Cross Slot Antenna with U-Shaped Tuning Stub for Ultra Wideband Applications

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Abstract – A novel design of an Ultra Wideband (UWB) slot antenna is presented. This antenna operates as a transmitter and receiver antenna. Effects of the antenna dimensional parameters are studied through experimental and simulation results. Design procedures are developed and verified for different frequency bands. The experimental and simulation results exhibit good impedance bandwidth, radiation pattern and relatively stable gain over the entire band of frequency. Antenna gain and directivity at boresight and in their maximum states are close to each other and indicate high radiation efficiency. To use the antenna as a linearly polarized antenna, the radiation pattern in E-plane is better than that in H-plane.

I. INTRODUCTION

The Federal Communication Commission (FCC) issued a ruling for ultra-wideband (UWB) implementation in data communication [1]. A UWB technology promotes communication system, particularly in wireless multimedia system with high data rate. According to FCC, a UWB antenna should provide a gain and impedance bandwidth from 3.1 GHz to 10.6 GHz. A microstrip slot antenna may be a good choice as it is low profile, low cost, lightweight, easy integration with monolithic microwave integrated circuits (MMICs). Feed interactions of wideband slot antennas are analyzed using finite element -optimization methods and effects of feeding mechanisms on dimensions of slots have been discussed in [2]. Several methods have been proposed to increase the bandwidth of microstrip-fed slot or cavity-backed slot antenna, such as printed radial stub [3]. A printed wide-slot antenna is fed by a microstrip line with a fork-like tuning stub for bandwidth enhancement [4]. A design of a microstrip-line-fed printed wide-slot antenna had been studied in [5]. An ultra-wideband coplanar waveguide (CPW) fed slot antenna was excited by a 50-Ω CPW with a U-shaped tuning stub [6]. Experimental investigations on a wideband slot antenna element have been proposed [7] as a building block for designing single- or multi-element wideband or dual-band slot antennas. This element shows bandwidth values up to 37%, if used in the wideband mode.

A circular slot antenna is fed by a circular open-ended microstrip line to provide UWB impedance bandwidth [8]. Also an ultra-wideband square-ring slot antenna (SRSA) has been proposed which is fed by a microstrip line with a U-shaped tuning stub [9]. However, the SRSA is split inside the U-shaped feed, so it is called split square-ring slot antenna (SSRSA). A printed rectangular slot antenna with a U-shaped tuning stub is backed with reflector for improvement in the impedance bandwidth and unidirectional radiation patterns [10].

In this paper, we propose a novel structure that is driven by wide-slot antenna and merged by a cross- slot for improvement in gain and impedance bandwidth. The measurement and simulation results of the impedance bandwidth are in good agreement with each other.

II. ANTENNA STRUCTURE

Figure 1 shows the proposed printed slot antenna. The antenna structure is a split square ring slot in the ground plane of dielectric substrate with a cross slot in center of square ring. This structure is fed by a single microstrip line with a U- shaped tuning stub. The slot antenna is fed near an edge by a microstrip line and a fictitious short circuit that produces more resonant frequencies [7].

The SSRSA can be considered as a combination of numerous of narrow slot radiators which are connected to each other, so it can provide a couple of resonances at different frequencies. The split in one arm actually increases the number of resonances by introducing new resonant lengths. The cross slot is located in center of the square ring. Actually it can resonate more than resonant frequencies of square ring slot and this improves the impedance matching rather than [9]. This structure is fabricated on a 0.5mm RO4003B substrate with a dielectric constant equal to 3.4. Photograph of the proposed antenna is shown in Fig. 2. The antenna includes a microstrip feed line with the U-shaped tuning stub. By splitting the square ring slot antenna (SRSA) and optimization of the feeding network, the required impedance bandwidth is achieved over the UWB frequency range (3.1 to 10.6 GHz).The ground plane size is $Lg \times Wg$ =100mm × 100mm.

