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A Penta Band Slot Loaded Circular Microstrip Antenna for WLAN and WiMAX Applications

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ABSTRACT: This paper presents the design and development of slot loaded circular microstrip antenna for penta band operation. Thepenta band antenna has been realised by incorporating plus type equal arm length slots at the centre of the conventional circular microstrip antenna. The proposed antenna is operating between the frequencies range from 2.57 GHz to 11.09 GHz, covering the application bands of WLAN and WiMAX. The antenna gives broadside radiation characteristics at each operating band. The presented antennas are simulated and are analysed using commercial electromagnetic (EM) HFSS simulation software. The experimental and simulation results are given and are discussed in this paper. A close agreement is obtained between the simulated and experimental results.

Keywords: Circular microstrip antenna, penta band operation, PTCMSA, WLAN, WiMAX.

I. INTRODUCTION

Microstrip antennas (MSAs) are occurred in the early 1970s and since then the continuousof research activities in this area is going on rigorously. The MSAs have well-known advantages over other microwave antenna structures such as simple to construct, lightweight, inexpensive, low-profile, conformal to the surface, low cost of fabrication, compatibility with monolithic integrated circuits (MMICs) and optoelectronic integrated circuits (OEICs) technologies [1] etc.

The growing of rapid advances in the modern wireless communication sectors demands the design and development of antenna that could be used for more than one operating frequency bands with compact in physical size. The Wireless Local Area Network (WLAN)and Worldwide Interoperability for Microwave Access (WiMAX)technologies need multi frequency operations. Thus, the multiband antennas are more attractive for modern wireless communications, because a single device can operates for various frequency bands. Several researchers have published the dual, triple and quad band antennas and are reported in [2-6]. Introducing L- shaped slot in circular disk patch is presented in [2] which can operate at two resonance frequencies for 5.087 and 8.445 GHz and useful for dual band operation. Recently, reported a novel coplanar waveguide (CPW)-fed monopole antenna with simple structure and compact in size suitable for 2.4 and 5 GHz WLAN systems [3]. A novel design of a simple microstrip-fed monopole is proposed in [4] which cover WLAN/WiMAX triple-band operations. Multiband printed and double-sided dipole antenna is proposed in [5] for WLAN/WiMAX applications using a 50-Ω coaxial cable through a microstrip-to-twinline tapered transition. A compact single-feed planar antenna with three wide 2 : 1 VSWR operating bands around 1.8, 2.4 and 5.8 GHz covering four useful frequency bands, namely Global Positioning System(GPS: 1575.4 MHz), Digital Cellular Service(DCS:1800 MHz), 2.4 GHz (2400–2485 MHz) and 5.8 GHz (5725–5825 MHz) WLAN is presented in [6].The modified penta-band two-strip monopole antenna using thicker substrate is discussed in [7] which areused for Wireless Fidelity (WiFi) and WiMAXapplications.However, a simple slot loaded circular microstrip antenna fed by 50-Ω microstripline technique capable to operate for penta frequency bands useful for WLAN and WiMAX applications is found to be rare in the literature.

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II. DESIGNING OF ANTENNA CONFIGURATIONS

The proposed antennas are printed on low cost modified glass epoxy substrate material of thickness 0.16 cm and a dielectric constant of 4.2. The Fig.1 shows the top view configuration of the conventional circular microstrip antenna (CCMSA). The CCMSA has been designed for the resonating frequency of 3 GHz. The CCMSA consists of a circular patch of radius ‘a’ which equal to 1.361 cm. The antenna is fed through a simple 50-Ω microstripline with dimensions $W_f \times L_f$. The quarter wavelength transformer is used for matching the impedance between the radiating patch and the 50-Ω microstripline with dimensions $W_{tr} \times L_{tr}$. The bottom surface of CCMSA is tight copper shielding.

