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Design and Development of Circular Microstrip Antenna for multiband operations

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Abstract. This paper presents design and development of circular microstrip antenna for multiband operation using low cost substrate material realized from conventional circular microstrip antenna. The proposed antenna is a novel geometry consisting crossed slot equal arm length with truncated edges of a circular patch. The antenna uses the feed line same as that of the conventional circular microstrip antenna. The antenna operates in the frequency range of 2.03 to 9.56 GHz and gives a virtual size reduction of 31% with broadside radiation characteristics at each operating band. The experimental and simulated results are in good agreement with each other. This antenna may find applications in WLAN, WiMax and other wireless communication applications.

Keywords: Circular microstrip antenna, cross-slot, multiband.

1 Introduction

Microstrip antennas have many advantages such as low profile, conformable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology and compatible with MMIC designs which leads to use this type of antenna in different applications. On the other hand major operational disadvantages of microstrip antennas are their low efficiency, low gain, very narrow bandwidth, yet it has been one of the most suitable candidates for modern wireless communication technology. The practical applications of microstrip antennas for mobile systems are in portable or pocket-size equipment and in vehicles. Antennas for VHF/UHF handheld portable equipment, such as pagers, portable telephones and transceivers, must naturally be small in size, light in weight and compact in structure. There is a growing tendency for portable equipment to be made smaller and smaller as the demand for personal communication rapidly increases, and the development of very compact hand-held units has become urgent. However these antennas are less suited to modern communication [1], [2] as they efficiently resonate at single frequency and shows narrow bandwidth at lower microwave frequencies. As they are compact in nature and hence are popular structures in modern wireless communication system.

A number of patch structures available but the rectangular and the circular are basic shapes [3] used in practice. The performance of antenna is affected by patch geometry, substrate property and feed technique. Circular patch antenna is more favorable in some applications such as arrays as it takes less space than rectangular patch antenna operating at the same frequency. In many applications, antenna operating at several discrete frequency bands that are far from each other is more useful. Dual, triple and multiband antennas have gained wide attention in cellular phone, WiMax, Bluetooth, high performance radio local area network (HIPERLAN) and radar communication particularly in synthetic aperture radar (SAR) etc. In order to meet the rapidly growing demands of the modern communication systems, the antenna should be responsible to operate in many frequency bands apart from wider impedance bandwidth, high gain, compactness and good radiation characteristics. The multiband antennas realized by using many methods such as, variable inductive or capacitive loads to the patch [4]. But in this paper truncated edges circular microstrip antenna with equal arm lengths of cross-slot to work as a multiband operations is found to be rare in the literature. Truncating the antenna makes its size compact.

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2 Description of the Antenna Geometry

The proposed antenna is designed and developed using a commercial low cost modified glass epoxy substrate material of area X × Y having a thickness h = 0.16 cm, with relative permittivity ε_r= 4.2. The artworks of these antennas are outlined using AutoCAD software to achieve better accuracy. The photolithographic processes are used for the fabrication of these antennas. Figure 1 shows the top view planar geometry of conventional circular microstrip antenna (CCMSA). The antenna has been designed for the resonating frequency of 3 GHz. The CCMSA consists of a radiating patch of radius ‘a’. The antenna is excited through a simple microstripline feeding of length L_f and width W_f. The quarter wavelength transformer having length L_{tr} and width W_{tr} technique [3], [4] is used to match the impedance of the circular patch with the microstripline. A 50 Ω semi miniature-A (SMA) connector is used at the tip of the microstripline to feed the power.

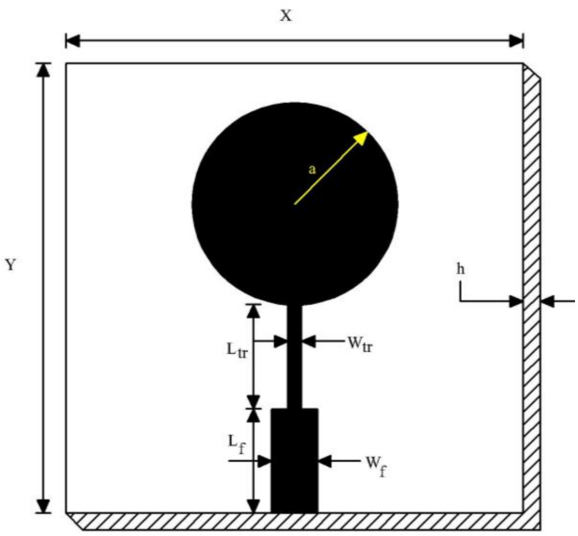

Figure 1 Top view geometry of CCMSA.

