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Slotted Circular Microstrip Patch Antennas for Dual Band Applications

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***Abstract* – This paper presents a circular shaped microstrip patch antenna having a single rectangular slot at the top and two symmetrical slots on either side of the feed which is excited through an inset feed. Simulation results show that the designed antenna can be used as a single band and dual band modes (TM01& TM11). For the proposed antenna TM11 is the fundamental as well as the dominant mode. For the proposed antennas with two rectangular slots, there is an increase in the percentage bandwidth by 0.7% and return loss by -5.1dB with respect to no slot circular patch antenna. The single band antenna is converted into dual band by introducing rectangular slots on circular patch antennas which are mainly used for WLAN, GPS and DCS applications.**

***Keywords* - Microstrip Antenna; Wireless Local Area Network (WLAN), Dual Frequency Band, Rectangular Slot.**

I. Introduction

In today's modern communication industry, antennas are the most important components required to create a communication link. Through the years, microstrip antenna structures are the reliable and common option used to realize millimeter wave monolithic integrated circuits for microwave, radar and communication purposes. Microstrip antennas are the most suited for aerospace and mobile applications. They can be designed in a variety of shapes in order to obtain enhanced gain and bandwidth, dual band and circular polarization to even ultra wideband operation. Major advances in millimeter wave antennas have been made in recent years, including integrated antennas where active and passive circuits are combined with the radiating elements into one compact unit to form monolithic circuits [1].

Radar and modern communication systems such as synthetic aperture radar (SAR), global position system (GPS) and wireless local area networks (WLAN) often require low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a large spectrum of frequencies [2]. Dual band or multi frequency operations are main requirement of this type communication. A single antenna is highly desirable if it can operate at these two bands. The antenna should be in the planar form, lightweight and compact, so that it can easily be embedded in the cover of communication devices [3]. For reduce the transmission line length and the radiation losses a simplified feeding circuit are also an important component.

Main disadvantage of Microstrip patch antenna is the bandwidth limitation which is due to the resonant characteristic of the patch structure [4]. Dual-frequency microstrip antenna is the alternate method for bandwidth enhancement, which required in various applications for the operation of two separate sub bands. For generating a dual frequency behavior in the single-fed microstrip antenna, by creating or etching slots on the radiating element of the microstrip patch antenna [5]. This creates a strong modification of the resonant modes, particularly when the slots are configured to obstruct and cut the current lines of the unperturbed modes. [6] explained that by introducing a small rectangular slot, a new resonant mode in the vicinity of the fundamental resonant mode can be excited. Multi-band antennas have been widely used for WLAN/ Cellular applications and can be built on a double-sided printed circuit board or stamped from thin metal sheets [7].

In this paper a circular microstrip patch antenna is designed and rectangular slots are cut on it. The various parameters like resonant frequencies, VSWR, radiation pattern are compared for the designed three configurations.

II. Antenna Design

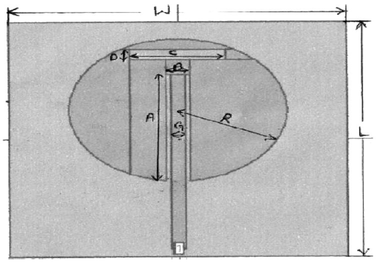

Fig.*a*. Antenna Dimensions

Figure shows the geometry and configuration dual frequency circular microstrip antenna with a rectangular slot. Antenna has a circular patch on ground plane with a rectangular slot and has inset feed. The antenna was fabricated on an h=1.6 mm FR4 epoxy substrate with the dielectric constant εr=4.4 and loss tangent tan δ=0.02. The design parameters (W=75mm, L=80mm, R=24.2mm, A=36.5mm, B=5mm, C=21mm, D=4 mm, G=3mm).