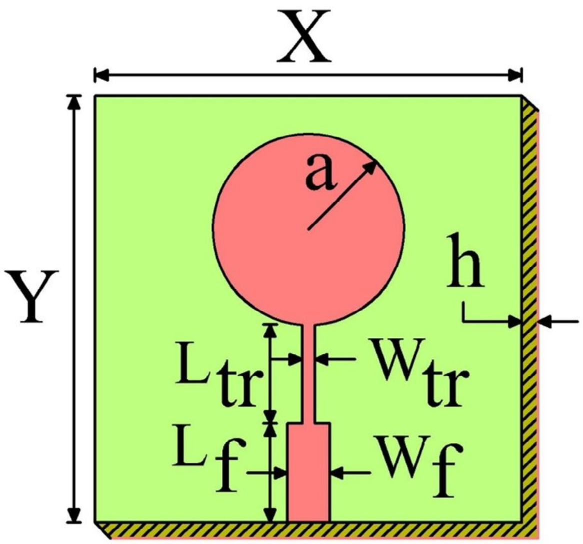

Fig. 1 Top view configuration of CCMSA

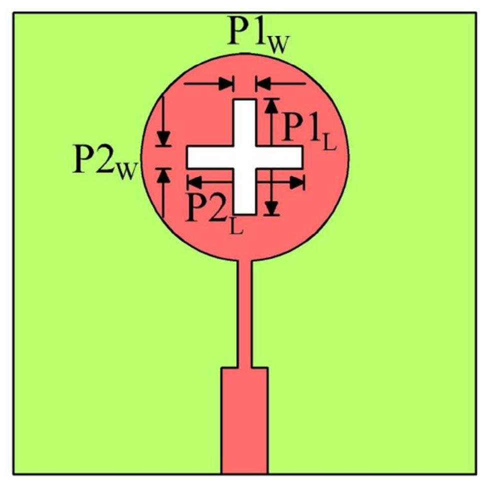

Fig. 2 Top view configuration of PTCMSA

Figure 2 shows the top view configuration of plus type circular microstrip antenna (PTCMSA). It is formed from CCMSA by etching plus type slots of equal arm at the centre of the circular radiating patch. The slot dimensions of PTCMSA are taken in terms of free space wavelength λ_0. The dimensions width of two rectangular slots are $P1_W$ and $P2_W$ which are equal to $\lambda_0/50$ (i.e. 0.2cm) and length of two rectangular slots are $P1_L$ and $P2_L$ which are equal to $\lambda_0/7.34$ (i.e. 1.361cm).

The actual radius of the circular radiating patch is calculated by using the equation [8],

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

where,

$$F = \frac{8.791\times 10^9}{f_r\sqrt{\varepsilon_r}}$$

Thus the effective area of the circular radiating patch is given by,

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$$a_e = a\left\{1+\frac{2h}{\pi a\varepsilon_r}\left[\ln\left(\frac{\pi a}{2h}\right)+1.7726\right]\right\}^{\frac{1}{2}} \quad (2)$$

The designed parameters of proposed antennas are shown in Table –I.

TABLE I
DESIGNED PARAMETERS OF PROPOSED ANTENNAS

Antenna Parameters	a	L_f	W_f	L_{tr}	W_{tr}	$P1_W$ and $P2_W$	$P1_L$ and $P2_L$
Dimensions in cm	1.361	1.23	0.317	1.23	0.066	$\lambda_0/50$	$\lambda_0/7.34$

The schematics of CCMSA and PTCMSA antennas for the fabrication process are outlined using AutoCAD tool toachieve better accuracy. A 50-Ω semi miniature-A (SMA) connector is used at the tip of the microstripline to feed the microwave power.

III. EXPERIMENTAL RESULTS AND DISCUSSION

The parameters of proposed antennas are measured on Vector Network Analyser (Rohde and Schwartz Germany make ZVK model). The equation used for calculating the impedance bandwidth is,

$$BW = \left[\frac{f_H - f_L}{f_C}\right]\times 100\% \quad (3)$$

where, f_H and f_L are the higher and lower cut-off frequency of the band respectively when its return loss becomes -10dB and f_C is the centre frequency between f_H and f_L. These antennas are also simulated using 3D full wave electromagnetic (EM) Ansys HFSS simulation software.

Figure 3 shows the variation of return loss versus frequency of CCMSA. From this figure it is clear that, the antenna resonates at 3 GHz (i.e. f_r), which is exactly equal to the design frequency of 3 GHz. The impedance bandwidth BW of CCMSA is found to be 2%. The HFSS simulated result of CCMSA is also illustrated in Fig. 3. A good agreement is obtained between simulation and experimental results.

