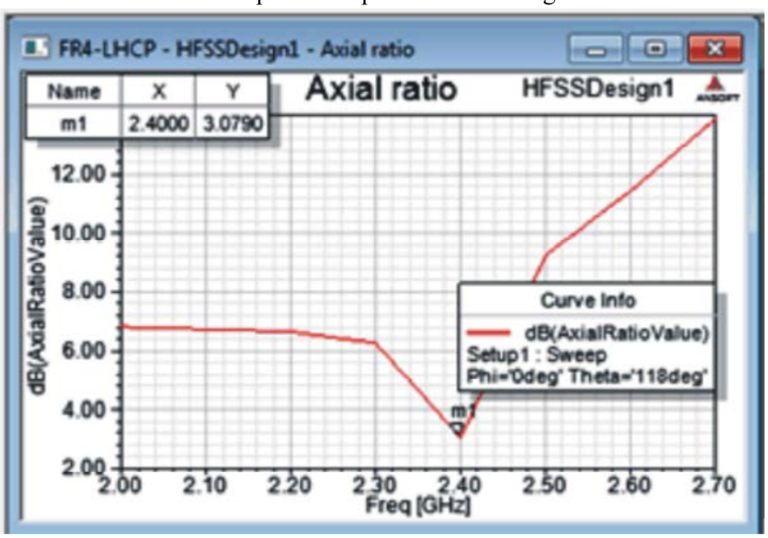

Fig. 8: Axial ratio of 2.4 GHz microstrip circular patch-LHCP using Ansoft HFSS

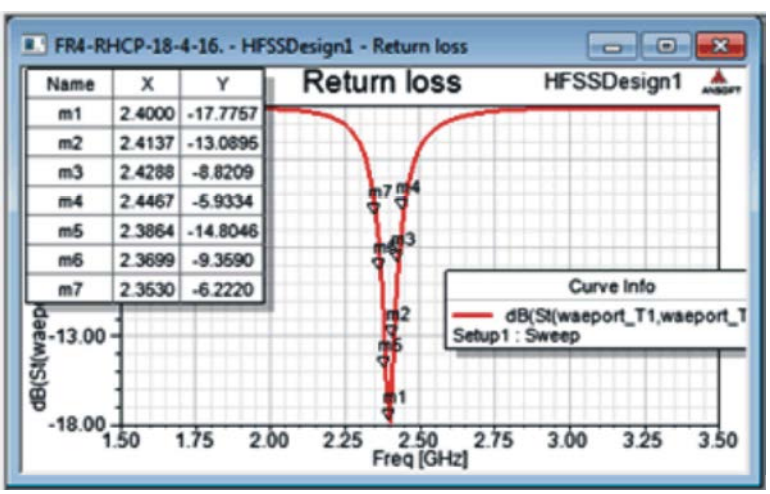

Fig. 9: Rectangular plot (Frequency Vs S_{11}(dB)) of 2.4 GHz microstrip circular patch-RHCP using Ansoft HFSS

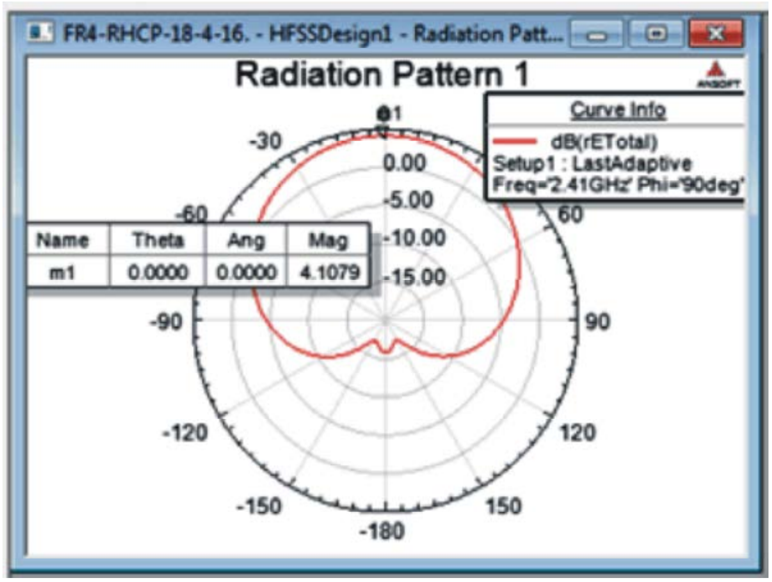

Fig. 10: Radiation pattern of 2.4 GHz microstrip circular patch-RHCP using Ansoft HFSS