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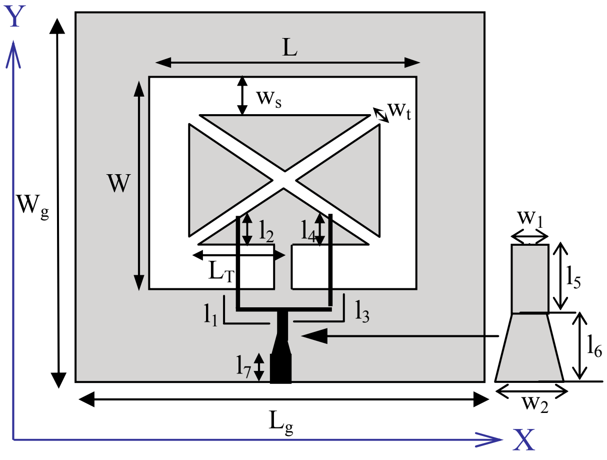


Fig. 1. Configuration of the proposed antenna.

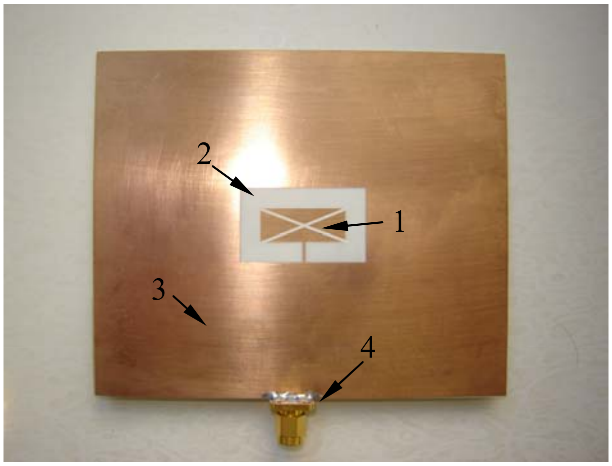


Fig. 2. Photograph of the antenna, (1) Cross slot, (2) square slot, (3) Ground plane, and (4) Input port connected to microstrip line.

III. RESULTS AND DISCUSSIONS

Effect of L_T variations on the return loss of antenna, which has been evaluated by IE3D software [11], is shown in Fig. 3.

The longer the L_T, the better the impedance matching, for the coupling between the square ring and the cross-slot.

It is obvious the upper resonances are created by off-center microstrip feed [7].

The U-shaped tuning stub is employed for wideband performance. The impedance matching of the proposed antenna is unfavorable when the L_T is less than 13mm. The prototype antenna was simulated by IE3D software and fabricated with L_T= 13mm and W_t= 1mm. The simulation and measurement results are shown in Fig. 4.

The resonant frequencies of the simulation and measurement results are in good agreement within the matching frequency band 3 GHz to 12 GHz, which corresponds to the impedance bandwidth (S_{11}<-10 dB). This structure is more compact than [8]. The antenna provides a VSWR lower than 2 (S_{11}<-10dB) from 3 GHz to 12 GHz.

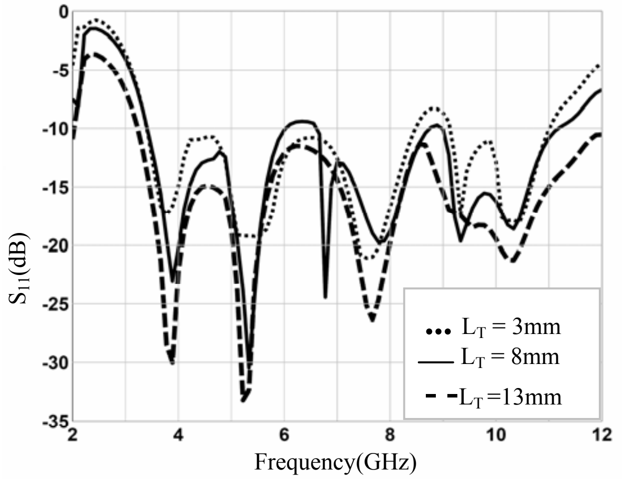


Fig. 3. Effect of L_T changes on return loss. L_T is distance between the center of the cross slot and the square ring .

