An Optimal Design of Compact CPW-Fed Slot Antenna for Broadband Applications

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Abstract **– A compact coplanar waveguide (CPW) fed slot antenna is developed and presented, in this paper. The proposed antenna has a simple structure consisting of rectangular slot, semicircular feeding structure and notch in the ground plane. The introduction of notch in the ground plane improves the impedance bandwidth and impedance matching. The analysis of the designed structure is investigated using MoM based commercially available electromagnetic solver, IE3D. The designed antenna is fabricated using FR4 substrate with 1.6mm thickness. The return loss and VSWR of the developed antenna are measured, compared with the simulated results and are found to be almost similar. The overall dimension of the antenna with the above structural features comes around 19×20×1.6 mm^3 and the impedance bandwidth of the antenna is about 69% with return loss better than -10 dB over the frequency range of 5 GHz to 10.3 GHz. It is also shown that the proposed antenna has relatively stable omni directional radiation pattern in the H plane and bidirectional radiation pattern in the E plane.**

Index Terms- **CPW, slot antenna, radiation pattern, return loss, VSWR**.

I. INTRODUCTION

Printed antennas attract much attention in the recent years by its light weight, low profile, small size and easy to fabricate features. Though they have narrow bandwidth it can be eliminated by the use of slot antennas [1]. To meet the increasing demand for high speed wireless communication systems more wideband systems are to be developed. For such wireless systems, antennas are the key elements to radiate and receive the signals. They should have many characteristics including low radiation loss, less dispersion, high gain etc. Proper design of the antenna reduces the system requirements and improves the system performance. For wireless applications, various antenna configurations including planar monopoles, slot antennas and dipoles have been suggested [2-8]. Among them, planar slot antennas are more promising because of their simple structure, easy to fabricate and wide impedance bandwidth characteristics. CPW-fed antennas have many salient features like less radiation loss, less dispersion, easy integration with monolithic microwave integrated circuits (MMIC), simple configuration, the ability to effectively control their characteristic impedance and their ease of integration with active devices and passive devices over their counterpart microstrip antennas [9]. Because of the slot antenna's wideband characteristics square slot antenna with coplanar waveguide (CPW) feed lines [10-11] and CPW-fed triangular patch antennas [12] are demonstrated in the literature. In general, the wideband CPW-fed slot antenna can be developed by tuning their impedance value. Several impedance tuning techniques are reported in literatures by varying the slot dimensions. These tuning techniques have been carried out with various slot geometries like bow-tie slot [13], wide rectangular slot [14-15], circular slot [16] and hexagonal slot [17]. The impedance tuning can also be done using coupling mechanisms like inductive and capacitive coupled slots [18], dielectric resonator coupling [19-20] and other techniques such as using photonic bandgap (PGB) [21] etc. Though large impedance bandwidth could be obtained from the above techniques, their complexity is quite high.

In general, two parameters affect the impedance bandwidth of the planar slot antenna, the slot width and the feed structure. The wider slot gives more bandwidth, and the optimum feed structure determines good impedance matching [22]. The CPW feed line with various possible patch shapes, such as T, cross, forklike, volcano and square are used to obtain wider bandwidth [23-25]. The proposed antenna is designed with a compact rectangular slot, semicircular feeding structure at the anterior portion of the feed and notches at the ground planes. The notches are introduced at the ground planes to increase the bandwidth and to get better impedance matching. The antenna has less number of design parameters compared to the existing wideband antennas in the literature [14-16,26-27] which makes its design simple. The details of the proposed design and its experimental results are presented and discussed in the following sections. The paper is organized as follows: Section II brings out the geometry of the antenna. In Section III simulation results and analysis are discussed. Obtained experimental results are given in Section IV. Section V concludes the work.

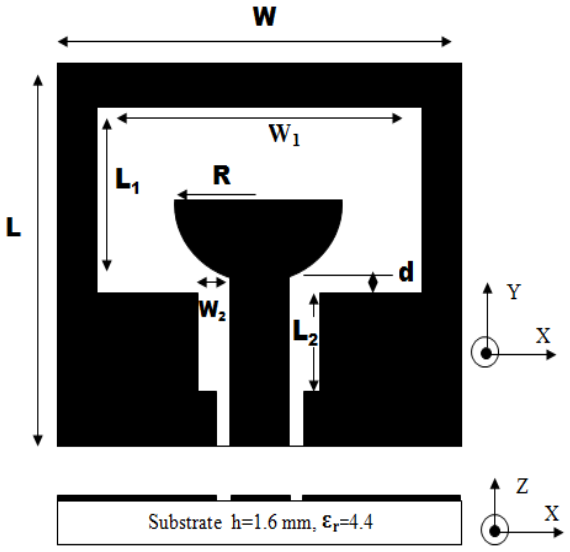


Fig. 1. Geometry of the proposed slot antenna.