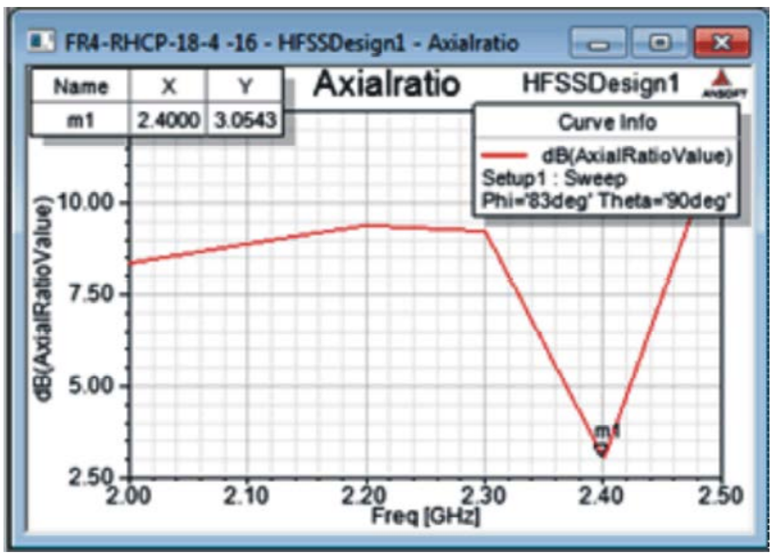

Fig. 11: Axial ratio of 2.4 GHz microstrip circular patch-RHCP using Ansoft HFSS

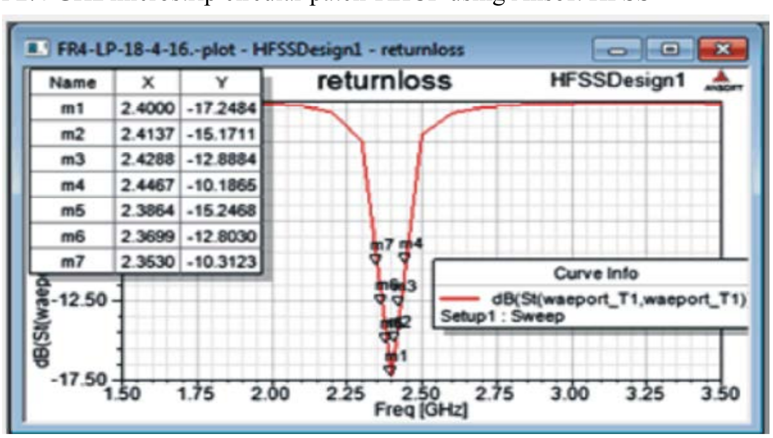

Fig. 12: Rectangular plot (Frequency Vs S_{11}(dB)) of 2.4 GHz microstrip circular patch-LP using Ansoft HFSS

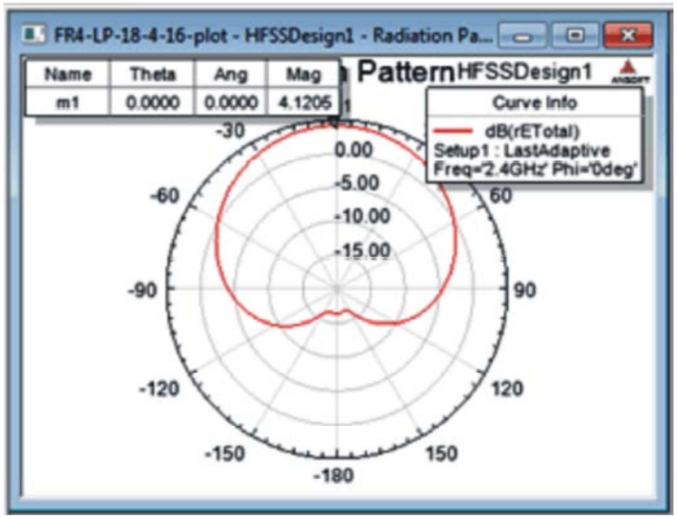

Fig. 13: Radiation pattern of 2.4 GHz microstrip circular patch-LP using Ansoft HFSS

