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New Design of CPW-Fed Rectangular Slot Antenna for Ultra Wideband Applications

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Abstract: A printed rectangular slot antenna excited by a 50 Ω Co-Planar Waveguide with a triangular shaped tuning stub is proposed for UWB applications. The triangular shaped tuning stub is used to remove the high and low frequency limitations of UWB operation, improving the impedance matching. A prototype has been designed and fabricated and both the impedance bandwidth and radiation characteristics are experimentally studied. Experimental result shows that impedance bandwidth of 131% ($|S_{11}| < -10$ dB) is well achieved when the antenna is fed by a CPW feed with a triangular shaped tuning stub. The impedance bandwidth and radiation characteristics have also been investigated by using ADS simulation software. The measured and simulated results show excellent agreement.

Keywords: Slot Antenna, UWB Operation, Frequency Limitations, Triangular Stub

1. INTRODUCTION

The Federal Communication Commission [FCC] issued a ruling for UWB implementation in data communication [1].The UWB technology promotes the communication system particularly wireless multimedia system with high data rate. A UWB antenna should provide a gain and impedance bandwidth from 3.1 GHz to 10.6 GHz. For numerous applications, these antennas must be compact, low cost and must present Omni directional radiation pattern.

Recently, printed slot antennas have attracted much attention due to its low profile, light weight and ease of integration with monolithic microwave integrated circuits (MMIC).Various techniques [2-16] have been proposed to broaden the bandwidth of printed slot antennas and improve their performance. Accordingly, Slot antennas can be realized by using either micro strip line [2-6] or CPW feed line structure [6- 10].

A design of a micro strip line fed printed slot antenna with a fork-like tuning stub for bandwidth enhancement and suitable radiation has been studied in [3, 5].It covers UWB range. But, due to the introduction of micro strip line feed with a fork-like tuning stub, it leads to a complex structure. It will also result in misalignment problem. The alignment errors can be eliminated if a CPW feed is used to excite the slot [6, 8]. In [6], the micro strip line feed structure removes the high frequency resonance whereas the CPW feed structure removes the low frequency portion of UWB range. In [8], both low and high frequency portions are affected. These two studies could not cover the whole FCC defined UWB frequency band. The study [11] covers the entire UWB range. But, the circular structure with a tapered feed line and U shaped tuning stub needs more parameters which will make the structure more complex.

In this paper, another design for a CPW fed rectangular slot antenna which has a simple structure and less parameters, is proposed. In the design, a 50Ω CPW transmission line with a triangular shaped tuning stub that supports ultra wideband characteristics is presented. This structure improves the impedance bandwidth and covers the entire Ultra wideband of frequencies, removing the high and low frequency limitations of UWB range. The proposed antenna is with simple geometry. Parametric studies and radiation characteristics are also considered. Measured and simulated results of impedance bandwidth indicate good agreement between them.

2. ANTENNA STRUCTURE

Fig.1 shows the structure and dimensions of the proposed antenna which is printed on an inexpensive FR4 substrate with the dielectric constant of $\varepsilon_r = 4.3$ and the substrate thickness of $h = 1.5$ mm. This slot antenna has a simple structure with one layer of dielectric and metal.

Table 1
Geometrical Parameters of the Proposed Antenna

parameters	Lg	Wg	L	W	Lf	Wf	G	S	Ws	Ls
mm	42	46	17	26	17	2.8	0.5	1.8	9.0	8.2

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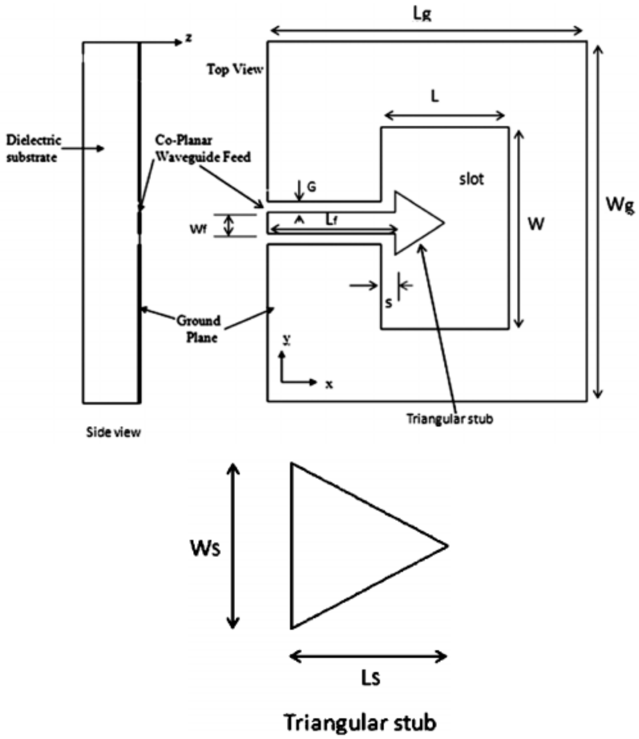