The actual radius of the circular radiating patch is given by using the equation [2].

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

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 [2]

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

Figure 2 shows the top view geometry of truncated edges cross-slot circular microstrip antenna (TECCMSA) which is modified from the CCMSA.

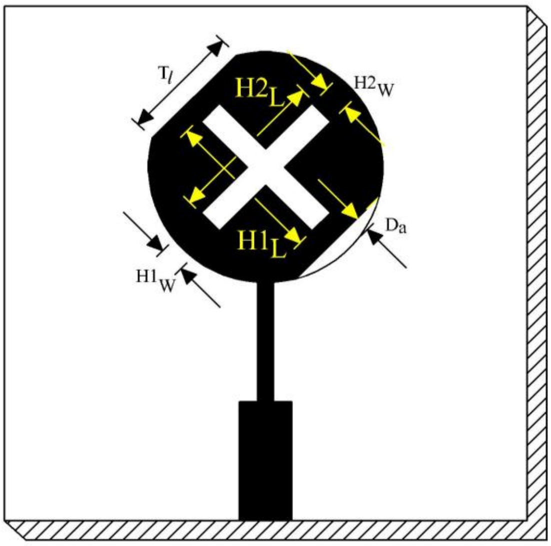

Figure 2 Top view geometry of TECCMSA.

In Figure 2 two crossed slot of equal arm lengths with truncating two opposite edges from a circular patch at 45° to the feed on the conventional circular radiating patch is used. The two equal arm lengths $H1_L$ and $H2_L$ and widths $H1_W$ and $H2_W$ of cross-slot which are taken as $\lambda_0/5$ and $\lambda_0/50$ respectively, where λ_0 is free space wavelength in cm corresponding to the design frequency of 3 GHz. The slot cut of edges length and width T_l and D_a which are taken as $\lambda_0/7.04$ and $\lambda_0/50$. Table 1 shows the designed parameters of proposed antennas.

Table 1. Design Parameters of proposed antennas.

Antenna Parameters	Dimensions in cm
a	1.361
L_f	1.23
W_f	0.317
L_{tr}	1.23
W_{tr}	0.066
$H1_L$	$\lambda_0/5$
$H2_L$	$\lambda_0/5$
$H1_W$	$\lambda_0/50$
$H2_W$	$\lambda_0/50$
T_l	$\lambda_0/7.04$
D_a	$\lambda_0/50$

3 Experimental Results and Discussions

Figure 3 shows the variation of return loss versus the frequency of CCMSA. It is seen that, the antenna resonates at 3 GHz, which is accurately equal to design frequency of 3 GHz. The percentage of experimental impedance bandwidth is calculated using the relation is given in Equation 3.

$$Impedance\ Bandwidth = \left[\frac{f_2 - f_1}{fc}\right] \times 100\% \tag{3}$$

where, f_2 and f_1 are the upper and lower cut off frequency of the resonated band when its return loss reaches -10 dB and f_c is a centre frequency between f_1 and f_2. The impedance bandwidth of CCMSA is found to be 2%. The HFSS simulated result of CCMSA is also shown in Figure 3.

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Figure 4 shows the variation of return loss versus frequency of TECCMSA. From this figure it is found that the antenna resonates at five modes of frequencies f_1, f_2, f_3, f_4 and f_5 with their respective impedance bandwidths are BW_1= 2.91% (2.03-2.09 GHz), BW_2 = 2.59% (2.28-2.34 GHz), BW_3= 2.25% (3.50-3.58 GHz), BW_4 = 7.74% (7.32-7.91 GHz) and BW_5 = 9.79% (8.64-9.53 GHz) respectively. The first band BW_1 is due to the fundamental resonance of the patch. The remaining bands BW_2, BW_3, BW_4 and BW_5 are due to the truncation insertion of equal arm lengths of cross-slot on the circular radiating patch as they resonate independently. The simulated result of TECCMSA is also shown in Figure 4 which is close agreement for f_1 to f_5 with experimental results. By comparing the resonant frequency f_r of Figure 3 to f_1 in Figure 4 it is found that the TECCMSA gives virtual size reduction of 31 %.

