QUAD BAND RECTANGULAR MICROSTRIP ANTENNA FOR S AND C-BAND APPLICATIONS

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ABSTRACT
This paper presents the study of two rhombus shape slot loaded rectangular microstrip antenna for quad band operation. The quad bands are achieved at S and C band of frequencies. Effect of slot embedded on the patch is studied experimentally for enhancing the bandwidth. It is found that by using two rhombus shape slots on the patch element with copper as ground plane, the bandwidth at C-band is enhanced from 2.06 % to 20.4 % without much affecting the operating bandwidth at C-band. Further enhancement of bandwidth at the C-band does not affect the nature of broadside radiation characteristics. Details of antenna design are described and experimental results are discussed. The proposed antennas may find applications for the systems operating at S and C-bands.

KEYWORDS—*Microstrip antenna, Quad band, Rhombus, VNA, Bandwidth.*

1. INTRODUCTION

The microstrip antennas (MSAs) are the most widely used for the last few years due to their attractive features such as light weight, low volume, ease in fabrication and low cost [1]. However, the major disadvantage associated with MSAs is their narrow bandwidth [1-2] which restricts their many useful applications. Numbers of studies have been reported in the literature for enhancing the bandwidth [3-6]. Further, the dual frequency patch antennas have gained wide attention in radar communication particularly in synthetic aperture radar (SAR), as they avoid the use of two separate antennas for transmit and receive applications. Variety of methods have been proposed to obtain dual band operation, such as by loading slits [7], using slots in the patch [8], loading the patch with shorting pins [9], using stacked patches [10] etc. But the antenna operating at more than two different bands of frequencies and their enhancement are found rare in the literature. Hence a simple patch with rhombus shape slot technique has been used in this study for constructing the proposed antennas useful for S and C band applications.

2. DESCRIPTION OF ANTENNA GEOMETRY

The art work of the proposed antennas are developed using computer software AutoCAD-2012 and are fabricated on low cost glass epoxy substrate material of thickness h=0.16 cm and permittivity ϵ = 4.4. Figure 1 shows the geometry of conventional rectangular microstrip antenna (CRMA) which is designed for the resonant frequency of 3.5 GHz, using the equations available in the literature [1]. The substrate area of the CRMA is A=M×N. The antenna is fed by using microstripline feeding. This feeding has been selected because of its simplicity and it can be simultaneously fabricated along with the antenna element. Figure 1 consists of a radiating patch of length and width (L x W) of the patch are (18.99 *x* 26.92), quarter wave transformer of length L_t and width W_t used between the patch and 50

Ω microstripline feed of length L_f and width W_f. At the tip of microstripline feed, a 50 Ω coaxial SMA connector is used for feeding the microwave power. Figure 2 shows the geometry of two rhombus shape slot rectangular antenna (TRSRMSA). The dimension of TRSRMSA shown in Fig. 2 remains same as that of rectangular patch and feed line as shown in Fig.1, but two rhombus shaped slot which are placed horizontal on patch are etched on the patch plane of CRMA as shown in Fig. 2. Hence, this antenna is named as two rhombus shape slot rectangular antenna (TRSRMSA). The dimensions of all the slots are taken in terms of λ_0, where λ_0 is the free space wavelength corresponding to the designed frequency of conventional RMA i.e. 3.5 GHz. The length and width (L x W) of the patch are (18.99 x 26.92). The side length x is 6.8 mm. The horizontal and vertical slot lengths (L_1 and L_2) slots are 9.6 mm and 13.5 mm.

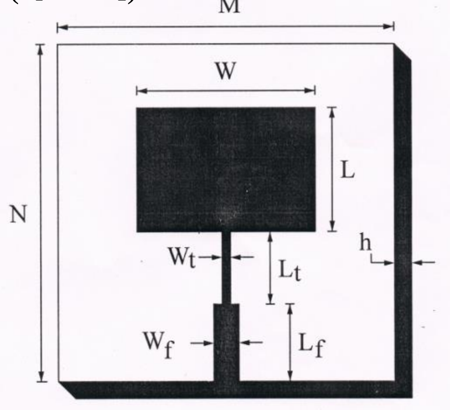


Figure 1. Geometry of CRMA

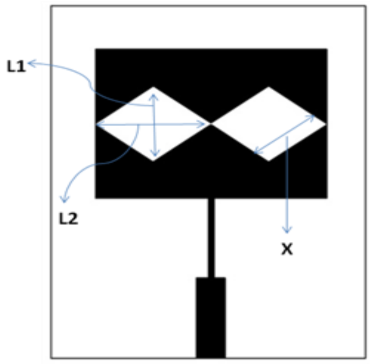


Figure 2. Geometry of TRSRMSA

3. EXPERIMENTAL RESULTS

The impedance bandwidth over return loss less than -10 dB for the proposed antennas is measured at S and C band of microwave frequencies. The measurements are taken on Vector Network Analyzer (Rohde and Schwarz, Germany make ZVK model 1127.8651). The variation of return loss versus frequency of CRMA is as shown in Fig. 3. From the figure it is clear that, the antenna resonates at f_{r1} = 3.6 GHz of frequency which is very much close to the designed frequency of 3.5 GHz and hence validates the design. From this graph, the experimental impedance bandwidth is calculated using the formula,

