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A wideband antenna with defected ground plane for WLAN/WiMAX applications

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ABSTRACT

A microstrip-fed wideband antenna with defected ground structure is proposed for WLAN and WiMAX band applications. The proposed antenna uses an annular ring radiator which is encircled by a rhombus shaped strip and the defected ground plane. The ground plane is cambered shaped and cut out by rectangular-shape slot and thus forms a defected ground structure. The parametric study is carried out to study the effects of varying dimensions on the antenna performance. To validate simulation results of the design a prototype is fabricated on the commercially available FR4 material. Measured results shows a good agreement with the simulated results. It is found that the antenna shows wide bandwidth of 86.71% (2.4–6.0 GHz) which covers entire WLAN and WiMAX bands. Thus the proposed antenna is well suitable for WLAN/WiMAX applications.

1. Introduction

The modern wireless communication systems have a great demand for compact designs, wideband and low-cost antennas that can operate at various communication standards simultaneously. These antennas can allow the designer to integrate wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) into one single system. Since the WLAN standards are ranges from 2.4 to 2.484 GHz (IEEE 802.11b/g)/5.15 to 5.825 GHz (IEEE 802.11a) and the WiMAX standards ranges from 2.5 to 2.69 GHz/3.4 to 3.69 GHz/5.25 to 5.85 GHz, thus, these wireless devices will require an antenna with large impedance bandwidth and excellent radiation characteristic throughout entire operating band [1]. Due to low cost, light weight, and good performance, the microstrip antennas are promising candidate in such wireless communication systems. However, these antennas are often limited in their applicability due to their narrow bandwidth. The impedance bandwidth of this type of antennas can be increased by modifying the geometry of the radiating patch by cutting the slot of different shapes [2–7]. Further, a solid ground plane can also be replaced by a recently invented defected ground structure to enhance the impedance bandwidth of the patch antennas [8,9]. The advantage of defected ground plane is reduction of size and excitation of additional resonance bands [10]. Recently, many types of antenna designs for WLAN/WiMAX applications have been reported in the literature [11,12]. A few antenna designs are suitable for both WLAN and WiMAX applications [13–18].

In this paper, a novel microstrip-fed wideband antenna with defected ground structure is proposed that can operate over the entire 2.4/5.2/5.8-GHz WLAN operating bands and 2.5/3.5/5.5-GHz WiMAX bands. The proposed antenna mainly consists of an annular ring radiator which is encircled by a rhombus strip and a defected ground plane on the other side of the dielectric substrate as shown in Fig. 1. The simulation of various parameters are conducted to understand their behaviour and to optimize for wideband operation using Ansoft “HFSS” [19], a commercial electromagnetic simulator based on a finite element method (FEM). The antenna design is practically fabricated on commercially available FR4 material. The measured results are compared with the simulated results which shows a relatively good agreement. The detailed dimensions of the proposed wideband antenna are listed in Table 1. The entire details of the proposed design is given in the following sections.

2. Antenna design

The proposed antenna is designed and fabricated on a commercially available FR4 substrate with relative permittivity of 4.4, and a loss tangent of 0.02. The total size of the antenna

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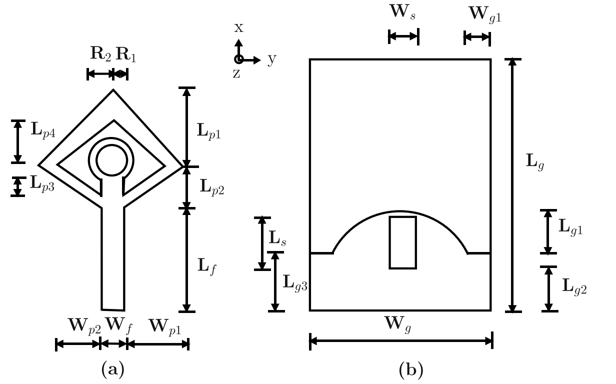

Fig. 1. Schematic configuration of the proposed microstrip-fed wideband antenna.

Table 1
Design parameters of the proposed microstrip-fed wideband antenna with defected ground structure shown in Fig. 1.

Parameters	L_{p1}	L_{p2}	L_{p3}	L_{p4}	L_{g1}	L_{g2}
Unit (mm)	13	7	2.17	7.3	4.5	4
Parameters	W_{p1}	W_{p2}	W_{g1}	W_f	W_s	W_g
Unit (mm)	11	11	3.63	3	4	25
Parameters	L_{g3}	R_1	R_2	L_f	L_s	L_g
Unit (mm)	7	3	4.5	14	6.5	38

is 38 mm × 25 mm × 1.6 mm. The proposed antenna has a simple configuration, consisting of an annular ring encircled by a rhombus-shaped strip and a defected ground plane. The main radiating element of the antenna uses an annular strip with inner radius R_1 and outer radius R_2 encircled by a rhombus-shaped strip with a height of L_{p1} plus L_{p2} and width of twice of W_{p1} plus W_f as shown in Fig. 1(a). A 50-Ω microstrip feed line with a width of 3.0 mm is used to feed the antenna. In place of conventional solid ground plane, a cambered ground plane is etched on the other side of the dielectric substrate as shown in Fig. 1(b). Further, a rectangle-defect is etched in the cambered ground plane under the microstrip feed line to achieve better impedance matching.