The dominant and fundamental mode responsible for the first resonance in the circular microstrip antenna is TM11 mode. For the dominant and fundamental mode TM11, the expression for the resonant mode is given by [8]

$$(f_r)_{11} = \frac{1.8412 c_0}{2\pi R\sqrt{\varepsilon_r}} \quad (1)$$

Where c_0 is the velocity of light in free space, R is is the radius of the circular microstrip antenna, εr is the dielectric constant of the substrate. The resonant frequency of equation (1) does not take into account fringing. fringing makes the patch look electrically larger and it was taken into account by introducing a radius correction method

Similarly for the circular patch a correction is introduced by using an effective radius *Re*, to replace the actual radius R, given by [9]

$$R_e = R\{1+\frac{2h}{\pi R\varepsilon_r}[\ln(\frac{\pi R}{2h})+1.7726]\}^{\frac{1}{2}} \qquad (2)$$

Where h is the height of the dielectric substrate. After the radius correction, the resonant frequency for the dominant mode TM11 is modified by eq. (2) and is expressed as

$$(f_r)_{11} = \frac{1.8412\,c_0}{2\pi R_e\sqrt{\varepsilon_r}} \qquad (3)$$

Hence, putting all the numerical values of the design parameters into eq. (2) and eq. (3), the theoretical first resonance frequency (f1) was found to be 1.67 GHz.

III. Simulation

HFSS utilizes a 3D full-wave Finite Element Method (FEM) to compute the electrical behavior of high-frequency and high-speed components [10]. With HFSS one can extract the parameters such as S, Y, and Z, visualize 3D electromagnetic fields (near and far-field), and optimize design performance. An important and useful feature of this simulation engine is the availability of different kinds of port schemes. It provides lumped port, wave port, incident wave scheme etc. The simulation for this paper is done using lumped port.

IV. Results

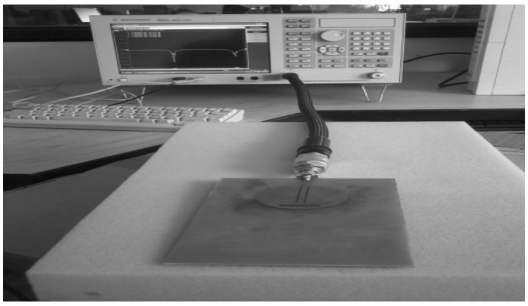

Fig.b. Experimental Set-up

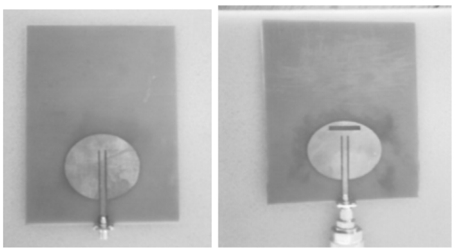

Fig.c. Fabricated Patches

Above figures show the fabricated patches and the experimental set up using Vector Network Analyzer E5071C.

1. Circular patch without slots:

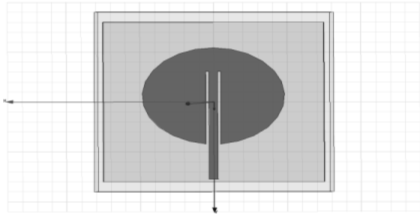

Fig.1.a. Simulated circular patch

The antenna resonates at 1.58 GHz (TM11 mode) at the return loss value of –13.68 dB, which is shown by Fig.2.shows the return loss (|S11|) (dB) vs. frequency of the dual frequency circular microstrip antenna. The resonance band extends from 1.565 GHz to 1.605 GHz at –10 dB having the percentage bandwidth of 2.53% .
Fig 1c shows the 3-D radiation pattern of the antenna.

