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Cross Slot Loaded Proximity Coupled Equilateral Triangular Microstrip Antenna for Enhancing Bandwidth

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Abstract: A new design of a slot-loaded proximity coupled equilateral triangular microstrip antenna for quad-frequency operation is presented. Results show that, by loading a cross slot centered in the triangular patch and oriented parallel to the patch's center line, a quad-frequency operation can be achieved between 2.83 GHz to 8.62 GHZ. The bandwidth has been enhanced to a maximum value of 21.96% in comparison to that of conventional microstrip antenna which resonates at 3 GHz with bandwidth of 6.97%, by introducing a cross slot on the patch. The antenna exhibits broadside radiation characteristics. The results are presented and discussed. This antenna may find applications in WIFI IEEE 802.11, IMT (International Mobile Communication) and in radar systems.

Keywords: Proximity Coupled, Equilateral Triangular, Bandwidth, Radiation Patterns and Gain.

1. Introduction

The microstrip antennas have achieved popular position in today's communication system because of their inherent attractive features like light weight, planar structure, ruggedness, different geometries and shapes, easy installation, low fabrication cost etc., [1]. It is need of the hour to select the antenna that uses single antenna for transmit/receive purpose. The microstrip antenna designers worked hard to put forth many methods and techniques such as cutting slots of different geometries like triangular, circular ring, rectangular narrow slot, square slot on the radiating patch [2-6], use of H-shape patches, multi slots on the patches [7-10] etc. to achieve dual, triple and multiband operations. But the proposed antenna operating at four independent bands is presented with a better bandwidth and gain by introducing simple cross slot loading technique on proximity coupled equilateral triangular microstrip antenna. This kind of study is found to be rare in the literature.

2. Antenna Design and Consideration

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

The Fig. 1 shows the top view geometry of proximity coupled equilateral triangular microstrip antenna (PCETMSA), which is designed 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 S1 with thickness 'h' cm. The value of 'a' is calculated by the equation (1).

$$a = \frac{2C}{3 f_r \sqrt{\varepsilon_r}} \tag{1}$$

The Lf and Wf are the length and width of the microstripline feed on the top surface of substrate S2, which is used to excite the patch. The substrate S2 is placed below the substrate S1 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.

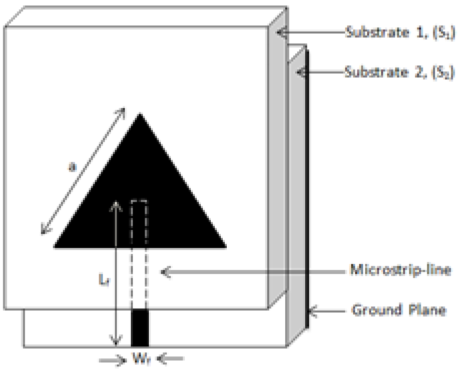

Figure 1: Geometry of PCETMSA

Fig. 2 and Fig. 3 show the top view and geometry of cross slot loaded proximity coupled equilateral triangular microstrip antenna (CSPCETMSA) 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.