Figure 1: Geometry of the Proposed Antenna (Units in mm)

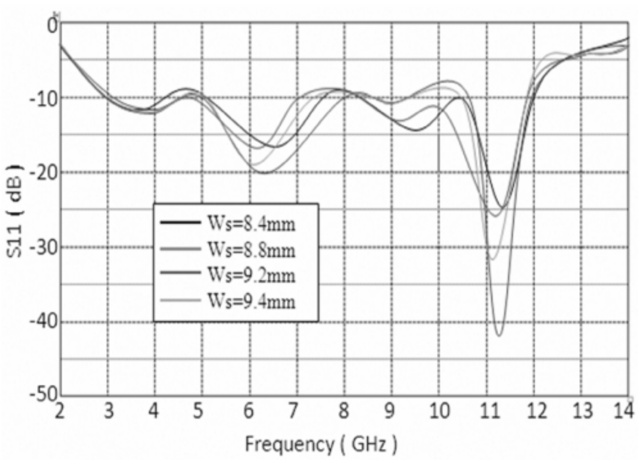


Figure 2: Effects of Parameter Ws

The antenna is excited by a 50Ω CPW feed with a triangular shaped tuning stub. The antenna slot has a length of L mm and width of W mm. The dimension of the dielectric substrate is Lg mm x Wg mm. The width and the length of the 50Ω CPW feed center strip is W_{fmm}, L_f mm respectively. G is the gap distance between the metal strip and the co-planar ground plane.

The triangular shaped tuning stub is used at the center of the slot to enhance the coupling between the slot and the feed line. Ws and Ls are the side on the feed side and the length of the tuning stub. The center strip of the CPW feed is protruded in to the slot up to the tuning stub. S is the spacing between the tuning stub and the ground plane, which is taken to be 1.8 mm for enhancing the coupling between the stub and the ground plane [7].

In fact, the parameters of the tuning stub Ws, Ls and the spacing S affect the broad band operation of the proposed antenna. By carefully adjusting the width Ws and length Ls, the high and low frequency limitations of UWB range are removed. Hence, the antenna operation will cover the entire UWB range of frequencies. A photograph of the proposed antenna is shown in figure 4.

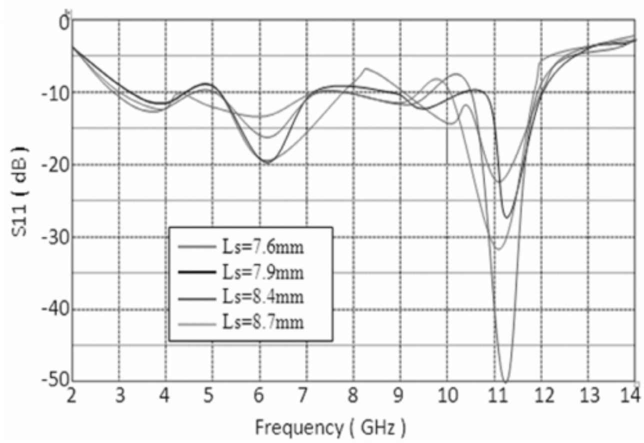


Figure 3: Effects of Parameter Ls

3. RESULT AND DISCUSSION

The UWB behavior of the antenna is well known by a parametric study. The antenna shape and dimensions were studied by using the momentum software package of the Advanced Design System [17], which is based on the method of moments. The measurement was carried out by using HP8722ES vector network analyzer.

