International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 1, Issue 4, April 2014)

A Compact Wideband Slot-loaded Truncated Circular Microstrip Antenna with DGS for Radar Applications

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***Abstract*— This paper presents the design and development of a compact wideband slot loaded truncated circular microstrip antenna with defected ground structure (DGS) for radar applications. The proposed antenna is consists of a novel geometry of equal arm dimensions of plus shape slot orthogonally placed at the center of radiating circular patch at the top side of the antenna and DGS at the bottom side of the antenna. The antenna is fabricated on low cost modified glass epoxy substrate and excited through the 50-Ω microstripline feed with a quarter-wavelength impedance matching transformer. The antenna gives a single wide band which operates between the frequencies range from 6.07 GHz to 9.25 GHz and gives an impedance bandwidth of 41.51% which is 14.16 times more than the impedance bandwidth of conventional circular microstrip antenna (CCMSA). The proposed antenna also becomes more compact in its physical size by 43.71% when compared to the size of CCMSA. The peak gain is also increased, which is about 8.25 dB and shows stable broadside radiation characteristics in its operating band with low cross-polarization levels. This antenna may suitable for C-band radar and downlink of X-band satellite communication systems.**

***Keywords*—Circular microstrip antenna, plus shape slot, DGS, wideband, Radar.**

I. INTRODUCTION

With the fastest continues growths in modern wireless communication technology, the microstrip antennas (MSAs) are in strong requirement to cover the various wireless communication applications with wider impedance bandwidth. Among many conventional microwave antennas the MSAs offer several advantages such as simple structure, tiny size, light weight, compatibility, ease of fabrication, versatility, low cost and multi-frequency operations [1]. MSAs are made conformal to planar and non-planar surfaces. These antennas are generally fabricated using printed-circuit board (PCB) technology, so that mass production can be inexpensive and also easily integrate with other planar circuits such as monolithic microwave integrated circuits (MMIC) and optoelectronic integrated circuits (OEICs). However, for different type of new wireless communication applications the MSAs are restricted by some drawbacks such as by the narrow impedance bandwidth (about 1%), low radiation efficiency and low gain parameters etc. [2]. For these main reasons, much technical efforts have been devoted to improving the parameters of MSAs. In recent decades many novel techniques are adopted to improve the antenna parameters such as impedance bandwidth, gain, broadside radiation characteristics by suitably loading and slotting the patch and slits on the radiating patch, selecting a low dielectric constant substrate material with higher thickness, stacking technique, adding shorting pins, coupling parasitic elements electromagnetically to the corresponding patch and by the reactive loading method etc. [3-6]. In order to achieve the rapidly growing demands of the modern wireless communication systems, the antenna should be responsible to operate in single frequency band with wider impedance bandwidth.

The MSAs are constructed using different geometries such as rectangle, square, ellipse, circle, triangle, ring, pentagon, etc. The rectangular and circular are most widely used geometry due to their simplicity in design fabrication and ease of analysis. Recently, the researchers have already been introduced the concept of DGS used to enhance the impedance bandwidth and gain of the MSA. A MSA with DGS is realized by etching a slot on the bottom side metallic ground plane. The DGS disturbs effectively the current distribution in the ground plane of MSA and the results in resonant characteristics [7]. In this DGS technique, the metallic ground plane of the MSA is intentionally modified to enhance the impedance bandwidth and gain [8].

In this paper, a novel truncated edges circular MSA with DGS is designed to realize a wide impedance bandwidth and gain which is found to be rare in the literature. Two rectangular DGSs with appropriate width and length dimensions are etched into the ground plane to enhance the impedance bandwidth and gain of the antenna. The designing details of the proposed antenna with both simulation and experimental results are also carried out. The proposed

International Journal of Ethics in Engineering & Management Education
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antennas design and is analyzed by using 3D-FEM HFSS simulation software package and the experimental verification is also carried using vector network analyzer.

II. DESIGNING OF ANTENNAS

Figure 1 shows the top view configuration the CCMSA. The CCMSA antenna has been designed for the resonating frequency of 3 GHz. All the electromagnetic (EM) optimizations have been performed using software package of Ansoft high frequency structure simulator (HFSS). The proposed antennas are fabricated using a widely available and low cost modified glass epoxy substrate material of area 8 × 8 cm with relative permittivity ε_r= 4 with a height of 0.6 cm and a loss tangent of 0.02. The CCMSA consists of a radiating patch of radius '*a*'. The antenna is excited through a simple 50 Ω microstripline feeding of length L_f and width W_f. The quarter wavelength transformer having dimensions length L_{tr} and width W_{tr} is used to match the impedance of the circular patch with the microstripline feed. A 50 Ω semi miniature-A (SMA) connector is used at the tip of the microstripline to feed the power. Below the patch a continuous copper layer is used as ground plane. The architectures of these antennas are outlined using AutoCAD tool to achieve better accuracy.

