Dual band Dual Polarized Rhombic Slot Antenna for ISM Band Applications

[1]Toshika Chand, [2]Saurabh Singh, [3]Sudhanshu Verma

[1]Student, [2]Co-Guide, [3]Guide

[1]Department of Electronics and Communication Engineering,

[1]Madan Mohan Malaviya University of Technology, Gorakhpur, Uttar Pradesh, India.

Abstract: This paper aims to present a dual band dual polarized rhombic slot antenna (RSA) for ISM band applications. The proposed antenna of size 60×60×1.6 mm^3, consist of a rhombic slot with a pair of L shaped slits etched at two of its opposite arms and a rectangle etched at two of its corners. Two ports are placed perpendicular to each other. Both the ports are excited by a 50-Ω microstrip line due to which the impedance bandwidth (BW) of proposed antenna is enhanced and radiated with horizontal and vertical polarizations. The proposed rhombic slot antenna achieved a dual band 10 dB return loss bandwidth of $|S_{11}|$ 23.4% (1.96-2.48 GHz) and 36.4% (4.09-5.91 GHz) and for $|S_{22}|$ 30% (1.96-2.64 GHz) and 36.5% (4.8-6.95 GHz) respectively. Hence both the ports can operate in 2.45 GHz and 5.8 GHz ISM band applications, with isolation greater than 20 dB in the entire band and achieved a peak realized gain of 3.6 dBi in lower band and 5.6 dBi in higher band. The simulated results of proposed antenna show good radiation characteristics for ISM band applications.

Index Terms **- Dual Band, Dual Polarized Antenna, Rhombic Slot Antenna, Isolation, ISM band.**

I. INTRODUCTION

During recent years, due to the rapid innovations in the use of various communication system has increase the demand of printed slot antennas because they are characterized by a low cost, low profile, greater flexibility and are easy to fabricate on any planar or non-planar surfaces [1]. ISM frequency bands are mainly used in industrial, scientific, and medical purposes and also offer the advantages of low power consumption They are widely used in many industrial and home appliances like microwave oven working at 2.45 GHz frequency band, baby monitors, wireless surveillance systems, and also in some biomedical applications like diathermy machines operating at 2.45 GHz [2]. In a recent study of NASA, microwave power transmitting at a frequency of 2.45 GHz is used to send the microwave energy gathered by the solar power satellites back to the earth [3]. 5.8 GHz frequency band is also used to transmit data at high speed. This band is also used for wireless LAN 802.11/a. The pilot project of google 'Loon', also utilizes the ISM freq. bands (2.45 GHz and 5.8 GHz) for communications between balloon to balloon and balloon to ground [4]. 5.8 GHz bands are also used for RFID applications such as tracking and tracing [5]. An antenna is said to be dual polarized when they radiate in both polarizations (horizontal and vertical polarization) and are able to improve the channel efficiency of the system.

There are several dual polarized antennas supposed from [6]-[10] such as, in paper [6] antenna of 60×60 mm^2 uses an isosceles triangular slot for broadband WLAN applications. It has a common narrow bandwidth of 19.7% (5.2-5.8 GHz) with an isolation of 30dB over entire bandwidth. To enhance bandwidth, in paper [7] cross electric dipole is loaded on antenna of size 150×150 mm^2 to obtain symmetric radiation pattern. This antenna achieved a bandwidth (BW) of 23% (1.71- 2.17 GHz). In paper [8] single layer slot antenna of dimension 45×40 mm^2 which uses a microstrip feed and a power divider at T shaped junction is used for in band full duplex operation applications. It achieves -10 dB return loss BW for port 1 of 8.5% (5.62-6.11 GHz) and for port 2 of 18.3% (5.27-6.33 GHz). This antenna is able to radiate in only 5.8 GHz ISM band. In paper [9] dual band is achieved by slot planar antenna of dimensions 55×57 mm^2 having a microstrip fed line and a CPW to excite both horizontal and vertical polarizations. The -10 dB return loss BW of 16.4% (2.34-2.76 GHz) and 18.5% (3.22-3.88 GHz) is achieved. This antenna is able to operate in 2.4 GHz WLAN and 3.5 GHz WIMAX bands. This antenna is not able to radiate in 5.8 GHz ISM bands. In paper [10] antenna of dimension 70×70 mm^2 having stacked patch shape and a truncated corner which is directly fed by probe is able to radiate in MBAN and 5.8 GHz ISM band. It is able to attain an impedance bandwidth (BW) of 2.8% (2.385-2.445 GHz) for MBAN and 9.0% (5.63- 6.16 GHz) for 5.8 GHz ISM band. This antenna is notable to radiate in 2.45 GHz ISM bands.