The variation of return loss versus frequency of PTCMSA is as shown in Fig. 4. From this figure it is observed that, the antenna is resonating for five resonant modes at f_{r1}, f_{r2}, f_{r3}, $f_{r4}$and f_{r5} with a corresponding impedance bandwidths of BW_1= 2.66% (2.59 GHz-2.66 GHz), BW_2= 7.14% (6.24 GHz-6.69 GHz), BW_3= 3.35% (7.34 GHz-7.59 GHz), BW_4= 2.71% (8.80 GHz-9.04 GHz) and BW_5= 15.67% (9.51 GHz -11.09 GHz) respectively. Hence by the construction of PTCMSA from CCMSA the operating frequency modes fr_1 to fr_5 is possible. It is also seen from this figure that, the highest impedance bandwidth of 15.67% is found at BW_5. The simulated variation of return loss versus frequency result is also illustrated in the Fig. 4. Hence the use of plus shaped slot on the circular patch is effective in producing the multiband operation of an antenna. However the dimension of slots may possible to vary to control the operating bands of the antenna.

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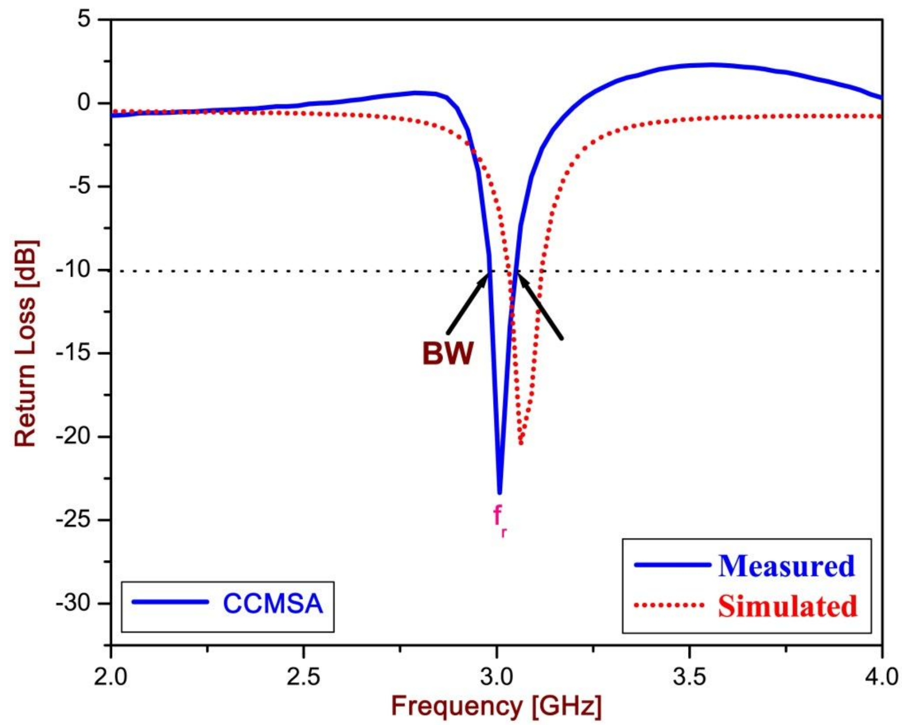

