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Design and Development of Dual Band Square Microstrip Antenna and Effect of Corner Truncation on the Operating Bandwidth

Kishan Singh, NM Sameena, RB Konda, and SN Mulgi

Department of PG Studies and Research in Applied Electronics, Gulbarga University, Gulbarga-585106, Karnataka, INDIA,
E-mail: kishanskrish@gmail.com, sameena.nm@rediffmail.com, rbkonda@yahoo.com, and s.mulgi@rediffmail.com

Abstract: This paper presents a novel design of square microstrip antenna for dual band operation. The dual bands are achieved by changing the thickness of substrate used in the conventional square microstrip antenna. The impedance bandwidth of each operating band is found to be 6.58% and 27.53%. These bands are enhanced to 22.68% and 36.03% respectively by truncating four corners of square patch, which also reduces the overall size of the patch by 27.48% when compared to conventional square microstrip antenna. The enhancement of impedance bandwidth does not affect the nature of broadside radiation characteristics. Design concept of antennas is given and experimental results are discussed.

Keywords: Square microstrip antenna, Dual-band, Bandwidth, Corner truncation.

1. INTRODUCTION

Microstrip antennas (MSAs) have attracted wide spread interest due to their small size, light weight, low cost and low profile. They are simple to manufacture, suitable to planar and non-planar surfaces, mechanically robust, easily integrated with circuits and possible to get multi frequency operation. However, they possess the intrinsic limitation as the narrow impedance bandwidth [1]. Many techniques are available in the literature for the enhancement of impedance bandwidth of MSAs [2 – 5]. Further the dual band antennas are more attractive in many cases where each band can be used independently for transmit/receive applications, particularly in SAR [6]. The dual band operation of antenna is achieved by many methods [7 – 9]. In the present study a simple concept has been used to achieve the dual-band operation by changing the thickness of substrate used in the conventional square microstrip antenna. The square microstrip patch has been designed by using equations available for the design of square patch [10] and it has been excited through microstripline feed, which is designed by using the equations available for the design of microstripline feed for the rectangular patch [1, 11]. It is shown that enhancement of impedance bandwidth at each operating band may be achieved by truncating the corners of square microstrip patch. This also reduces the overall size of the antenna to a greater extent compared to conventional square microstrip patch.

2. DESCRIPTION OF ANTENNA GEOMETRY

The artwork of the proposed antennas are sketched using computer software Auto-CAD 2004 and fabricated on commonly available glass epoxy substrate material of thickness h = 0.16 cm, 0.32 cm and permittivity $\varepsilon_r = 4.2$.

Figure 1 shows the geometry of conventional square microstrip antenna (SMSA) designed by using the substrate of thickness h = 0.16 cm, for the resonant frequency of 9.4 GHz. The value of L is determined by using the equation [10],

$$L = \frac{0.49\lambda_0}{\sqrt{\varepsilon_r}} \quad \ldots (1)$$

where, λ_0 is free space wavelength in cm.

It is found to be 0.76 cm. The antenna is fed by using microstripline feeding. This feeding has been selected because it is simple in design and can be simultaneously fabricated along with the antenna element. A quarter wave transformer of dimensions L_t = 0.42 cm, W_t = 0.05 cm is used for better impedance matching between microstripline feed of dimension L_f = 0.41 cm, W_f = 0.31 cm and center point C_p along the L of the square microstrip patch. At the tip of microstripline feed a 50 Ω coaxial SMA connector is used for feeding the microwave power.

The geometry of dual band square microstrip antenna (DSMSA) is as shown in Fig. 2. It is designed by using the substrate of thickness h' = 0.32 cm. When the thickness changes the dimension of square patch remains same [10] as per the Eq. (1). However, the dimensions of feed arrangement shown in Fig. 1 changes. The new values are L'_t = 0.41 cm, W'_t = 0.10 cm and L'_f = 0.40 cm, W'_f = 0.63 cm as shown in Fig. 2. This antenna is truncated at its corners with $L_s = W_s$ = 1 mm which is equal to $\lambda_o/30$ and the antenna is named as truncated dual band square microstrip antenna (TDSMSA) as shown in Fig. 3, where λ_o is the free space wavelength in cm. Figure 4 shows the geometry of extended truncated dual band square microstrip antenna (ETDSMSA). In this antenna the dimension of the truncated corners are taken as $L'_s = W'_s = 2$ mm which is equal to $\lambda_o/15$.