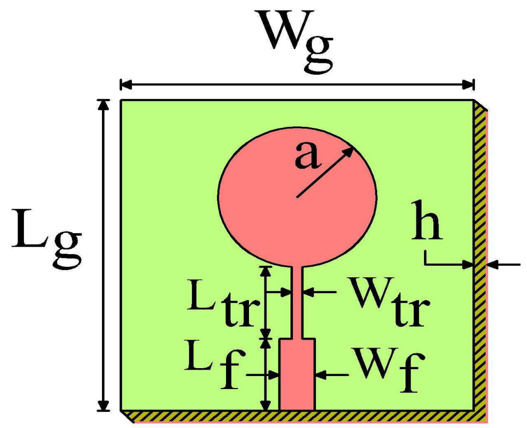


Fig. 1. Top view configuration of CCMSA

For the design of radius of the circular radiating patch, the equation is used [9],

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

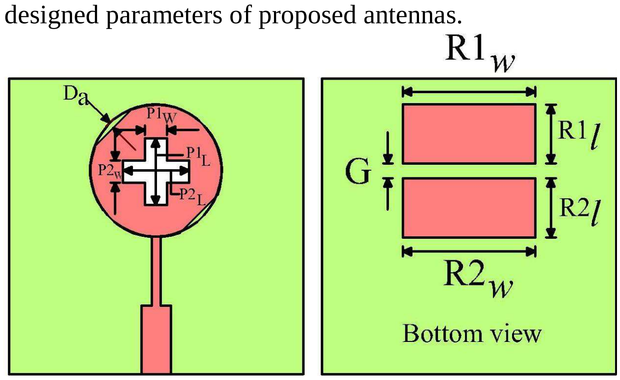
where,

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

According to the fringing fields along the circumference of the circular patch are taken into account by substituting the patch radius '*a*' by the effective radius 'a_e'. Thus the effective area of the circular radiating patch is given by the equation [9],

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

Figure 2(a) shows the top view configuration of two rectangular defected ground plus slot circular microstrip antenna (TRGDPCMSA) which is realized from the CCMSA. The antenna is truncated at two opposite edges by an angle of 45° from the center of the circular patch. The truncated portion (D_a) of two edges of circular patch is λ_0/50 (i.e. 0.2 cm). The length of the slot cut is λ_0/7 (i.e. 1.4204 cm). A plus type slot is inserted at center of the truncated circular radiating patch. This plus type slot has equal rectangular slot lengths and widths and is centered at circular radiating patch. The dimensions length of two horizontal rectangular slots ($P1_L$ and $P2_L$) is λ_0/10 (i.e. 1 cm) and width of two rectangular slots ($P1_W$ and $P2_W$) is λ_0/33.33 (i.e. 0.3cm). Further two rectangular slots are created on the ground plane. The length of the two rectangular slots ($R1_L$ and $R2_L$) is λ_0/3.67 (i.e. 2.722 cm) and width of two slots ($R1_W$ and $R2_W$) is λ_0/8.25 (i.e. 1.211 cm). The gap (G) between two rectangular slots is λ_0/33.33 (i.e. 0.3cm) is as shown in Fig. 2(b). Table –I shows the designed parameters of proposed antennas.



(a) (b)

Fig. 2. Bottom view configuration of TRGDPCMSA

TABLE I
THE DESIGNED PARAMETERS OF PROPOSED ANTENNAS

Antenna Parameters	Dimensions in cm
a	1.361
W_g and L_g	8 × 8
L_f	1.23
W_f	0.317
L_{tr}	1.23
W_{tr}	0.066
D_a	0.2
$P1_L$ and $P2_L$	1
$P1_W$ and $P2_W$	0.3
$R1_l$ and $R2_l$	2.722
$R1_w$ and $R2_w$	1.211
G	0.3

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III. 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 the design frequency of 3 GHz. The percentage of experimental impedance bandwidth is calculated using the relation,

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

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 fc is a center frequency between f_1 and f_2. The impedance bandwidth BW of CCMSA is found to be 2%. The HFSS simulated result of CCMSA is also shown in Fig. 3. The simulation result predicts the resonant frequency and impedance bandwidth of the CCMSA with reasonable accuracy with that of the experimental result.