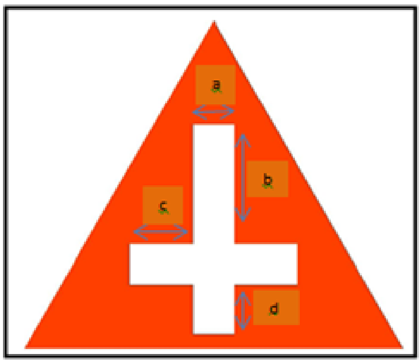

Figure 2: Top view of CSPCETMSA

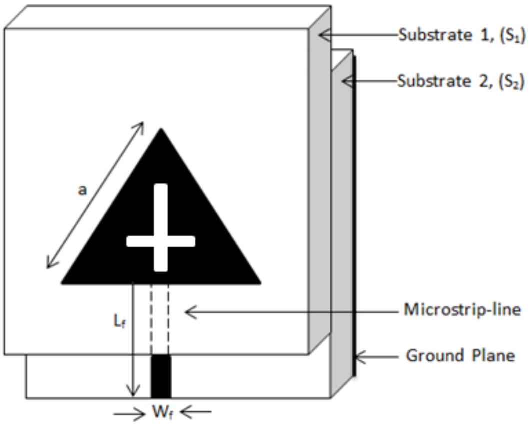

Figure 3: Geometry of CSPCETMSA

Table 1: Design parameters of PCETMSA and CSPCETMSA

Antenna Parameters	*Dimensions in cm*
Side length of equilateral triangle (a)	2.70
Length of the feedline L_f	2.5
Width of the feedlineW_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	0.3
b	0.85
c	0.45
d	0.35

3. 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.

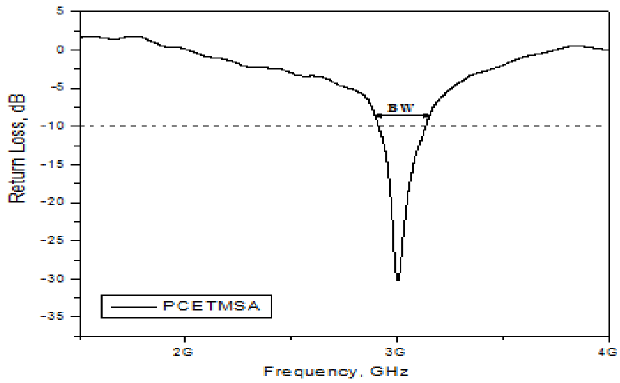

Figure 4: Variation of Return Loss v/s Frequency of PCETMSA

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,

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

where, f_2 and f_1 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%.

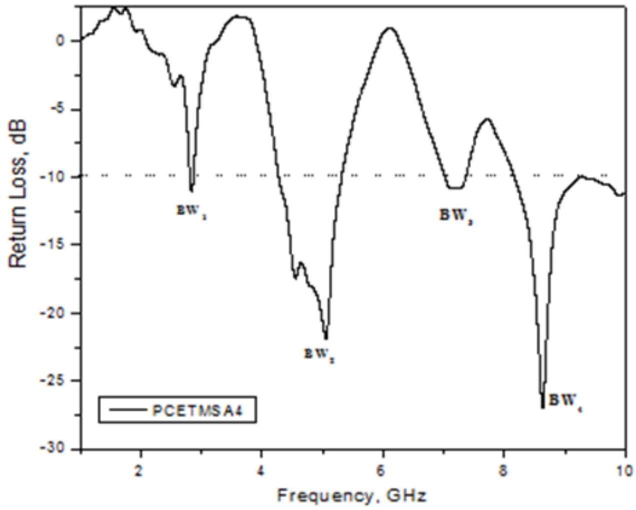

Figure 5: Variation of Return Loss v/s Frequency of CSPCETMSA

The results obtained by interpreting Fig. 5 indicate CSPCETMSA resonates at four frequencies f_1, f_2, f_3, and f_4 with their respective impedance bandwidths BW_1 = 1.75% (2.82-2.87 GHz), BW_2 = 21.96% (4.26-5.31 GHz), BW_3 = 5.01% (7.00-7.36 GHz) and BW_4 = 20.26% (8.16-10.00 GHz). The minimum return loss and VSWR measured are shown in Table. 2.

Table 2: Measured Min. Return Loss and VSWR

Antennas	Freq. in GHz.	Min. Return loss in dB.	VSWR
PCETMSA	3	-30.26	1.12
	2.83	-11.11	1.75
	5.04	-21.75	1.75
	7.2	-10.86	1.78
CSPCETMSA	8.62	-26.77	1.8

The X-Y plane co-polar and cross-polar radiation patterns of PCETMSA and CSPCETMSA 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.