Fig. 3 Variation of return loss versus frequency of CCMSA

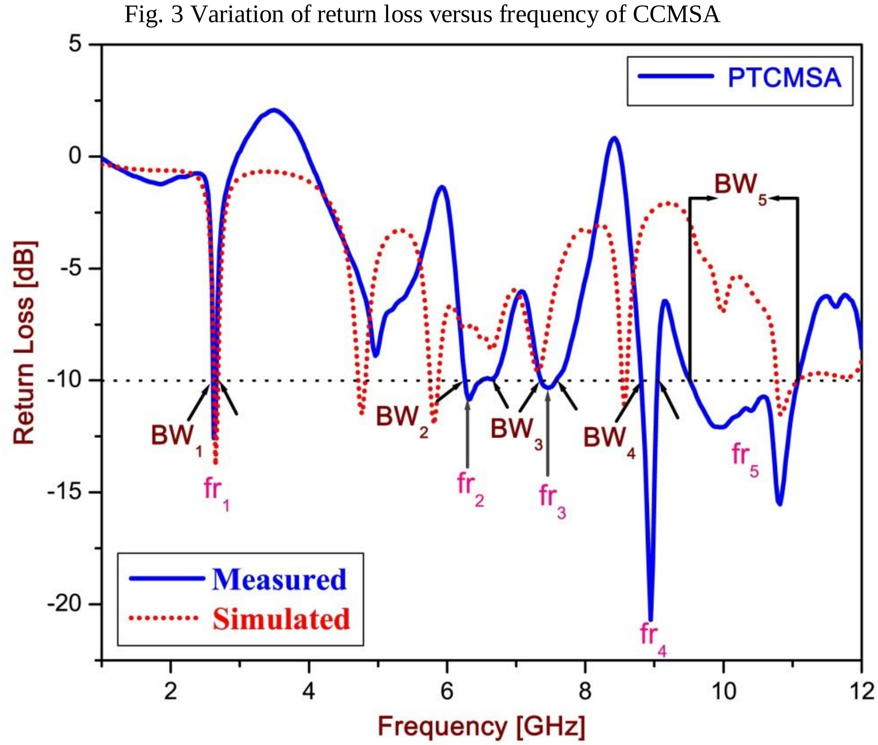

Fig. 4 Variation of return loss versus frequency of PTCMSA

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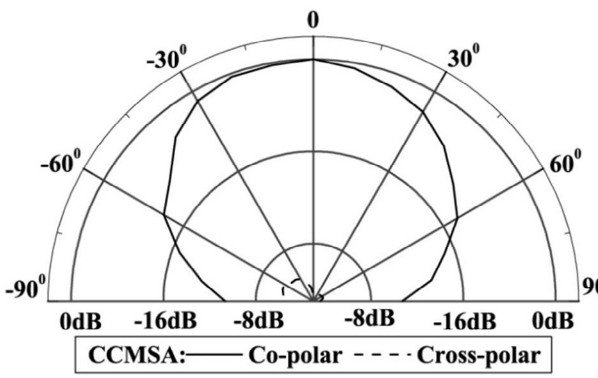

Fig. 5(a)

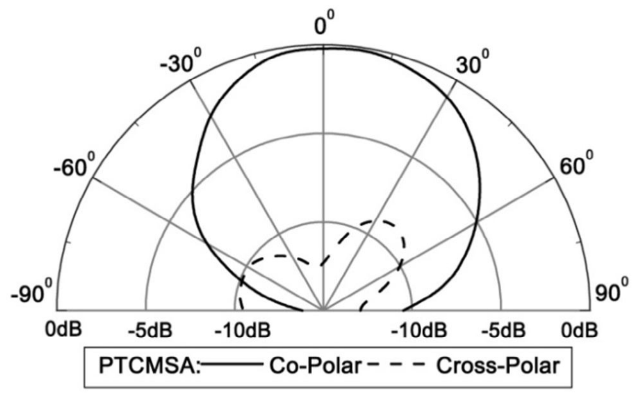

Fig. 5(b)

Fig. 5 Typical co-polar and cross-polar radiation pattern of CCMSA and PTCMSA measured at 3 GHz and 2.62 GHz respectively.

The typical radiation patterns of co-polar and cross-polar are measured in the far field region at the resonating frequencyf_r (3GHz) of CCMSA and at fr_1 (2.62 GHz) of PTCMSA are as shown in Fig. 5. From this figure, it can be observed that, the patterns are broadside and linearly polarized.

Figure 6(a) and (b) shows the E- plane field distribution of CCMSA and PTCMSA observed atf_r (3 GHz) and f_{r1} (2.62 GHz) respectively.Figure 7(a) and (b) shows the H-plane field distribution of CCMSA and PTCMSA observed at f_r (3 GHz) and f_{r1} (2.62 GHz) respectively. From the figures 6 and 7 it is seen that, the field distribution is adequate on the patch at the resonant frequencies indicates the effective radiation by the patch.

