A DESIGN OF TRIPLE-BAND SLOT LOADED CIRCULAR MICROSTRIP ANTENNA FOR C- AND X- BAND APPLICATIONS

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Abstract

The design and development of a triple-band slot loaded circular microstrip antenna is demonstrated in this paper for the applications of C (4.66-8 GHz) and X (8.91-9.93 GHz) bands. The proposed antenna design consists of a pair of connected square slots which are centrally inserted on the circular radiating element. The antenna resonates at three frequencies of 4.76, 7.45 and 9.27 GHz with impedance bandwidths of 3.98% (4.67-4.86 GHz), 17.40% (6.82-8.12 GHZ) and 14.48% (8.58-9.92 GHz) respectively. The antenna is excited through a simple 50-Ω microstripline feed. The proposed antenna may suitable for uplink and downlink of C-band satellite communication and of X band radar applications. The simulation results are obtained by utilizing 3-D full-wave finite element method based high frequency structural simulator (HFSS) for comparison of experimental results. Acceptable agreement is observed between the both simulation and experimental results.

Keywords: *Connected square slots, circular microstrip antenna, triple-band, C- and X- band.*

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1. INTRODUCTION

Nowadays most of the modern wireless communication systems especially in the field of satellites and modern radar systems, radio frequency identification (RFID), personal communication services (PCS) etc. finds the microstrip antennas (MSAs) are most useful and successful element for transmitting and receiving the electromagnetic (EM) signals, due to their special advantages such as less expensive, compact physical profile, easy to manufacture and easy to integrate with other microwave systems [1-2]. Also the recent technologies are more expecting the improved parameters of MSAs and antenna should operate for more than one frequency bands. Hence, in the recent consecutive decades there is lot of innovative techniques to improve the performance of the MSAs and multi-frequency operations were reported by many antenna designers. Since then a great amount of research activities are taking place throughout the world for both academic and industrial societies. The antenna parameters such as return loss, wider impedance bandwidth, efficiency, radiation characteristics and gain etc. have been investigated and reported in numerous technical papers by several techniques including the cutting slots in both radiating patch or ground plane [3-6], use of shorting pins and shoring walls [7-9], gap coupled [10], aperture coupled [11-12], proximity coupled [13-14] etc.

Also for several wireless communication applications the requirement of dual-frequency and triple-frequency operation with wider impedance bandwidth is more useful. A single element MSA for dual-frequency operation using shorting pins was proposed in [15]. A rectangular notch square patch for dual-frequency operation by using coaxial feed is proposed in [16]. The compact multiband antenna configuration for GPS, DCS and WLAN applications is reported in [17] using FR4 substrate fed by single feed. But in this paper a circular microstrip antenna with connected slots loaded on the patch is demonstrated for the triple band operation which is found to be rare in the literature.

2. ANTENNA DESIGN CONSIDERATIONS

The conventional circular microstrip antenna (CCMSA) and connected two square slot loaded circular microstrip antenna (CTSCMSA) are manufactured using a commercially available low cost glass epoxy substrate material of thickness h = 0.16 cm with relative permittivity ε_r= 4.2 and dielectric loss tangent tan δ = 0.02. The structures of these antennas are drawn by using AutoCAD software.

Figure 1 shows the top view geometry of CCMSA. The CCMSA geometry consisting a circular radiating element of radius ‘*a*’. This antenna is powered through a simple 50 Ω microstripline feed of dimensions length L_f and width W_f is used for impedance matching. Also the quarter wavelength transformer having length L_t and width W_t is fixed to match the impedance between the circular patch and the microstripline feed. A 50 Ω semi miniature-A (SMA) connector is connected at the end point of the microstripline for feeding the microwave power.

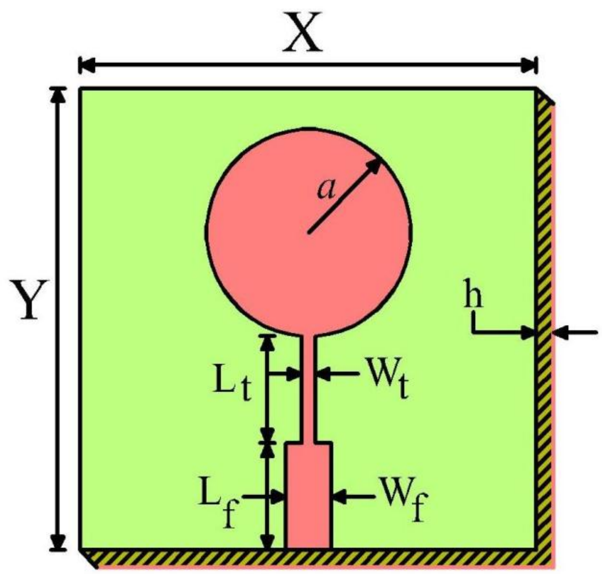


Fig -1: Top view geometry of CCMSA

The CCMSA has been designed for 3 GHz. The physical radius '*a*' of the circular radiating patch is approximately determined from equation [18],

