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Trident-shape strip loaded dual band-notched UWB MIMO antenna for portable device applications

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ABSTRACT

In this paper, a novel compact dual band-notched ultra-wideband (UWB) multiple-input multiple-output (MIMO) antenna of size 22 × 26 × 0.8 mm^3 is proposed for portable devices. The antenna comprises of two stepped slot UWB antennas fed by 50 ohms microstrip line, T-shape slot and narrow slot. Dual band-notches from 5.4 to 5.86 GHz and 7.6–8.4 GHz are achieved by loading trident-shape strips on microstrip line. A T-shape slot is used on the ground plane to enhance impedance matching characteristics and to minimize mutual coupling above 4 GHz. To improve isolation further at 3–4 GHz, a narrow slot is used on ground. The proposed antenna is giving a good bandwidth ranging from 3.1 to 11.8 GHz with $|S_{11}| > 10$ dB and mutual coupling larger than 20 dB in the entire operating band except at two rejected bands. The simulation and measurement results demonstrate that the antenna is more suitable for portable device applications.

1. Introduction

Multiple-input multiple-output (MIMO) is a promising system for increasing communication data rate without extra bandwidth or total transmission power. Thus, MIMO system has been grabbing more attention in recent times. MIMO system uses multiple transmitting and receiving antennas [1]. Several MIMO antenna designs have been proposed for different wireless communication systems like UMTS and WLAN for uses in portable devices [2–4]. It is well known that use of MIMO system technology in UWB system significantly provides high channel capacity, high rate of transmission, and better immunity to multipath fading as compared to that in narrow-band system [5]. As space is limited in portable devices, maintain less mutual coupling between antennas is always big challenge. Some experiments were done to mitigate the effects of coupling in UWB MIMO antenna systems such as use of small strip [6], tree-like structure [7], annular slot [8], and protruding ground structure [9].

Ultra-wideband technology has been developing rapidly, since Federal Communications Commission (FCC) officially authorized unlicensed band of frequencies from 3.1 to 10.6 GHz for UWB applications with less emission power level (less than −41.3 dBm/MHz) [10]. However, UWB band easily interfere with existed narrow-band systems like wireless local area network (5.15–5.35 and 5.725–5.825 GHz) and X-band communication services (7.9–8.395 GHz). Therefore, to minimize the interference problem with other systems, UWB antennas with band notched characteristics has to be designed. UWB MIMO antennas to achieve single notch at WLAN band were proposed in [11–14,22], which includes the use of two stubs along the ground edges [11], placing of split ring resonators on the patch [12], loading of strips on the ground plane [13], receded steps with protruding ground structure [14], and etching of λ/2 and λ/4 resonators [22]. Several compact UWB MIMO antenna designs exhibiting dual notched functions to reject the interference at WLAN and WiMax/X-bands were presented in [15–19]. In [15], pair of inverted L-shape strips added on ground to obtain notch at WLAN band and slots on the radiating patch to get notch at WiMax band. Two metal strips having lengths of λ/3 and λ/4 are used on the radiator in [16], two metal strips are loaded on ground plane in [17], meandered slots are etched on the patches and C-shape strips near to the feeding lines in [18], open -ended slots and split ring resonators are used in the ground in [19], use of C-shaped slot on radiating element and incorporating an L-shaped strip on ground plane in [20], and etching two nested C-shaped slots on the patch in [21] were proposed to achieve dual band notches. Thus, band-notch filter structures incorporated in [11–22] is more complex and also it occupies more space.

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In this paper, an ultra-wideband MIMO antenna with dual band-stop functions is proposed. The MIMO antenna has a size of 22 mm × 26 mm = 572 mm^2, which is very small compared the antenna proposed by Zhu in [19]. Two defected ground structures are used to improve isolation in the UWB band. T-shape slot extends the current path and suppress the surface currents. Hence, the mutual coupling of <−20 dB is obtained which is very less compared to the mutual coupling obtained by the antennas in [11–22]. A narrow slot further minimizes the mutual coupling between antennas from 3 to 4 GHz. A simple notch filter is implemented by trident-shaped strips which are loaded on microstrip lines to obtain dual notched characteristics at 5.7 and 8.2 GHz with efficiency of about 9% at the notch frequencies.

2. Proposed antenna design

The proposed compact ultra-wideband MIMO antenna geometry is shown in Fig. 1. The size of the antenna is 22 mm × 26 mm × 0.8 mm. It is fabricated on the low-cost FR4 dielectric substrate with thickness of 0.8 mm, a dielectric constant of 4.4 and a loss-tangent of 0.02. The top layer of proposed antenna consists of two 50 ohm microstrip lines loaded with trident-shaped strips to provide dual band-notched characteristics. The bottom layer is ground plane with two stepped slots, a T-shape slot, and a narrow slot. A T-shape slot and a narrow slot are used on the ground plane to improve isolation in the entire UWB band.