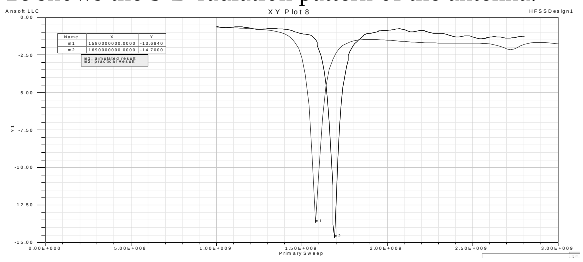

Fig.1.b Simulated and measured return loss

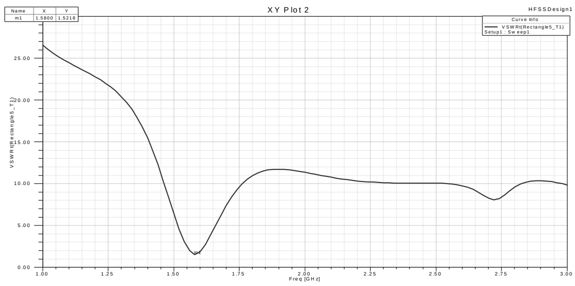

Fig.1.c. VSWR

2. Circular patch with two symmetrical rectangular slots:

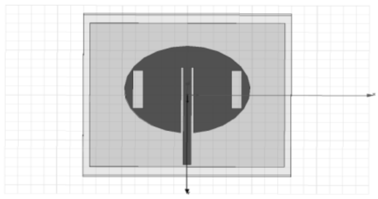

Fig.2.a. Simulated circular patch with two symmetrical rectangular slots.

The antenna resonates at 1.6 GHz at the return loss value of –18.8 dB. Fig.2b shows the return loss (|S11|) (dB) vs. frequency of the circular microstrip antenna with 2 rectangular slots on the circular patch. The resonance band extends from 1.5675 GHz to 1.62 GHz at –10 dB having the percentage bandwidth of 3.28%. Fig.2c shows the 3-D radiation pattern of the antenna.

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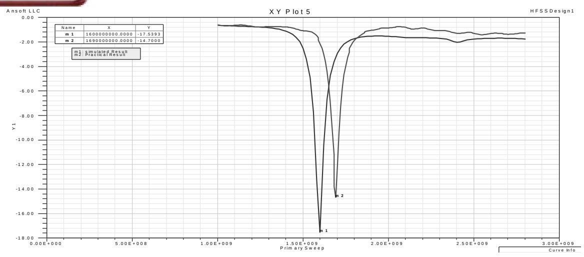

Fig.2.b. simulated and measured return loss.

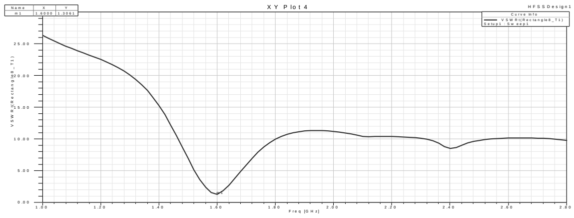

Fig.2.c: VSWR

3. *Circular patch with rectangular slot:*

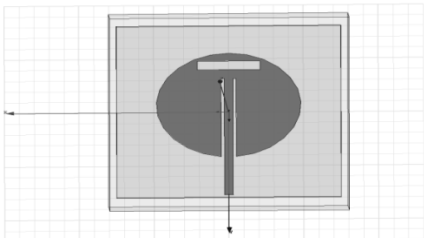

Fig.3.a. Simulated circular patch with rectangular slot.

The antenna resonates at 1.58 GHz (TM11 mode) and 2.56 GHz (TM01 Mode) at the return loss values of –11.32 dB and –16.07 dB respectively, which is shown by Fig.3b.shows the return loss (|S11|) (dB) vs. frequency of the dual frequency circular microstrip antenna with a rectangular slot on the tip of the circular patch. The first resonance (f1=1.58 GHz) band extends from 1.57 GHz to 1.60 GHz at –10 dB having the percentage bandwidth of 1.89% and the second resonance (f2=2.56 GHz) band extends from 2.523 GHz to 2.59 GHz at –10 dB having the percentage bandwidth of 2.61%.