II. ANTENNA GEOMETRY

The proposed CPW-fed wideband slot antenna having a single layer copper metallic structure is shown in Figure 1. The parameters 'W_1' and 'L_1' are the width and height of the rectangular slot respectively. 'R' is the radius of the semi-circular feeding stub. 'd' is the distance between the patch and feed line. 'W_2'and 'L_2' are the width and notch of the ground plane respectively. For this study, a dielectric substrate (FR4) of 1.6mm thickness with a relative permittivity of 4.4 is chosen, so as to easily integrate the antenna with the Printed Circuit Board. The CPW is designed for a 50Ω characteristic impedance with fixed 1.8mm feed line width and 0.3 mm ground gap. By properly adjusting the dimensions of the slot, feeding structure and notch, the impedance matching of the proposed antenna is improved, which produces wide impedance bandwidth with satisfactory radiation pattern. The wide impedance matching with reduced size of the antenna is the resultant of the introduction of notches in the ground planes, which disturb the surface magnetic currents to obtain a wide bandwidth.

Table 1: Optimal parameter values of the antenna

Parameter	Description	Optimal Value
L	Length of the antenna	19 mm
W	Width of the antenna	20 mm
L_1	Length of the slot	10 mm
W_1	Width of the slot	15 mm
L_2	Length of the notch	3.8 mm
W_2	Width of the notch	0.3 mm
d	Feed gap distance	1.2 mm
R	Radius of the patch	4.5 mm

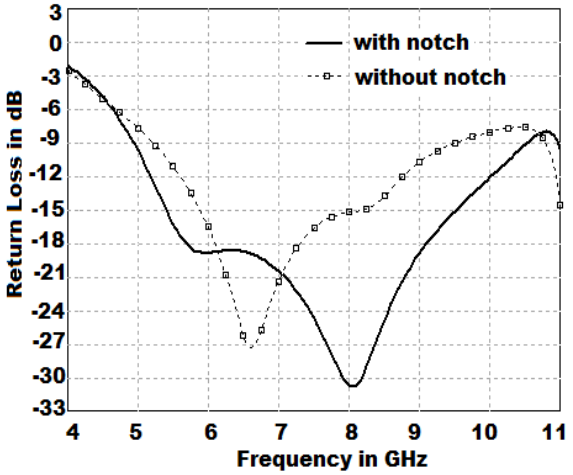


Fig. 2. Simulated return losses with and without notch

III. SIMULATED RESULTS AND ANALYSIS

To evaluate the performance of the proposed antenna, the antenna is first simulated using the method of moments based simulation tool, IE3D [28]. To analyze the wide band coverage of the antenna, the effects of adjusting the antenna parameters are investigated. The analysis of the antenna for different parameter values has been carried out by varying one parameter and keeping all the other parameters as constant. The final optimal values of the parameters of the antenna are listed in the Table 1.

A. Effect of Notch in the Ground Planes

Figure 2 shows the effect of notch in the return loss characteristics and it also shows that the notch in the ground plane improves the impedance bandwidth and impedance matching. The impedance bandwidth of the antenna is 5.3 GHz (5 GHz-10.3GHz) for the values of S_{11} which are less than -10 dB.