The EM simulator Ansoft HFSS is used to design the proposed antenna. The optimized dimensions of the antenna were calculated with L = 22 mm, W = 26 mm, A = 5 mm, B = 3.74 mm, C = 1 mm, D = 7.5 mm, L1 = 15 mm, W1 = 2 mm, Ls = 5.1 mm, Ws = 0.2 mm, L2 = 6.8 mm, W2 = 1.5 mm, L3 = 12 mm, W3 = 0.2 mm, T1 = 7.5 mm, T2 = 7.4 mm, T3 = 2 mm, and R = 3.1 mm. The photograph of the fabricated UWB MIMO antenna is given in Fig. 2.

3. Working mechanism of the proposed antenna

The step by step design process of proposed MIMO antenna was given in Fig. 3(a) through (f). The following sub sections illustrate the construction and working of UWB MIMO antenna along with the effects of T-shape slot and narrow slot.

3.1. UWB antenna

The trident shaped strip is formed by combining rectangular slot and strip is given in Fig. 3(a) to (c). The microstrip line with trident shaped strip results dual notches at 5.7 and 8.2 GHz. The stepped slot which is similar to the stepped slot proposed by Zheng et al. and Chao et al. [22,23] and a microstrip line with trident-shaped strip form an element of proposed MIMO antenna is depicted in Fig. 3(d). By proper tuning of the stepped slot dimensions and feed line position, broadband characteristics can be obtained. However, from the antenna proposed by Zheng et al. [22], the impedance bandwidth obtained is only from 3.8 to 10.6 GHz, which does not meet the complete UWB range i.e., 3.1–10.6 GHz. The UWB antenna element without open -ended slot is shown in Fig. 3(d) and with open -ended slot is shown in Fig. 3 (e). By cutting open -ended slot on the ground, impedance matching characteristics will be improved in the lower frequency band. And also, the length of open -ended slot controls the lowest resonant frequency of antenna.

Fig. 4 illustrates the return loss (S_{11} parameter) plot of ultra-wideband antenna element with and without open-ended slot. It

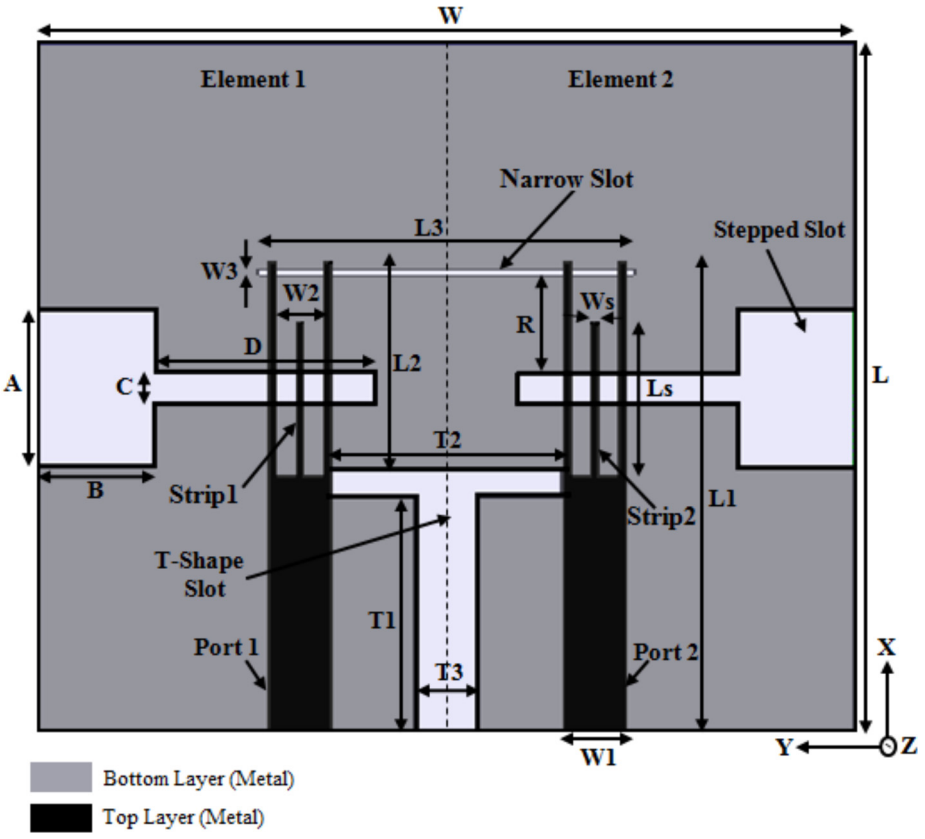

Fig. 1. Geometry of the proposed antenna.