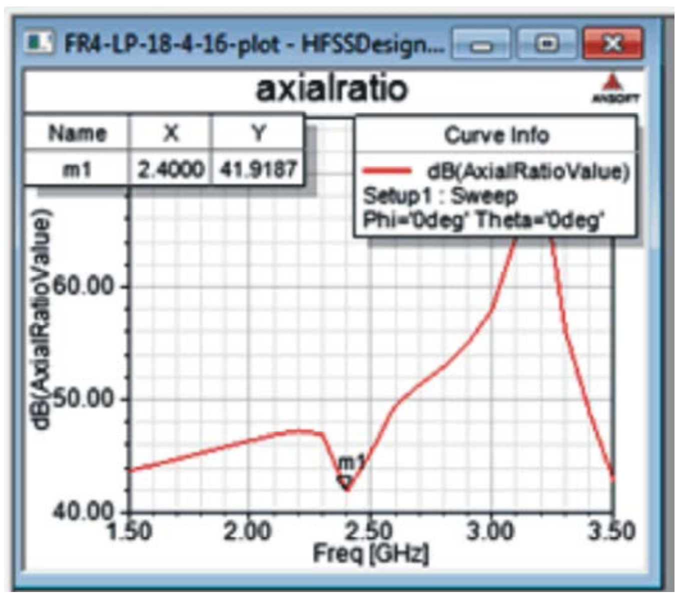

Fig. 14: Axial ratio of 2.4 GHz microstrip circular patch-LP using Ansoft HFSS

Fig. 15: Fabrication Process of the designed antenna

Fig. 16: Fabricated Antenna Images

Fig. 17: The real time measurement setup

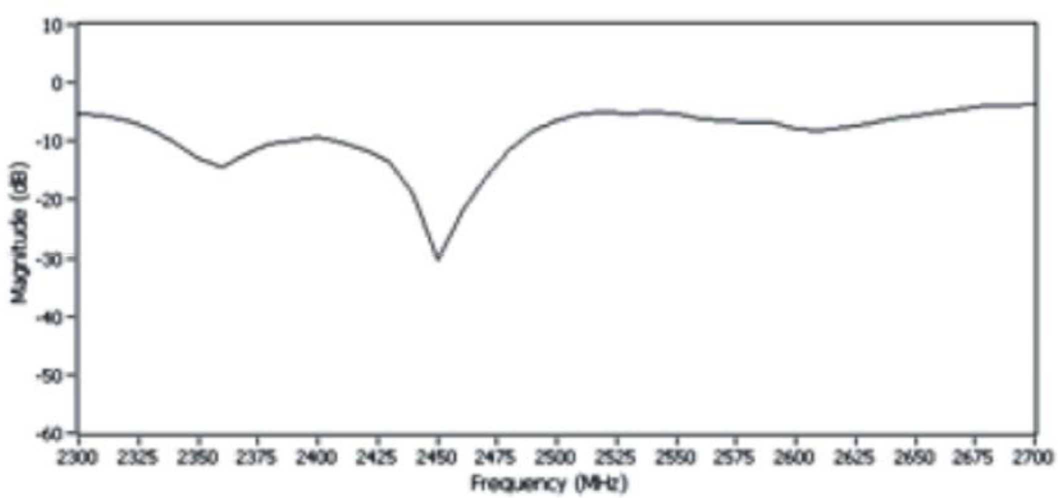

Fig. 18: Measured S_{11} of the patch using VNA for LP

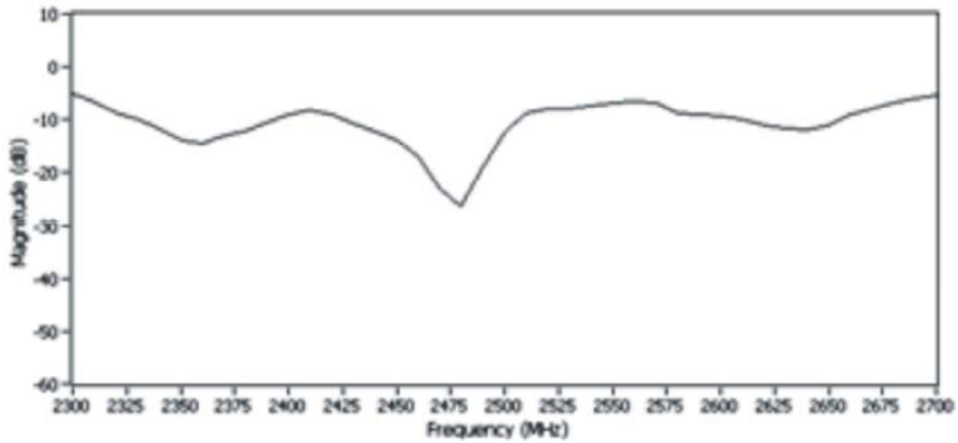

Fig. 19: Measured S_{11} of the patch using VNA for LHCP

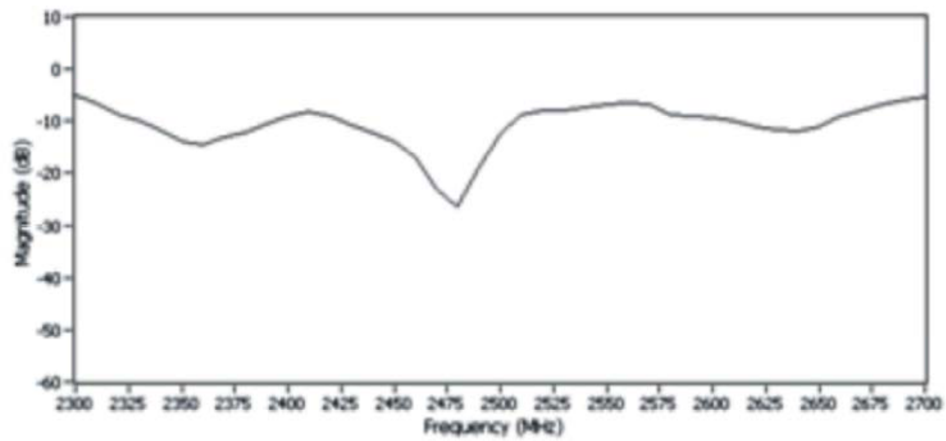

Fig. 20: Measured S_{11} of the patch using VNA for RHCP

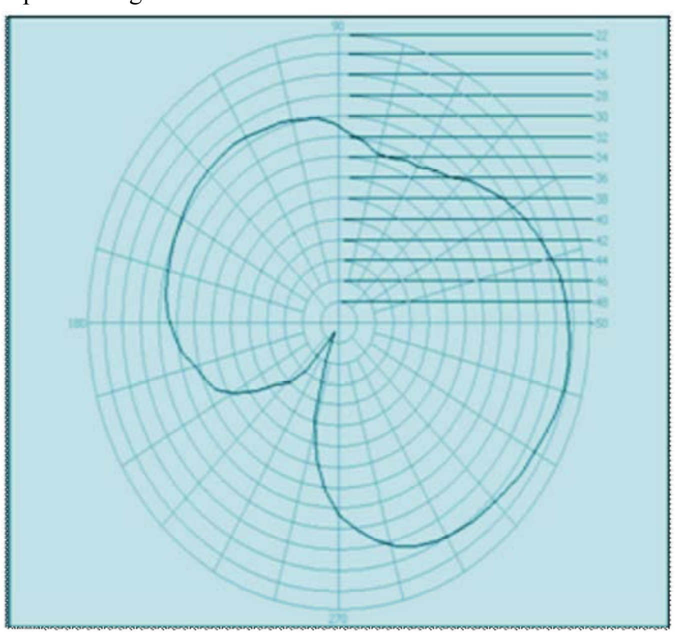

Fig. 21: Broadside radiation pattern of LHCP Transmitter-LHCP receiver

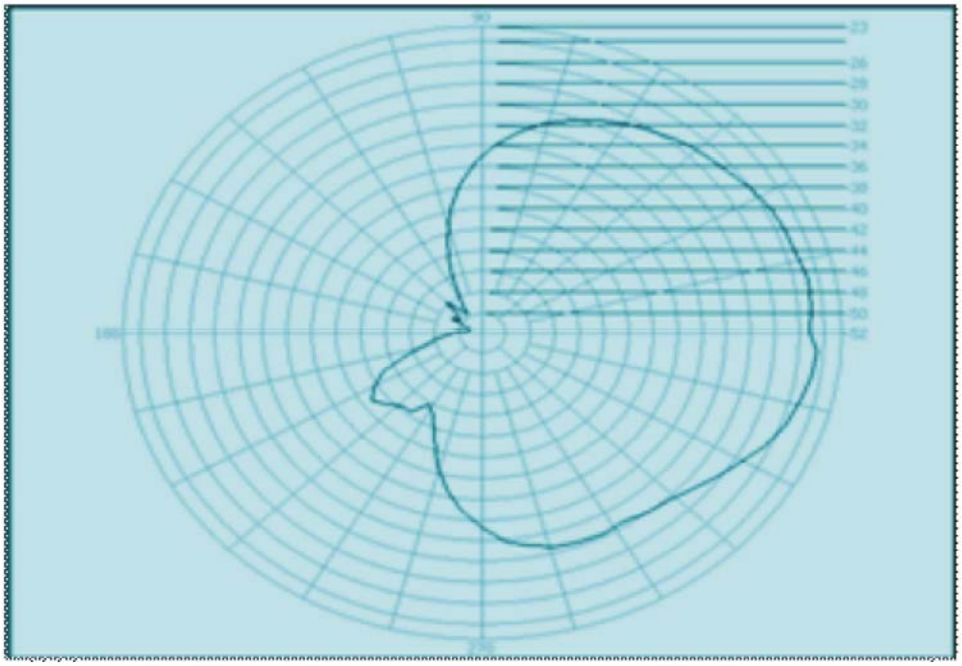

Fig. 22: Broadside radiation pattern of RHCP Transmitter-RHCP receiver

Fabricated Antenna Images & Results: Fig. 15 shows the fabrication process of antenna using antenna designer kit with three processes namely drilling, milling and routing. First the starting position has to be marked on the fabricating sheet using drilling bit. By performing milling process the patch is designed on the substrate. Finally the antenna is cut from the fabrication sheet using routing process. Fig. 16. shows the fabricated single layer microstrip patch antenna with switchable polarization with SMA connector.

Fig. 17. shows the real time measurement setup of 2.4 GHz microstrip circular patch antenna using FR-4 substrate. The antenna is connected to the setup and this setup is interfaced with the laptop to obtain the real time measurement such as radiation pattern and gain.