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

Where,

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}}$$

Along the circumference of the conventional circular radiating patch the fringing fields are appears, thus by replacing the physical radius '*a*' by effective radius 'a_e' which is given by [18],

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

The top view geometry of CTSCMSA is as shown in Fig -2. This antenna structure is adopt from CCMSA and consists of two equal dimensions of square slots which are connected together and inserted centrally on the circular radiating patch. The one offset square slot is exactly placed at the center from left side of the circular radiating patch. The length and width of the offset square slot ($S1_W$ and $S1_L$) are equal to λ_0/14.28. The other offset square slot is placed exactly at centered from right side of the patch. The dimensions of left off square slot ($S2_W$ and $S2_L$) are same as that of the right offset square slot and are connected together. The total length *l* of the two square slots is λ_0/7.14 and distance '*d*' between the connected offset square slots is λ_0/28.56 which is also shown in Fig -2. The parameters of the designed antennas are given in Table-I.

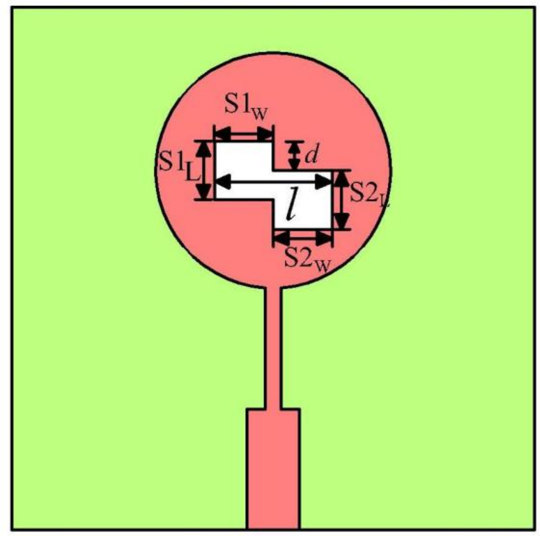


Fig -2: Top view geometry of CTSCMSA

Table –I: The designed parameters of proposed antennas.

Antenna geometry parameters	Parameter dimensions in cm
a	1.361
L_f	1.23
W_f	0.317
L_t	1.23
W_t	0.066
$S1_W$ and $S1_L$	0.7
$S2_W$ and $S2_L$	0.7
d	0.35

3. EXPERIMENTAL RESULTS & DISCUSSIONS

The impedance bandwidths over return loss less than -10dB for the proposed antennas are measured. Figure 3 shows the variation of return loss versus frequency of CCMSA. It is keen observed from this figure that, the CCMSA resonates at 3 GHz which is highly accurate to the design frequency of 3 GHz. The experimental impedance bandwidth is defined as

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

Where, f_H is the higher cutoff frequency and f_L is the lower cutoff frequency and f_C is central frequency of the bands. The impedance bandwidth BW of CCMSA is determined when its return loss reaches the 10-dB found to be about 2.93%. The HFSS simulation result of CCMSA is also shown in Fig-3. The reasonable agreement is obtained between simulation and experimental results.

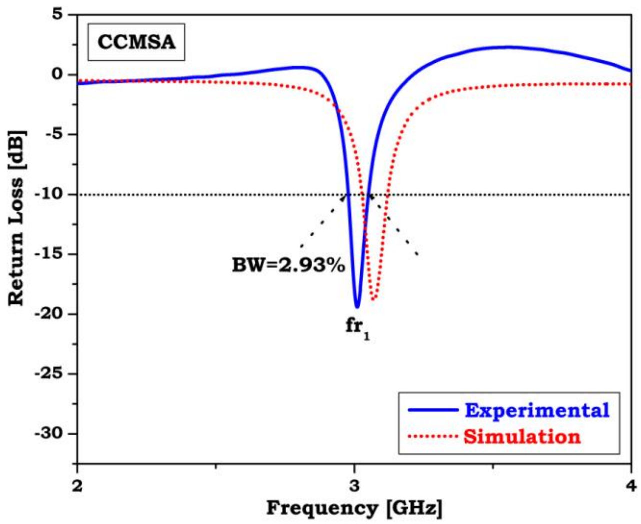


Fig -3: Variation of return loss versus frequency of CCMSA.

The variation of return loss versus frequency of CTSCMSA is as shown in Fig. 4. From this figure it is evident that, the antenna resonates for three resonant frequency modes at f_{r1}, $f_{r2,}$ and f_{r3}, having an impedance bandwidth of BW_1= 3.56% (4.69 GHz-4.86 GHz), BW_2= 16.84% (6.85GHz-8.11GHz) and BW_3= 14.5% (8.60 GHz-9.91 GHz) respectively. It is also clear that, each operating bands are quit large compared to the impedance bandwidth of CCMSA and triple bands are possible by constructing CTSCMSA from CCMSA. For the first and second operating bands, the obtained impedance bandwidth is BW_1=3.56% and BW_2= 16.84% which effectively covers the requirement of the uplink and downlink of C-band satellite communication application. For the third operating band, the impedance bandwidth BW_3= 14.5% is obtained, this range is useful for covering the X-band uplink satellite communication. The simulated result is in good agreement with the measured result.