$$\text{BW} = \left[\frac{f_H - f_L}{f_C}\right] \times 100\% \qquad (1)$$

where, f_H and f_L are the upper and lower cut-off frequency of the band respectively when its return loss becomes -10dB and f_c is the center frequency between f_H and f_L. Hence by using equation (1) the bandwidth BW_1 of CRMA is found to be 2.06 %. The theoretical bandwidth of this antenna is calculated using [2],

$$\text{Bandwidth}(\%) = \left[\frac{A \times h}{\lambda_0\sqrt{\varepsilon_r}}\right] \times \sqrt{\frac{W}{L}} \qquad (2)$$

where, A is the correction factor, which is found to be 180 as per [11]. The theoretical bandwidth of CRMA is found to be 3.42 %, which is in good agreement with the experimental value. Figure 4 shows the variation of return loss versus frequency of TRSRMSA. The antenna resonates for four band of frequencies, fr_1=2.63 GHz, fr_2 = 4.64 GHz, fr_3 =5.94 GHz and fr_4 = 7.78 GHz. The respective bandwidths at fr_1, fr_2, fr_3 and fr_4 are 1.52 %, 1.07 %, 2.02 % and 20.4 %. It is clear that the BW_1 lies in the S-band (2-4 GHz), where as BW_2, BW_3 and BW_4 lies in the C-band (4-8 GHz).

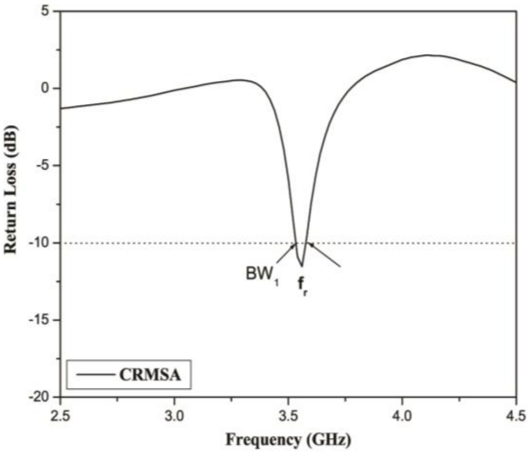


Figure 3. Variation of return loss Vs frequency of conventional RMSA

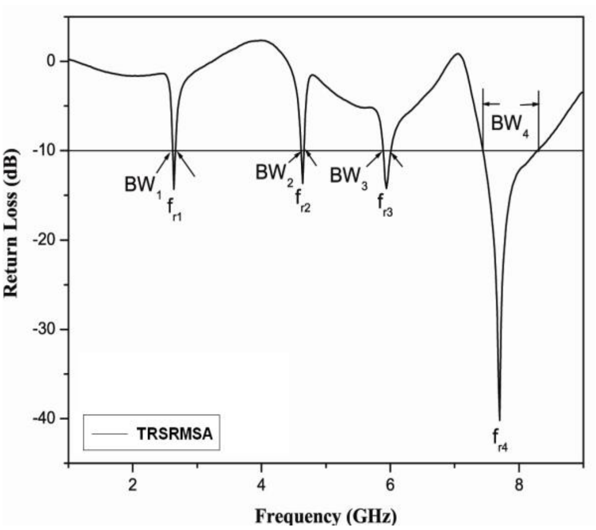


Figure 4. Variation of return loss Vs frequency of TRSRMSA

Hence the construction of TRSRMSA does not affect the basic resonant property of antenna that is the primary band BW_1 which lies at S-band but gives other three bands BW_2, BW_3 and BW_4 at C-band. However, it is seen that the resonant frequency fr_2 of TRSRMSA in the primary band shifts to 4.64 GHz, when compared to resonant frequency fr_1 of CRMA i.e. 2.63 GHz in BW_1. The shift of resonant frequency is mainly due to feed used in TRSRMSA. The dual bands are due to independent resonance of patch and slot elements in TRSRMSA. Hence it is clear that, TRSRMSA is quite effective in enhancing the bandwidth of antenna at S, C-band retaining the resonant property of antenna.

Figures 5 - 6 shows the co-polar and cross-polar radiation patterns of CRMA and TRSRMSA, which are measured at their respective resonant bands. From these figures, it is clear that the patterns are broadsided and linearly polarized. The quad band operation and enhancement of bandwidth does not affect the nature of broadside radiation characteristics.

