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Proximity-fed Rectangular Microstrip Antenna With different substrate thickness

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Abstract: In this article, proximity-fed rectangular microstrip antenna (PRMSA) has been designed to enhance the antenna parameters. The fabricated antenna uses two-layer substrate, microstrip-line feed and the ground on the lower layer and the radiating patch on upper layer such that the feed line finishes in an open end underneath the patch. The study is made by using different thickness of substrate of two layers. Further, by increasing the thickness of substrate, improvement in impedance bandwidth and gain is observed and also the virtual size of the antennas which is found to be reduced. The other antenna parameters such as radiation pattern, reflection coefficient, VSWR and HPBW are presented and discussed.

Keywords: microstrip patch, proximity feed, impedance bandwidth, gain.

INTRODUCTION:

The fast growth in wireless communications promises to make interactive voice, data, and video services available at anytime and anyplace[1]. Wireless communication systems come in a variety of different sizes, ranging from small hand-held devices to wireless networks. During the years, microstrip antenna structures are the most common option used to realize for microwave, radar and communication purposes[2]. The desirable features of microstrip antennas, such as performance, flexibility, simplicity, high gain and low fabrication cost, make them very popular for many applications. Conversely, these antennas have a main drawback by its narrow operating bandwidth[3].

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In non-contacting method, the electromagnetic field coupling is done to transfer power between the microstrip-line and the radiating patch[4][5][6]. A configuration of this non-contacting non-coplanar microstrip feed is studied. It uses a two–layer substrate with the microstrip-line on the lower layer along with the ground plane and the radiating patch on the upper layer. The feed-line terminates in an open end underneath the patch. This feed is better known as an “electromagnetically coupled” or “Proximity coupled” microstrip feed. Coupling between the patch and microstrip is capacitive in nature[7].

ANTENNA CONFIGURATION:

The PRMSA is fabricated using a commercially available low cost glass epoxy substrate material with relative permittivity $\varepsilon_r = 4.2$ and dielectric loss tangent tan $\delta = 0.02$. The study is made by varying the substrate thickness such as 1.6 mm, 3.2 mm and 6.4 mm. The structures of these antennas are drawn by using AutoCAD software.

The PRMSA consists of a patch of length L and width W is etched on top surface of substrate S_1. The microstrip-line feed of length L_f and width W_f is etched on the top surface of substrate S_2. The substrate S_2 is placed below substrate S_1 and the bottom surface of the substrate S_2 acts as the ground plane. The feed on surface of the substrate S_2 is aligned such that the tip of the feed-line and the center of the radiating patch coincide one over the other. A 50 Ω Semi Miniature-A (SMA) connector is connected at the feed point of the microstrip-line for feeding the microwave power. Figure 1 shows the geometry of the proposed antennas.