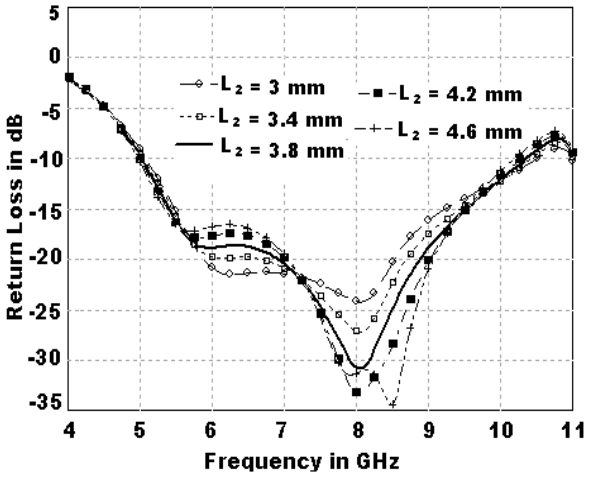


Fig. 3a. Simulated return loss curves for different notch lengths

Figure 3a depicts the effects on bandwidth for different notch lengths in the ground planes. It also discloses the profiles of the impedance matching for various notch lengths. It can be seen from the Figure 3a that the variation of the notch length introduces not much change in the return loss curve. However, decreasing the notch length leads to poor impedance matching while increasing the notch length causes improvement in the matching with slight changes in the impedance bandwidth. The optimal value obtained for this case is 3.8 mm.

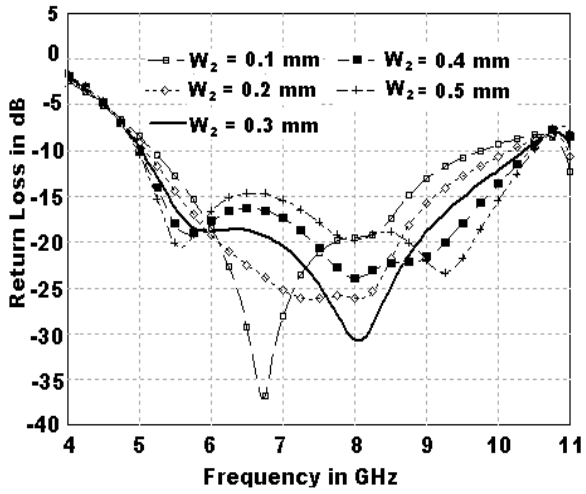


Fig. 3b. Simulated return loss curves for different notch widths

Figure 3b illustrates the effects of varying the width of the notch in the ground plane. While increasing the width of the notch makes poor impedance matching, decrease in width gives shift in the resonance and decrease in the impedance bandwidth. The width of the notch for this case is 0.3mm.

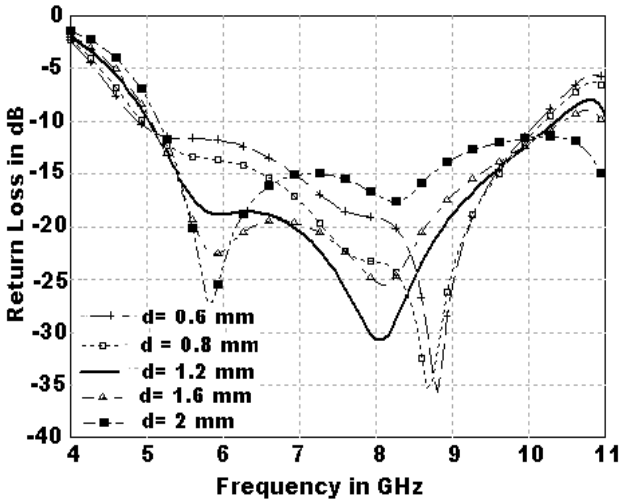


Fig. 4. Simulated return loss curves for different feed gaps

B. Effect of Feed Gap

Figure 4 displays the simulated return loss for different feed gaps (d=0.8, 1.6, 1.8 and 2mm). The responses clearly bring out that as the feed width increases, the impedance matching becomes poor and the resonant frequency moves towards lower frequencies. If the feed gap decreases, the impedance matching over the band becomes poor and there is a shift in the resonant frequency towards higher frequencies. It is found that the optimal value for this case is 1.2mm.

C. Effect of Radius of the Semicircular Stub

The effect of varying the radius of the semicircular structure is depicted in the Figure 5, and it shows that for larger values of radius the impedance matching becomes less and for smaller values of radius the impedance bandwidth is condensed. The optimal value for this case is 4.5 mm.

