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Corner Truncated Rectangular Microstrip Antennas with Ominidirectional Radiation Characteristics

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Abstract: This paper presents the design and development of corner truncated rectangular microstrip antenna for quad band operation and ominidirectional radiation characteristics. The antenna operates for four bands of frequencies in the range of 2 to 16 GHz. If vertical and horizontal length of truncated edges is made equal with each other the antenna operates for triple bands of frequencies duo to the merging of bands which results widening the operating bands. This antenna also gives highest gain of 11.50 dB. In both cases the antenna gives ominidirectional radiation characteristics. Experimental results are in close agreement with the simulated results. The proposed antenna may find application in microwave communication systems.

Keywords: corner truncated, microstip antenna, monopole, slot, ominidirectional, virtual size.

1. INTRODUCTION

Emerging trends in microwave communication systems often require antennas with compact size, simple in design, low cost and capable of operating more than one band of frequencies. Owing to its thin profile, light weight, low cost, planar configuration and easy fabrication, the microstrip antenna is the better choice for these requirements. Number of investigations has been reported in the literature for dual, triple, and multiband operation [3-6]. Slotted rectangular microstip antenna for bandwidth enhancement [7], open L-slot antenna with rotated rectangular patch for bandwidth enhancement [8], corner truncated microstrip antennas for virtual size reduction and bandwidth enhancement [9-11] etc. But the design and development of corner truncated monopole antennas for quad band and triple band operation with high gain is found to be rare in the literature. Further most of the antennas presented in the literature are either complex in their structure or bigger in size and hence require carful manufacturing procedure than that of the regular microstrip antenna for practical applications.

2. DESIGN OF ANTENNA GEOMETRY

The art work of the proposed antenna is sketched by using computer software Auto-CAD to achieve better accuracy and is fabricated on low cost FR4-epoxy substrate material of thickness of h = 0.16 cm and permittivity ε_r = 4.4.

Figure 1 shows the top view geometry of corner truncated rectangular microstrip antenna (CTRMA). In Fig.1 the area of the substrate is $L \times W$ cm. On the top surface of the substrate a ground plane of height which is equal to the length of microstripline feed L_f is used on either sides of the microstripline with a gap of 0.1cm. On the bottom of the substrate a continuous ground copper layer of height L_f is used below the microstripline. The CTRMA is designed for 3 GHz of frequency using the equations available for the design of conventional rectangular microstrip antenna in the literature [2]. The length and width of the rectangular patch are L_p and W_p respectively. The feed arrangement consists of quarter wave transformer of length L_t and width W_t which is connected as a matching network between the patch and the microstripline feed of length L_f and width W_f. A semi miniature-A (SMA) connector is used at the tip of the microstripline feed for feeding the microwave power. In Fig.1 four corners are truncated with the vertical and horizontal length of X cm and Y cm respectively.

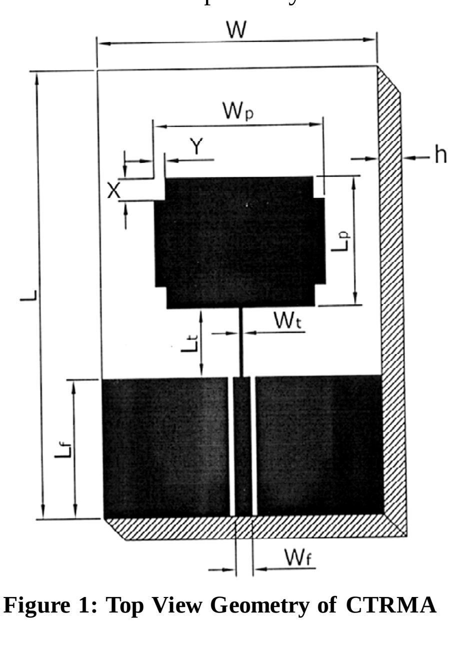

Figure 1: Top View Geometry of CTRMA

Figure 2 shows the geometry of symmetrical corner truncated rectangular microstrip antenna (SCTRMA). In this figure four corners of the patch are truncated symmetrically with equal vertical and horizontal lengths (i.e. 0.4 cm). The other geometry of Fig. 2 remains same as that of Figure 1. The design parameters of the proposed antenna is shown in Table 1.