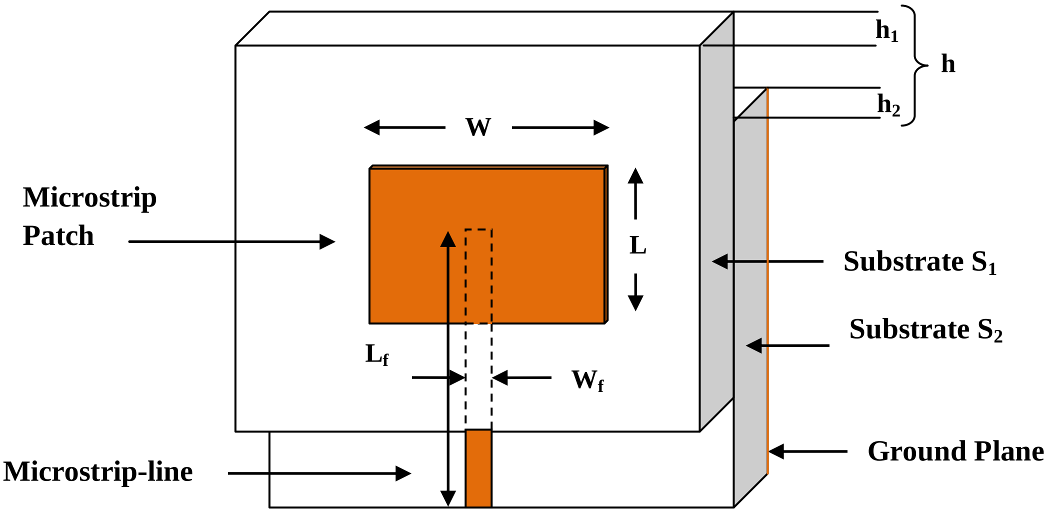


Fig. 1: Geometry of PRMSA

The PRMSAs have been designed for 3 GHz. The physical dimension of rectangular radiating patch and feed-line are determined from equations[8] and are shown in the Table 1.

Table 1: Designed parameters of proposed antennas

Antenna Geometry Parameters	**Dimensions in mm**
Length of the patch, L (for thickness) = 1.6 mm = 3.2 mm = 6.4 mm	24.20 23.90 23.40
Width of the patch, W	31.00
Length of feedline, L_f	12.69
Width of feedline, W_f (for thickness) = 1.6 mm = 3.2 mm = 6.4 mm	1.58 3.16 6.33
Thickness of the substrate S_1 and S_2, ($h=h_1+h_2$)	1.6 3.2 6.4

EXPERIMENTAL RESULTS:

The experimental readings are carried on VNA (Vector Network Analyzer, Rohde & Schwarz, German make ZVK Model No. 1127.8651). The impedance bandwidths are measured over return loss less than -10dB for the proposed antennas. The variation of return loss versus frequency of PRMSA for different thickness is shown in Figures 2 - 4. The impedance bandwidth is obtained by using the given formula;

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

where, f_H is the higher cutoff frequency and f_L is the lower cutoff frequency and f_C is central frequency of the bands.

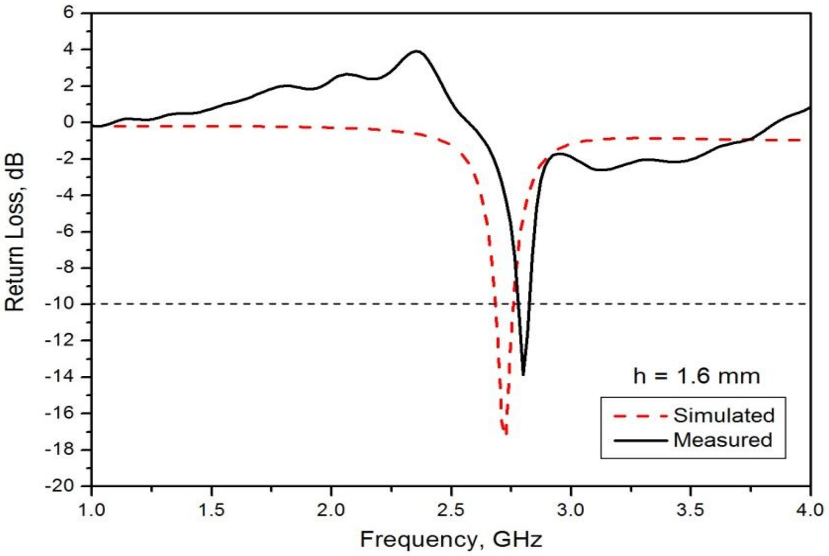


Fig. 2: Variation of Return loss Vs Frequency of PRMSA with h= 1.6 mm thickness

The Figure 2 shows that, PRMSA with thickness, h = 1.6 mm resonates at 2.88 GHz. The impedance bandwidth is found to be 40 MHz (1.38 %). The return loss obtained for this antenna is -13.86 dB. Also the simulated result is found to nearly match with measured return loss. Similarly, the Figure 3 shows that the antenna with thickness h = 3.2 mm resonates at 2.75 GHz and impedance bandwidth is found to be 90 MHz (3.29 %), which is 2.38 times more when compared with the antenna with thickness (h = 1.6 mm). At return loss of -19.82 dB which is also found to be improved.

