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A Novel J Slot Antenna for UWB WiMedia

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Abstract

A novel J shaped slot antenna for ultra-wide band (UWB) WiMedia is presented. The proposed antenna is designed using a microstrip to slot line cross transition on FR4 substrate with permittivity 4.4. Return loss of the antenna is from 2.8- 13 GHz and occupies just 28x10 mm^2 on the PCB. Radiation patterns are stable and omni-directional. Antenna transfer function and impulse response are analyzed to study the pulse handling capability of the antenna.

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Keywords: UWB; microstrip to slot line transition; printed antennas; small antennas

1. Introduction

Compared to traditional carrier based systems, Ultra Wide Band (UWB), the carrier less way of communication, jointly uses excess bandwidth and very low transmitted power to provide a reliable radio link. Large bandwidth enables very fine time-space resolution for accurate location of the UWB nodes as well as high data rate communication, use of very short pulses aid in combating multipath fading and use of low power density leads to low probability of signal detection as well as coexistence with existing narrow band systems.

In the emerging UWB application known as WiMedia, compact, radiation efficient printed antennas are desired. The present paper discusses the design and performance of a slot antenna intended for WiMedia systems. In slot antennas, the transverse electric field constricted between a short ended slotline is transformed to free waves at the open end. Typically, a microstrip-to-slot line cross transition is used to excite the antenna. Bandwidth limitation of the crossjunction transition results mainly from the frequency dependance of the slot reactance and microstrip reactance [1]. In [2], a tapered slot antenna with such an arrangement is proposed that operates in the lower UWB. In this design, the mictrostrip feed extends beyond the slotline to create a virtual short to minimize internal reflections in the transmission

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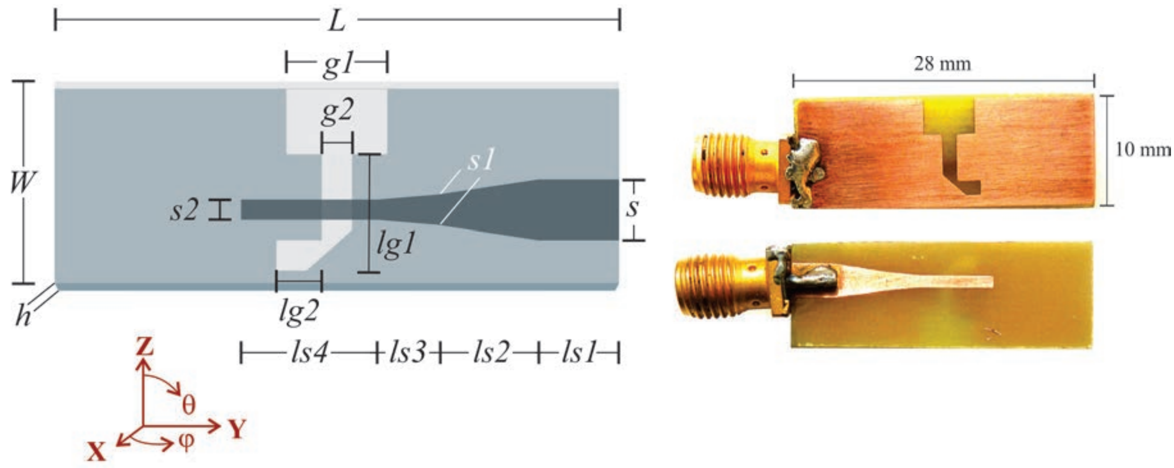

Fig. 1: Configuration of the proposed antenna.

line. Alternately, the microstrip line can be terminated in a stub as in[3] to realize ultra-wide bandwidth. The tapered slot antenna proposed in[4] has a novel design idea that combines electric and magnetic resonances in the geometry to realize operation in the full UWB. Novel design techniques to realize ultra wide bandwidth in slot antennas by modifying the microstrip feed at the cross-junction is proposed in[5] and[6]. These antennas, in addition, have compact dimension and onmi directional radiation that aid their use in commercial handheld devices. In this work, we have attempted to reduce the overall PCB area still further, without making any compromise on the radiation characteristics of the antenna. The antenna operates in the 3.1-10.6 GHz UWB with omni directional radiation that is constant throughout the entire UWB.