VNA Results: A Agilent Vector Network Analyzer (VNA) N9918A is used to measure the return loss, bandwidth, VSWR and input impedance of the fabricated patch antenna. The return loss measured using the VNA is shown in Fig. 18. It shows the minimum return loss of the fabricated antenna as -30.47dB at 2.45 GHz frequency for LP. The return loss measured using the VNA is shown in Fig. 19. It shows the minimum return loss of the fabricated antenna as -26.37 dB at 2.48 GHz frequency for LHCP.

The return loss measured using the VNA is shown in Fig. 20. It shows the minimum return loss of the fabricated antenna as -26.22 dB at 2.44 GHz frequency for RHCP. Fig. 21. shows the obtained radiation pattern of LHCP Transmitter and LHCP receiver. Measured results show that the antenna has a broadside radiation pattern at the resonant frequency Fig. 22. shows the obtained radiation pattern of RHCP Transmitter and RHCP receiver. Measured results show that the antenna has a broadside radiation pattern at the resonant frequency.

Comparison of Simulated and Measured Results for LP, LHCP, RHCP: Table 3 shows the simulated and measured values of return loss for LP, LHCP, RHCP. The results shows that the 2.4 GHz microstrip circular patch using FR-4 substrate is more efficient.

CONCLUSION

A novel compact microstrip patch antenna was presented. The proposed antenna is a circular patch with coaxial feed and four switches embedded across the slits, the slit length is altered, hence producing a phase difference between two degenerated orthogonal resonant modes. The Reflection coefficient of -17.25 dB for linear polarization, -17.78 dB dB for RHCP and -17.98 dB for LHCP and an Axial ratio of 41.9 dB for Linear polarization, 3dB for RHCP and 3dB for LHCP are obtained. It provides. The antenna can be used for military applications where secure communication is required.

