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Comparative Study of Conventional and Elliptical Slot loaded Rectangular Microstrip Antenna for Various Applications

Nagraj Kulkarni[1*], and S.N. Mulgi[2]

[1,2]Department of PG Studies and Research in Applied Electronics, Gulbarga University, Gulbarga-585106, Karnataka, India

Abstract: A novel geometry of rectangular microstrip antenna containing two mutually perpendicular elliptical slots on the patch and an array of circular slots on the ground plane has been designed and fabricated. The performance of this antenna has been compared with the conventional rectangular microstrip antenna for pentaband operation. The proposed antenna has a volume of 80 × 50 ×1.6 mm^3 and operates between 2.29 – 12.7 GHz. The antenna exhibits a virtual size reduction of about 27.72 % when compared to the size of conventional rectangular microstrip antenna. The simple microstripline feed has been used to excite the antenna. A peak gain of 2.91 dB is achieved with broadside and linearly polarized radiation characteristic. The experimental and simulated results are in good agreement with each other. The design concepts of the antenna are given and experimental results are presented and discussed. This antenna may find applications in Wireless Local Area Network (WLAN), C and X bands of microwave frequencies.

Keywords: Microstrip antenna, elliptical slots, circular slots, penta band.

1. INTRODUCTION

Since for the past few decades, the microstrip antennas (MSAs) have attained a great gain of popularity and have become the major research topic in both theoretical and applied electromagnetics. Microsttrip antennas possess the attractive features like light weight, low profile, easy installation, compatibility with other microwave and millimeter wave components, conformability to curved surfaces, low fabrication cost [1] etc. It is the need of this modern communication era to select the suitable antenna intelligently for specific application. The microstrip antenna designers put their efforts to establish methods and techniques to realize various applications of microstrip antennas comprising slots of different geometries like triangular, bow-tie, square, annular ring etc. on the radiating patch [2-5]. They have used corner truncated patches, stubs and shorts on the patches [6-8] etc. to achieve dual, triple and multiband antennas. But the antenna consisting of a pair of crossed elliptical slots with array of circular slots on the ground plane is found to be rare in the literature. The proposed antenna geometry provides more possibilities in designing by varying the slots parameters on the patch and the ground plane to achieve even better antenna results.

2. DESIGNING

The conventional rectangular microstrip antenna (CRMSA) is fabricated using low cost glass epoxy substrate material of area $X \times Y$, thickness $t = 0.16$ cm and dielectric constant $\varepsilon_r = 4.2$. The artwork of the antenna is sketched using computer software Auto CAD to achieve better accuracy. The photolithography process is used to fabricate the antenna.

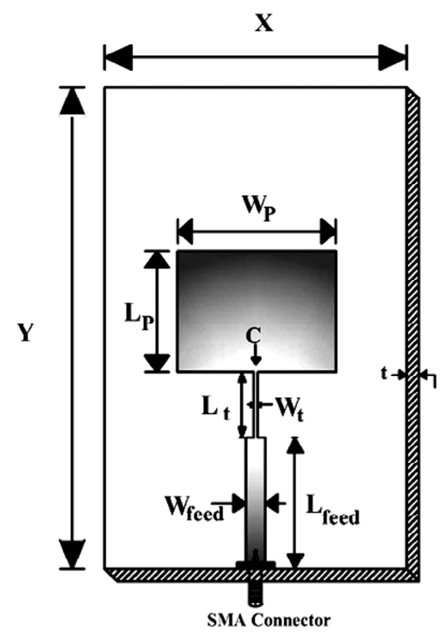


Figure 1: Top View Geometry of CRMSA

Fig. 1 shows the top view geometry of CRMSA which is designed for the resonant frequency of 3.5 GHz using the equations available in the literature for the design of CRMSA

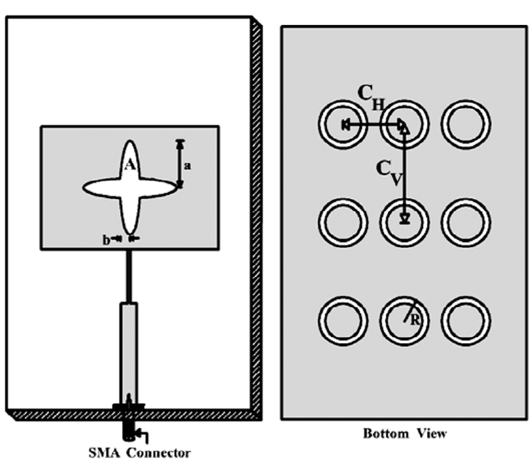
*Corresponding author: *E-mail: nag_kulb@rediffmail.com*