In this paper a dual band dual-polarized rhombic slot antenna (RSA) is proposed with four L-shaped strips etched at the opposite arms and rectangles etched at two of its corners. A T shaped strip is used to improve isolation. It is desirable for ISM band applications. This antenna consists of two ports. Both the ports are placed perpendicular to each other and are excited by a micro-strip fed line. The presented antenna also attains a high isolation. In this proposed design the rhombic slot has a major role in achieving a broad impedance bandwidth with dual bands. The antenna is designed by a 3-D simulation software that is Ansys HFSS 19.2.

II. ANTENNA DESIGN

The designed geometry of the dual-polarized microstrip fed rhombic slot antenna (MRSA) is represented by Fig. 1. The dimension of this antenna is 60×60×1.6 mm^3, printed on a FR-4 substrate of relative permittivity (ε_r=4.4) and loss tangent (tan δ = 0.02) consists of a rhombic slot of dimensions $l_3 \times l_3$ mm^2 with a pair of L - shaped slits of dimensions $d_1 \times d_2$ etched at two of its opposite edges and a rectangle each of dimensions $d_3 \times d_4$ etched at two of its corners. A parasitic T-shaped strip is introduced between the port 1 and port 2 to reduce the mutual coupling. It has two ports placed in perpendicular direction. The width W_1 of port 1 (MS_1) and W_2 of port 2 (MS_2) are considered 4 mm and 3.4 mm, respectively.

