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CPW FED UWB MONOPOLE ANTENNA WITH COMPACT SIZE AND GOOD FEDILITY ANSWER

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Abstract *— In this paper, design and analysis of compact coplanar waveguide (CPW) fed ultra-wideband (UWB) slot antenna is presented. The proposed antenna has a simple structure consisting of a rectangular slot and a Trapezoid patch at the anterior portion of the feed that acts as tuning stub of the antenna. The analysis of the proposed antenna is performed by using FEM based electromagnetic solver, HFSS. The designed antenna is fabricated using FR4 substrate with 1.6 mm thickness. The return loss and standing wave ratio of the developed antenna are measured and compared, which shows that measured result is in good agreement with simulation. With the above structural features the overall dimension of the antenna is 20mm×20mm×1.6mm and the fractional impedance bandwidth of the antenna is about 124.32% with return loss better than -10 dB (VSWR < 2). It is also seen that the proposed antenna has relatively stable Omni-directional radiation pattern in the H plane and bidirectional radiation pattern in the E plane over the frequency range of 2.8 GHz to 12 GHz. To verify the suitability of the antenna for transmission and reception of narrow pulses, the time domain analysis is also investigated and presented.*

I. INTRODUCTION

In this modern wireless communication era there is an increase in the demand for systems, which are smaller in size and support high data rate providing high performance. After the release of Ultra Wideband (UWB) for unlicensed applications by the FCC it has been receiving much attention both from the industry and academic sectors due to its inherent properties like low power consumption, high secured data rate support and simple configuration over conventional wireless communication systems [1]. With the rapid developments of such wireless systems, a lot of attention is being given to the design of antennas since they are the key elements to radiate and receive the signals. In the recent years miniaturization of antenna receives much attention. Contemporary researchers have been working for the development of small size and cost effective antennas. By modifying the antenna geometries and using high permittivity material, the size reduction of the antenna is possible [2]. Nowadays Printed antennas attract much attention due to its features like light weight, low profile, small size and easy fabrication although its narrow bandwidth can be eliminated by the use of slot antennas [3]. For wireless applications, various antenna configurations including planar monopoles, slot antennas and dipoles have been suggested. Among them, planar slot antennas combined with coplanar waveguide feed are more promising because of its simple structure, lower profile, easy fabrication, wide impedance bandwidth, less radiation loss, less dispersion and its easy integration with monolithic microwave integrated circuits (MMIC) [4]. Owing to slot antenna's wideband characteristic, some square slot antenna with coplanar waveguide (CPW) feed lines [5-6] and CPW fed Trapezoid patch antennas [7] are demonstrated in the literature. In general, the wide bandwidth in CPW-fed slot antenna can be achieved by varying the dimensions of its structure which in turn will modify the impedance value. Several impedance tuning techniques are also reported in literatures by varying the slot dimensions. These tuning techniques has been carried out in various slot geometries like bow-tie slots [8-10], wide rectangular slot [11-13], circular slot [14] and hexagonal slot [15]. The impedance tuning can also be performed using coupling mechanisms like inductive and capacitive coupled slots [16] and dielectric resonator coupling [17-18] and other techniques such as using photonic bandgap (PGB) [19]. Even though large impedance bandwidths could be obtained using these techniques, they are quite complicated. In planar slot antennas two parameters affect the impedance bandwidth of the antenna, the slot width and the feed structure. The wider slot gives more bandwidth and the optimum feed structure gives good impedance matching [20]. The CPW feed line with various possible patch shapes, such as T, cross, forklike, volcano and square are used to give wide bandwidth [21-24]. A Trapezoid patch is frequently used in microstrip antennas, which provides radiation characteristics similar to rectangular patch with smaller area [25]. The proposed antenna in this paper is designed with a compact rectangular slot and a Trapezoid feed structure at the anterior portion of the feed. The antenna is distinctive in its structure and it has simple design with less number of design parameters compared to the existing antennas in the literature [26-28]. The pattern obtained from the simulation is relatively stable across the matching band with an average gain of 4dBi. The simulation software used for this analysis is HFSS 14 [29]. The paper is organized as follows: Section II brings out the geometry of the antenna. In Section III simulation results and analysis are presented. Obtained experimental results are given in Section IV. Section V explains time domain analysis of the antenna. Section VI concludes the paper.