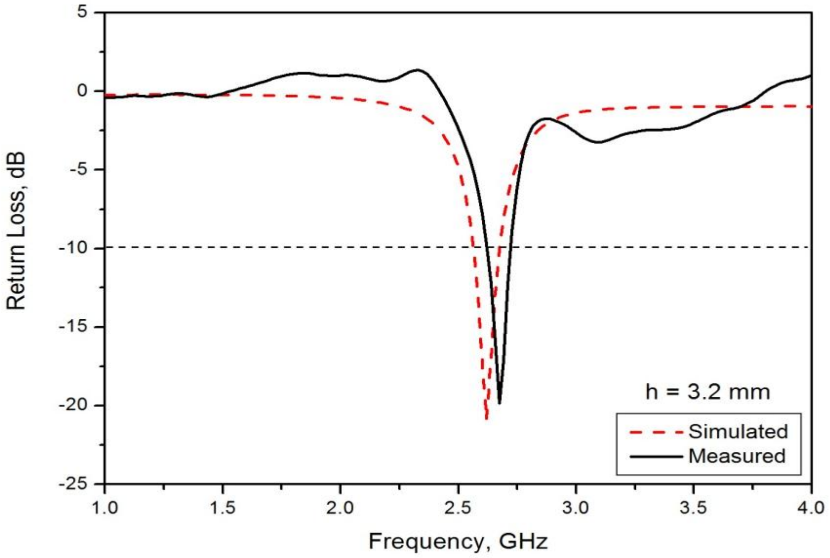


Fig. 3: Variation of Return loss Vs Frequency of PRMSA with h= 3.2 mm thickness

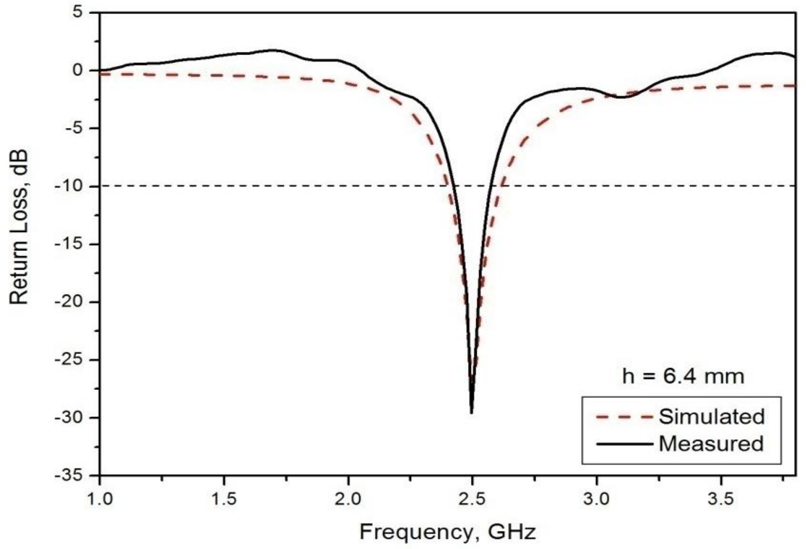


Fig. 4: Variation of Return loss Vs Frequency of PRMSA with h= 6.4 mm thickness

Further, the antenna with thickness h = 6.4 mm resonates at 2.56 GHz is shown in the Figure 4. The impedance bandwidth is 150 MHz (5.87 %) which is 4.25 times and 1.78 times more than the antennas with height h = 1.6 mm and 3.2 mm respectively. The return loss measured is at -29.53 dB which shows again improvement compared with earlier antennas. Also the simulated results match with the measured return loss.

X-Y plane with respect to co-polar and cross-polar radiation patterns of PRSMA with different thickness are measured at their resonating frequencies and are shown in Figures 5, 6 & 7. From Figures 5 and 6 it is seen that the antennas show broader side radiation pattern and the antenna with thickness h = 6.4 mm shows nearly omni-directional pattern. The cross-polarization levels of all the proposed antennas are found to be minimum which is below -10 dB, -16 dB and -18 dB respectively.