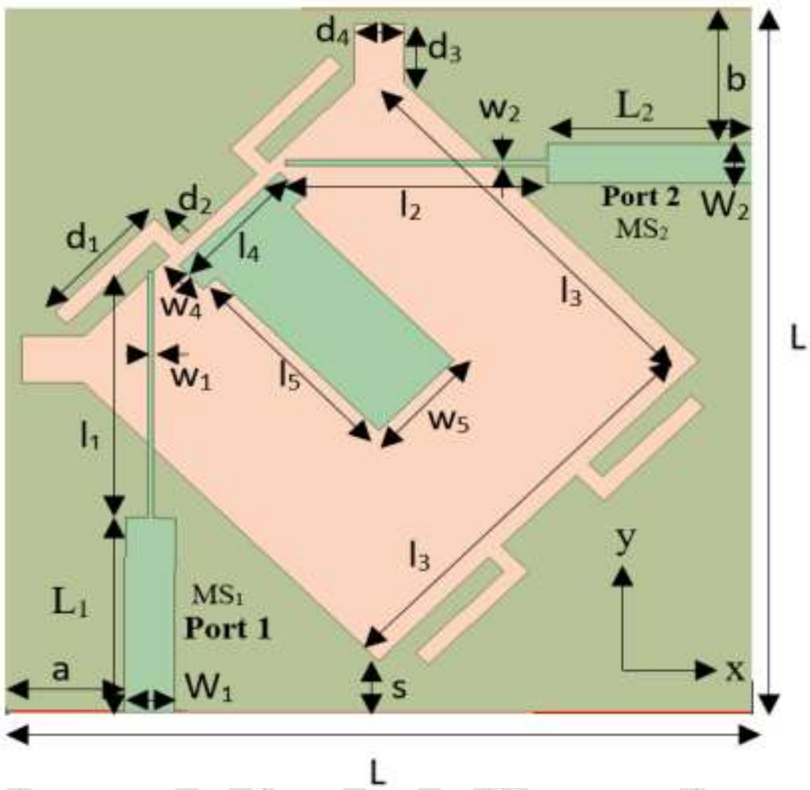

Fig. 1 Antenna Geometry of the proposed (RSA) antenna

Table 1: Antenna Parameters

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
L	60	l_2	21	d_3	5.13	w_5	8.52
L	60	w_1	0.4	d_4	4	a	10
L_1	16.5	w_2	0.5	l_4	11.31	b	11.5
L_2	16.5	d_1	11.31	w_4	2.9	s	4.37
l_1	21	d_2	3.11	l_5	18.39		

This antenna with size 60×60 mm^2 is fed by a 50-Ω micro-strip line (L_2×W_2) with a thin strip of dimension l_2×w_2 along x-axis for horizontal polarization and a micro-strip feed line (L_1×W_1) with a thin strip of dimension l_1×w_1 along y-axis for vertical polarization on the bottom layer of substrate. The position of the rhombic slot is taken as (s=4.37 mm) from all the corners. By choosing the right dimension of widths of both ports and distance a and b from the ports, antenna is able to operate in both 2.45 GHz and 5.8 GHz ISM bands. The design stages to realize the presented (RSA) rhombic slot slot antenna is depicted in Fig. 2 with the four antennas involved in the evolution steps and their simulated reflection coefficients $|S_{11}|$ is represented in Fig. 3.

In the evolution steps, Ant. 1 of Fig. 2(a) having dimensions of 60×60mm^2 consists of an isosceles triangular slot with two microstrip feed line perpendicular to each other, which acquire the bandwidth of 19.7% (5-6 GHz). In Ant. 2 of Fig. 2(b) by replacing a isosceles triangular slot by a regular rhombic slot with two rectangles etched at the two corners, antenna radiates in the dual band and achieves the 10 dB return loss bandwidth of $|S_{11}|$ 21.2% (1.93-2.39 GHz) and 18.3% (4.86-5.84 GHz) and of $|S_{22}|$ 28.9% (1.91-2.56 GHz) and 33.6% (4.92- 6.91 GHz). In Ant. 2 of Fig. 2(c) by cutting pair of four L-shaped strips on the opposite edges, antenna achieves a 10 dB return loss bandwidth of $|S_{11}|$ 20.2% (1.95-2.39 GHz) and 27.02% (4.48-5.88 GHz) and of $|S_{22}|$ 27.5% (1.97-2.60 GHz) and 36.19% (4.82-6.95 GHz). By introducing T shaped strip between both the ports of Ant.2 in Fig. 2(d), the proposed (RSA) antenna operates in dual ISM bands with frequency 2.45 GHz and 5.8 GHz and achieves a 10 dB return loss bandwidth of $|S_{11}|$ 23.4% (1.96-2.48 GHz) and 36.4% (4.09-5.91 GHz) and for $|S_{22}|$ 30% (1.96-2.64 GHz) and 36.5% (4.8-6.95 GHz) with an isolation of greater than 20 dB in the entire operating band.