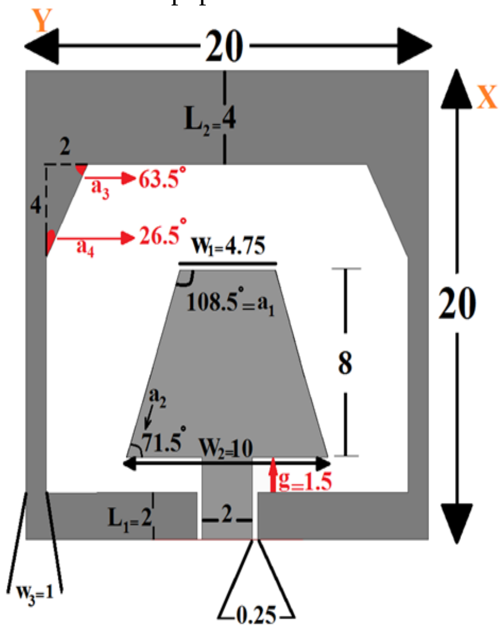

Figure 1. Geometry of the proposed CPW-fed Rectangular slot antenna

II. ANTENNA GEOMETRY

The structure of the antenna is shown in Figure 1. The CPW-fed slot antenna studied in this paper has a single layer copper metallic structure. The H=8mm is the height of the Trapezoid patch, g is the distance between the patch and feed line, W_1 and W_2 are the small and large width of the patch respectively. In this study, a dielectric substrate (FR4) with 1.6mm thickness and a relative permittivity of 4.4 is chosen, so that it can be easily integrated with Printed Circuit Board. The CPW feed is designed with fixed 2 mm feed line width and 0.25 mm. ground gap for 50 Ω characteristic impedance. By properly adjusting the dimension of the slot and feeding structure the impedance matching of the proposed antenna improves, which produces wider impedance bandwidth with satisfactory radiation pattern. The wide bandwidth and impedance matching with reduced size of the antenna is achieved by the different surface magnetic currents of the structure.

III. RESULTS AND ANALYSIS

In order to evaluate the performance of the proposed antenna, the antenna is simulated through the simulation tool HFSS. 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 parameters has been carried out by varying one parameter and keeping other parameters are constant. The designed values of the antenna are optimized with HFSS tool. The optimization was performed for the best impedance bandwidth. The comparison between simulated and measured return loss S11 of the proposed antenna is shown in Figure 2, which clearly indicates that the impedance bandwidth of the antenna is 9.2GHz (2.8GHz -12 GHz) for VSWR less than 2.

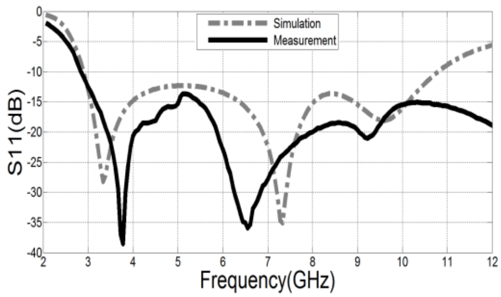

Figure 2. The comparison between simulated and measured return loss S_{11}

A.Effect of Feed gap

For fixed values of all other parameters, Figure 3 displays the simulated return loss for different feed gaps (g=0.3, 0.8, 1.5, and 2.1 mm). The response clearly shows that as the feed width increases the impedance matching becomes poor at the middle frequencies and the resonant frequencies moves to the lower side. If the feed gap decreases the impedance matching over the band becomes poor and there is a shift in the resonant frequency to the higher frequencies. Hence, feed width is one of the parameters which affect the impedance matching. It is found that the optimal value for this case is 1.5 mm.

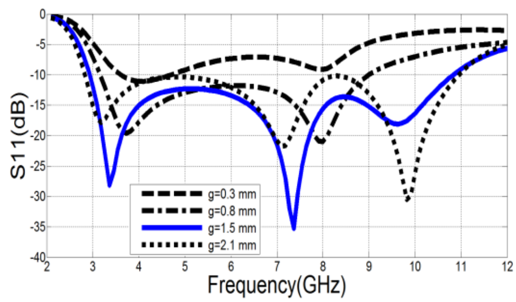

Figure 3. Simulated return loss curves for different feed gaps.

B.Effect of Trapezoid patch large side (W2)

The effect of bandwidth for different width W2 of the Trapezoid patch, depicted in Figure 4 which discloses the profiles of the impedance matching. While increasing the width W2 the return loss S11 decreases and there is a shift in the resonance frequency, which implies poor impedance matching. Similarly if the height W2 is decreased, there is a decrease in the return loss S11 and shift in the resonance frequency. Variation in the values of 'H' influences variation in the responses and the optimal value for this case is 10 mm.