In this case, the width Ws and length Ls of the triangular tuning stub are varied and the effect on the impedance matching is investigated. The simulated return loss curves of the CPW fed slot antenna for various values of Ws and Ls are illustrated in figures 2 and 3. From the figures it is seen that curves for different Ws and Ls have similar shape and variation trend. But, the optimal value is Ws = 9.0 mm and Ls = 8.2 mm (fig.6) which has been found after performing an optimization and identified in table 1.Because, it can provide the widest -10 dB bandwidth. The wide bandwidths are due to the resonances introduced by the combination of the rectangular slot and the triangular shaped tuning stub. It is clearly seen that owing to the configuration of the triangular shaped tuning stub, new resonant modes are excited. When proper dimensions (Ws and Ls) are selected, the resonant modes can be shifted close to the antenna's fundamental resonant mode, resulting in the removal of high and low frequency limitations of UWB operation. Thus it covers the entire UWB range of frequencies.

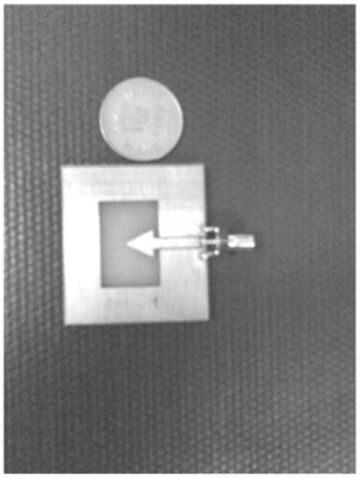


Figure 4: Photograph of the Antenna

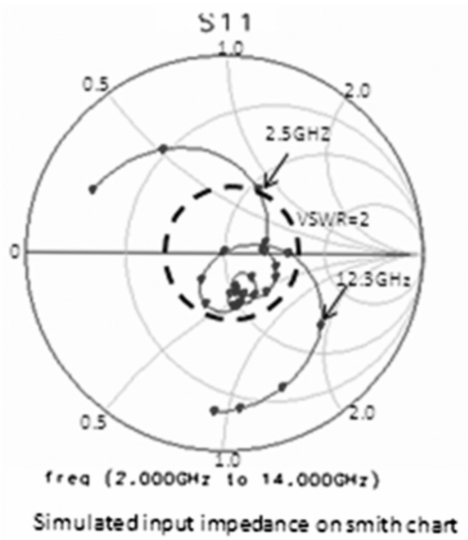


Figure 5: Simulated Input Impedance

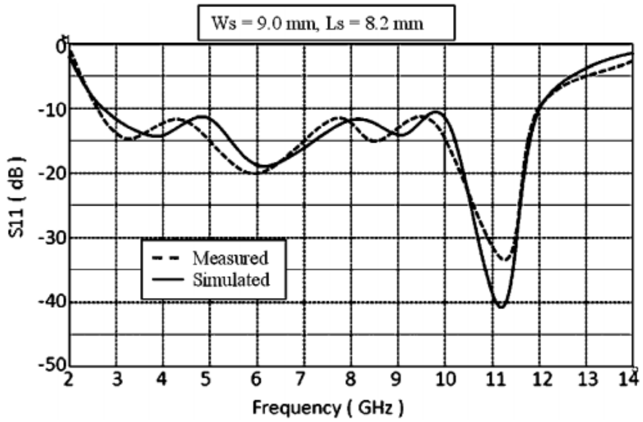
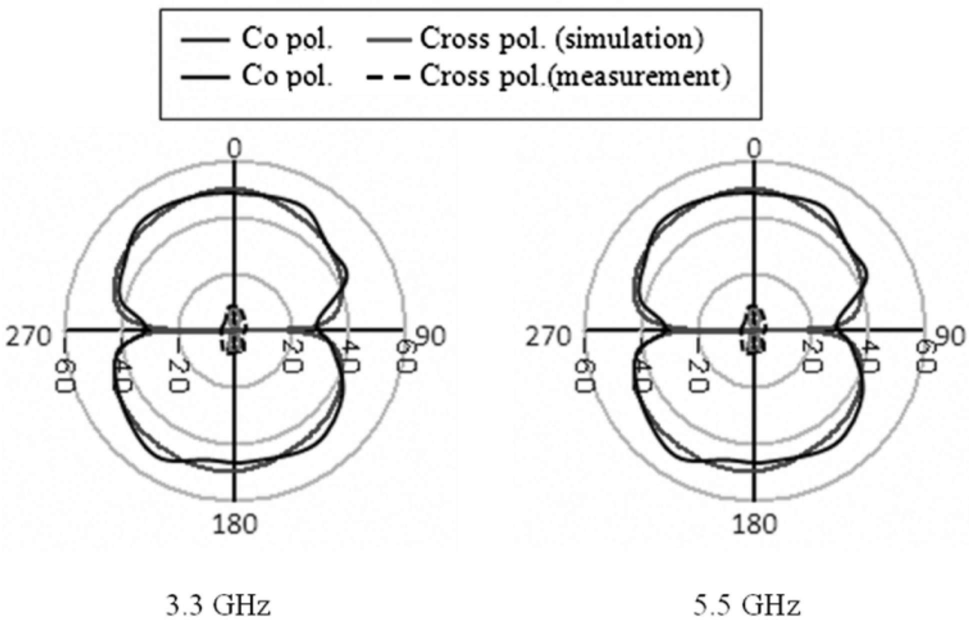


