Bandwidth Enhancement of T-Slot Loaded Proximity Coupled Equilateral Triangular Microstrip Antenna for Multiband Operation

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ABSTRACT   *In this paper, a compact size proximity coupled equilateral triangular microstrip antenna is designed, analyzed and fabricated. The bandwidth enhancement of microstrip antenna is done by cutting T-slot on radiating patch of equilateral triangular. The characteristics of the antenna are obtained in terms of bandwidth, gain and return loss, these properties are compared with the conventional microstrip antenna. It is shown that by choosing suitable slot dimension and location of the slot, the impedance bandwidth can be improved up to 22.03% as compared to conventional antenna with an bandwidth of 6.97%. This antenna may find its applications in WIFI IEEE 802.11, IMT (International Mobile Communication) and in radar systems. The results are presented and discussed.*

INTRODUCTION

The rapid development of wireless communication technology has increased the demand for compact microstrip antennas with high gain and wideband operating frequencies. A microstrip antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. However, other shapes, such as the circular, square, triangular, semicircular, rectangular shapes are also used. Microstrip patch antennas are popular because of their low cost, low profile, light weight and simple fabrication process. However, the general microstrip patch antennas have some disadvantages such as lower gain and narrow bandwidth [1, 2, 3]. There are so many well-known methods to increase the bandwidth of antennas, including increase of the substrate thickness, the use of a low cost dielectric substrate, slot loaded patch antennas, pin shorted and the use of feeding techniques [4-10].

In the present work we have successfully design and developed a new T-shape slot loaded on radiating patch antenna for enhancing the bandwidth. By selecting the suitable slot shape, choosing a proper feed and setting their dimensions, a higher operating bandwidth is obtained. The summery of the obtained results showed that the bandwidth has achieved a good match.

ANTENNA DESIGN AND CONSIDERATION

The low cost glass epoxy substrate material of thickness h = 0.32 cm and dielectric constant εr = 4.2 is used to fabricate the design antenna. The proposed antenna is made by using computer software AUTOCAD to gain better accuracy. The photolithography process is used to fabricate the antenna.

Figure 1: Geometry of PCETMSA

The Fig. 1 shows top view geometry of proximity coupled equilateral triangular microstrip antenna (PCETMSA), which is de-

signed for the resonant frequency of 3 GHz using the equations present in the literature for the design of equilateral triangular microstrip antenna. The equilateral triangular microstrip patch antenna is made up of equal side length 'a' cm over a substrate S_1 with thickness 'h' cm. The value of 'a' is calculated by the equation (1).

$$a = \frac{2C}{3f_r\sqrt{\varepsilon_r}} \qquad (1)$$

The L_f and Wf are the length and width of the microstripline feed on the top surface of substrate S_2, which is used to excite the patch. The substrate S_2 is placed below the substrate S_1 such that the tip of the feedline and the center of the radiating patch coincide one over the other. The bottom surface of the substrate acts as the ground plane.
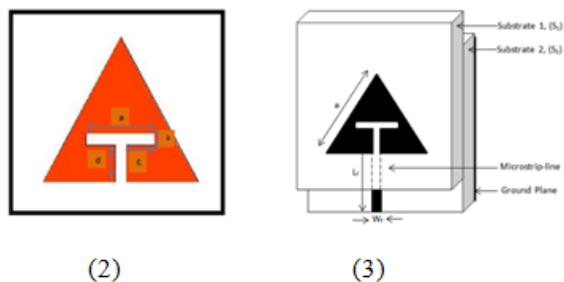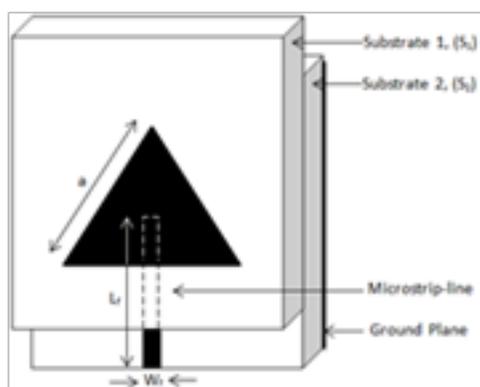

Figure 2, 3: Top view and Geometry of TSPCETMSA

The Fig. 2 and Fig. 3 show the top view and geometry of T-slot loaded proximity coupled equilateral triangular microstrip antenna (TSPCETMSA) respectively, in which the proposed antenna is modified by employing cross slot on the radiating patch, where a, b, c and d are the dimensions of the slot, which is shown in Fig. 2. All the specifications of the designed antenna are given in Table. 1.

