DESIGN OF A T-SHAPED SLOT ANTENNA FOR UWB COMMUNICATIONS

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Abstract: This paper presents a design of T-shaped slot antenna for ultrawideband (UWB) communications. Multiple resonances are generated and unified to form a large bandwidth from 2.5 to 10.5 GHz for S11 < –10dB by constructing open ended modified T-shaped slot antenna and by extending a small section of the microstrip feed line. The simulated result shows that it has good radiation patterns and pulse handling capabilities within the band of interest.

Keywords: Ultrawideband, Microstrip feed, Group delay.

I. INTRODUCTION

Ultrawideband communication is fundamentally different from conventional narrowband wireless communication system as it employs extremely narrow RF pulses, with duration of few nanoseconds or less. Unlike conventional systems, UWB offers several advantages like large throughput, security, robustness to jamming and implementation simplicity. UWB has been widely used in applications like wireless personal area networks (WPAN) and wireless body area network (WBAN) are seen as the emerging fields which exploits UWB characteristics[1]-[4]. For these applications, an antenna which operates from 3.1 to 10.6 GHz needs to be in compact in size. Thus designing of UWB antennas becomes more challenging when compactness and performance are needed, for this printed planar antenna have been proposed [2]-[4].

Strip line slot antennas are proposed because of its wideband characteristics. To further reduce the size of UWB antenna, many designs are proposed which suggest that an open ended slot (i.e. either L shape or T shape) be embedded in a small ground plane [5]-[8]. The basic design approach to obtain ultra wideband characteristics is to generate multiple resonant and match them using appropriate technique.

In this paper we proposed a modified T-shape open ended antenna in the ground plane that is excited by a micro strip feed line. By inserting a small notch in left wing of "T" section improves the impedance matching around the lower resonant frequencies. Further by extending a small section to feed line improves impedance matching for middle and higher frequencies [9]-[10]. This paper is organized as follows. Section II describes the antenna architecture. Section III discusses the antenna design evolution. Section IV presents results and discussion. Section V concludes the paper.

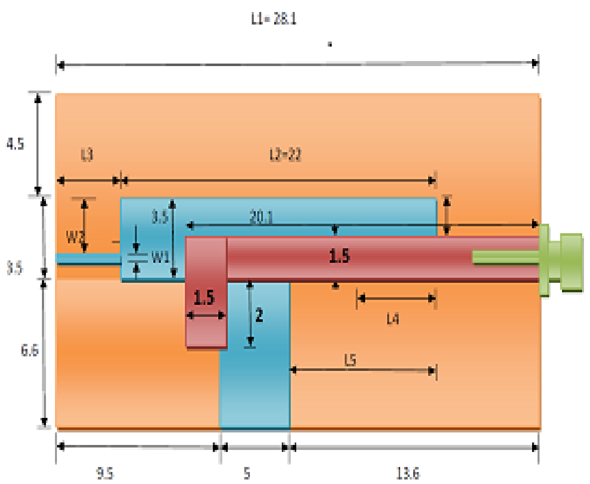

Figure. 1. Geometry of the proposed antenna.W1= 0.3, W2= 2, L1= 28.1, L2= 22, L3= 2.5, L4=2, L5= 7.6 (Unit: mm).

II. ANTENNA ARCHITECTURE AND DESIGN

Fig. 1 shows the geometry of modified T-shaped antenna. The antenna is fabricated on a thin FR4 substrate of thickness 0.8 mm with relative permittivity of 4.4 and loss tangent 0.2. The modified T-shape antenna has two individual open ended slots along horizontal vertical direction. The one along vertical direction has dimension of 6.6 mm x 5 mm and horizontal slot is designed with a

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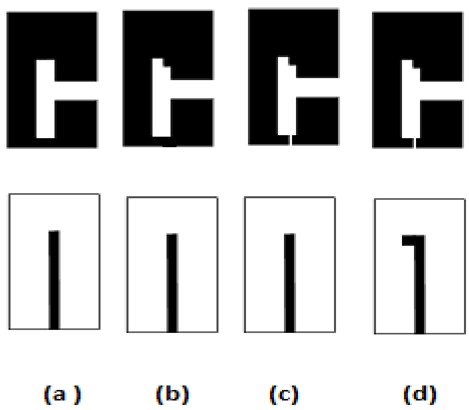

Figure. 2. Design evolution of an antenna.

unsymmetrical stair case as depicted in Fig. 1. A small notch with dimensions 2x1.5mm is embedded at the right bottom corner of the horizontal slot. On the other side of the ground plane, a micro strip feed with dimension 2x1.5mm and a small additional feed section is embedded in such way that entire feeding section appears like "L" shape.