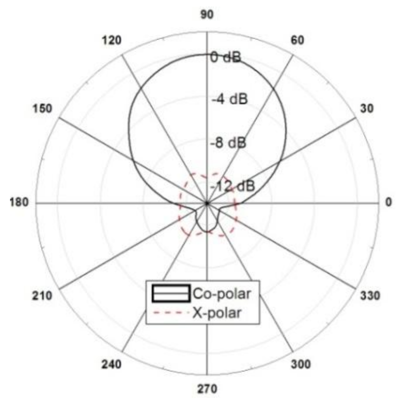


Fig. 5: Radiation pattern at 2.88 GHz

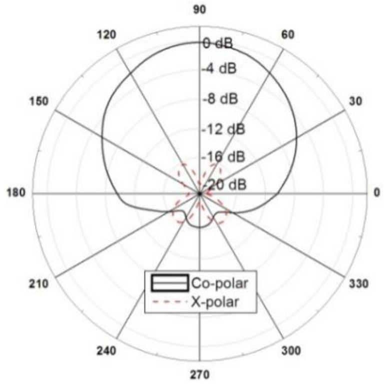


Fig. 6: Radiation pattern at 2.75 GHz

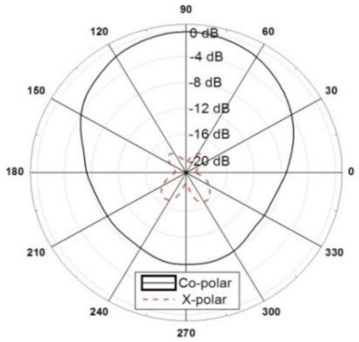


Fig. 7: Radiation pattern at 2.56 GHz

Half power beam width (HPBW) and the gain for the proposed antennas are calculated at their resonating frequencies and are presented in Table 2.

The power received (*Ps*) by the pyramidal horn antenna and the power received (*Pt*) by the antenna under test are measured independently[9] [10]. From experimental data, the gain of antenna under test (G_T) in dB is calculated using the formula,

$$(GT)_{dB} = (GS)_{dB} + (Pt / Ps) \quad \ldots\ldots\ldots\ldots(2)$$

where, *Gs* is the gain of pyramidal horn antenna.

Further, the size reduction of the antennas is also calculated and is presented in Table 2.

Table 2: Antenna Parameters

Antenna with thickness (h) mm	**Gain in dB**	**HPBW in deg.**	**VSWR**	**Size reduction in percentage**
1.6mm	1.2	86	1.41	7.98
3.2mm	3.75	86	1.26	13.66
6.4mm	4.94	--	1.07	20.19

From the above table, it is observed that the gain of the antennas improve as the thickness of the substrate increases and also the VSWR is reduced considerably and is found to be less than 2 which implies that maximum signal is received [9].

The input impedance is measured for all the proposed antennas. From the Smith chart of antenna with h = 6.4 mm it is seen that at the centre, the loop is observed which illustrates the matching of the feedline and the radiation patch and because of which impedance bandwidth is improved which is shown in Figure 8.