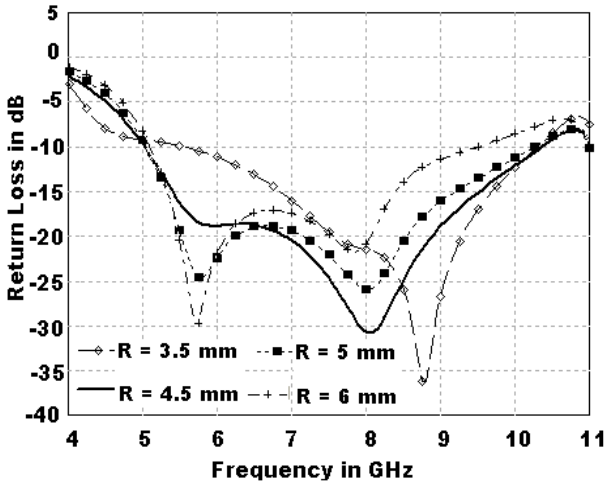


Fig. 5. Simulated return losses for different radius of the semicircular patch

D. Radiation Patterns

The simulated radiation pattern of the E plane and H plane are obtained for the frequencies 5 GHz, 7.5 GHz and 9 GHz and it is shown in Figure 7. It is noticed that in H plane the radiation pattern is omni directional and in E plane the radiation pattern is bidirectional. Proper geometrical selection of the antenna results in the variation in field distribution which in turn affects the characteristics of the proposed antenna.

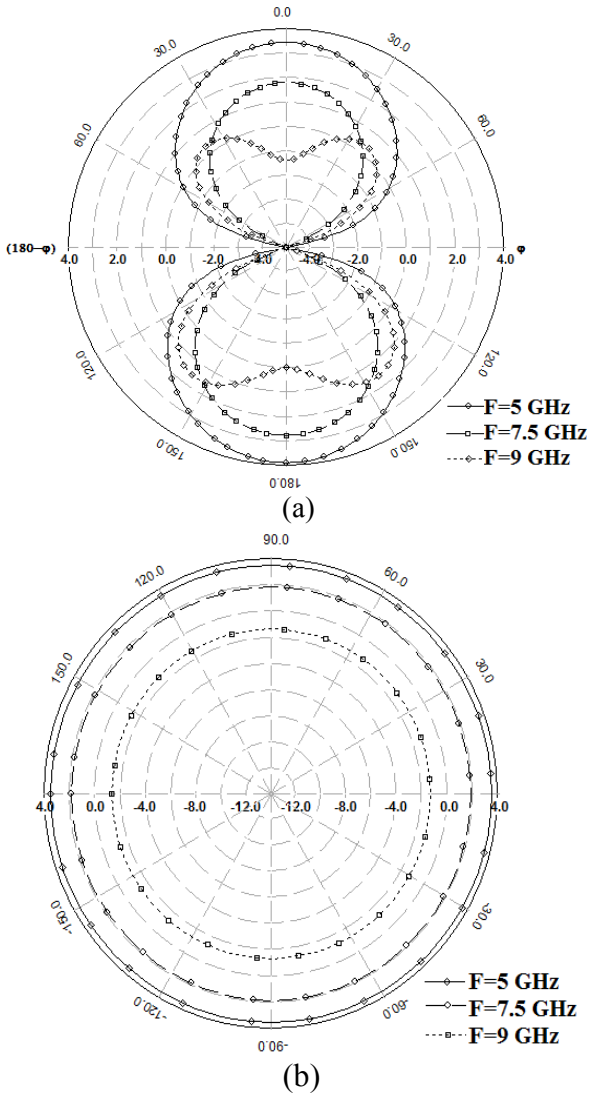
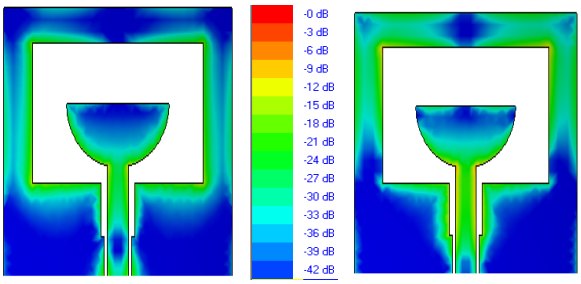


Fig.7. Radiation pattern of the proposed antenna at 5,7.5 and 9 GHz a) E-Plane (yz-plane) b) H-Plane (xz-plane)

E. Simulated Current Distributions

The simulated current distributions for the frequencies 5.5 GHz and 8 GHz are presented in Figure 6. The current distributions of the proposed antenna are obtained by accounting the optimal design parameter values at frequencies

5.5 GHz and 8 GHz. It is seen that the maximum radiation is possible at these frequencies owing to the current distribution near the edges of the slot and in the patch.