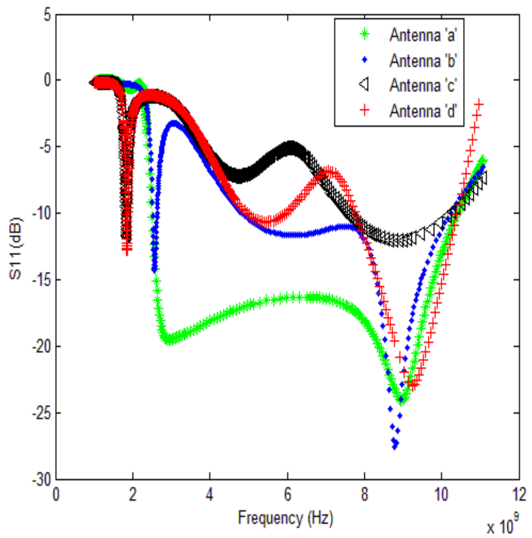

Figure. 3. Return losses of antennas.

Table 1. Resonant Frequencies as Function of Antenna Parameters.

(SIGN : --- SMALL OR NO VARIATION)

	F1	f_2	f
L1	—	↑	↓
L2	↑	↑	↓
L3	↑	↑	↓
L4	—	↑	↑
L5	—	↓	↓
W1	—	↑	↓
W2	—	—	↓

Further analyzing the antenna parameters on resonant frequencies of proposed antenna, we found that W1, W2, L4 are crucial for obtaining wider bandwidth. Table I provides information about how resonant frequencies are dependent on antenna parameters. From the above table, it is realized that increase in the parameter L4 (arrow sign pointing up) will shift resonant frequencies f_2 and f_3 towards right side of frequency axis, which is shown in the table by pointing the arrow upward direction. Similar for all other parameters are mentioned in the table for conciseness. There are two interesting cases, which are not discussed in the table, they are when the narrow opening which is located at left wing of 'T' is completely closed (i.e. it appears like one side open ended) and when narrow opening is completely opened (i.e. it appears like two sided open ended). In former case, first resonant frequency f_1 shifted towards right side of frequency axis to 3.55 GHz and return loss S_{11} is depicted in the Fig. 4. and in the later case, first resonant frequency f_1 shifted towards right side of frequency axis to 3.68GHz and return loss S_{11} is depicted in the Fig. 5. By making small opening in left wing of 'T', we observed that there is significant improvement in lower frequencies which will shift resonant frequency f_1 to left side of frequency axis to 2.5GHz. `.

III. ANTENNA DESIGN EVOLUTION

Design evolution of proposed antenna is shown in Fig. 2(a)-2(d) and their respective simulated return loss diagram are shown in Fig. 3. A similar design is proposed in [5]-[8] which suggest that choosing either "L" shape or "T" shape open ended ground plane enhances the bandwidth. The design in Fig. 2(a) exhibits single band behavior with resonance frequency at 8.8GHz. From the Fig.3 the resonance at 4.1GHz is mismatched for the design in Fig. 2(a). After simulations on various parameters, it is found that when the notch is inserted in ground plane, the improved design Fig. 2(b) exhibits dual band behavior whose lower and upper bands ranges from 4.95-5.95 GHz and 8-10.5 GHz, mismatch around 3GHz and 7GHz. Further simulation on various parameters, it is found that by making small slot along horizontal direction as depicted in Fig. 2(c) this design exhibits matching from 4.9-10.2 GHz while there is mismatch at lower frequencies. Finally resonances in lower frequencies can be matched by inserting a small rectangular notch with dimensions at the end of the feed section in the form of "L" shape as shown in Fig .2(d).

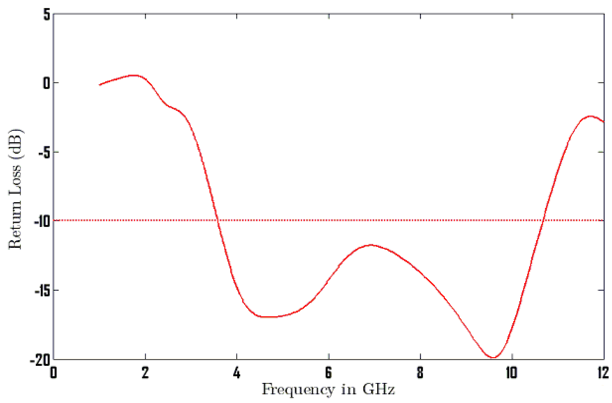

Figure 4. Return losses of one side open ended 'T' shape antenna.