[9]. The CRMSA consists of a rectangular radiating patch of length L_P and width W_P. The L_{feed} and W_{feed} are the length and width of the microstripline feed used to excite the patch. A semi miniature-A (SMA) connector of 50Ω characteristic impedance is used at the tip of the microstripline to supply the microwave power. A quarter wave transformer of length L_t and width W_t is used to match the impedances between the point C and microstripline feed.

Fig.2 shows the geometry of elliptical slot loaded rectangular microstrip antenna (ESRMSA) with array of circular slots on the ground plane. Two mutually perpendicular elliptical slots each of area A which is equal to ?ab, where a is are the semi major and b is semi minor axis of the ellipse, are placed at the center of the patch. The ground plane consists a total of nine circular slots each of width 1 mm and radius R is placed in three rows such that each row contains three slots. The C_H and C_V are the horizontal and vertical distances between the circular slots. The dimensions a, b, A, C_H and C_V are taken in terms of λ_0, where, λ_0 is a free space wave length in cm corresponding to the designed frequency of 3.5 GHz. The various dimensions of the CRMSA and ESRMSA are listed in Table 1. Fig. 3 (a) and (b) show 3D view and photograph of ESRMSA respectively.

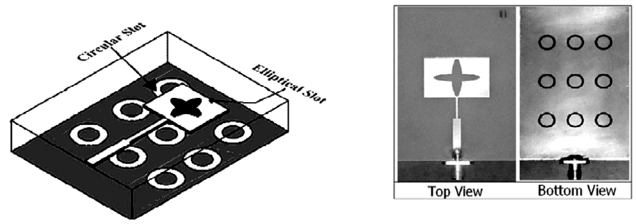
Table 1
Design Parameters of CRMSA and SCSRMSA (in cm)

Parameters	*Dimensions (cm)*	*Parameters*	*Dimensions (cm)*
L_P	2.04	b	2.14
L_{feed}	2.18	A	$1.33/\lambda_0$
L_t	1.09	R	$\lambda_0/22$
W_P	2.66	G_H	$\lambda_0/7$
W_{feed}	0.32	G_V	$\lambda_0/4.28$
W_t	0.06	X	5
a	9.52	Y	8



(a) (b)

Figure 2: Geometry of ESRMSA



(a) 3D View of ESRMSA (b) Photograph of ESRMSA

Figure 3: 3D View and Photograph of ESRMSA

3. EXPERIMENTAL RESULTS

The German make (Rohde and Schwarz, ZVK model 1127.8651), Vector Network Analyzer is used to measure the experimental return loss of CRMSA and ESRMSA. The simulation of the CRMSA and ESRMSA is carried out using High Frequency Structure Simulator (HFSS) software.

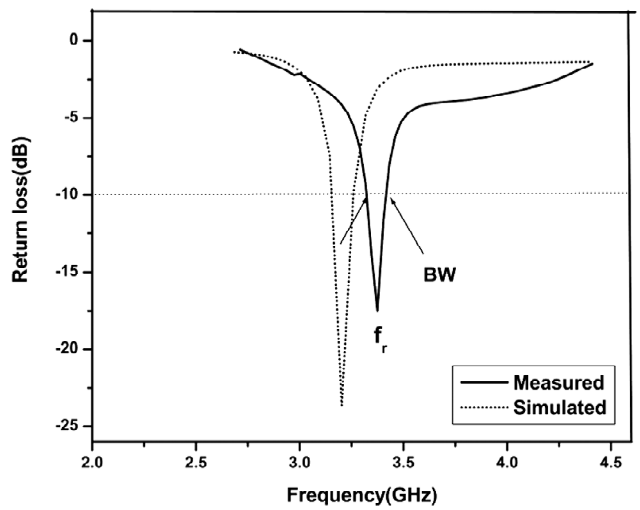


Figure 4: Variation of Return Loss Versus Frequency of CRMSA

Fig. 4 shows the variation of return loss versus frequency of CRMSA. From this figure it is seen that, the CRMSA resonates at 3.39 GHz of frequency which is nearer to the designed frequency of 3.5 GHz. The experimental impedance bandwidth over return loss less than –10 dB is calculated using the formula,