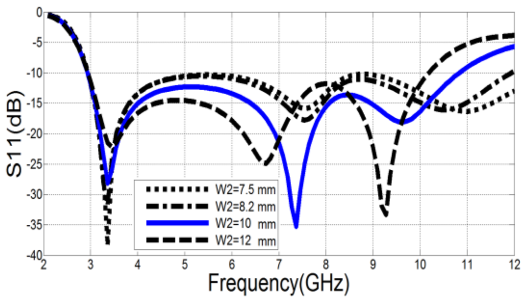

Figure 4. Simulated return losses for different Trapezoid patch width

C.Simulated Current Distribution

The current distributions of the proposed antenna are obtained by accounting the optimal design parameter values at frequencies 3.3, 6.5, 7.3 and 11GHz, which is shown in Figure 5. 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.

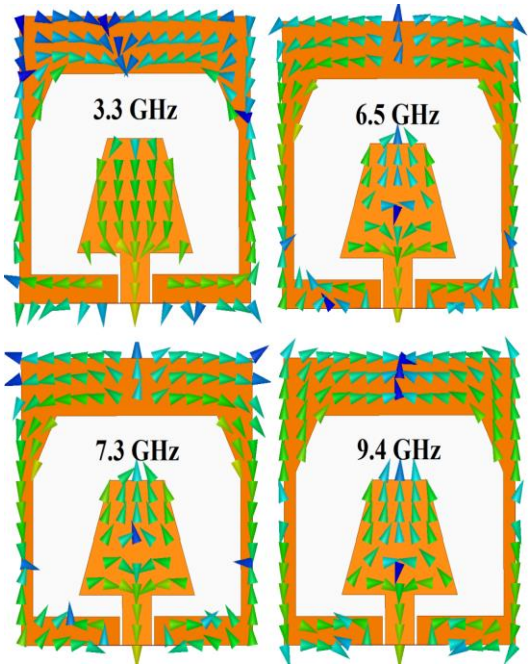

Figure 5. Current distributions

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The prototype of the proposed antenna shown in Figure 1 was fabricated for different parameters with their optimal values and tested that is depicted in Figure 7. Using Packard Network Analyzer (8722ES), the return loss and VSWR are measured and plotted. The schematic of the measurement setup is shown in Figure 2. There is a shift in the measured response at the low frequency, this discrepancy between the measured and the simulated one is due to the effect of soldering the SMA connector or fabrication tolerance. The simulation results were obtained by assuming coplanar input port, whereas practically SMA connector was used, the imperfect transition between SMA feed to coplanar may introduce losses [30-34] and the capacitances can lead to shift in the frequency. The soldering position of the feed point may also be reason for shift in the frequency [33-36]. The measured radiation pattern of the E plane and H plane are obtained at 3.2, 4.4, 6.5 and 9.8 GHz as shown in Figure 6. It is noticed that in H plane, the radiation pattern is omni directional and in E plane the radiation pattern is bidirectional. As the frequency increases there is a decrease in the gain due to low profile of the proposed antenna structure. Proper geometrical selection of the antenna results variations in field distribution, which in turn affects the characteristics of the proposed antenna.