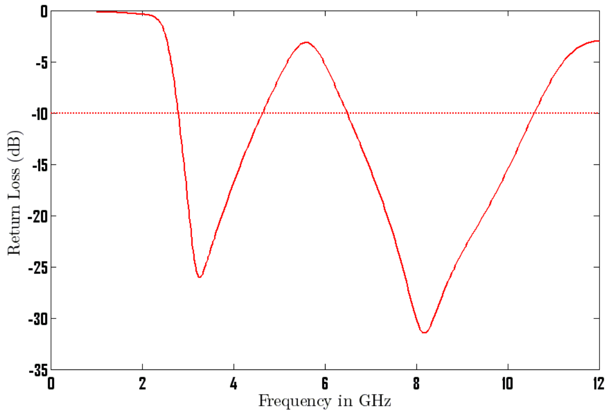

Figure 5. Return losses of two side open ended 'T' shape antenna.

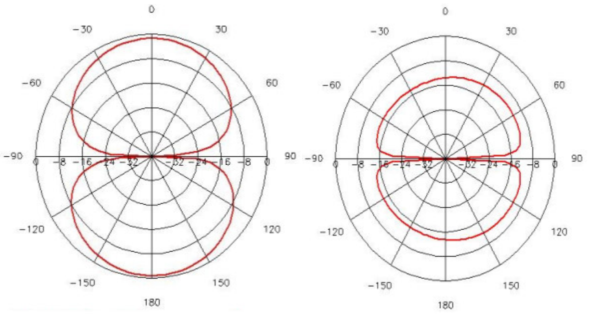

Figure 6. Copolarization and Cross Polarization pattern of antenna at 3.75 GHz in $\varphi=90^0$.

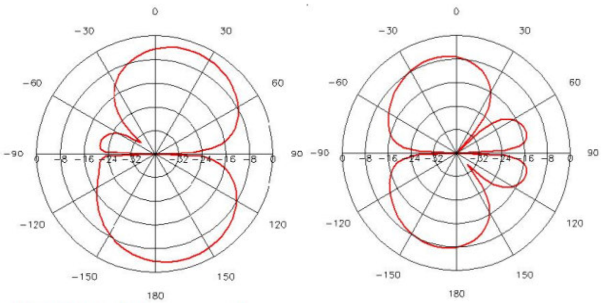

Figure 7. Copolarization and Cross Polarization pattern of antenna at 6.5 GHz in $\varphi=90^0$.

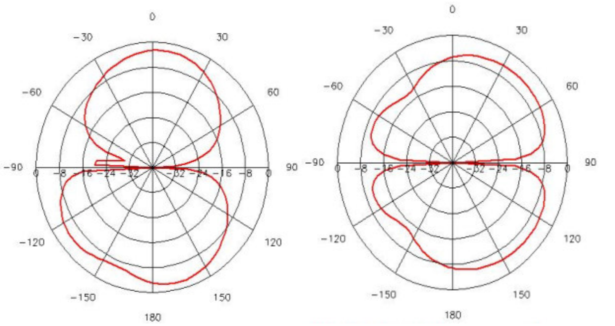

Figure 8. Copolarization and Cross Polarization pattern of antenna at 9.25 GHz in $\varphi=90^0$.

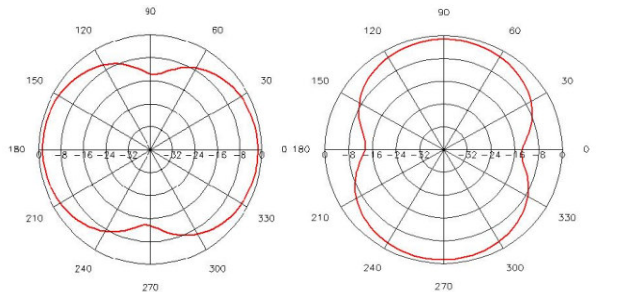

Figure 9. Copolarization and Cross Polarization pattern of antenna at 3.75 GHz in $\theta=90^0$