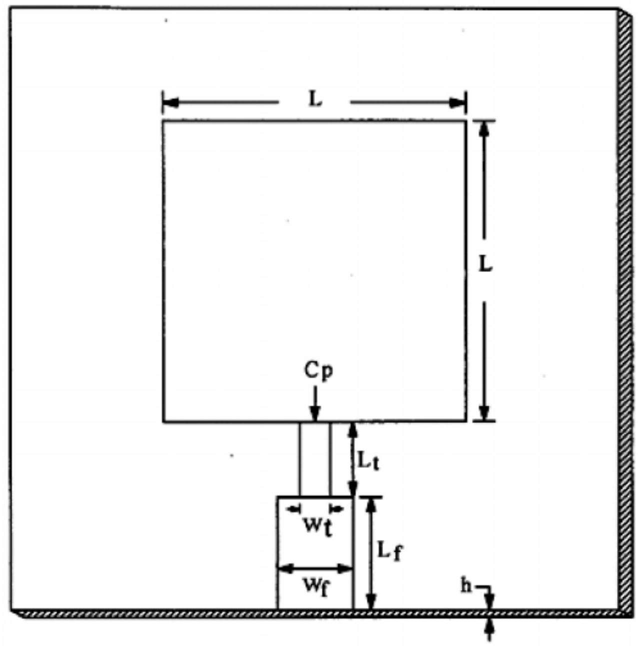

Fig. 1: Geometry of SMSA

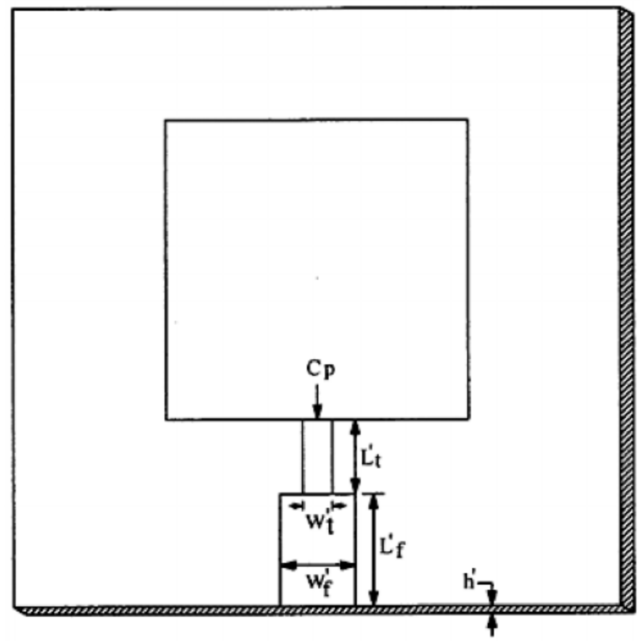

Fig. 2: Geometry of DSMSA

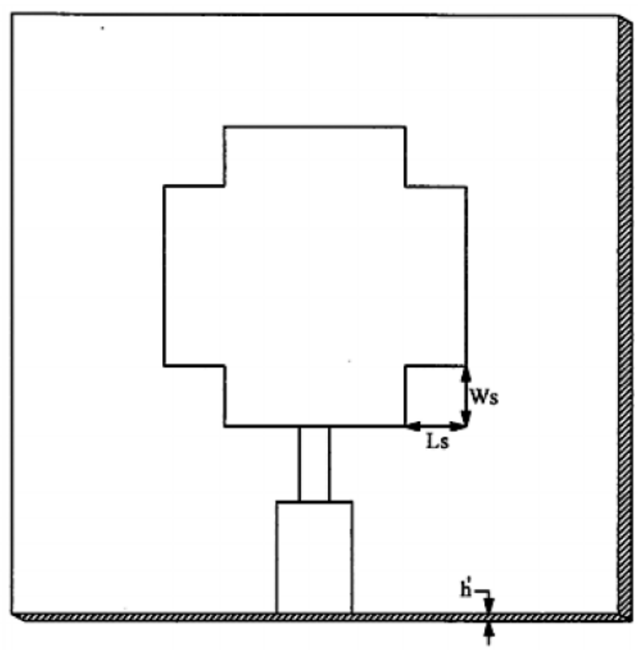

Fig. 3: Geometry of TDSMSA

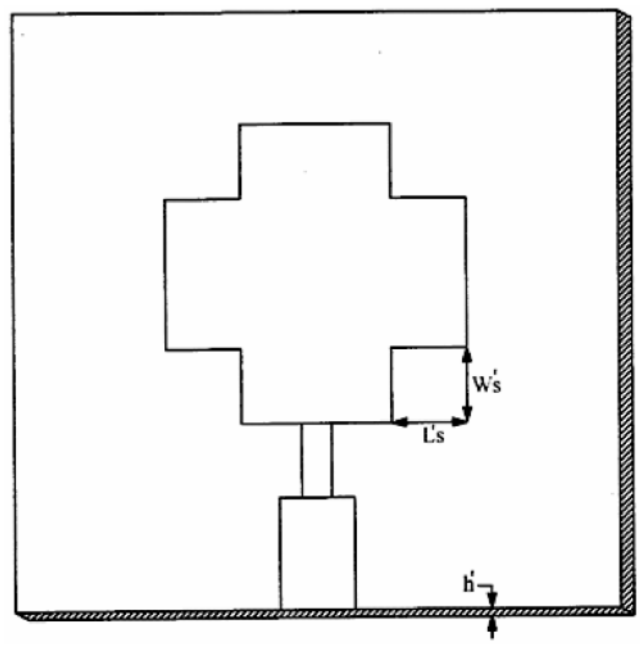

Fig. 4: Geometry of ETDSMSA

3. EXPERIMENTAL RESULTS

The impedance bandwidth over return loss less than 10 dB for the proposed antennas is measured on Vector Network Analyzer (Rohde and Schwarz, Germany make ZVK model 1127.8651). The variation of return loss versus frequency of SMSA is as shown in Fig. 5. From this figure it is seen that, the SMSA resonates for single band of frequency BW_1. The impedance bandwidth BW_1 is 5.11% which is determined by using the equation,

$$BW = \left[\frac{(f_2 - f_1)}{f_c}\right] \times 100\% \qquad \dots (2)$$

where, f_1 and f_2 are the lower and upper cut-off frequencies of the band respectively, when its return loss becomes – 10 dB and f_c is the center frequency between f_1 and f_2. Since the SMSA is designed for 9.4 GHz the shift in the resonant frequency of BW_1 to 8.80 GHz is due to the variation of temperature dependent permittivity of substrate material and effect of 50 Ω microstripline feed[1].

The variation of return loss versus frequency of DSMSA is as shown in Fig. 6. It is clear from this figure that, antenna resonates for two bands of frequencies BW_2 and BW_3. The impedance bandwidth of each operating band is found to be 6.58% and 27.53% respectively. The dual band operation is due to increase in the thickness of substrate from *h* to *h*' and effect of microstripline feed. By comparing Figs 5 and 6 it is clear that, the lower operating band BW_2 in Fig. 6 is more (6.58%) when compared to BW_1 (5.11%) of Fig. 5. Hence by increasing the thickness of substrate, not only the dual bands are achieved but also enhancement in the primary resonance band is obtained.