Figure 6: Measured and Simulated Return Loss Curves of the Proposed Antenna

From the results obtained, the antenna has a VSWR of lower than 2($|S_{11}| < -10$ dB) from 2.5 GHz to 12 GHz and the maximum impedance bandwidth is 131 % centered at about 7.25 GHz. With Ws = 9.0 mm and Ls = 8.2 mm, a prototype antenna is fabricated, simulated by ADS software and the return loss is measured (fig.6).

There is a good agreement in resonant frequencies between the simulations and measurement results. Radiation characteristics are also considered. Figures 7 and 8 show the measured and simulated E plane and H plane radiation patterns for both co-polarization and cross-polarization at 3.33GHz, 5.5GHz, 7.5GHz and 10.5 GHz respectively. From the results, it demonstrates that all the operating frequencies have the same polarization plane and similar radiation patterns throughout the UWB range of frequencies. The pattern is found to be figure of eight shape along the E plane and nearly Omni directional pattern in the H plane.



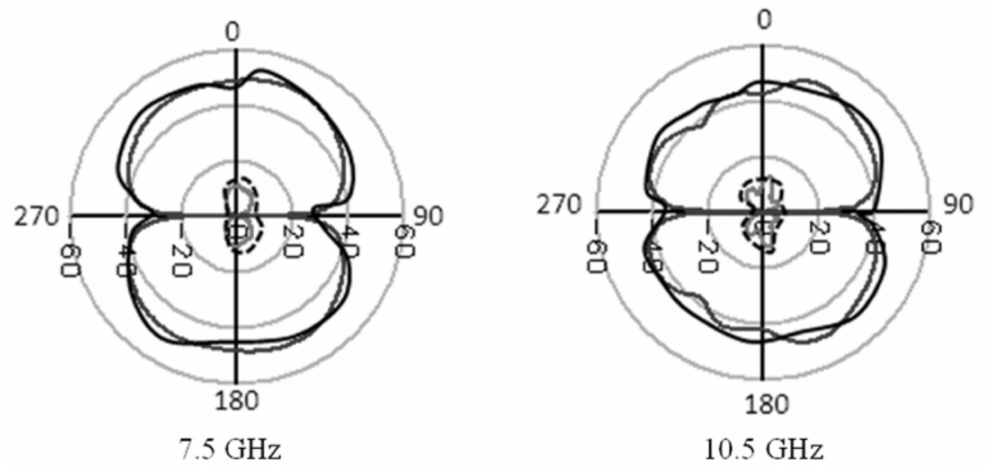


Figure 7: Simulated and Measured E Plane Radiation Patterns at 3.3, 5.5, 7.5 and 10.5 GHz

To use the antenna as a linear polarized antenna, the radiation pattern in the E plane is better than that in H plane. It is noted that H plane pattern shows relatively large cross-polarization than E plane pattern. This behavior is largely due to the strong horizontal components of the surface current and Electric field. Because, the vertical component of the surface current is the main contributor to the radiation and the horizontal component contributes to the cross-polarization.