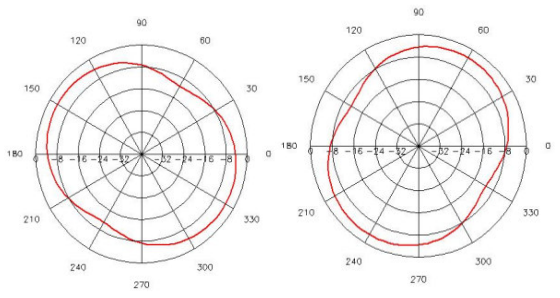

Figure 10. Copolarization and Cross Polarization pattern of antenna at 6.5 GHz in θ=90^0

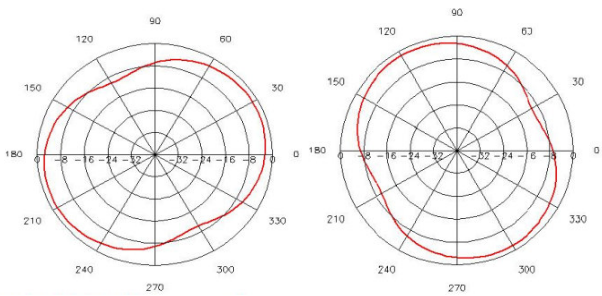

Figure 11. Copolarization and Cross Polarization pattern of antenna at 9.25 GHz in θ=90^0

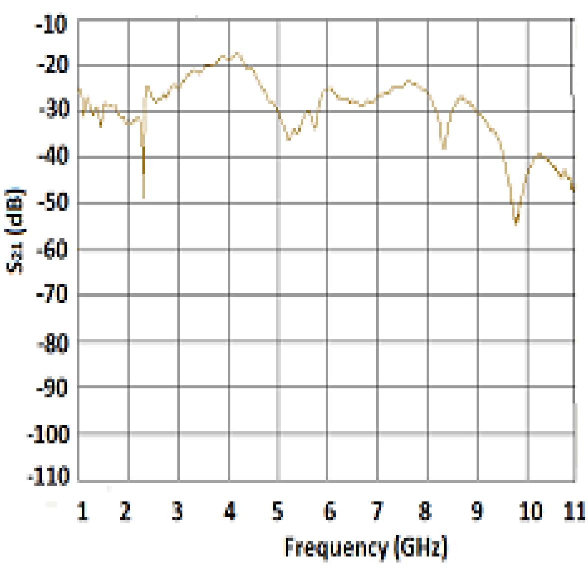

Figure 12. Measured S_{21} of proposed antenna when antennas are placed face to face.

IV. RESULTS AND DISCUSSION

The measured radiation pattern of the antenna in the φ=90^0 and θ=90^0 planes for the 3.75GHz, 6.5GHz and 9.25GHz frequencies are shown in Fig. 6 to Fig. 11. For θ=90^0 plane, approximately Omni directional pattern at co polarization for all frequencies are observed and for θ=90^0 plane, cross polarization pattern almost appears to be Omni directional. On the other hand for φ=90^0 plane, approximately eight shape is observed at co polarization and for φ=90^0 plane, cross polarization pattern distorted version of eight.

In order to achieve distortionless transmission for the UWB systems, it is necessary for antenna to maintain constant group delay. A linear phase is required for constant group delay, since group delay is derivative of unwrapped phase. In order to find group delay we require the knowledge of y(t) and x(t), where x(t) is the input pulse waveform (i.e. it may be Gaussian or rectangular pulse) and y(t) the received pulse waveform is the convolution of h(t) and x(t). Where h(t) is the inverse Fourier transform of H(ω). We can determine antenna transfer function from below formula, given in [10].

$$H(\omega) = \sqrt{\{(2\pi R C S_{21} e^{j\omega R/C})/(j\omega)\}} \quad (1)$$

Where 'C' is the free space velocity and 'R' is the distance between two antennas. Simulated value of S_{21} is as shown in fig. 10. By using (1), we found that group delay is less than 2ns, which ensures reliable communication without any significant pulse distortion.

V. CONCLUSION

A compact T-shaped slot antenna is proposed for UWB communications. This structure offers a stable radiation patterns, good time domain behavior with delay less than 2ns and wider bandwidth from 2.5-10.5 GHz. This antenna can be easily fabricated on commercially available FR4 substrate and well suited for UWB applications.

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