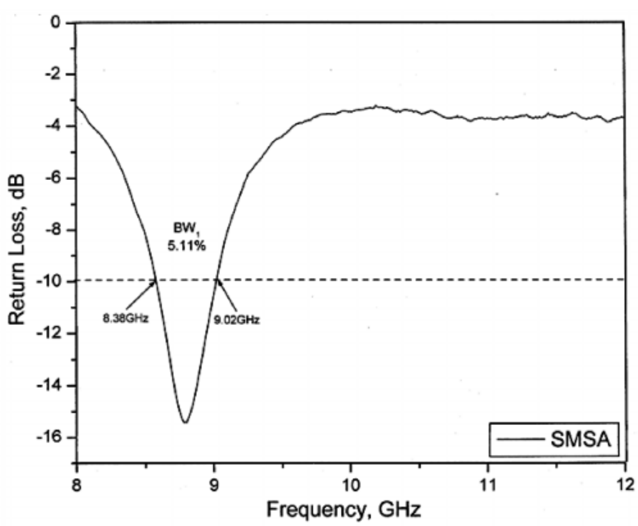

Fig. 5: Variation of Return Loss Versus Frequency of SMSA

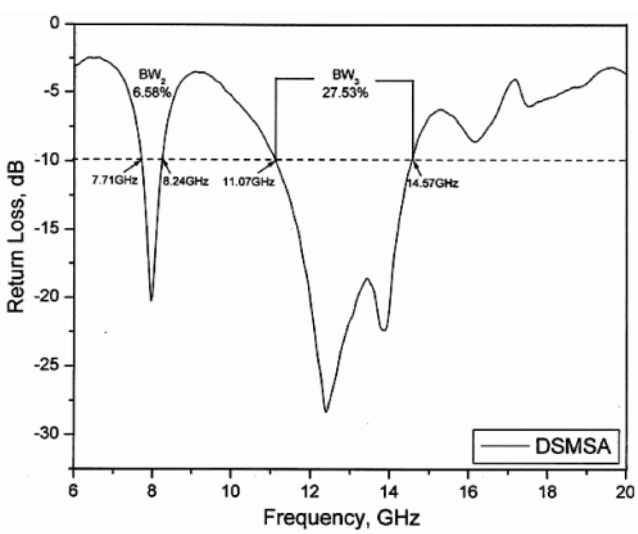

Fig. 6: Variation of Return Loss Versus Frequency of DSMSA

Figure 7 shows the variation of return loss versus frequency of TDSMSA. The antenna resonates again for two bands of frequencies BW_4 and BW_5. The impedance bandwidth of each operating band is found to be 16.33% and 20.37% respectively. It is clear from this figure that by truncating the corners of TDSMSA, the lower operating band BW_4 shown in Fig. 7 increases from 6.58% to 16.33% and upper operating band BW5 decreases from 27.53% to 20.37% when compared to BW_2 and BW_3 respectively of Fig. 6. The enhancement of BW_4 in Fig. 7 is due to combined resonance effect of patch and truncating corners as they resonates near to the patch resonance [12]. This antenna is compact in its size by 6.87% when compared to SMSA.

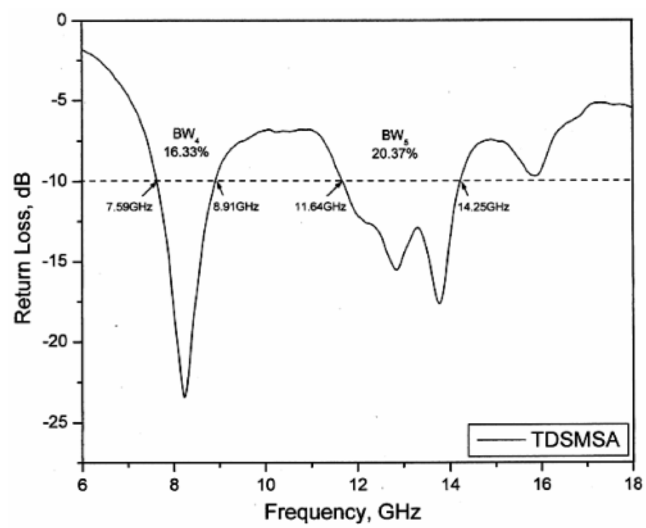

Fig. 7: Variation of Return Loss Versus Frequency of TDSMSA

The variation of return loss versus frequency of ETDSMSA is as shown in Fig. 8. The antenna resonates for two bands of frequencies BW_6 and BW_7 each of impedance bandwidth is found to be 22.68% and 36.03 % respectively. The bandwidth BW_6 is 1.38 times and BW_7 is 1.77 times more when compared to BW_4 and BW_5 respectively as shown in Fig. 7. It is clear that, when corner truncation is extended by 2 mm at the edges, i.e. ETDSMSA the antenna enhances maximum impedance bandwidth of both BW_4 and BW_5. These enhancement of impedance bandwidths as shown in Fig. 8 (i.e. BW_6 and BW_7). This antenna also reduces the patch size by 27.48% when compared to SMSA. Figure 9 shows the co-polar and cross-polar radiation pattern of SMSA measured at 8.80 GHz. From this figure it is clear that, the pattern is broad sided and linearly polarized. Among the proposed dual band antennas the ETDSMSA gives highest impedance bandwidth. The radiation patterns are measured in both the operating bands BW_6 and BW_7 of this antenna at 8.67 and 12.21 GHz of frequencies respectively and are shown in Figs 10-11. From these figures it is clear that the nature of broadside radiation pattern remains same