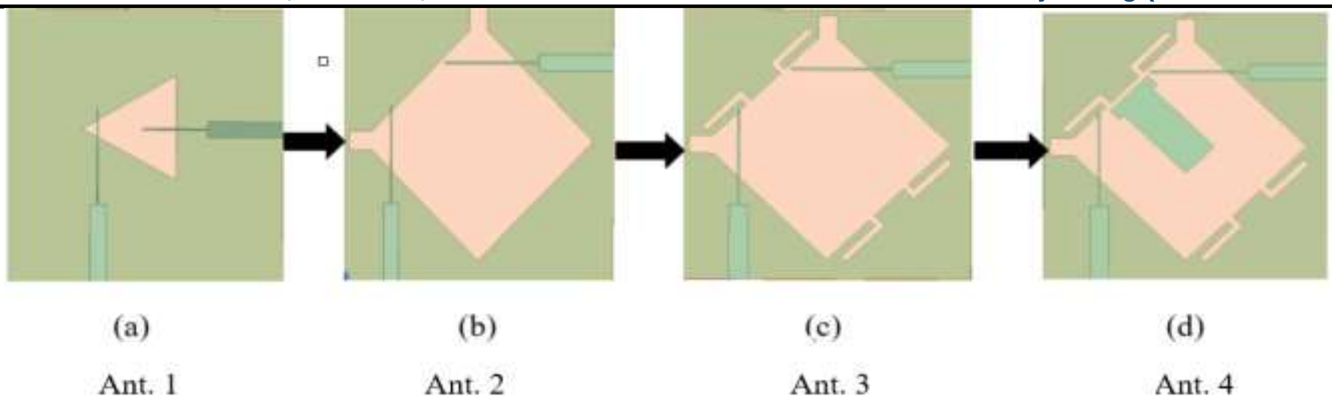

Fig. 2 Evolution stages to realize the designed antenna (1-4)

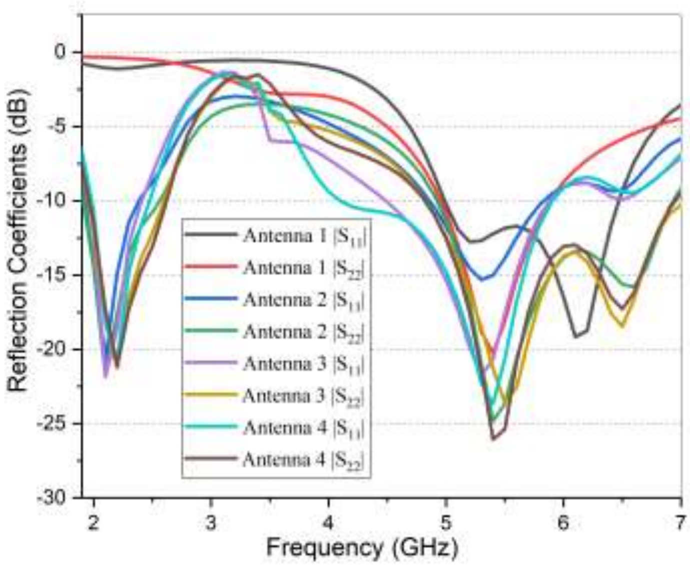

Fig. 3 Performance of simulated Reflection Coefficients in dB of the three antennas at 2.45 GHz.

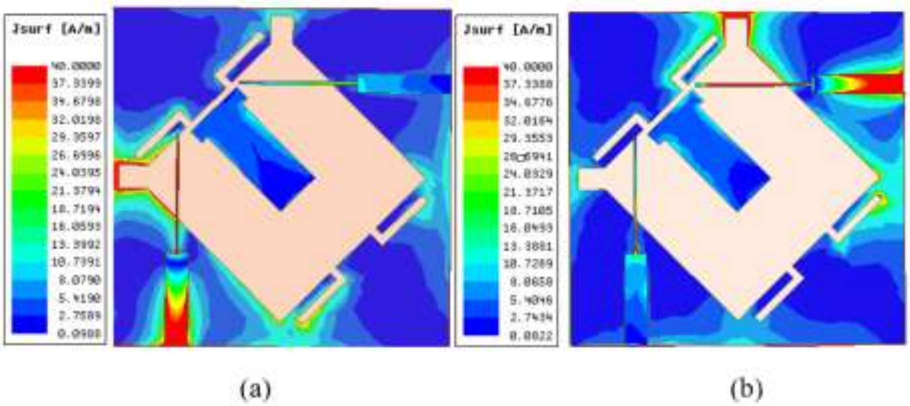

Fig. 4. Current distribution in proposed antenna at 2.45 GHz fed by (a) Port 1 and (b) port 2

The Fig. 4 shows the flow of current distribution at centre frequency 2.45 GHz of proposed antenna by port 1 and 2. It is observed that on exciting port 1, by terminating port 2, current is distributed along y-direction which generate vertical polarization. Similarly, on exciting port 2, by terminating port 2 flow of current distribution is along x-direction which demonstrate that horizontal polarization is generated.