The typical radiation patterns are measure at 3, 7.48 and 9.25 GHz of the CCMSA and CTSCMSA which are presented in Fig-5. The proposed antenna gives good broadside radiation characteristics at three operating bands.

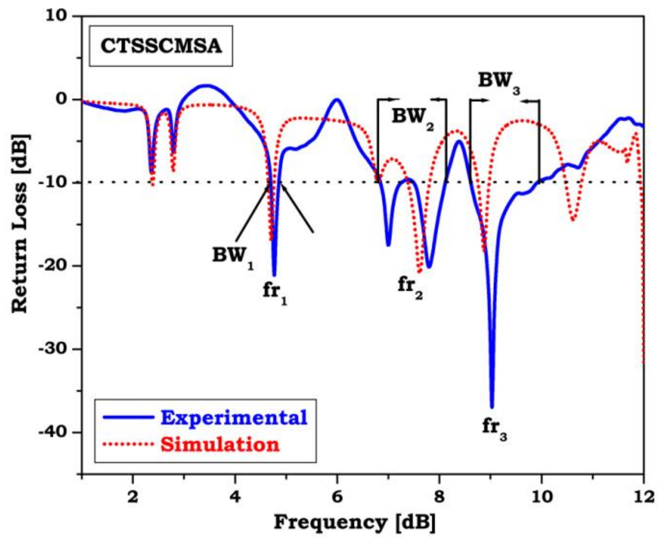
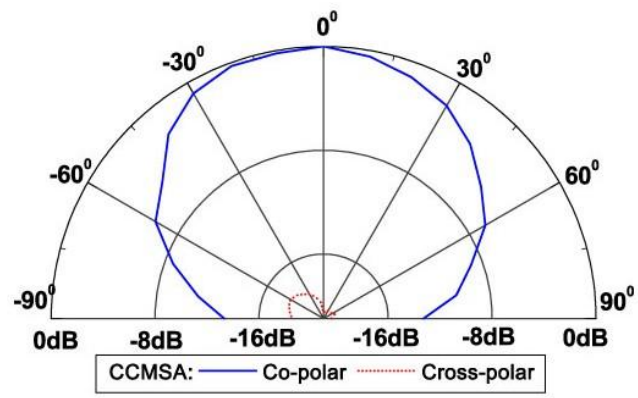
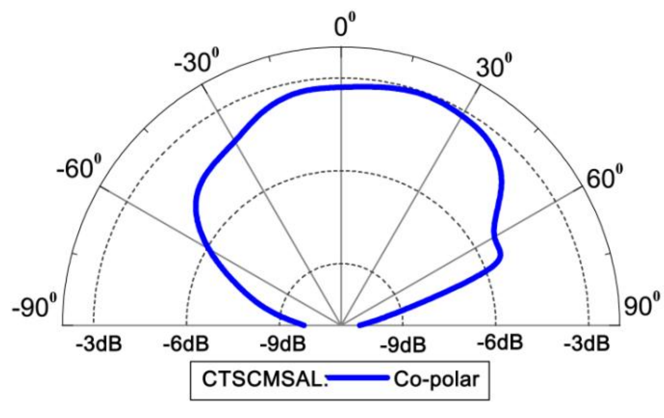


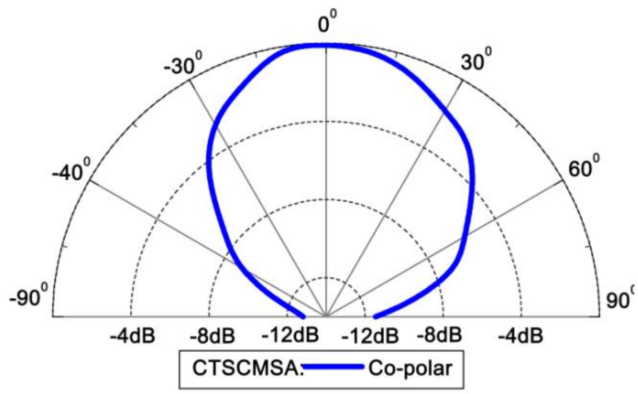
Fig -4: Variation of return loss versus frequency of CCMSA.



(a)



(b)



(c)

Fig-5: Typical radiation patterns of the CCMSA and CTSCMSA **(a)** CCMSA at 3 GHz, **(b)** CTSCMSA at 7.48 GHz and **(c)** CTSCMSA at 9.25 GHz.

4. CONCLUSIONS

This paper presents a design and development of triple-band circular microstrip antenna for C- and X-band applications. The proposed antenna design consists of a novel geometry of a pair of connected square slots which are etched at the center of circular patch. The proposed design is simple to construct and fabricate and uses low cost substrate material. The HFSS simulation software is used for comparison of experimental results. The obtained radiation patterns are broadsided in nature. The proposed triple-band operation is more useful for wireless communication and may find applications in uplink and downlink of C- and X-band satellite communication.

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BIOGRAPHIES

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