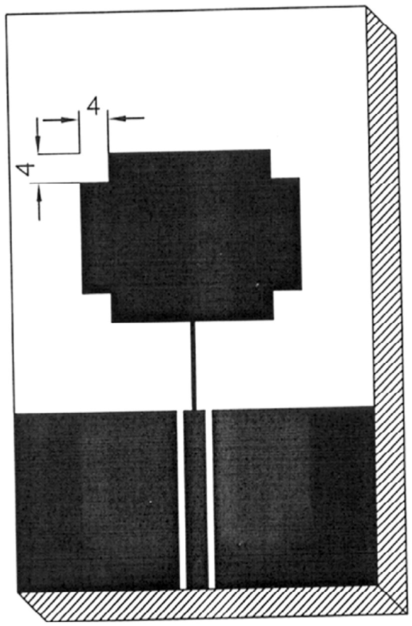

Figure 2: Top View Geometry of SCTRMA

Table 1
Designe Parameters of Proposed Antenna

Antenna parameter	*L*	*W*	L_p	W_p	L_f	W_f	L_t	W_t	*X*	*Y*
Dimensions in cm	8.0	5.0	2.34	3.04	2.48	0.3	1.24	0.05	0.2	0.4

3. EXPERIMENTAL RESULTS

The antenna bandwidth over return loss less than -10 dB is simulated using HFSS simulating software and then tested experimentally on Vector Network Analyzer (Rohde & Schwarz, Germany make ZVK model 1127.8651). The variation of return loss verses frequency of CTRMA is as shown in Fig. 4. From this graph the experimental bandwidth (BW) is calculated using the equations

$$BW = \left[\frac{f_2 - f_1}{f_c}\right] \times 100\% \qquad (1)$$

were, f_1 and f_2 are the lower and upper cut of frequencies of the band respectively when its return loss reaches – 10 dB and fc is the center frequency of the operating band. From this figure, it is found that, the antenna operates between 2 to 16 GHz and gives four resonant modes at f_1 to f_4, i.e. at 4.78, 7.76, 8.85, and 15.39 GHz. The magnitude of experimental –10 dB bandwidth measured for BW_1 to BW_4 by using the equation (1) is found to be 50 MHz (1.05 %), 780 MHz (10.15 %), 1.57 GHz (17.22 %), and 5.42 GHz (40.90 %) respectively.

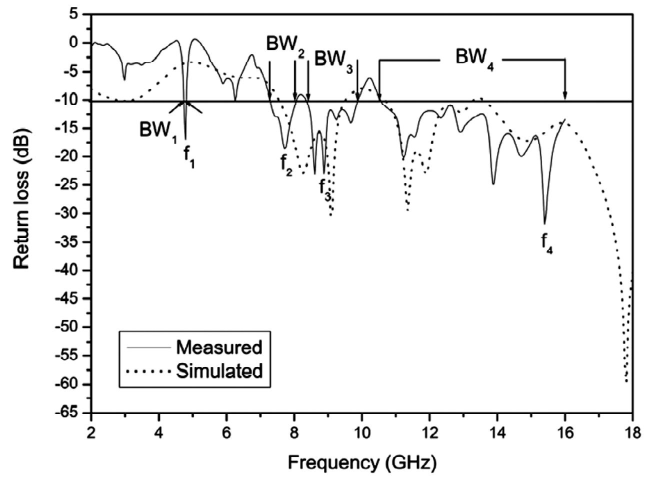

Figure 3: Variation of Return Loss Versus Frequency of CTRMA

The resonant mode at 4.78 GHz is due to the fundamental resonant frequency of the patch and others modes are due to the novel geometry of CTRMA. The multi mode response obtained is due to different surface currents on the patch. The fundamental resonant frequency mode shifts from 3 GHz designed frequency to 4.78 GHz due to the coupling effect of microstripline feed and top ground plane of CTRMA.

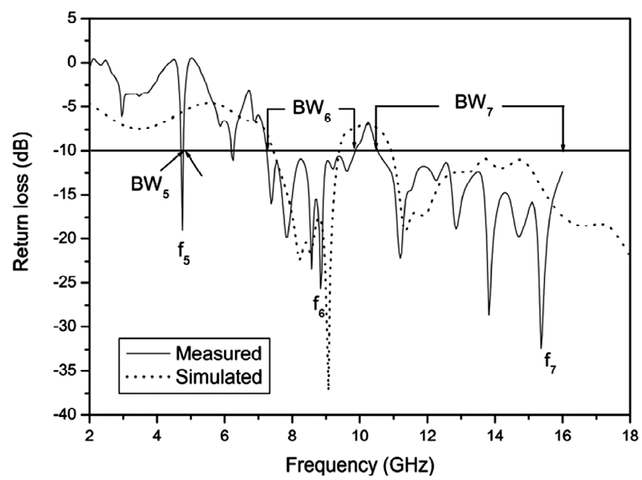

Figure 4: Variation of Return Loss Versus Frequency of SCTRMA

Figure 4 shows the variation of return loss verses frequency of SCTRMA. It is seen that, the antenna operates for three bands of frequencies BW_5 to BW_7. The magnitude of these operating bands measured at BW_5 to BW_7 is found to be 180 MHz (13.53 %), 2.64 GHz (30.84 %), and 5.46 GHz (41.20 %) respectively. The resonating modes f_5, f_6, and f_7 remain same when compared to f_1, f_3, and f_4 of Fig. 3 were as f_2 and f_3 of BW_2 and BW_3 of Fig. 3 are merged together into single band BW_6 as shown in Fig. 4. Further from Fig. 4 it is clear that, the SCTRMA is capable of widening its operating bands when compared to the operating bands of CTRMA. The simulated results of CTRMA and SCTRMA are also shown in Fig. 3 and 4. The experimental and simulated results are in close agreement with each other.