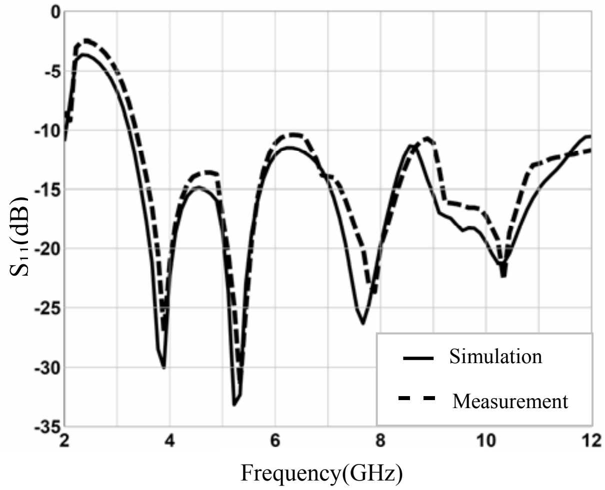


Fig. 4. Measured and simulated return loss of the proposed antenna.

The parameter dimensions are obtained after performing an optimization and identified in Table1. These dimensions were obtained by performing an optimization for improving the impedance bandwidth by ADS software [12]. Figure 5 shows the gain of optimized antenna at broadside (φ=0, θ=0) from 2 GHz to 12GHz. The directivity at the direction of maximum radiation is shown in this figure. The antenna gain and directivity at boresight and in their maximum states are close to each other and indicate high radiation efficiency.

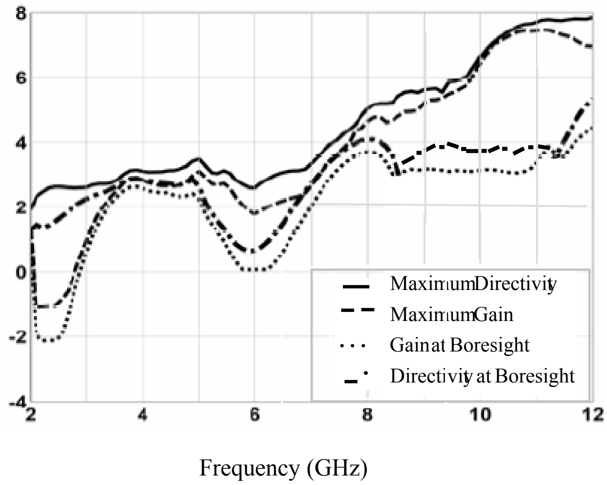


Fig. 5. Simulated values of gain and values of directivity (dBi).

Figure 5 also shows that above 10.5 GHz the directivity and gain at boresight increase and it is a reason for this: each slot of the cross slot is a branch of the square ring. These branches have the W_t= 1mm and this is less than W_S= 6mm. This causes high current distribution flows to the cross-slot rather than square-ring slot and the gain increases at boresight above the 10.5 GHz. So the combination of the cross-slot and square ring slot improves the gain and directivity more than [9]. Figure 6 shows the measured maximum gain and gain at boresight.

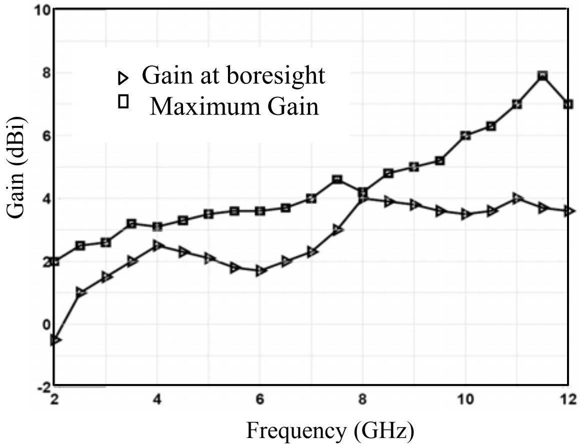


Fig. 6. Measured values of the gain.

This figure shows the gain at boresight is more than 2dBi and is relatively constant from 8 to12 GHz. The electric field distribution on the square-ring and cross-slot for proposed antenna was simulated with the IE3D simulation software. Figure 7 shows the electric field distribution on the slots.