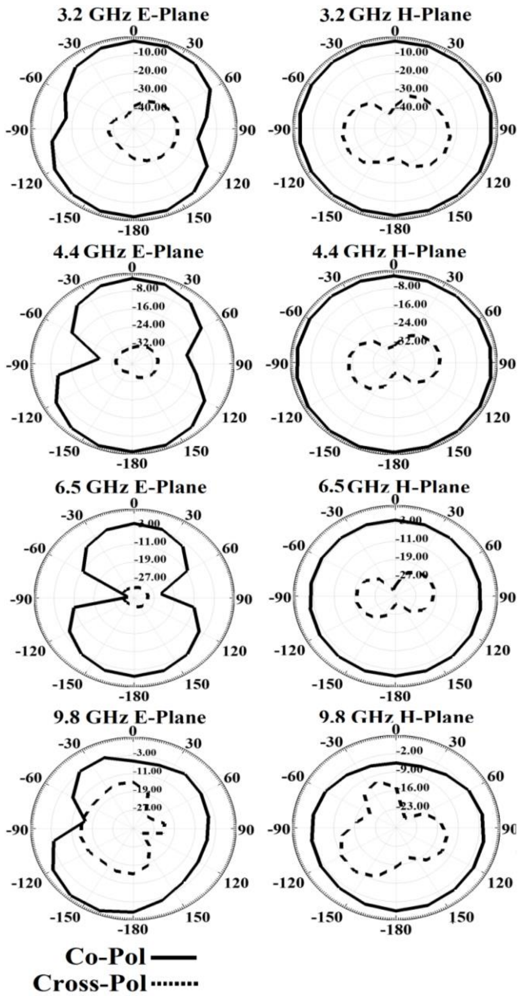

Figure 6. Measured Radiation pattern

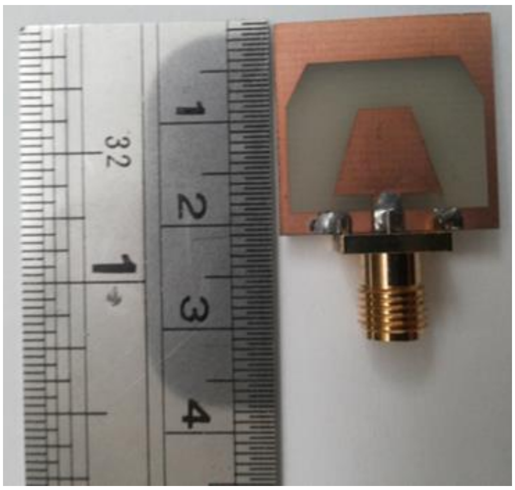

Figure 7. Fabricated antenna

V. TIME DOMAIN ANALYSIS

In ultra-wideband systems, the information is transmitted using short pulses. Hence it is important to study the temporal behavior of the transmitted pulse. The communication system for UWB pulse transmission must provide as minimum as possible distortion, spreading and disturbance. The channel is assumed to be linear time invariant (LTI) system to verify the capability of the proposed antenna for transmission and reception of these narrow pulses. The transfer function of the entire system is computed using simulated value of ‘S21’ parameter [32]. The received output pulse is obtained by taking the Inverse Fourier Transform (IFT) of the product of transfer function and spectrum of the test input pulse. While computing ‘S21’, two identical antennas are placed face to face at a distance of 100 cm that is greater than the far-field distance of the antenna. The cosine modulated Gaussian pulse is considered for this analysis with center frequency of 6.85 GHz and pulse width of 220 picoseconds, whose spectrum is shown in Figure 10. It satisfies the requirement of FCC mask for UWB indoor emission. The comparison of input and output responses of the system for the antenna with notch and without notch is shown in Figure 11, which ensures the distortion less pulse transmission and also guarantees that the designed antenna is capable of transmitting and receiving short pulses. The ringing effect in the waveform may be due to the transmission properties of the system.

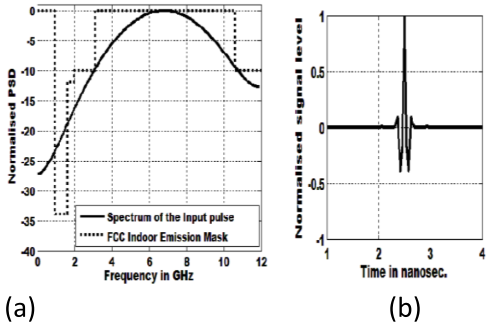

Figure 10. a) Spectrum of the test input pulse with FCC mask b) input pulse in time domain

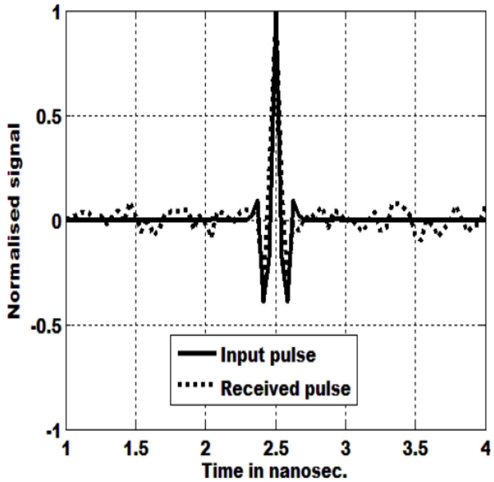

Figure 11. Comparison of input pulse and received pulse in time domain.

VI. CONCLUSION

In this paper, a simple antenna structure has been proposed for better impedance matching with small in size. A Trapezoid tuning stub is introduced at the anterior portion of the feed to enhance the coupling between the slot and the feed. With the above structural features the overall dimension of the proposed antenna is 21×20×1.6 mm3. It is observed that 124.32% of bandwidth can be achieved with better size reduction over the frequency range of 2.8 GHz to 12 GHz. The computed time domain analysis of the antenna also ensures the suitability of the antenna working in the UWB environment. Hence, this type of antenna can be used for UWB indoor applications.

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