2. Evolution of the proposed antenna

The design idea of the antenna proposed in this paper is from[5,6] where microstrip to slotline cross transitions are suitable designed to minimize internal reflections in the antenna geometry and result in UWB. It is also observed that small element antennas are good candidates for UWB as their radiation patterns remain almost omni-directional even at higher frequencies. In these antennas, surface currents at different parts of the geometry are in phase and generate constant radiation patterns. In the present work, the authors have combined these aspects and designed an ultra-wide band antenna that occupies very small area in the printed circuit board, with constant radiation pattern over the entire bandwidth. Design of the antenna is shown in Fig. 1.

It is evolved from a simple microstrip to slot line transition as shown in Fig. 2(a). To achieve a broad band impedance matching better than -10dB, the microstrip feed is first tapered at the transition region (Fig. 2(b)). An additional step cut introduced at the end of the open slot further transforms the guide impedance to free space impedance as shown in Fig. 2(c). Size of the antenna can further be minimized by folding the shorted end of the slot line as indicated in Fig. 2(d). Impedance mismatches resulting from the folding is minimized by meandering the slot line as in Fig. 2(e). Simulations indicate that the resulting impedance bandwidth of the antenna is from 2.8 13 GHz.

3. Antenna design and performance

Geometrical parameters of the antenna (in mm) when designed on FR4 glass epoxy with relative permittivity ϵ_r = 4.4 and height h = 1.6 mm are: $s = 3$, $s_1 = 1.5$, $s_2 = 1$, $g_1 = 5$, $l_{s1} = 4$, $l_{s2} = 5$, $l_{s3} = 5$, $l_{s4} = 4$, $g_2 = 1.5$, $l_{g1} = 5.75$, $l_{g2} = 2.25$, $L = 28$, $W = 10$. Measured return loss of the antenna shows close correspondence with simulation as indicated in Fig. 3.

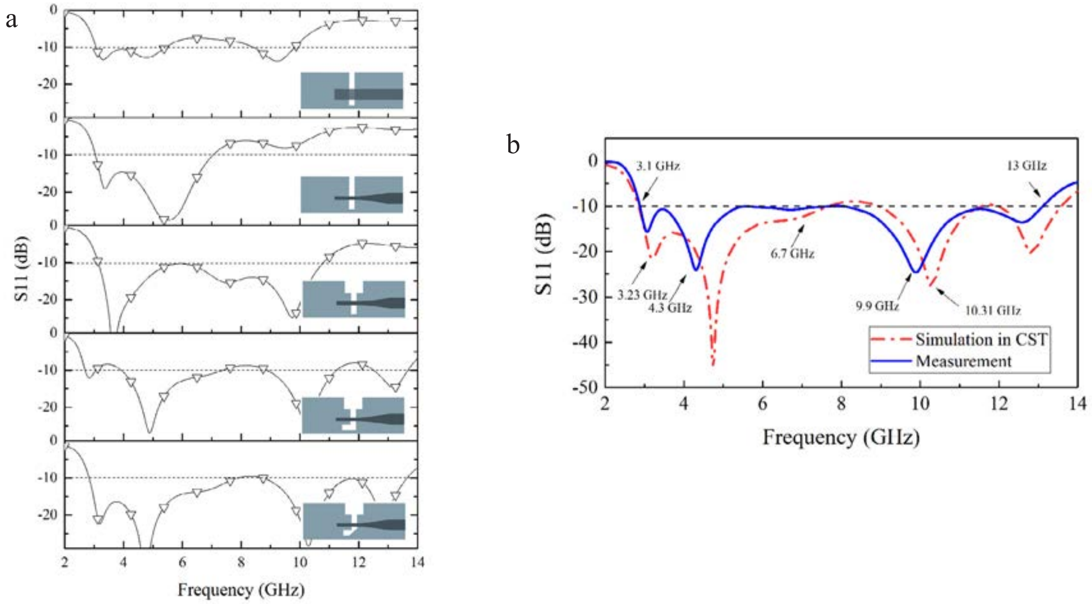

Fig. 2: (a) Design evolution of the proposed antenna (b) Measured and simulated return loss.