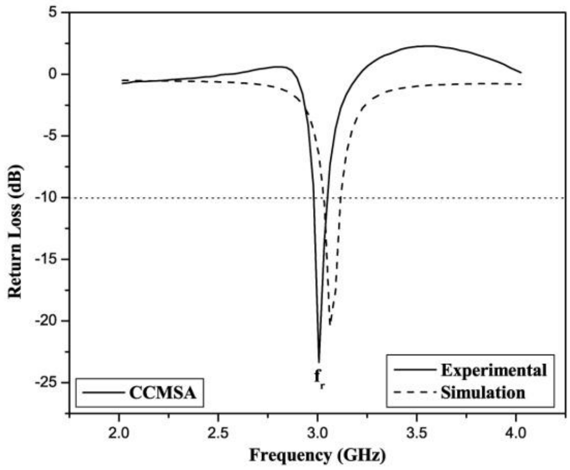

Figure 3 Variation of return loss versus frequency of CCMSA.

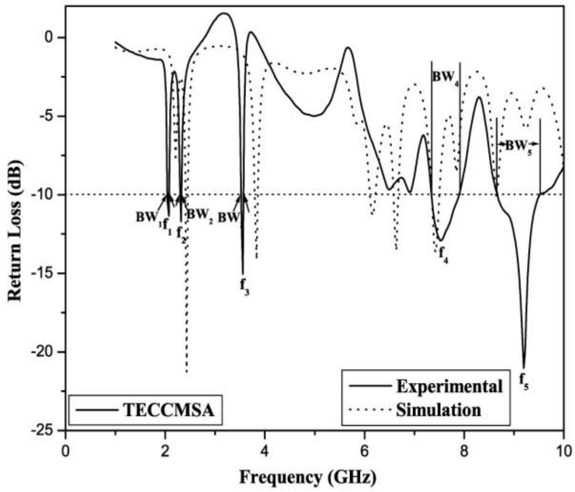

Figure 4 Variation of return loss versus frequency of TECCMSA.

The typical far field co-polar and cross-polar radiating patterns of CCMSA and TECCMSA measured in their matched bands are shown in figure 5 to 8. From these figures, it can be observed that the patterns are broadside and linearly polarized.

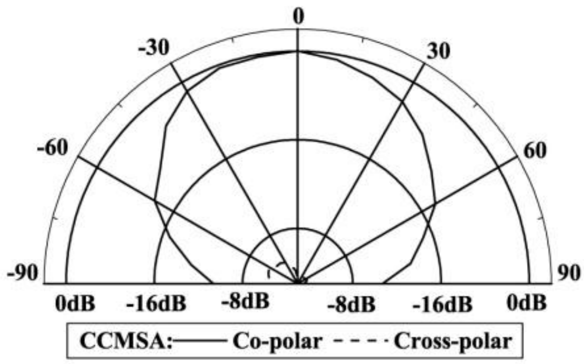

Figure 5 Radiation patter of CCMSA measured at 3GHz.

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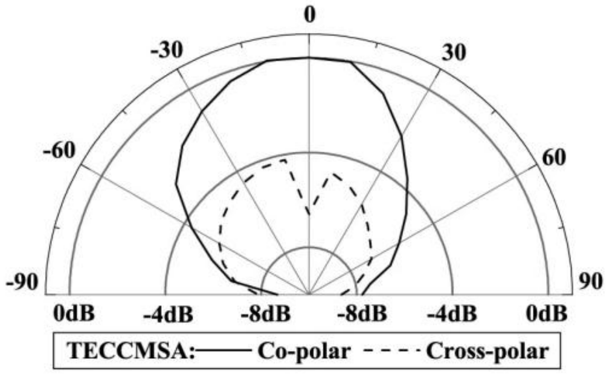

Figure 6 Radiation pattern of TECCMSA measured at 2.07 GHz.

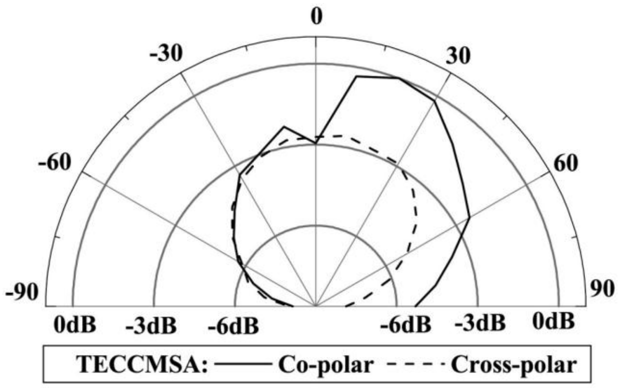

Figure 7 Radiation pattern of TECCMSA measured at 2.32 GHz.