TABLE - 1 DESIGNPARAMETERSOF PCETMSA AND TSPCETMSA

Antenna Parameters	Dimensions in cm
Side length of equilateral triangle (a)	2.70
Length of the feedline L_f	2.5
Width of the feedline W_f	0.633
Length and width of the ground plane (Lg and Wg)	4.6

Thickness of substrate S_1 and S_2 (h1+h2)	0.64
a	1.2
b	0.2
c	0.5
d	0.6

TABLE - 2 MEASURED MIN. RETURN LOSS AND VSWR

Antennas	Freq. in GHz.	Min. Return loss in dB.	VSWR
PCETMSA	3.00	-30.26	1.12
TSPCETMSA	2.85	-13.57	1.76
	4.95	-26.74	1.76
	7.20	-11.10	1.80
	8.77	-24.87	1.82

EXPERIMENTAL RESULTS AND DISCUSSION

The Vector Network Analyzer (Rohde & Schwarz, German make ZVK Model No. 1127.8651) is used to measure the experimental return loss versus frequency of PCETMSA and CSPCETMSA.
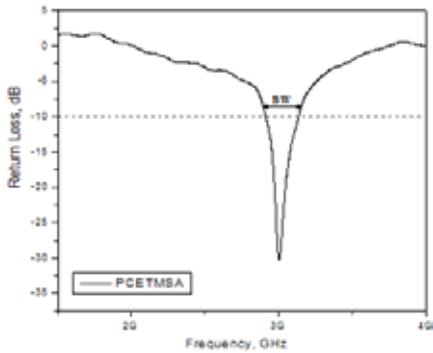

Figure 4: Variation of Return Loss v/s Frequency of PCETMSA

The Fig. 4 shows the variation of return loss versus frequency of PCETMSA. From this figure, it is found that, the PCETMSA resonates at 3 GHz of frequency which is equivalent to the designed frequency of 3 GHz. The experimental impedance bandwidth over return loss than -10dB is calculated using the formula,

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

where, f2 and f1 are the upper and lower cut of points of resonating frequency when its return loss reaches -10 dB. The impedance bandwidth of PCETMSA is found to be 6.97%.
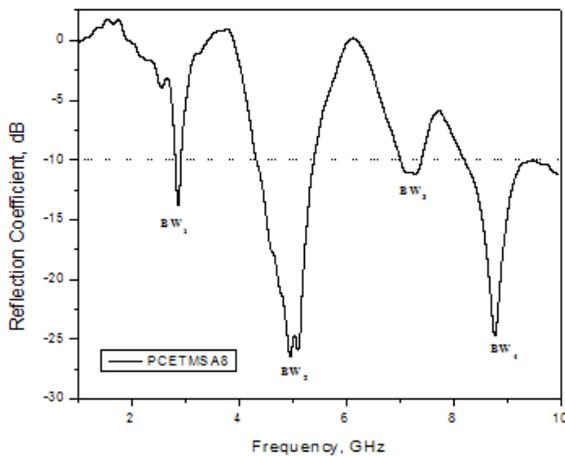

Figure 5: Variation of Return Loss v/s Frequency of TSPCETMSA

The results obtained by interpreting Fig. 5 indicate that the variation of return loss versus frequency of TSPCETMSA, resonates at four modes of frequencies f1, f2, f3, and f4 with their respective impedance bandwidths BW1 = 4.53% (2.80-2.93 GHz), BW2 = 22.03% (4.32-5.39 GHz), BW3 = 5.56% (6.99-7.39 GHz) and BW4 = 19.90% (8.19-10.00 GHz). The minimum return loss and VSWR measured are shown in Table. 2.

The X-Y plane co-polar and cross-polar radiation patterns of PCETMSA and TSPCETMSA are measured at their resonating frequencies and are shown in Fig.6 to Fig.10. These figures indicate that the antennas show broad side radiation characteristics. Further, the calculated HPBW is given in Table. 3.
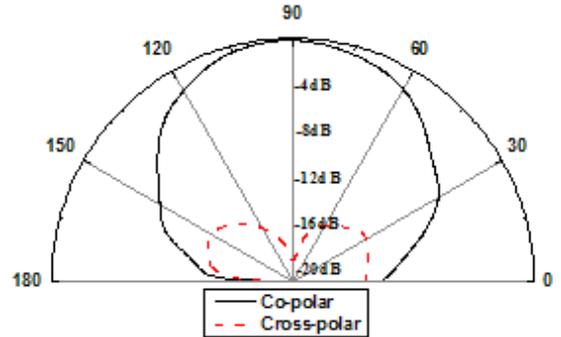