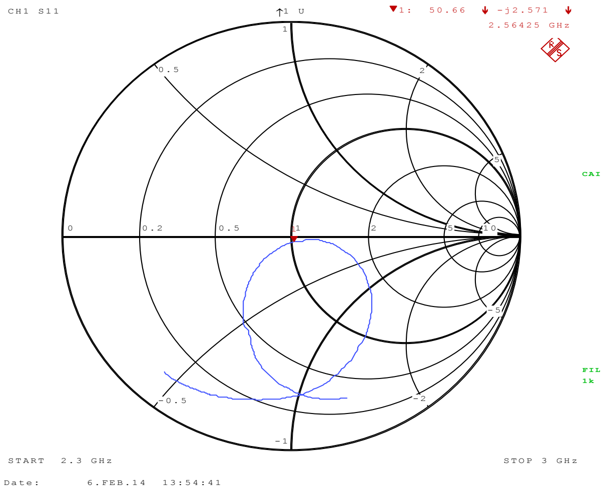
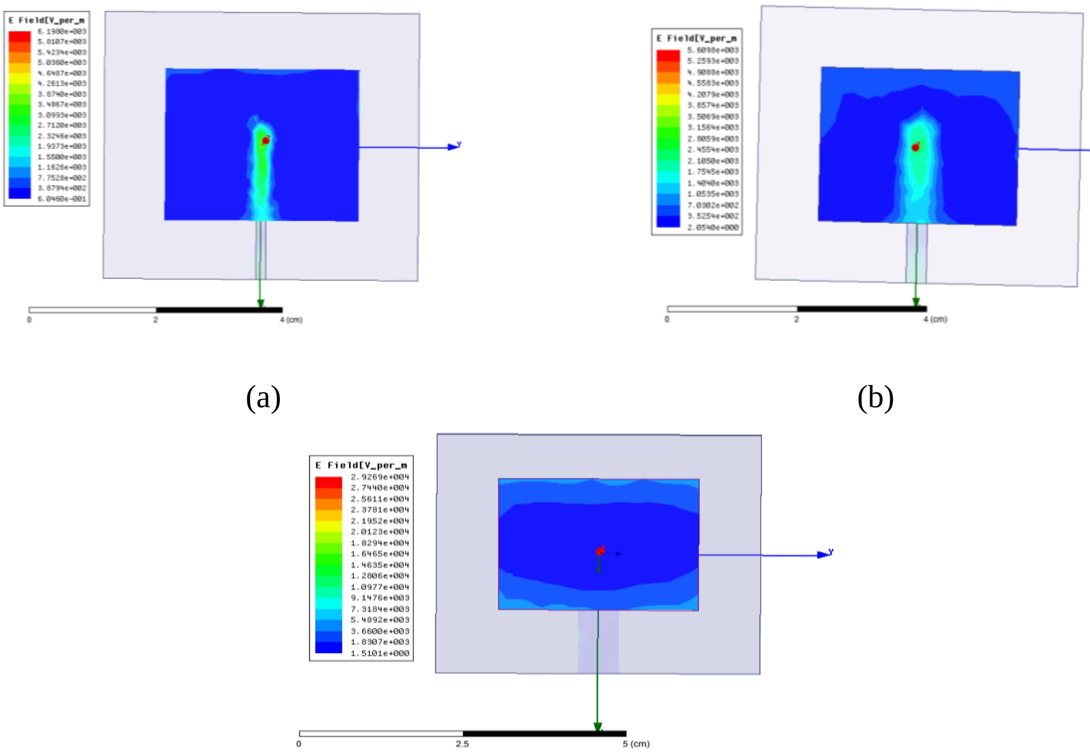


Fig. 8 Smith chart profile for the antenna with thickness h = 6.4 mm

The simulated surface current distributions for the minimum return loss of the proposed antennas at their simulated resonating frequencies 2.69, 2.61 and 2.49 GHz of different thickness such as 1.6 mm, 3.2 mm and 6.4 mm respectively are shown in Figure 9. From this figure, it is clear that the current densities are distributing at the center of the patch.



(a)

(b)

(c)

Fig. 9 Simulated Current distributions at (a) 2.69 GHz, (b) 2.61 GHz and (c) 2.49 GHz

CONCLUSION:

The complete experimental study illustrates that the proposed antennas are relatively simple in design and fabrication and quite good in enhancing the bandwidth by providing better broadside radiation pattern at the resonating frequencies along with improvement in gain as the thickness of antenna is increased. The antenna with h = 6.4 mm shows good improvement in all measured and calculated antenna parameters and shows nearly omni-directional radiation pattern with minimum cross-polarization level. Also the simulated results nearly match the experimental S_{11} parameters. These antennas are superior as they use low cost substrate material and find applications in S-band frequency range and modern wireless communication systems.

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