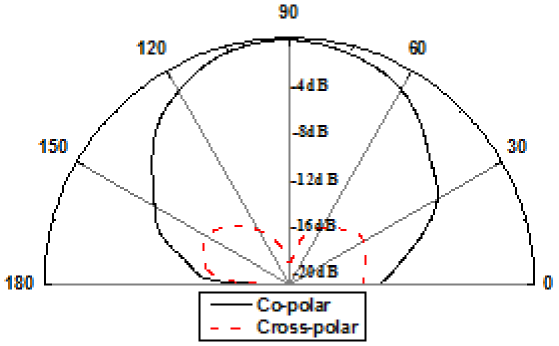

Figure 6: Radiation pattern PCETMSA at 3 GHz

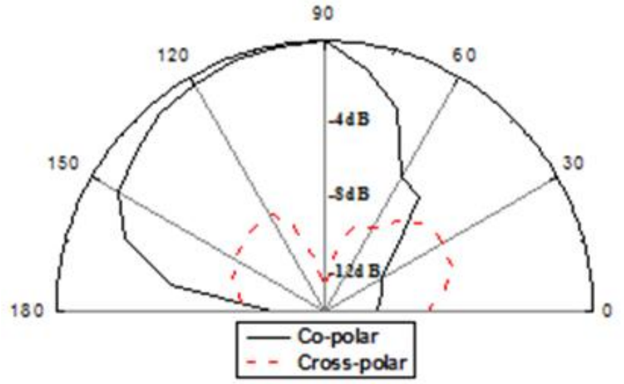

Figure 7: Radiation pattern CSPCETMSA at 2.83 GHz

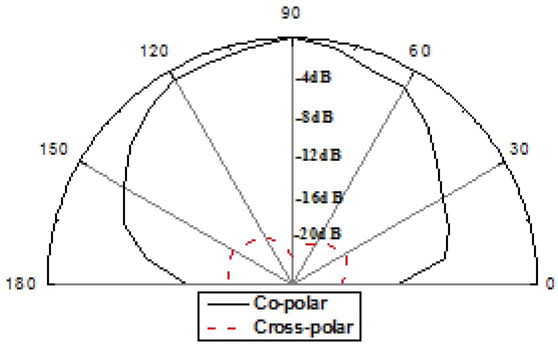

Figure 8: Radiation pattern CSPCETMSA at 5.04 GHz

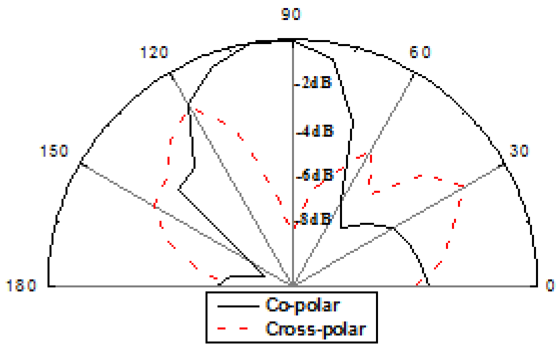

Figure 9: Radiation pattern CSPCETMSA at 7.20 GHz

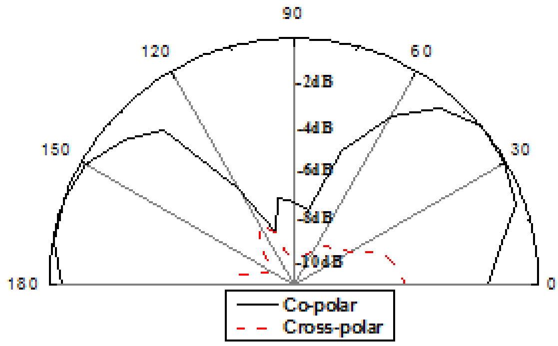

Figure 10: Radiation pattern CSPCETMSA at 8.62 GHz

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, P_t and P_r are transmitted and received powers respectively, G_t is 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
CSPCETMSA	2.83	83^0	6.68
	5.04	88^0	3.16
	7.20	52^0	3.61
	8.62	65^0	4.73

4. 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 cross 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 resonating frequencies. This antenna may be used for WIFI IEEE 802.11, IMT (International Mobile Communication) and in radar systems.

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