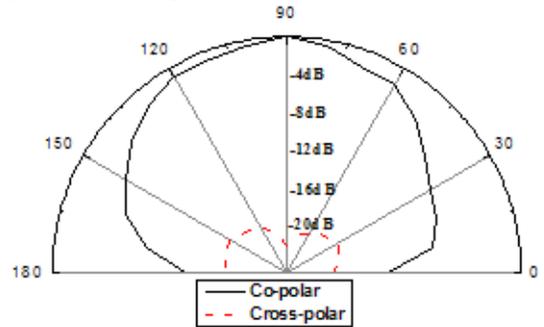**Figure 6: Radiation pattern PCETMSA at 3 GHz**

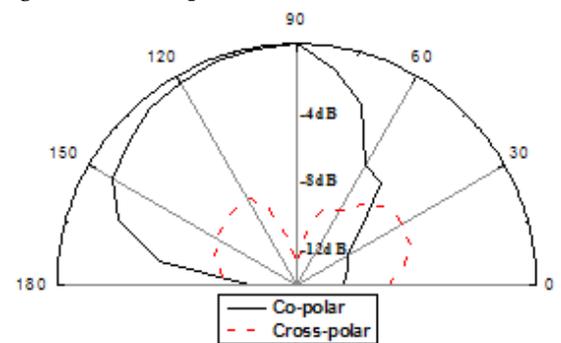**Figure 7: Radiation patternTSPCETMSA at 2.85 GHz**

Figure 8: Radiation patternTSPCETMSA at 4.95 GHz

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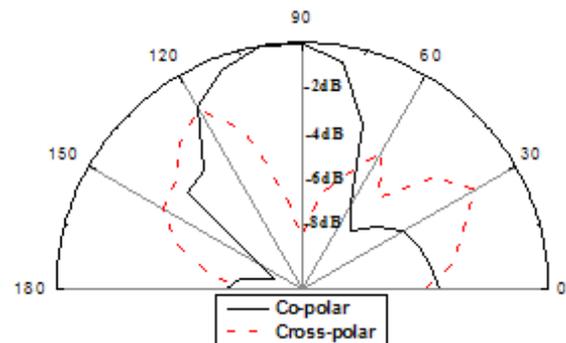
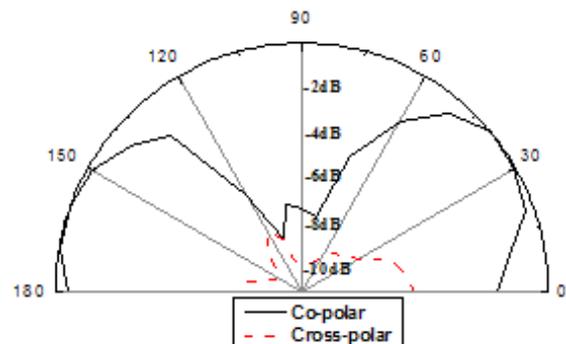**Figure 9: Radiation patternTSPCETMSA at 7.20 GHz**

Figure 10: Radiation pattern TSPCETMSA at 8.77 GHz

The gain of proposed antenna is calculated using absolute gain method given by the equation (3),

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

where, Pt and Pr are transmitted and received powers respectively, Gtis the gain of the pyramidal horn antenna and R is the distance between transmitting antenna and antenna under test. The gain of the antenna is also tabulated in Table 3.

TABLE - 3 CALCULATED HPBW AND GAIN

Antennas	Freq. in GHz.	HPBW in degrees	Gain in dB
PCETMSA	3	72^0	6.38
TSPCETMSA	2.85	82^0	6.85
	4.95	70^0	3.21
	7.20	64^0	5.08
	8.77	50^0	4.00

CONCLUSIONS

From this detailed study, it is concluded that the proposed antenna is simple in its geometry and construction. The PCETMSA antenna gives a single band but after loading a T-slot on radiating patch, which resonates for quad band operating frequency points and is quite good in enhancing the impedance bandwidth and gives better gain with broadside radiation patterns at examined resonating frequencies. This antenna may find applications for WIFI IEEE 802.11, IMT (International Mobile Communication) and in radar systems.

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