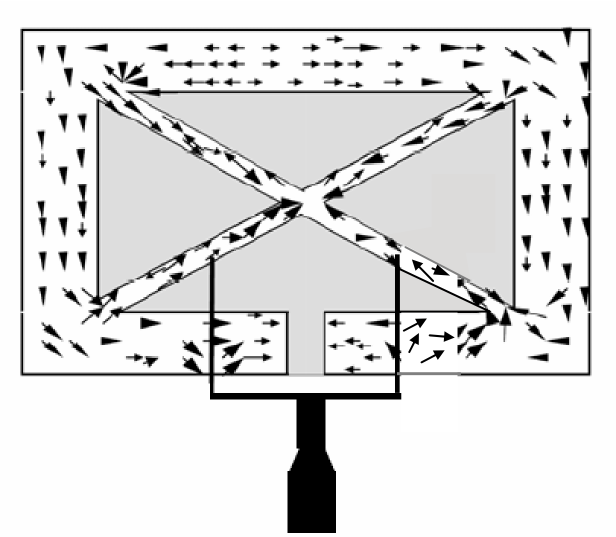


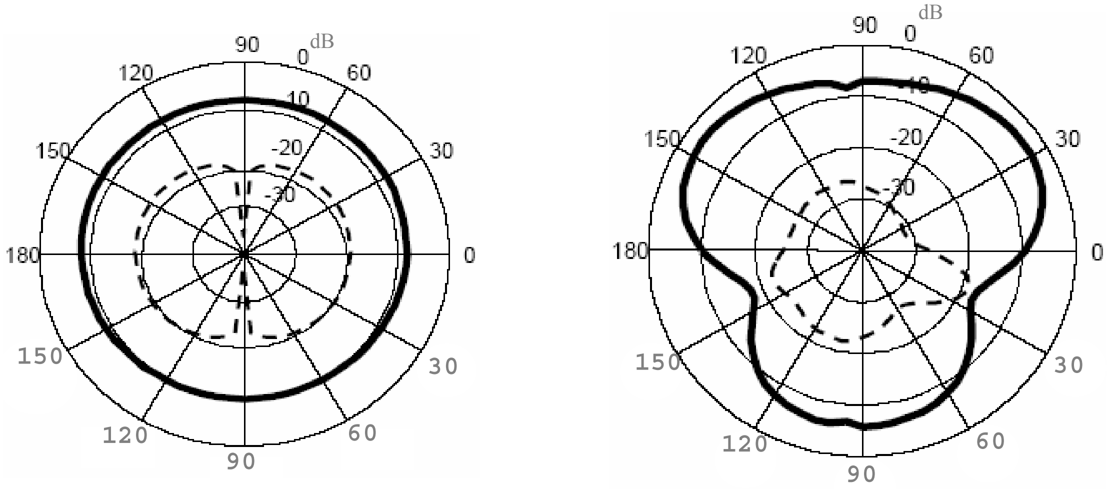
Fig. 7. Simulated electric field distribution on the slots at the frequency of 10 GHz.

Figures 8 and 9 show the measured H-plane (xz plane) and E-plane (yz plane) radiation patterns for both co- and cross-polarizations at f = 3.5, 5.5, 7.5 , 9.5 and 10.5 GHz . From the results, it is concluded that the proposed antenna in operating frequencies provides the same polarization planes and similar radiation patterns.

To use the antenna as a linearly polarized antenna, the radiation pattern in the E-plane is better than H-plane. The E and H plane patterns start to introduce spurious radiation in high frequency (i.e, from 8.5 GHz) because the U-shaped stub length is almost equal to a half wavelength. However, the radiation patterns start to change in high frequencies and show higher directivities in other directions. In the E-plane, the cross-polar radiation is at least -10 dB less than the co-polar radiation.