$$\text{Impedance bandwidth (\%)} = \frac{f_H - f_L}{f_C} \times 100\% \qquad (1)$$

where, f_H and f_L are the upper and lower cut off frequencies of the resonating bands when their return loss reaches –10 dB and f_C is a centre frequency of f_H and f_L. The impedance bandwidth of CRMSA is found to be 3.26 %. The simulated result of CRMSA is also shown in Fig. 4.

Fig. 5 shows the variation of return loss versus frequency of ESRMSA. 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 = 7.3 % (2.54-2.36 GHz), BW_2 = 5.28 % (5.44- 5.16 GHz), BW_3 = 5.03 % (6.11-5.81 GHz), BW_4 = 9.72 %

(8.41 –7.63 GHz) and BW_5 = 25.75 % (12.71 –9.81 GHz). The return losses measured at f_1 to f_5 are –13.43dB, –19.83 –2dB, –8.44dB, –15.63dB and –23.57 dB respectively. The first band BW_1 is due to the fundamental resonance of the patch and the bands BW_2 to $BW5$ are due to elliptical slots present on the radiating patch. The use of elliptical slots also helps in producing five bands having wider impedance bandwidth compared to the magnitude of primary band of CRMSA. Further it is noted that, the use of circular slots on the ground plane, the virtual size reduction of 27.72 % is achieved when compared to the size of the CRMSA. The virtual size reduction is calculated by comparing the primary resonant modes of f_r and f_1 shown in Fig. 4 and 5. By placing the elliptical and circular slots patch and the ground plane, the copper area of ESRMSA reduces by 28.31 % when compared to the copper area of CRMSA. The simulated result of ESRMSA is also shown in Fig. 5.

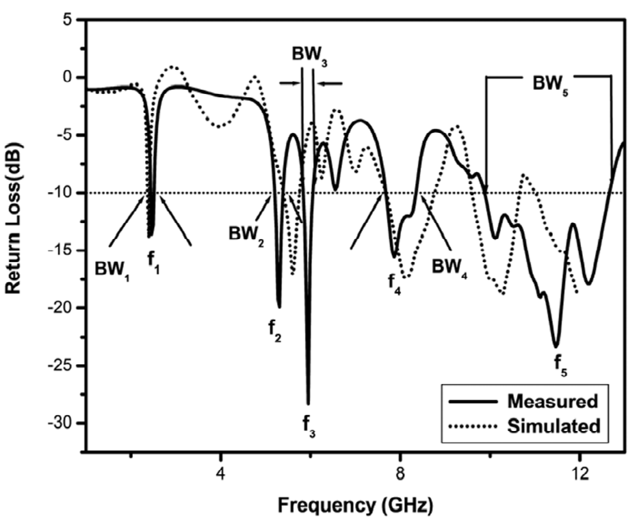


Figure 5: Variation of Return Loss Versus Frequency of ESRMSA

Figure 6 and 7 show the typical radiation patterns of CRMSA and ESRMSA respectively measured in their operating bands. It can be noted from these figures that, the patterns are broadside and linearly polarized. The cross-polar power level is nearly –15 dB down when compared to the co-polar power level indicates broadside nature of radiation. The gain of CRMSA and ESRMSA is calculated by using the absolute gain method given by the relation,

$$(G)dB = 10\log\left(\frac{P_r}{P_t}\right) - (G_t)dB - 20\log\left(\frac{\lambda_0}{4\pi R}\right)dB \qquad (2)$$

where, G_t is the gain of the pyramidal horn antenna and R is the distance between the transmitting antenna and the antenna under test (AUT). The power received by AUT, 'P_r' and the power transmitted by standard pyramidal horn antenna 'P_t' are measured independently. The gain of CRMSA in BW is found to be 0.9 dB maximum and the peak gain of ESRMSA is found to be 2.91 dB which is 3.23 times more than the gain of CRMSA. The operating bands of CRMSA and ESRMSA are listed in Table 2.