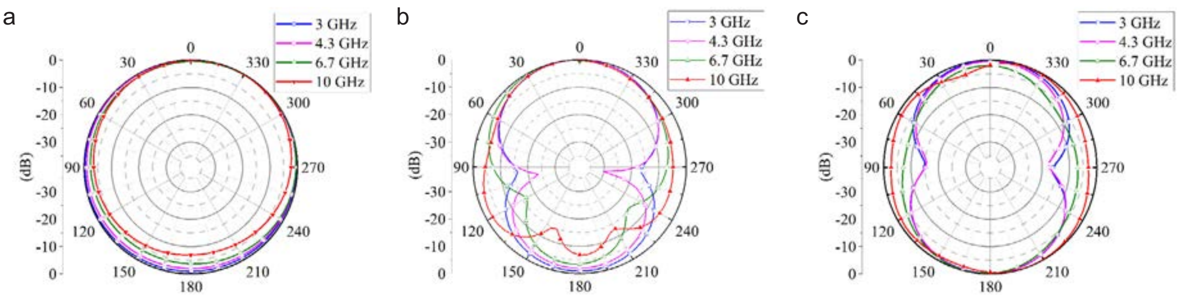

Fig. 3: Radiation patterns in the (a) X-Z (b) X-Y and (c) Y-Z planes

Return loss of the antenna better than -10dB is from 2.8 GHz to 13 GHz. Polarization of the antenna was found to be linear in the entire band and is oriented along the Y- direction. Measured radiation patterns of the antenna are shown in Fig. 3 . These are found to be stable and omni directional with peak gain in the $\theta = 0^0$, $\phi = 0^0$ direction.

4. Antenna transfer function and Impulse response

Even well matched antennas can behave differently while transmitting or receiving non-sinusoidal wave forms. To study the performance of the antenna in handling non-sinusoidal wave forms, virtual probes are inserted in the computation domain of CST as explained in[7]. The input signal used for computation is the fourth derivative of the Gaussian pulse given by Eqn. 1.

$$s_i(t) = A \cdot \left[3 - 6\left(\frac{4\pi}{T^2}\right)(t-\tau)^2 + \left(\frac{4\pi}{T^2}\right)^2 (t-\tau)^4\right] e^{-2\pi\left(\frac{t-\tau}{T}\right)^2} \quad \left(\frac{V}{m}\right) \tag{1}$$

This pulse conforms to the FCC spectral mask when A = 0.333 and T = 0.175 nS.