III. RESULTS AND DISCUSSION

The simulated results of a dual-polarized rhombic slot antenna (RSA) are analysed on the Ansys HFSS software version 19.2 with a solution frequency of 2.45 GHz. The plot of reflection coefficients against frequency in Fig. 5 shows the simulated impedance bandwidth of $|S_{11}|$ 23.4% (1.96-2.48 GHz) and 36.4% (4.09-5.91 GHz) and for $|S_{22}|$ 30% (1.96-2.64 GHz) and

36.5% (4.8-6.95 GHz). Both the ports have analogous impedance characteristics. The proposed rhombic slot antenna achieves dual resonant peaks at 2.45 GHz and 5.48 GHz. The designed antenna achieved an isolation level of nearly 20 dB over the entire frequency band. The peak realized gain of 2.80 dBi is achieved for both the ports at a frequency of 2.45 GHz.

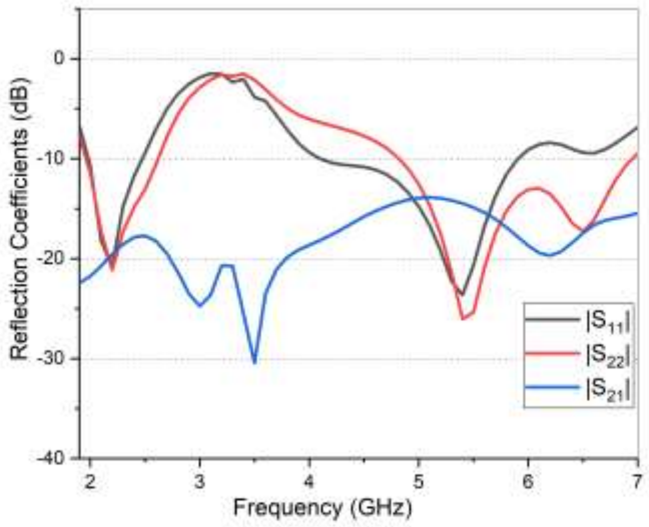

Fig. 5 Simulated Reflection Coefficient in dB of the proposed (RSA) antenna

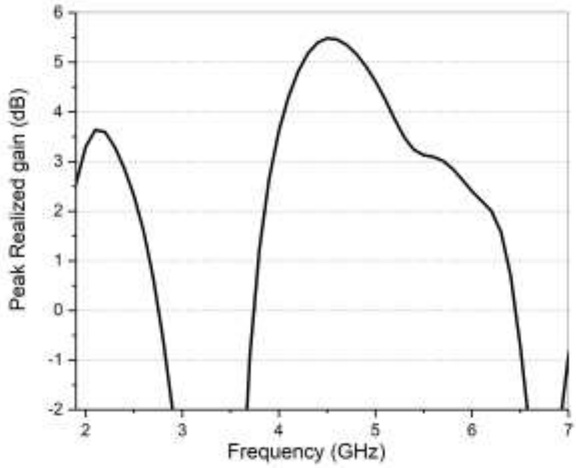

Fig. 6 Realized Antenna Gain of the proposed (RSA) antenna.

The Fig: 6 depicts the plot between realized antenna gain and frequency of the proposed dual-polarized circular slot antenna. Both ports have consistent gain. The simulated peak gain of 2.80 dBi is achieved over the entire bandwidth (BW) at a frequency of 2.45 GHz. The simulated results of radiation pattern of the proposed antenna plotted at a frequency of 2.45 GHz and 5.8 GHz is depicted in Fig. 7 and Fig. 8. It illustrates that proposed antenna is radiated in bidirectional pattern in *YZ*- plane and radiates with omnidirectional pattern in *XZ*-plane when excited from port 1 as shown in fig. 7(a & b) and 8 (a & b) whereas it radiates in bidirectional pattern in *XZ*- plane and radiates with omnidirectional pattern in *YZ*- plane as excited from port 2 as shown in fig. 7(c & d) and 8 (c & d). Co -polarization and cross polarization of YZ-Plane of port 1 and XZ-Plane of port 2 are like the shape of figure-8. Cross-polarization of XZ-Plane for port 1 and YZ-Plane of port 2 are not correlated.