Table 2
Comparative Results of CRMSA and SPSRMSA

Parameter	*CRMSA*	*ESRMSA*
Resonating modes	1	5
BW	WiMax	-
BW_1	-	WiMax
BW_2 to BW_5	-	Wireless Local area network (WLAN) applications in C and X band microwave communication systems
Frequency ratio	-	2
Gain	0.9 dB	2.91 dB
Maximum Bandwidth	3.26%	25.75%
Virtual size reduction	-	27.72%
Reduction in Copper area	-	28.31%

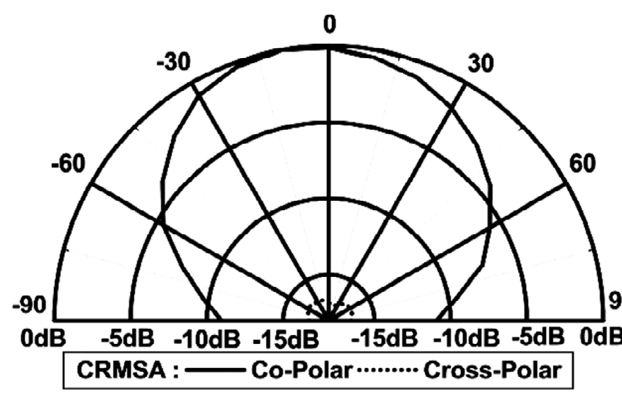


Figure 6: Radiation Pattern of CRMS Measured at 3.39 GHz

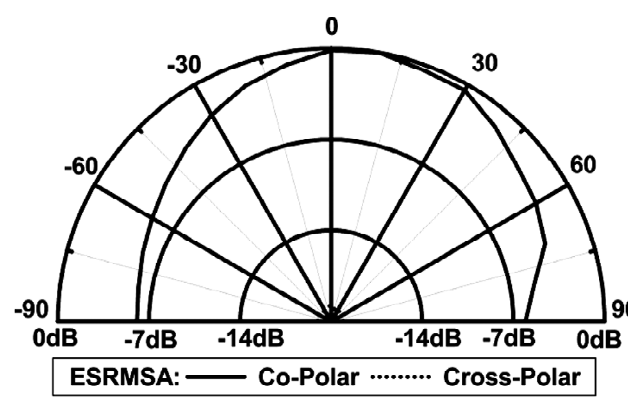


Figure 7: Radiation Pattern of ESRMSA Measured at 2.265 GHz

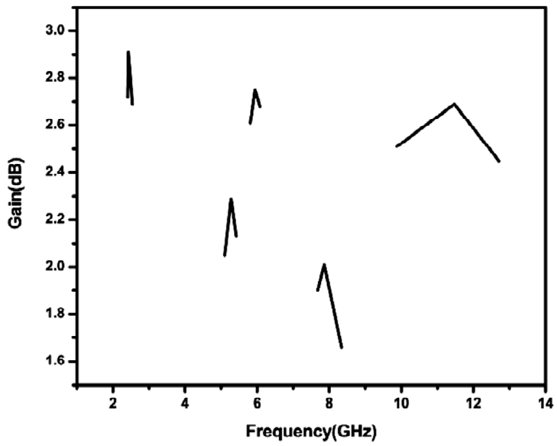


Figure 8: Shows Variation of Gain of ESRMSA with Frequency in its Operating Bands

4. CONCLUSION

From the detailed study, it is concluded that, the proposed antenna resonates for five independent modes between 2.29 – 12.7 GHz. The magnitude of each operating band is found wider when compared to the impedance bandwidth of CRMSA by using crossed elliptical slot on the patch. The ESRMSA gives highest impedance bandwidth of 25.75 % at BW5 The antenna also gives a virtual size reduction of 27.72 % and enhances the gain by 3.23 times in the primary band by comparing the gain of CRMSA. The construction of ESRMSA does not affect the nature of broad radiation characteristics. The implantation of slots also makes the antenna to use less copper area of about 28.31 % when compared to the copper area of CRMSA. The proposed antenna is simple in its geometry and construction. The ESRMSA may be used for microwave communication systems operating in the frequency range of 2.29 – 12.7 GHz (WLAN, *C* and *X* band microwave systems).

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