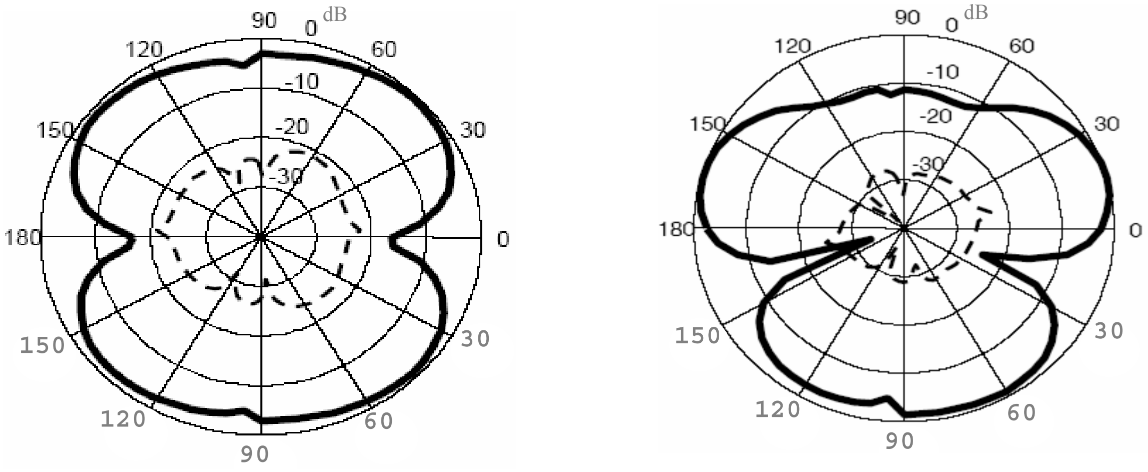
Table 1. The dimensions of proposed antenna.

Parameter	W	W_s	W_1	W_2	W_t	L	l_1	l_2	l_3	l_4	l_5	l_6	l_7	L_T
Magnitude (mm)	21	6	0.7	13	1	35	14.3	3	14	4.1	0.6	1.8	30	13