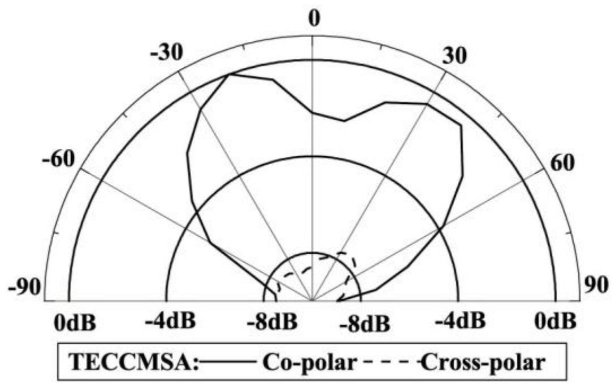

Figure 8 Radiation pattern of TECCMSA measured at 7.51 GHz.

4 Conclusions

From the detailed study it is clear that, the design and development of CMSA for multiband operations is possible by modifying CCMSA to TECCMSA. This antenna operates between the frequencies ranges from 2.03 to 9.56 GHz, and gives a virtual size reduction of 31% and shows broadside radiation characteristics at each operating band. The experimental results of return loss versus frequency of proposed antennas are in good agreement with simulation results. The proposed antennas are simple in their design and fabrication and they use commercially available low cost substrate material. This antenna may find applications in wireless local area network (WLAN), worldwide interoperability for microwave access (WiMax) and other wireless communication applications like Bluetooth and high performance radio local area network (HIPERLAN).

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References

1. I.J.Bahl and P.Bhartia, Microstrip Antennas. 1980, Boston: Artech House.
2. Constantine A Balanis, Antenna Theory Analysis and Design, John Wiley & Sons, 2005.
3. Kin Lu Wong, Compact broadband microstrip antennas, John willey & sons, Inc, New York, 2002.
4. Girish Kumar and K. P. Ray, Broadband microstrip antennas, London, Artech House, 2003.
5. S.A Long and M.D. Walton, "A dual frequency stacked circular disk antenna", IEEE Trans. Antennas Propagat., vol. 27, pp. 270-273, March, 1979.

6. K.L .Wong and K.B. Hsieh, "Dual frequency circular microstrip antenna with a pair of arc- shaped slots," Microwave Opt.Technol. Lett. vol. 19, pp. 410-412, Dec, 1998.
7. Kin-Lu Wong and Jen-Yea Jan, "Broadband circular microstrip antenna with embedded reactive loading", IEE Electron. Lett., vol.34, no.19, pp.l804-1805,1998.
8. Y. X. Guo, K. M Luk and K. F. Lee, "U-slot circular patch antennas with L-probe", IEE Electron. Lett., vo1.35, no.20, pp. 1694-1695, 1999.
9. W. K. Lo, J. L Hu, C.H Chan and K. M. Luk , "Circularly polarized patch antenna with an L-shaped probe fed by a microstrip line", Microwave Optical Technol. Lett., vol.24, no.6, pp.412-414, 2000.
10. Wen-Hsiu Hsu and Kin-Lu Wong, "A wideband circular patch antenna", Microwave Optical Technol. Lett.,vol.2S,no.5,pp.327-328,2000.
11. David M. Pozar, Microwave Engineering 2nd edition, John Wiley & Son, Inc.1998.
12. S. Sadat., M. Fardis., F. Geran, and G. Dadashzadeh, "A compact microstrip square- ring Slot antenna for UWB applications," Progress In Electromagnetic Research PIER 67, (2007), 173-179.
13. M.T. Islam, M.N. Shakib, and N. Misran, " Multi- slotted microstrip patch antenna for wireless communication," Progress In Electromagnetic Research Letters, vol. 10, (2009), 11-18.
14. K.M. Luk, K.F. Lee, and W.L. Tam, Circular U-slot patch with dielectric superstrate, Electron Lett 33 (1997), 1001–1002.
15. Jolani,F. and A. M. Dadgarpur and Hassani, "Compact M-slot folded patch antenna for WLAN," Progress In Electromagnetics Research B,Vol. 3,35–42,2006.
16. Nagraj Kulkarni, S. N. Mulgi and S. K. Satnoor, "Design and development of simple low cost Rectangular Microstrip Antenna for multiband operation", International Journal of Electronics and Electrical Engineering, Dec. 2011, Vol 1, Issue 1, pp.45-51.