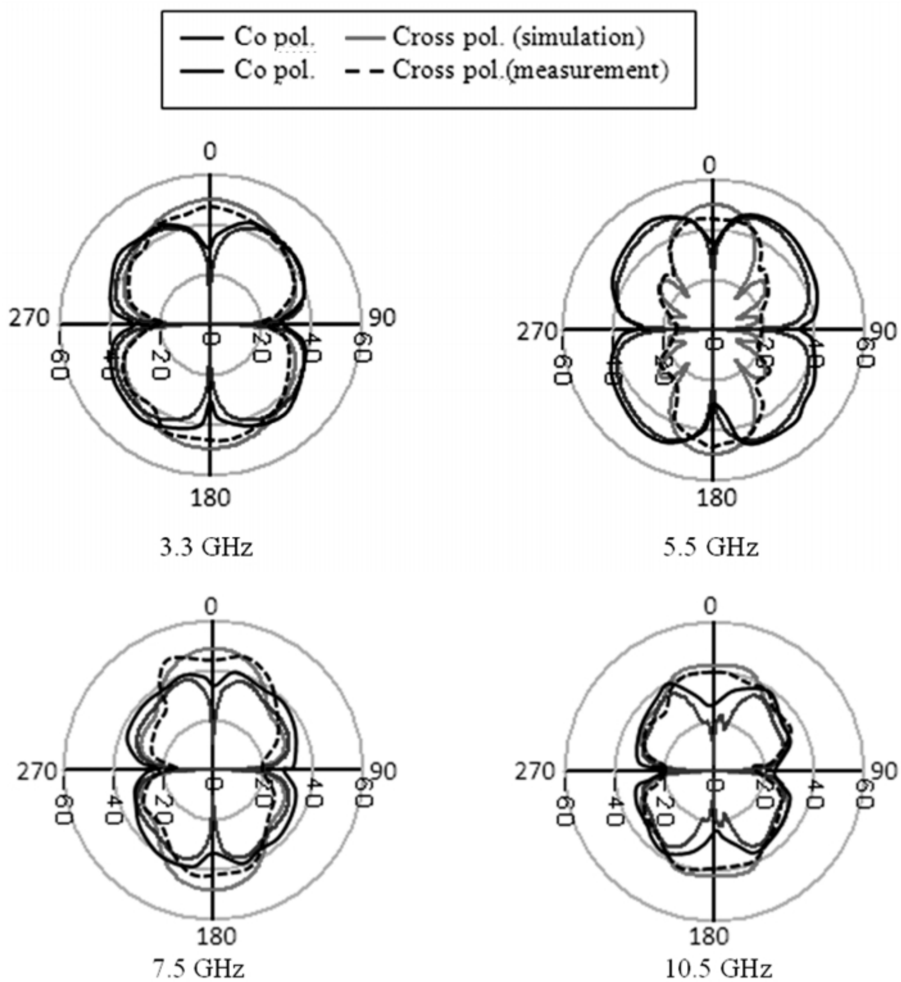


Figure 8: Simulated and Measured H Plane Radiation Patterns at 3.3, 5.5, 7.5 and 10.5 GHz.

Fig.9. shows the measured gain of the optimized antenna at broadside direction from 2.5 GHz to 12 GHz. The measured antenna gain throughout the operating bandwidth is within a range of 1.0-4.9 dBi and from 3.3 GHz, the gain is almost constant.

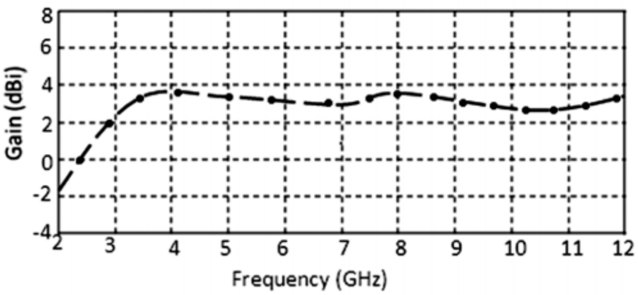


Figure 9: Measured Values of the Gain.

4. CONCLUSION

A new rectangular slot antenna fed by a 50Ω CPW for UWB applications was presented. Wide bandwidth of 131 % was achieved by using a triangular shaped tuning stub. The impedance bandwidth of VSWR lower than 2($|S_{11}| < -10$ dB) for the entire UWB range of frequency (3.1 GHz to 10.6 GHz) has been achieved with simple antenna structure. A Prototype antenna has been designed, simulated, optimized and measured for UWB operation. The novel antenna promotes impedance bandwidth and radiation pattern. The antenna structure offers constant radiation pattern and has a favorable field gain across the matching band as a desirable feature for UWB applications. The proposed antenna has a simple and effective feeding structure which is suitable for use in UWB applications.

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