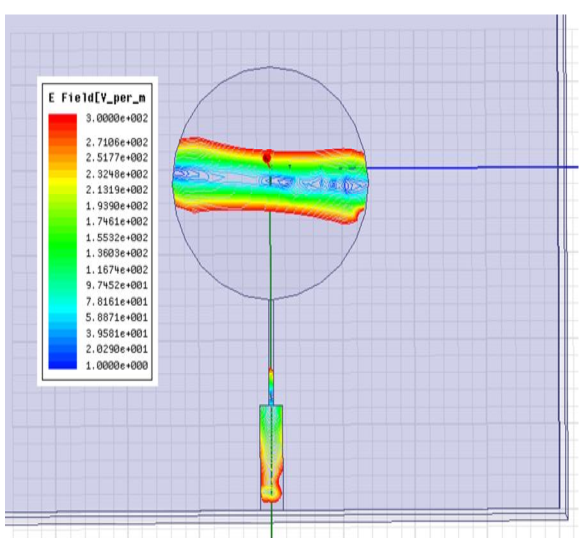

Fig. 6(a)

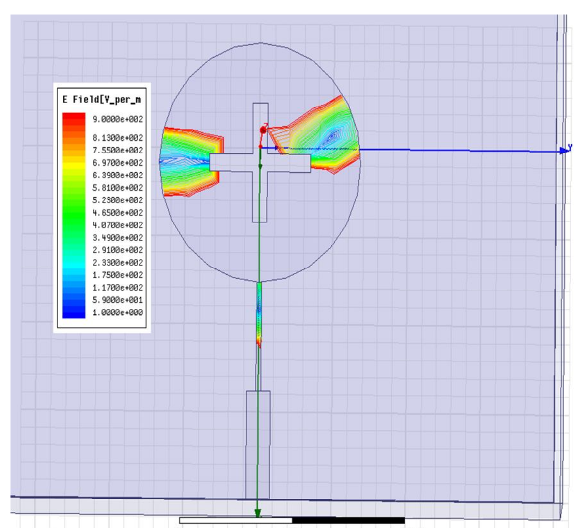

Fig. 6(b)

Fig. 6 E-plane field distribution of CCMSA and PTCMSA observed at f_r and f_{r1} respectively

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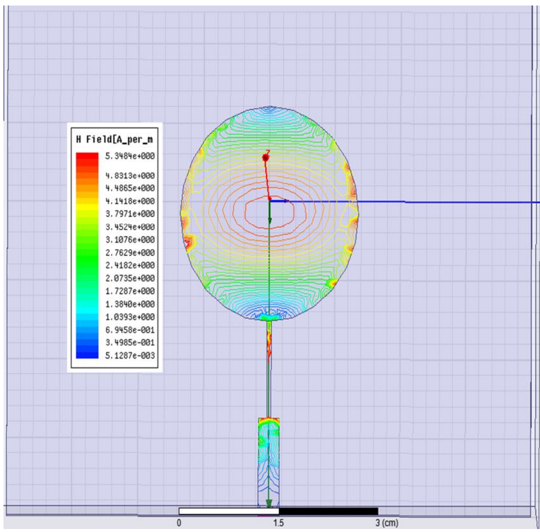

Fig. 7(a)

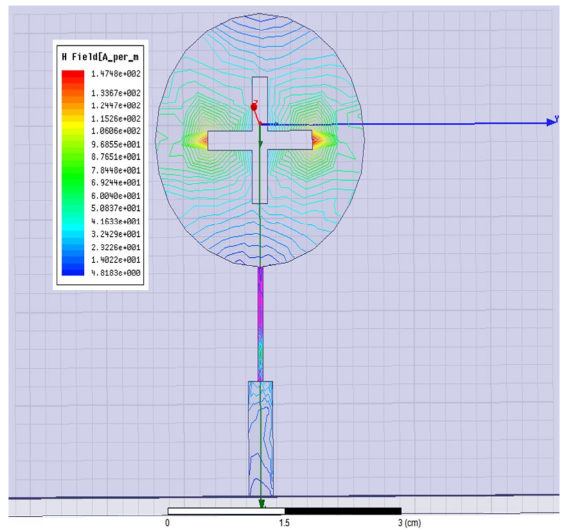

Fig. 7(b)

Fig. 7 H-plane field distribution of CCMSA and PTCMSA observed at f_r and f_{r1} respectively

IV. CONCLUSION

In this paper, a new geometry (i.e. PTCMSA) has been proposed for penta band operation. This geometry has been realized by placing the plus type slot at the centre of the CCMSA. The proposed antenna is operating between the frequency range of 2.57 GHz to 11.09 GHz which is useful for WLAN and WiMAX applications. The PTCMSA gives broadside radiation characteristics at each operating band. The PTCMSA is simple in its design and construction. This antenna has been fabricated using low cost substrate material. These features make the antenna more attractive for practical.

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