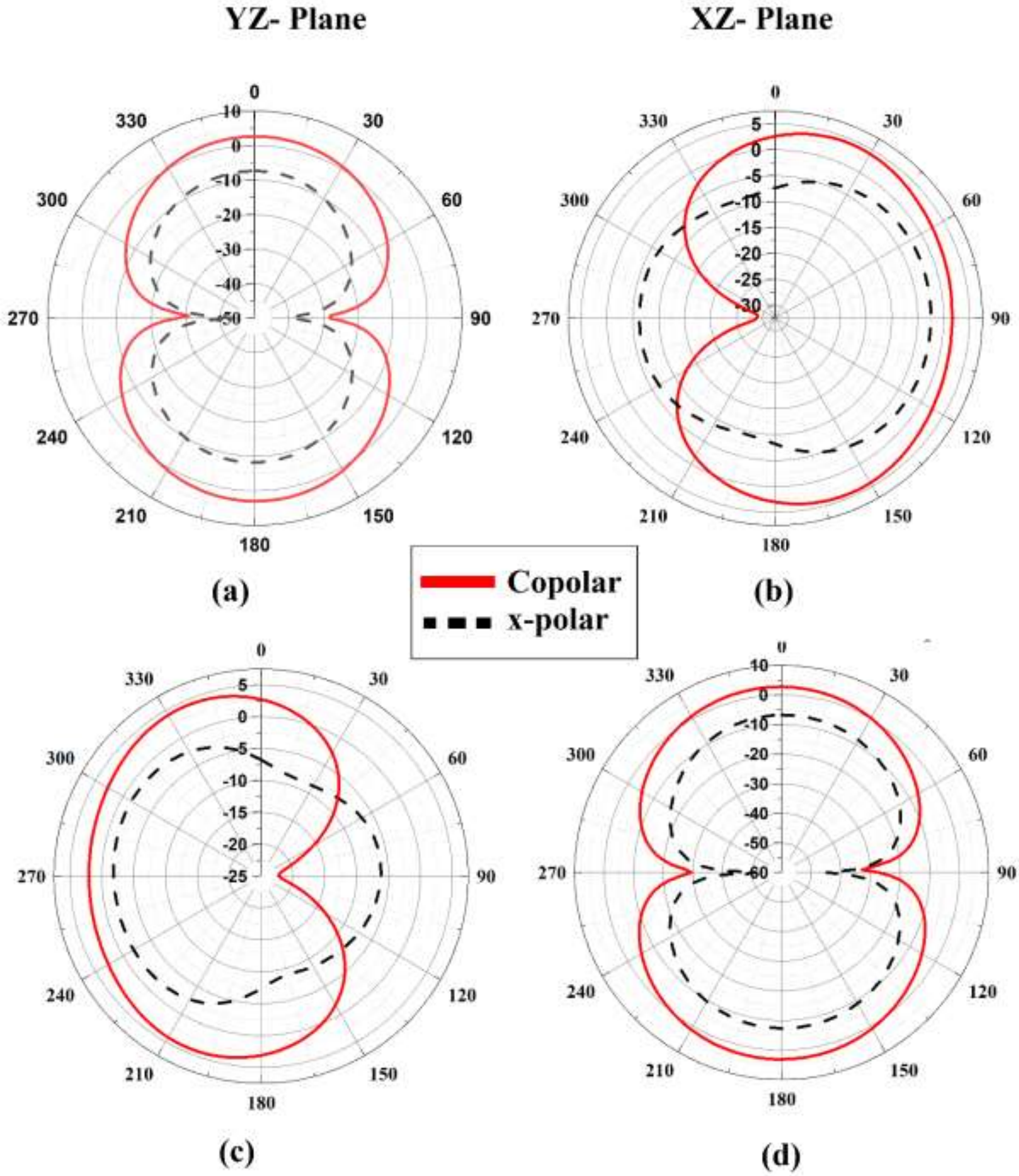

Fig. 7 Simulated Radiation patterns at 2.45 GHz of the proposed antenna for Port 1(a) E-plane and (b) H-plane and Port 2 (c) E-plane and (d) H-plane

