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Novel Compact Circular Patch Antenna Embedded with Rhombus Slot for 1 GHz -15 GHz Frequency Range

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Abstract— ***A new type of compact circular patch antenna with rhombus slot (CCPARS) is designed, fabricated and tested for various applications in high frequency range of wireless band. Results show that six distinct bands are obtained with better VSWR characteristics. The impedance bandwidth of CCPARS is enhanced from 2.06 % to 39.4 % by etching circular patch embedded with rhombus slot. The antennas also achieved better return loss characteristics and better VSWR. The design procedure and practical results are presented and discussed.***

Keywords— ***Circular; Wireless; Radars; Satellite; Bandwidth; Photolithography.***

I. INTRODUCTION

Microstrip patch antennas are widely used in wireless application due to great advantages such as low-profile, high transmission efficiency, light weight, low profile, conformal and planar structure, compactness, low cost and ease of integration with microwave circuit [1]. Now a day's Compact microstrip antennas are getting much more attention due to the increase in demands of small size antennas used in personal and commercial purpose applications. In order to design a compact microstrip antenna at a fixed operating frequency higher dielectric constant of substrate must be used [2-4]. In view of this, the simplest technique of etching slots is designed and fabricated to achieve these requirements.

II. ANTENNA DESIGN & RESULTS

To design the patch antenna, the length and the width are calculated by using below equations.
The patch width W shown in Fig. 1 is given by,

$$W = \frac{c}{2f_r}\sqrt{\left(\frac{\varepsilon_r+1}{2}\right)} \quad (1)$$

The length of patch is given by,

$$L = \frac{c}{2 f_r\sqrt{\varepsilon_r}} - 2\Delta l \quad (2)$$

The antenna design also includes, choice of a low cost glass epoxy substrate material of thickness h = 1.66 mm and permittivity ε_r = 4.4 for the proposed antennas. In order to get better accuracy, the antenna layouts are drawn using computer software AutoCAD-2013 and are fabricated using photolithography process. The conventional frequency for rectangular patch antenna (RPA) is designed for the resonant frequency (f_r) of 3.5 GHz using the basic equations available in literature [5-8]. The circular patch embedded with rhombus slot is etched on the patch plane of conventional RPA as shown in Fig. 2. This antenna is named as compact circular patch antenna with rhombus slot (CCPARS). The dimensions of all the slots are taken in terms of λ_0, where λ_0 is the free space wavelength corresponding to the designed frequency of conventional RPA i.e. 3.5 GHz. The radius (*R*) of the circular patch is 4.78 mm and equal side length of one side rhombus slot A is 13.46 mm. The antenna is called as compact since, it practical dimension (*L x W*) is (18.99 *x* 26.92 mm). The antenna is connected by 50 Ω SMA connector and is fed by microstrip fed line method. For the proposed antennas the impedance bandwidth over return loss less than −10 dB is measured on Agilent Technologies E8363B Network Analyzer (10MHz – 40GHz).

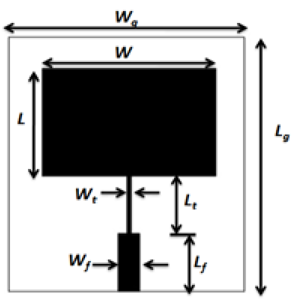

Fig. 1. Top view geometry of conventional RPA

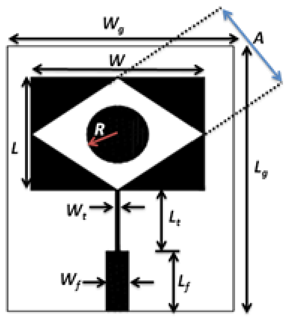

Fig. 2. Geometry of CCPARS

The return loss (RL) is a parameter which indicates the amount of power that is lost to the load and does not return as a reflection. As already known, waves are reflected leading to the formation of standing waves, when the transmitter and antenna impedance do not match. Hence, the return loss is a parameter similar to the VSWR to indicate how well the matching between the transmitter and the antenna has taken place. The variation of return loss verses frequency of RPA is as shown in Fig. 3. From the figure it is clear that, the antenna resonates at fr_1 = 3.7 GHz of frequency which is close to the designed frequency of 3.5 GHz and hence validates the design. From this graph, the experimental impedance bandwidth is calculated using the formula [9],

$$\text{Impedance Bandwidth} \left(\%\right) = \left[\frac{f_2 - f_1}{f_c}\right] \times 100 \qquad (3)$$