(a) (b)

Fig. 6. Current distributions at (a) 5.5 GHz and (b) 8 GHz

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The prototype of the proposed antenna shown in Figure 1 was fabricated for its optimal values and tested, which is depicted in Figure 8. Using Hewlett Packard Network Analyzer (HP8757D), the return loss and VSWR are measured and plotted. The schematic setup for the measurement is shown in Figure 9.

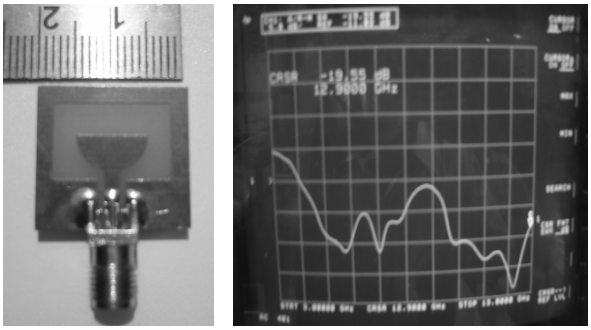


Fig. 8. Fabricated antenna and its measured return loss

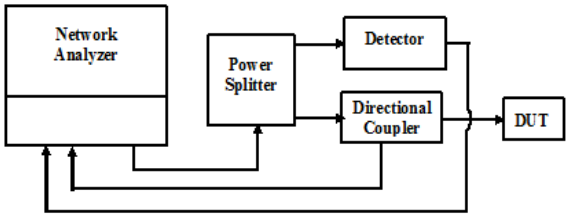


Fig. 9. Schematic of the measurement setup

The simulated and measured return losses of the proposed antenna are compared in Figure 10. There is a shift in the measured return loss response at the low frequency, this discrepancy between the measured and the simulated ones might be the effect of soldering the SMA connector or fabrication tolerance. The simulation results were obtained by assuming coplanar as input port, whereas practically SMA connector was used, the imperfect transition between SMA feed to coplanar may introduce losses [29] and also the capacitances can lead to shift in the frequency. The soldering position of the feed point may also be the reason for the shift in the frequency [30].

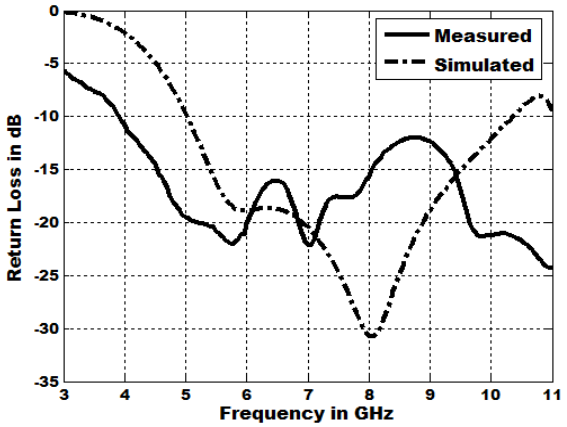


Fig. 10. Comparison of return losses of the proposed antenna

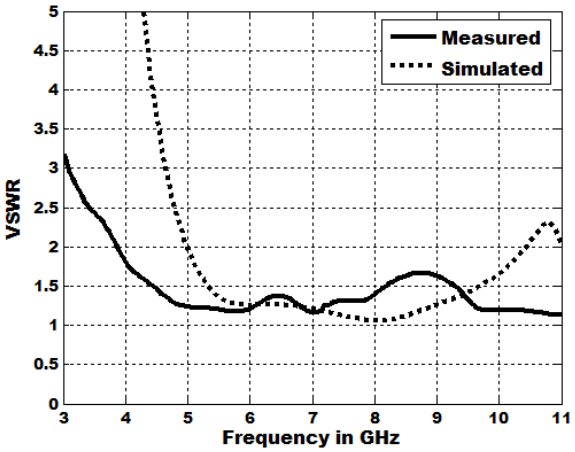


Fig. 11. Comparison of VSWR of the antenna

V. CONCLUSION

In this paper, a compact CPW fed slot antenna is proposed. To minimize the antenna size and also to get better impedance matching, a notch in the ground plane is introduced. The semicircular cub like tuning stub is introduced at the anterior portion of the feed to enhance the coupling between the slot and feed. With the above structural features in the proposed antenna configuration the overall dimension of the antenna comes around $19\times20\times1.6$ mm^3. The measured results of the fabricated antenna are almost similar to the simulated results. This type of antenna may be suitable for applications such as HIPERLAN/2, WLAN and WiMax.

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