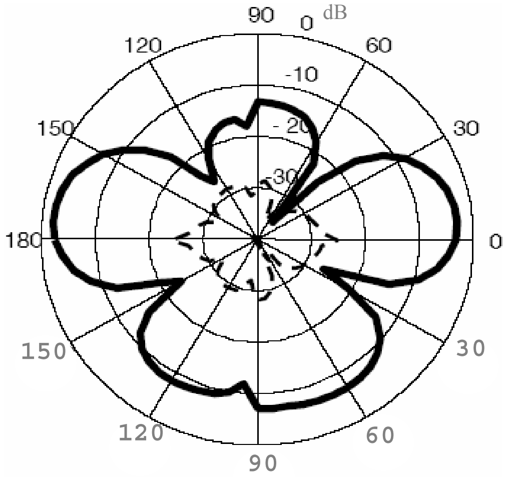
3.5 GHz

5.5 GHz



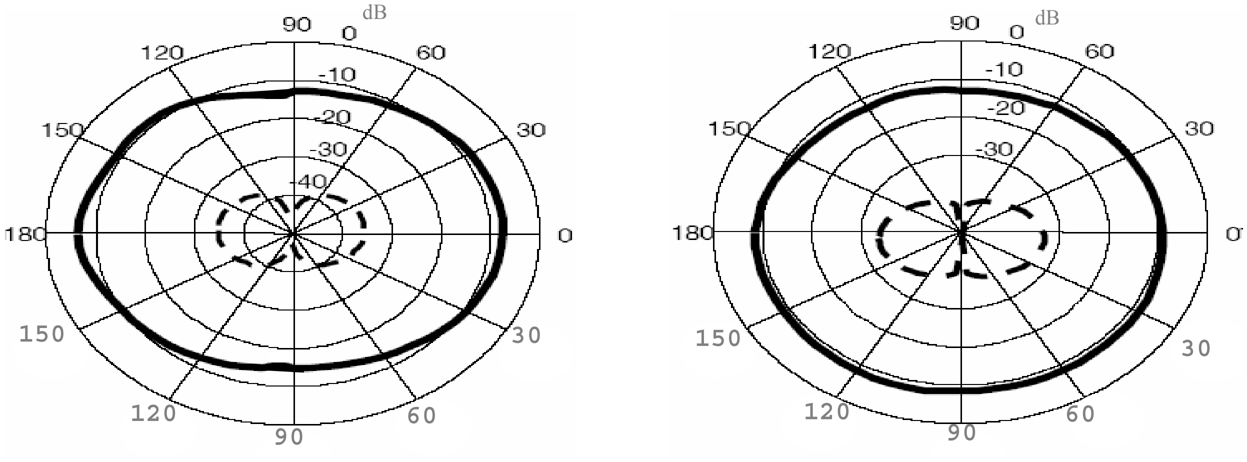
7.5 GHz

9.5 GHz

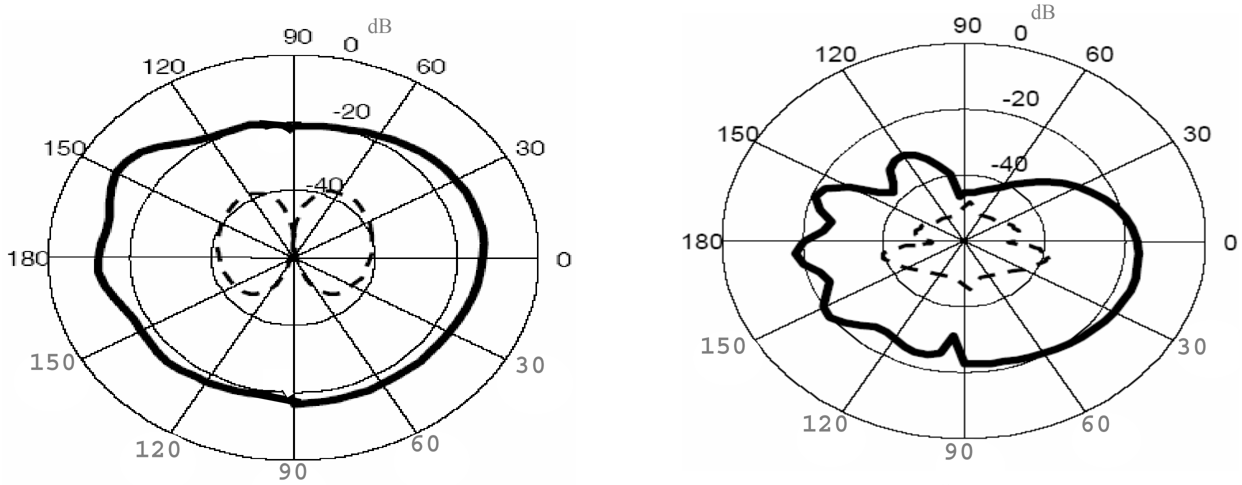


10.5 GHz

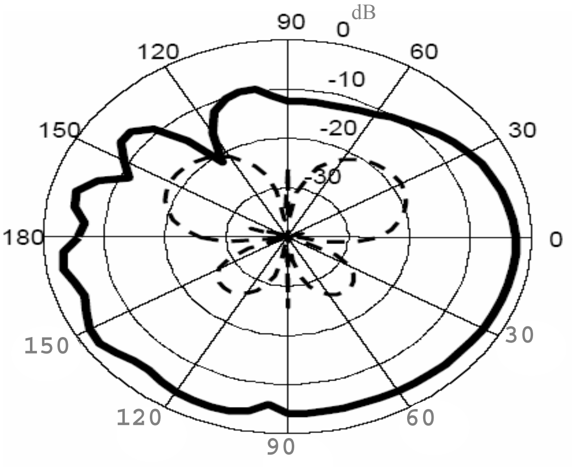
Fig. 8. Measured radiation pattern of cross slot antenna in H-plane ($\varphi = 0^\circ$). The solid line is co-polar and the dash line is cross-polar component.



5.5 GHz 3.5 GHz



7.5 GHz 9.5 GHz



10.5 GHz

Fig. 9. Measured radiation pattern of cross slot antenna in E-plane ($\varphi = 90^\circ$). The solid line is co-polar and the dash line is cross-polar component.

IV. CONCLUSIONS

A novel microstrip square ring slot is merged with cross-slot and fed with a U- shaped tuning stub. The proposed antenna has been designed, simulated, optimized and measured for the broadband operation. The novel antenna promotes gain, impedance bandwidth, and radiation pattern. The proposed antenna provides a good impedance matching from 3 GHz to 12 GHz. This antenna has a favorable field gain across the matching band as a desirable feature for UWB applications. The gain and directivity at boresight are close to each other and provide high radiation efficiency.

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