where, f_2 and f_1 are upper and lower cut-off frequencies of the band respectively when its return loss reaches −10 dB and f_c is the centre frequency between f_1 and f_2. The bandwidth of conventional RPA is found to be BW_1 = 2.06 %. Fig. 4 shows the variation of return loss verses frequency of CCPARS. The antenna resonates for six different bands with resonant frequencies of fr_1 = 3.8 GHz, fr_2 = 5.4 GHz, fr_3 = 6.9 GHz, fr_4 = 8.5 GHz, fr_5 = 10.58 GHz and fr_6 = 12.43 GHz with corresponding impedance bandwidths of BW_1 = 0.9 % for RL = -15.12 dB, BW_2 = 5.5 % for RL = -19.20 dB, BW_3 = 2.3 % for RL = -19.77 dB, BW_4 = 39.4 % for RL = -24.32 dB, BW_5 = 9.1 % for RL = -26.87 dB and BW_6 = 32 % for RL = -34.38 dB respectively.

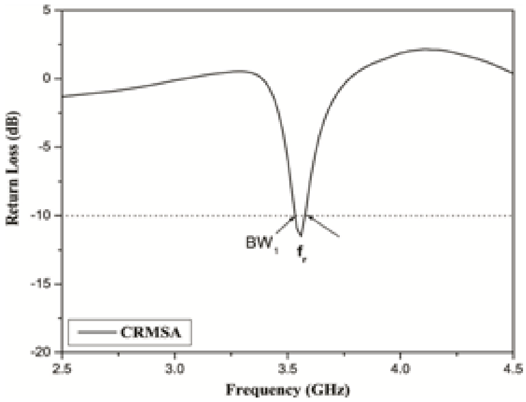

Fig. 3. Variation of return loss Vs frequency of conventional RPA

Fig. 4. Variation of return loss verses frequency of CCPARS

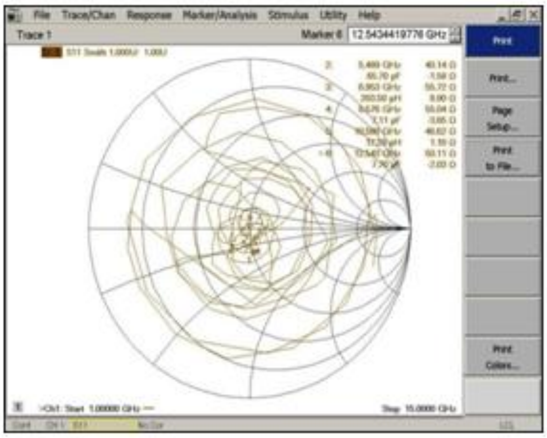

Fig. 5. Smith chart plot of CCPARS

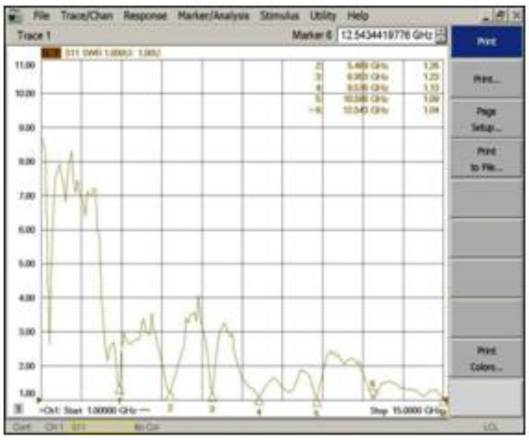

Fig. 6. VSWR plot of CCPARS

Fig.5 shows the smith chart plot of CCPARS and is quite clear that the resonant frequency points are near to the centre impedance point which validates better matching characteristics between input and load. Fig.6 shows the measured VSWR of 1.1, 1.2, 1.2, 1.1, 1.0 and 1.0 at respective resonant frequencies of CCPARS which are less than 1.5 signifying less reflected power back towards the feed.

III. CONCLUSIONS

In this paper, It is clear that, by using novel rhombus shape slot and circular patch plane, six distinct resonant bands are obtained. Further, the enhancement in bandwidth of CCPARS is 39.4% with better return loss characteristics compared to conventional RPA. This technique also achieves a compact nature antenna. The proposed antennas are simple, cost effective and may find application in wireless applications in L , S, C and X band frequency range.

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