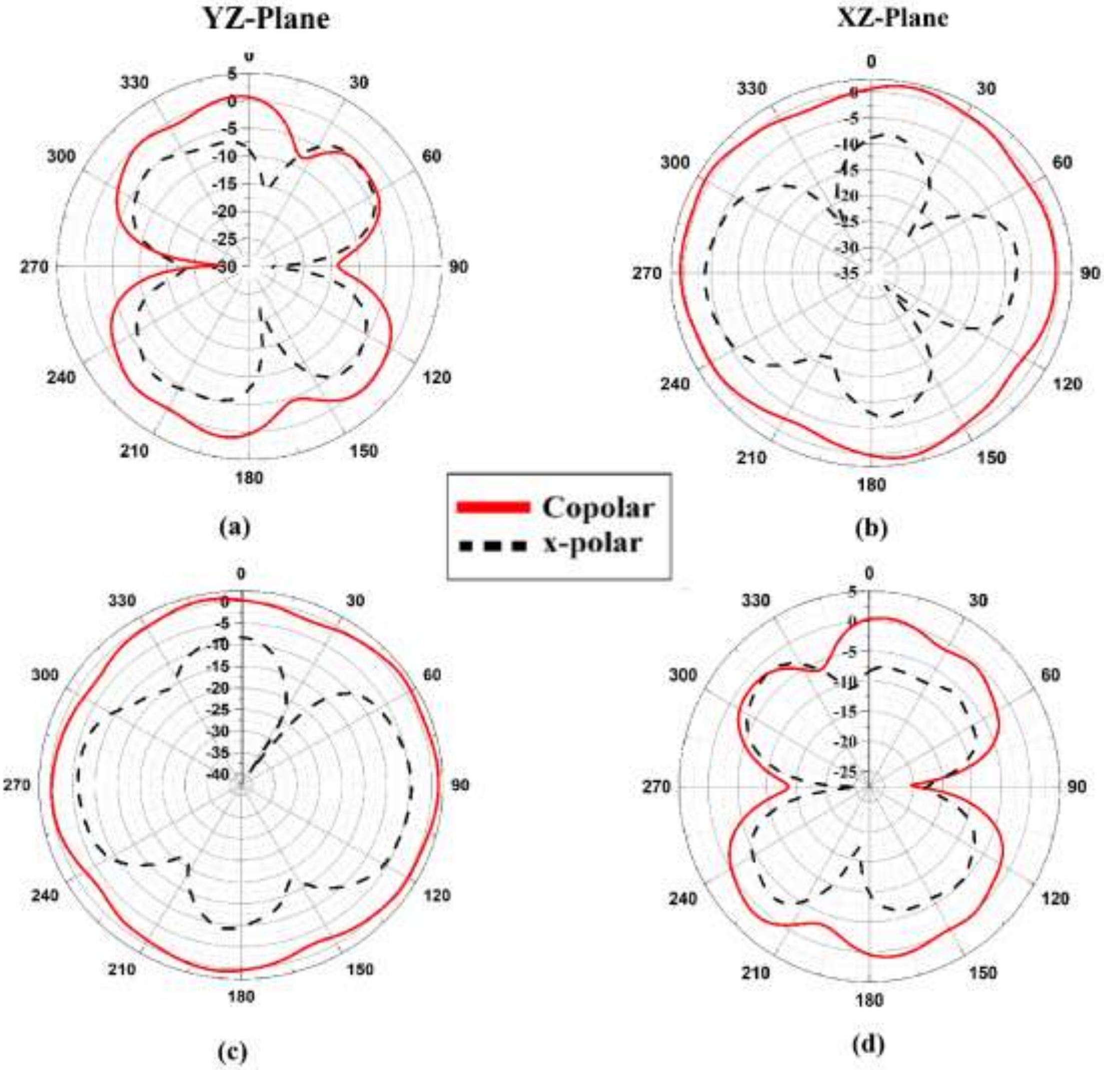

Fig. 8 Simulated Radiation patterns at 5.8 GHz of the proposed antenna for Port 1(a) E-plane and (b) H-plane and Port 2 (c) E-plane and (d) H-plane.