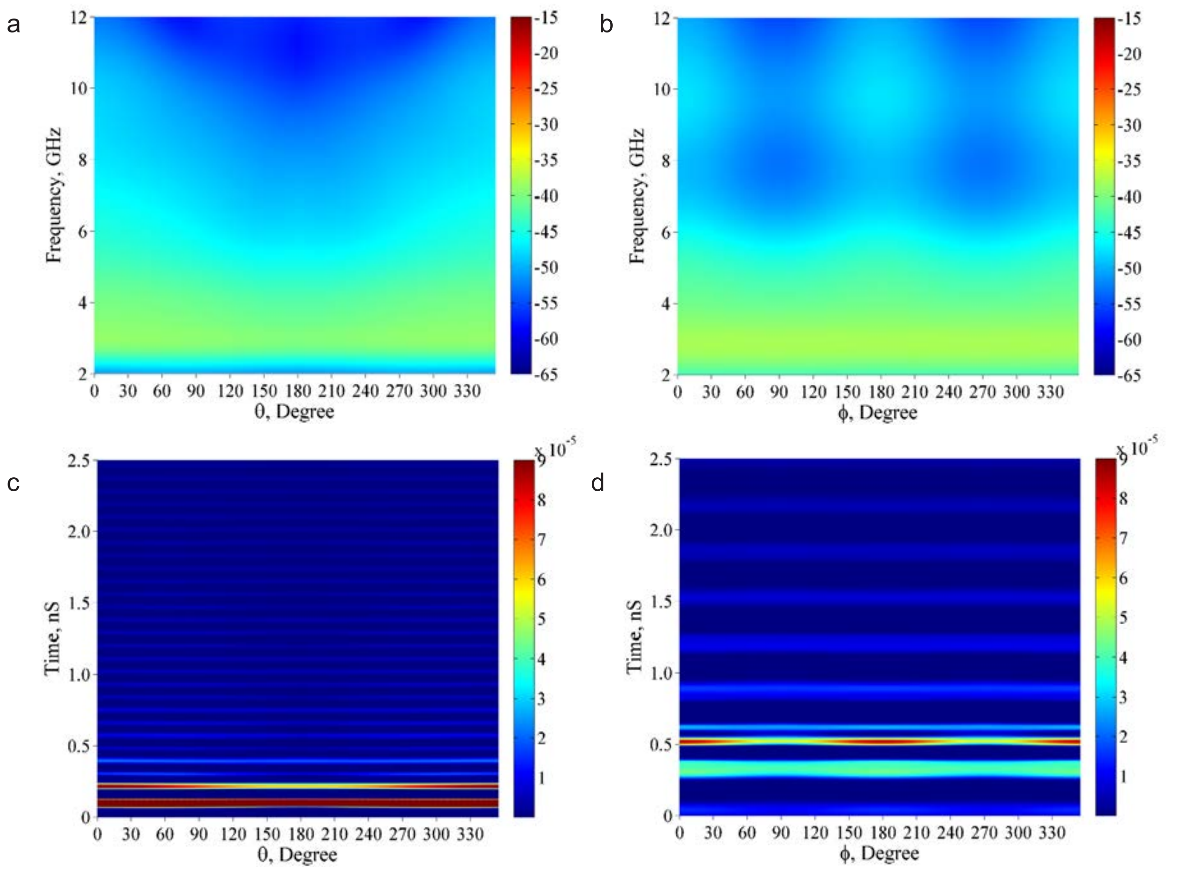

Fig. 4: (a) Antenna transfer function in the $\phi = 0$ plane (b) Antenna transfer funtion in the $\theta = 90^0$ plane (a) Antenna impulse response in the $\phi = 0$ plane (b) Antenna impulse response in the $\theta = 90^0$ plane

For the input voltage $s_i(t)$ specified in CST Microwave Studio, the radiated pulse is calculated on a sphere of radius 25cm for $\phi = 0^0$ and $\theta = 90^0$ planes. Fourier transforms of these two quantities are then calculated and equations mentioned in[7] are used to find the antenna transfer function. The impulse response is calculated by taking IFFT.

Transfer functions of the proposed antenna remains stable with variation remaining within 10dB as indicated in Fig. 4(a) for the $\phi = 0^0$ plane. There are variations in the transfer function in the $\theta = 90^0$ plane, which could be attributed to the design of the antenna and is shown in Fig. 4(b). This is also reflected in the impulse response of the antenna shown in Fig. 4 (c) and (d), where the pulse dispersion and ringing is minimal in the $\phi = 0^0$ plane than in $\theta = 90^0$ plane.

5. Conclusion

A compact UWB antenna, occupying only 28x10 mm^2 on the PCB and based on microstrip-slot line cross transition is proposed in this paper. Operating band of the antenna covers the 3.1-10 GHz UWB dedicated for communication and measurement. The antenna offers stable radiation pattern at all frequencies in its operating band by virtue of its novel design. A study on the pulse handling capabilities of the antenna reveals its absolute suitability for WiMedia systems.

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