REFERENCES

1. Osman, M.N., M.K.A. Rahim, P. Gardner, *et al*., 2015. “An Electronically Reconfigurable Patch Antenna Design for Polarization Diversity with Fixed Resonant Frequency” Journal of Radioengineering, 24(1).
2. Lieh-Hao Chang, Wen-Cheng Lai, Jui-Ching Cheng and Ching-Wen Hsue, 2014. “A Symmetrical Reconfigurable Multipolarization Circular Patch Antenna”, IEEE Transactions on Antennas and Wireless Propagation Letters, 13: 87-90.
3. Jeen-Sheen Row and Ming-Jyun Hou, 2014. “Design of Polarization Diversity Patch Antenna Based on a Compact Reconfigurable Feeding Network”, IEEE Transactions on Antennas and Wireless Propagation, 62: 5349-5352.
4. Xue-Xia Yang, Bing-Cheng Shao, Fan YangAtef Z. Elsherbeni and Bo Gong, 2012. ”A Polarization Reconfigurable Patch Antenna With Loop Slots on the Ground Plane” IEEE Antennas and Wireless Propagation Letters, 11: 5349-5352.
5. Ram Krishna, Rajkumar, R.V.S., 2015. ”Design of a square ring shape slot antenna for UWB polarization-diversity applications” International Journal of Electronics and Communication, ELSEVIER, pp: 339-342.
6. Panahi, A., X.L. Bao, K. Yang, O. O'Conchubhair, M.J. Ammann, 2015. “A simple Polarization Reconfigurable Printed Monopole Antenna”, IEEE Antennas and Wireless Propagation Letters, pp: 5110-5118.
7. Constantine A. Balanis, 2013. “Antenna Theory Analysis and Design” John Wiley & Sons Inc., 3rd Edition.