IV. CONCLUSION

A dual band dual-polarized rhombic slot antenna (RSA) for 2.45 GHz and 5.8 GHz ISM band applications is proposed in this paper. The dimensions of the antenna are 60×60×1.6 mm^3 and it radiates in both polarizations (horizontal and vertical). It consists of a rhombic slot with four pair of L- shaped slits etched at the opposite arms and rectangles etched at two of its corners. The proposed (RSA) antenna is excited by two microstrip feedline which are placed perpendicular (⊥) to each other and are responsible for antenna to radiate in both x-directed horizontal polarization and y-directed vertical polarization. The proposed antenna achieved a common impedance bandwidth with dual bands of $|S_{11}|$ 23.4% (1.96-2.48 GHz) and 21.8% (4.09-5.91 GHz) and of $|S_{22}|$ 30% (1.96-2.64 GHz) and 36.5% (4.80-6.95 GHz) respectively between both the ports with an isolation of almost greater than 20 dB in the whole working bandwidth. The peak realized gain of 3.6 dBi for 2.45 GHz band and 5.6 dBi for 5.8 GHz band is achieved at a frequency of 2.45 GHz. This antenna is compact in size, have greater flexibility and are easy to fabricate which makes it desirable for dual ISM band applications.

.

REFERENCES

[1] Q. Nasir. 2017. Patch antenna performance improvement using circular slots: International Conference on Wireless Networks and Mobile Communications (WINCOM), Rabat., pp. 1-5.

[2] T. S. P. See and Zhi Ning Chen. July 20, 2003. Design of dual- polarization stacked arrays for ISM band applications: Microwave and Optical Technology Letters / Vol. 38, No. 2.

[3] Ms. S.G. Satavekar. 2014. Solar Power Satellites and Microwave Wireless Power Transmission Technology: Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 4. Number 2 pp. 193-200.

[4] Shubhdeep Kaur and Sukhchandan Randhawa. 2018. Google LOON: Balloon-Powered Internet for Everyone: American institute of physics, AIP Conference Proceedings 2034, 020006 (), pp. 020006-1–020006-6.

[5] B. B. Dhengale and D. C. Karia. 2015. A 5.8 GHz ISM band microstrip antenna for RFID applications: 2015 International Conference on Nascent Technologies in the Engineering Field (ICNTE), Navi Mumbai, India, (), pp. 1-4.

[6] Chi-Hsuan Lee, Shih-Yuan Chen, and Powan Hsu. October 2009. Isosceles Triangular Slot Antenna for Broadband applications: IEEE Transactions on Antennas and Propagation, Vol. 57, No. 10.

[7] K.-M. Mak, H. Wong, and K.-M. Luk. 2007. A shorted bowtie patch antenna with a cross dipole for dual polarization: IEEE Antennas Wireless Propagation. Lett., vol. 6, pp. 126–129.

[8] N. -A. Nguyen et al. July 31,2020. Dual-Polarized Slot Antenna for Full-Duplex Systems with High Isolation," IEEE Transactions on Antennas and Propagation.

[9] M. Tan and B. Wang. 2015. A Compact Dual-Band Dual-Polarized Loop-Slot Planar Antenna: IEEE Antennas and Wireless Propagation Letters, vol. 14, () pp. 1742-1745.

[10] X. Zhu, Y. Guo and W. Wu. July 2016. Miniaturized Dual-Band and Dual-Polarized Antenna for MBAN Applications: IEEE Transactions on Antennas and Propagation, vol. 64, no. 7, pp. 2805-2814.