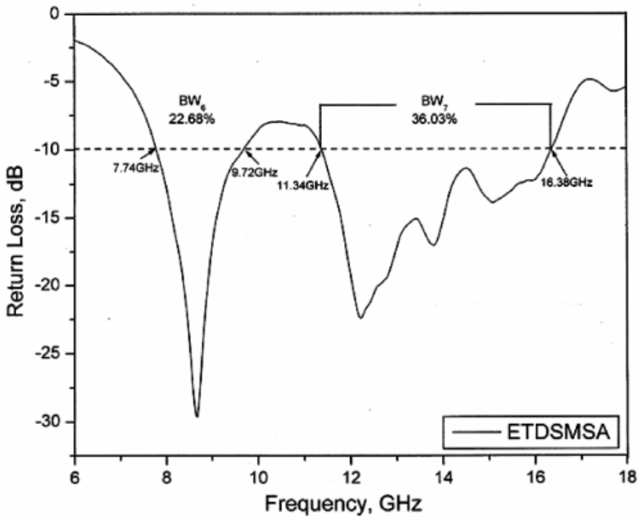

Fig. 8: Variation of Return Loss Versus Frequency of ETDSMSA

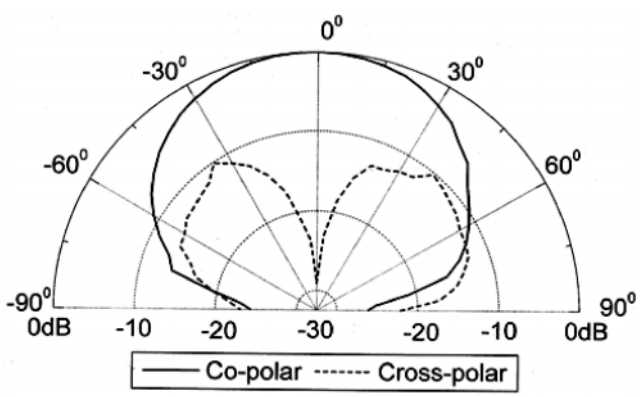

Fig. 9: Variation of Relative Power Versus Azimuth Angle of SMSA at 8.80 GHz

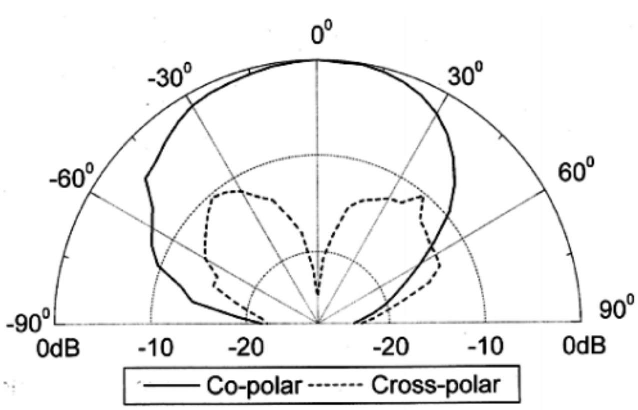

Fig. 10: Variation of Relative Power Versus Azimuth Angle of ETDSMSA at 8.67 GHz

in spite of enhancement of impedance bandwidth and reduction of antenna size.

For the calculation of gain of proposed antennas, the power transmitted 'P_t' by pyramidal horn antenna and power received 'P_r' by AUT (Antenna under test) are measured

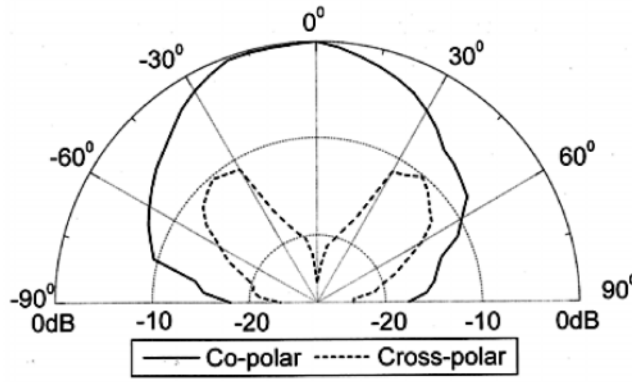

Fig. 11: Variation of Relative Power Versus Azimuth Angle of ETDSMSA at 12.21 GHz

independently. With the help of these experimental data, the gain G dB of AUT is calculated using the absolute gain method[13],

$$(G)\,dB = 10\log\left(\frac{P_r}{P_t}\right) - (Gt)\,dB - 20\log\left(\frac{\lambda_0}{4\ \ R}\right) dB \quad (3)$$

where, G_t is the gain of the pyramidal horn antenna, and R is the distance between the transmitting antenna and the AUT. Using (3), the gains of SMSA, DSMSA, TDSMSA, and ETDSMSA are found to be 7.37, 9.00, 7.51and 5.92 dB respectively. The reduction of gain of TDSMSA and ETDSMSA are due to the reduction of the affective area of the patch [13].

4. CONCLUSION

From the detail experimental study it is concluded that, the novel design of SMSA is quite capable in producing dual band operation by increasing the thickness of substrate from *h* to *h*'. The impedance bandwidth at each operating band can be enhanced to a maximum value of 22.68% and 36.03% by truncating the corners by 2 mm, i.e. ETDSMSA. This enhancement of impedance bandthwidth does not affect the nature of broad side radiation characteristics. Further the use of truncating corners at the edges of ETDSMSA reduces the overall size of antenna by 27.48% when compared to conventional SMSA. The proposed antennas are simple in their design and fabrication and they use low cost substrate material. These antennas may find application in radar communication.

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