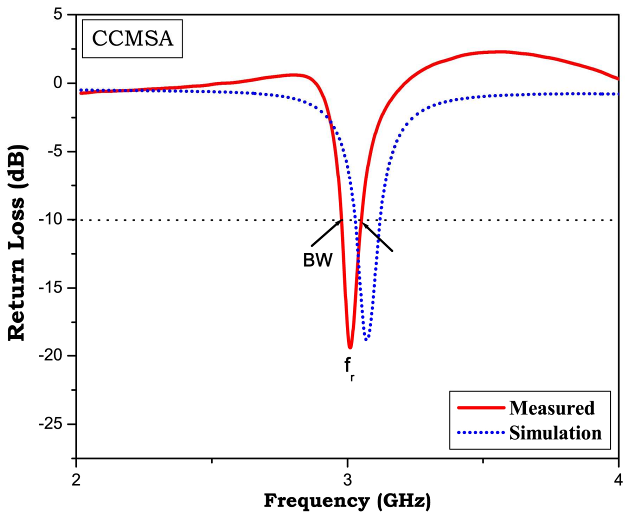

Fig. 3. Variation of return loss versus frequency of CCMSA

Figure 4 shows the variation of return loss versus frequency of TRGDPCMSA. From this figure it is observed that, the antenna resonates for single wide band of frequency and gives an impedance bandwidth of BW =48.61% (6.07 GHz-9.25 GHz) which is 14.16 times more than the impedance bandwidth of CCMSA. Hence it is quite clear that, the novel geometry of TRGDPCMSA is very much effective in enhancing the bandwidth of an antenna. It can also be seen that, this antenna becomes compact in its physical size by 43.71% when compared to with the size of CCMSA. The peak gain of this antenna is 8.25 dB and shows stable broadside radiation characteristics in its operating frequency band.

The typical far field co-polar and cross-polar radiating patterns of CCMSA and TRGDPCMSA measured in their operating bands i.e. at 3 GHz and at 8.15 GHz are as shown in Fig 5 and 6 respectively. From these figures, it can be observed that, the patterns are broadside and linearly polarized.

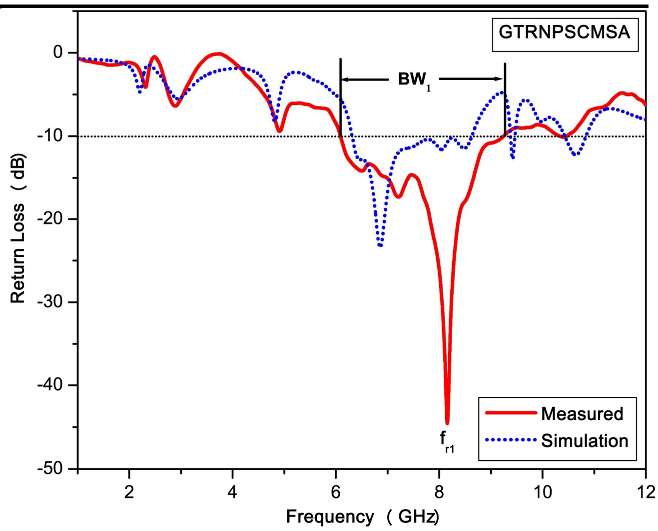

Fig. 4. Variation of return loss versus frequency of TRGDPCMSA

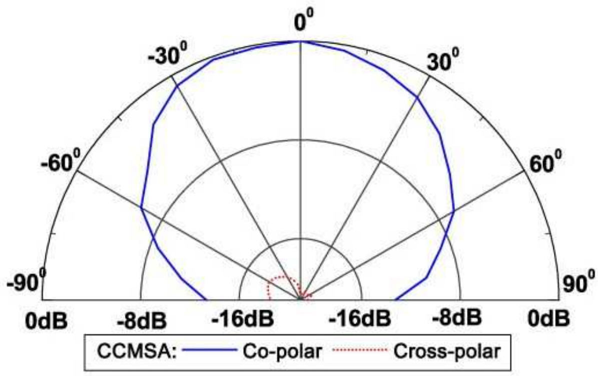

Fig. 5. Typical radiation pattern of CCMSA measured at 3 GHz

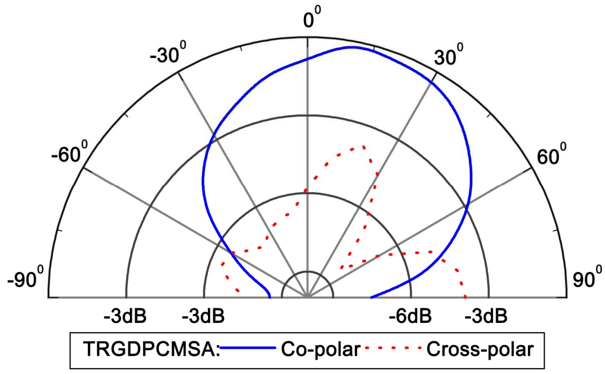

Fig. 6. Typical radiation pattern of TRGDPCMSA measured at 8.15 GHz

IV. CONCLUSION

A simple truncated edges circular microstrip antenna with DGS is designed for radar communication applications by placing the two wide ground rectangular slots parallel to the ground plane. The antenna is resonates for single wide band of

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frequencies. An impedance bandwidth of 48.61% is achieved which is 16.6 times more than the CCMSA without changing the nature of broadside radiation characteristics. The proposed antenna also reduces the physical size by 43.71% when compared to the size of CCMSA. The experimental result of return loss versus frequency of proposed antenna is in good agreement with simulation results. The TRGDPCMSA is simple in its design and fabrication and it use commercially available low cost substrate material. This antenna may find applications for C-band applications and downlink of X-band satellite communication systems.

ACKNOWLEDGMENT

The authors thank the authorities of Department of Science and Technology (DST), Govt. of India, New Delhi, for sanctioning the Vector Network Analyzer under the FIST project to the Department of Applied Electronics, Gulbarga University, Gulbarga.

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