To verify wideband operation, the simulated surface current distribution at different sampling frequencies 2.5, 3.8, and 5.65 GHz, are shown in Fig. 2. It is seen from Fig. 2(a), the strong surface current flows along both the rhombus-shape and annular strip. It is observed that the rhombus-shape and annular ring strips generate the first resonant mode of 2.5 GHz. For the sampling frequency at 3.8 GHz as shown in Fig. 2(b), it is found that the strong surface current is distributed over the annular ring and ground plane. Results in Fig. 2(c) reveals that surface current of the third resonant mode (5.65 GHz) is mainly distributed on the feed line, rhombus-shaped strip and the ground plane.

3. Parametric study

A parametric study is carried out to understand the effects of various parameters and to optimize the performance of the final design. The effect of the lengths L_{p1} and L_{p2} of the rhombus-shaped strip, outer radius R_2 of the annular ring strip and curved length L_{g1} of the defected ground plane are considered for parametric study. Fig. 3 shows the effect of the outer radius R_2 of the annular ring strip on the return loss of the antenna. It is seen from Fig. 3 as the outer radius of the annular ring strip is varied from 1.5 to 10.5 mm, the bandwidth for return loss less than 10 dB of the antenna increases greatly and the lower frequency band also shifts towards higher frequency. Thus, the optimum value of the outer radius R_2 is chosen 4.5 mm.

Fig. 4 shows the effect of length L_{p1} of the rhombus-shaped strip on the return loss of the proposed antenna. It is seen that by changing the value of L_{p1} from 13 mm to 17 mm, the bandwidth for return loss less than 10 dB of the antenna remains almost constant, however, total band shift towards lower frequency. Thus, the optimum value for L_{p1} is taken to be 15 mm.

The effect of the length L_{p2} of the rhombus-shaped strip on the return loss of the proposed antenna is illustrated in Fig. 5. It is observed that by changing the value of L_{p2} from 4.4 mm to 6.4 mm, the bandwidth for return loss less than 10 dB of the antenna increases greatly and decreases as furthermore increase.

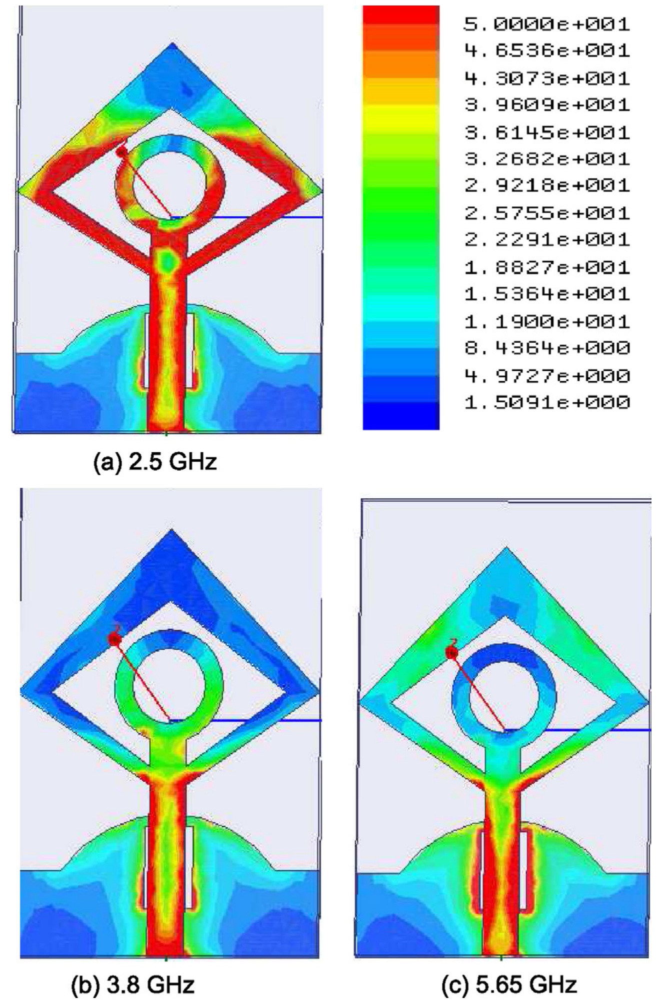

Fig. 2. Current distribution at various sampling frequency of the proposed microstrip-fed wideband antenna.

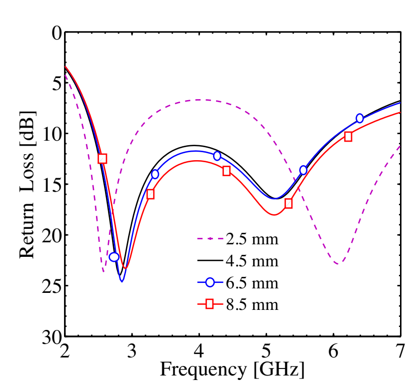

Fig. 3. Simulated return loss against frequency for the proposed microstrip-fed wideband antenna with various outer radius R_2; other parameters are the same as listed in Table 1.