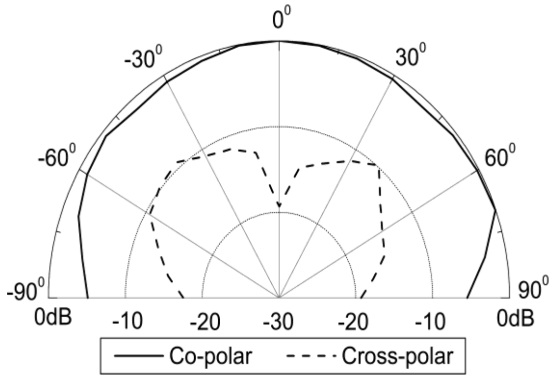
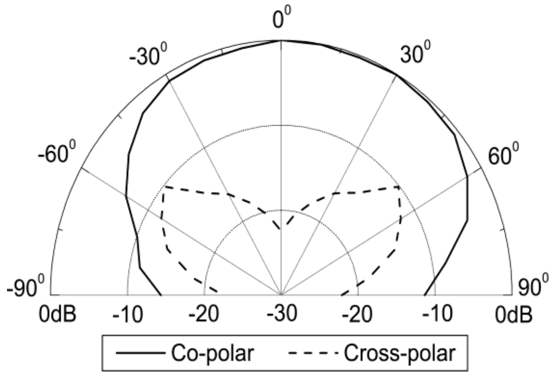
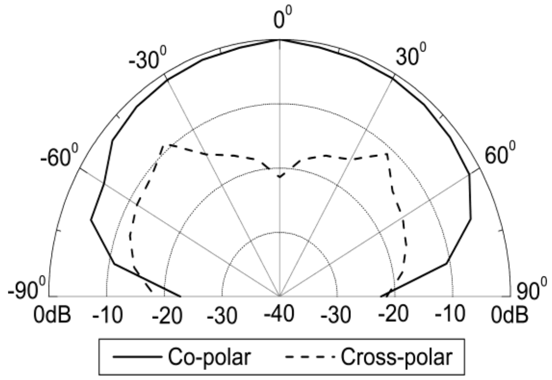


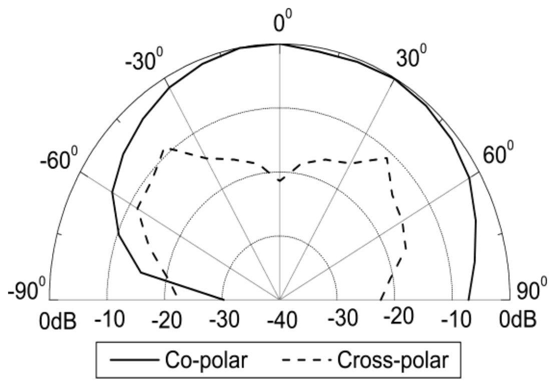
Figure 5. Measured radiation pattern of CRMA measured at 3.8 GHz



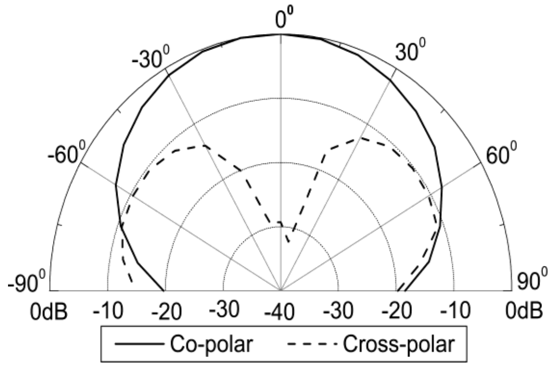
a. fr_1=2.63GHz



b. fr_2 = 4.64GHz



c.fr_3 =5.94GHz



d. $fr_4 = 7.78$ GHz.

Fig.6. Measured radiation pattern of TRSRMSA.

For the calculation of gain of antenna under test (AUT), the power transmitted 'P_t' by pyramidal horn antenna and power received 'P_r' by AUT are measured independently [11]. With the help of these experimental data, the maximum gain G (dB) of CRMA in BW_1 is calculated using the equation (3).

$$(G)dB = 10\ \log\left(\frac{P_r}{P_t}\right) - (G_t)dB\ -\ 20\log\left(\frac{\lambda_0}{4\pi R}\right)dB \qquad (3)$$

where, λ_0 is the operating wavelength in cm and R is the distance between the transmitting and receiving antenna. The gain of CRMA is found to be 2.3 dB. The gains of TRSRMSA is measured for all resonant frequencies and are found to be 2.6 dB, 3.1 dB, 3.8dB and 6.3dB respectively. The maximum gain is found to be 6.3 dB for 7.78 GHz. The proposed TRSRMSA finds application in S and C frequency band of wireless communication.

4. CONCLUSION

From the study, it is concluded that the quad band operation of antenna at four different bands of frequencies are possible by constructing two rhombus slots on rectangular microstrip patch element. Effects of slot of different shapes have been studied experimentally for enhancing the bandwidth. It is found that, the bandwidth at the C-band is enhanced to 20.4 % without much affecting the primary band. The enhancement of bandwidth at S, C-band does not affect the nature of broadside radiation characteristics. The proposed antennas are simple in their design and construction and they use low cost substrate material. These antennas may find applications for the systems operating at S and C-band of frequencies.

ACKNOWLEDGEMENTS

Authors thank the Department of Science and Technology (DST), Government of India, New Delhi, for sanctioning Vector Network Analyzer.

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