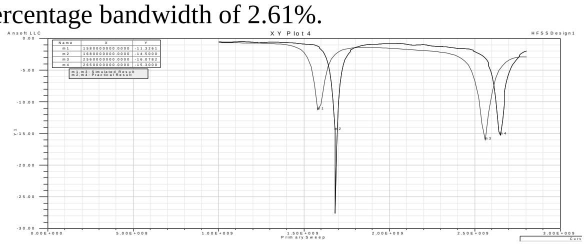

Fig.3.b. Simulated and measured return loss

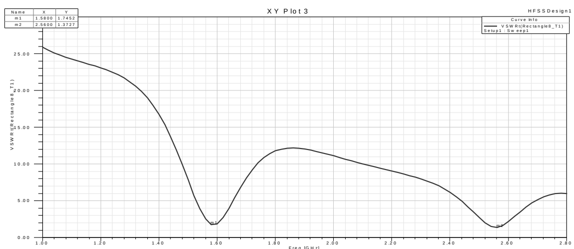

Fig.3.c. VSWR

4. *Circular patch with three rectangular slots:*

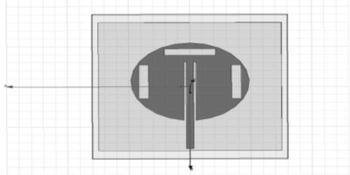

Fig.4.a. circular patch with three rectangular slots.

The antenna resonates at 1.54 GHz (TM11 mode) and 2.62 GHz (TM01 Mode) at the return loss values of –11.83 dB and –24.89 dB respectively, which is shown by Fig.4.b shows the return loss (|S11|) (dB) vs. frequency of the dual frequency circular microstrip antenna with a rectangular slot on the tip of the circular patch . The first resonance (f1=1.54 GHz) band extends from 1.53 GHz to 1.56 GHz at –10 dB having the percentage bandwidth of 1.95% and the second resonance (f2=2.62 GHz) band extends from 2.586 GHz to 2.665 GHz at –10 dB having the percentage bandwidth of 3.01%.

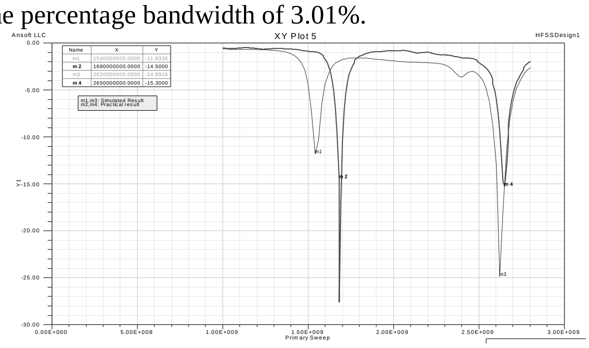

Fig.4.b. simulated and measured return loss.

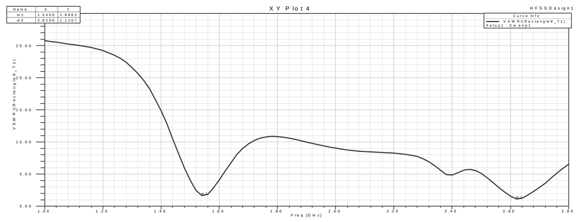

Fig.4.c. VSWR

Type of Antenna	Resonant Frequency (GHz)		Return Loss(S11) in dB		% Band-width
	(S)	(M)	(S)	(M)	
No slot	1.58	1.69	-13.6	-14.7	2.53
Two slots	1.60	1.69	-17.5	-16.7	3.28
One slot	1.58 2.56	1.68 2.65	-11.3 -16.0	-14.5 - 15.3	1.89 2.61
Three slots	1.54 2.62	1.63 2.69	-11.8 -24.8	-15.2 - 17.4	1.95 3.01

V. Conclusions

In this paper we try to obtain a dual band response by cutting a rectangular slot on the circular patch and further minimize the return losses by cutting two more slots by using HFSS simulator version 11. Our result indicates that the bandwidths around the two operating frequencies are sufficient for the dual band wireless operations. Here we assume all environmental conditions are standard.

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