The gain of the proposed antennas is measured by absolute gain method. The power transmitted 'P_t' by pyramidal horn antenna and power received 'P_r' by antenna under test (AUT) are measured independently. With the help of these experimental data, the gain (G) dB of AUT is calculated by using the formula,

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

where, G_t is the gain of the pyramidal horn antenna and R is the distance between the transmitting antenna and the AUT. Using equation (2), the maximum gain of the proposed antennas measured in their operating bands BW_1 to BW_7 are tabulated in Table 2. From this table it evident that the SCTRMA is capable of giving lager gains when compared to the CTRMA.

Table 2
Measured Gains of Antennas CTRMA and SCTRMA

Frequencies in GHz	*Gain of antenna CTRMA in dB*	*Gain of antenna SCTRMA in dB*
4.75 GHz	8.05	9.05
7.76 GHz	7.82	9.22
8.85 GHz	9.65	11.50
15.39 GHz	4.51	7.19

The co-polar and cross-polar radiation pattern of CTRMA and SCTRMA is measured in their operating bands. The typical radiation patterns measured at 7.76 GHz and 8.85 GHz are shown in Fig. 5 to 6 respectively. The obtained patterns are ominidirectional in nature.

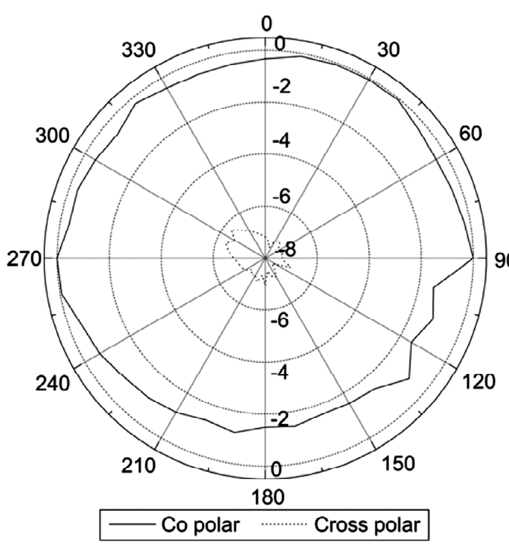

Figure 5: Typical Radiation Pattern of CTRMA Measured at 7.76 GHz

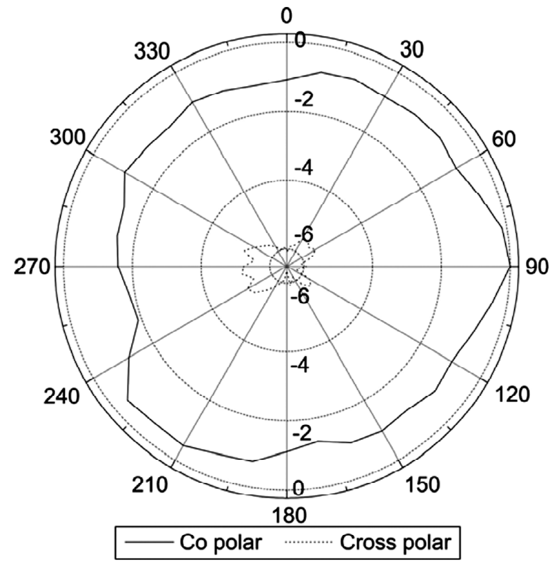

Figure 6: Typical Radiation Pattern SCTRMA Measured at 8.85 GHz

4. CONCLUSION

From the detailed experimental study, it is concluded that, the CTRMA with microstripline feed has been designed for quad band operation. The antenna operates for four bands of frequencies in the range of 2 to 16 GHz. If vertical and horizontal lengths of truncated edges are made equal with each other the antenna operates for triple bands of frequencies in which merging of bands takes place resulting widening the operating bands. The SCTRMA also enhances the gain when compared to the gain of CTRMA. In both the cases the antenna gives ominidirectional radiation characteristics. Experimental results are in close agreement with the simulated results. The proposed antennas are simple in their design and fabrication and they use low cost substrate material. With these features the proposed antennas may find application in microwave communication systems operating in the frequency range of 2 to 16 GHz.

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