Coplanar waveguide-fed ultra-wideband antenna with triple-band notched design

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Abstract: A novel coplanar waveguide-fed ultra-wideband antenna with triple band-notched function centred at 3.5, 5.5 and 7.5 GHz is proposed. It has small size of 26 × 26 mm². This antenna consists of an elliptical radiator and a square ground plane with an elliptical slot on one side of the substrate. Besides, two circles with a radius of 2 mm were dug from the edge of the outer ellipse to realise the bandwidth requirement. To avoid interference from Worldwide Interoperability for Microwave Access, a single open-ended elliptical arc-shaped slot was etched on the top side of the ground. Moreover, another elliptical arc-shaped slot notched at wireless local area network band was etched on the elliptical radiator and two systemically C-shaped slots working at 7.3–7.7 GHz was embedded on the structure. Measured voltage standing wave ratio shows the working frequency range was from 3.1 to 13.5 GHz except for notched bands of 3.35–3.8, 5.1–5.9 and 7.35–7.8 GHz.

1 Introduction

Ultra-wideband (UWB) technology becomes increasingly popular among researchers after the 3.1–10.6 GHz frequency band was available for commercial applications in 2002 due to the permission of Federal Communications Commission (FCC). UWB antenna, which has the advantage of low fabrication cost, small size and stable radiation patterns, has drawn much attention from both engineering and academia society [1, 2]. However, at the same time, the problem that there are some overlapped frequency between UWB frequency and some existing narrowband systems arises, such as the interference with Worldwide Interoperability for Microwave Access (WiMAX) band working at 3.3–3.7 GHz, wireless local area network (WLAN) (5.15–5.825 GHz) and the X-band satellite system from 7.3 to 7.7 GHz. Engineers and researchers have found many methods to solve this problem. For instance, different shapes of slots and strips such as U-shaped and T-shaped slots can be etched on appropriate locations of the designed antenna to obtain the aimed notched band [3, 4]. Moreover, some novel structure such as complementary split ring resonator and hollow-cross-loop resonator are also proposed in the literature [5–7].

However, many notched band antenna designs in the literature have too complex structures to fabricate on the substrate easily. In this letter, a new notched antenna which can avoid all the interference from WiMAX, WLAN and X-band was proposed and analysed. Novel structure was used to realise the UWB requirement and three simple slots are etched on the antenna to achieve the final notched frequency effectively. This antenna was fabricated on an FR4 substrate (relative permittivity $\varepsilon_r = 4.4$) and it has a compact size of $26 \times 26 \times 0.8$ mm³. The details of the band notched antenna are discussed in the following section.

2 Antenna design

Fig. 1 depicts the geometry of the notched antenna and the parameters of the slots. This antenna is made up of an elliptical radiator and a square ground plane with an elliptical slot on one side of the substrate. Two circles are dug from the edge of the outer ellipse to realise impedance matching. In the design, the two dug circles play an important role on the bandwidth requirement, especially the radius of the circles and the position of the centre of the circles significantly influence the function. After simulation, the final radius of the circle was set as 2 mm and the position of the centre was chosen as $L_3 = 4.5$ mm and $L_4 = 9$ mm. Moreover, in order to obtain the notched characteristics, three different slots are used during the design. On the top of the ground plane, a single open-ended arc-shaped slot with its total length equal to a quarter wavelength of the aimed notched frequency of 3.5 GHz is embedded to get the WiMAX notched band. By etching an elliptical arc-shaped slot with half of wavelength at 5.5 GHz on the radiating patch, WLAN band is avoided in 5.15–5.85 GHz. Furthermore, two symmetrically C-shaped slots are positioned on the ground plane to avoid the interference with X-band satellite at 7.3–7.7 GHz. Each notched band could be adjusted independently and effectively by changing the parameters of each slot.
Through simulations with CST Microwave Studio, final optimum parameters are as follows: \( W = 26 \text{ mm}, R_a = 11.5 \text{ mm}, R_b = 8 \text{ mm}, \ r_a = 6 \text{ mm}, \ r_b = 4 \text{ mm}, \ r = 2 \text{ mm}, \ s = 0.4 \text{ mm}, \ w_g = 3 \text{ mm}, \ L_g = 11.1 \text{ mm}, \ L_1 = 2.5 \text{ mm} \) and \( L_2 = 2 \text{ mm} \). To better understand the good level of the slots upon eliminating unwanted signals from other narrow band communication systems, simulated surface current distributions at 3.5, 5.5 and 7.5 GHz are shown in Fig. 2.

**3 Results and discussions**

To demonstrate the credibility of simulation, the fabricated antenna has been measured successfully. Fig. 3 depicts the comparison between the simulated and measured voltage standing wave ratio (VSWR) of the antenna. The results indicate that the two lines match very well, which strongly certifies the success of the novel design. More precisely, the measured VSWR is less than 2 between 3.1 and 13.5 GHz, which satisfies the UWB requirement while rejecting the unwanted signals from WiMAX (3.35–3.8 GHz), WLAN (5.1–5.9 GHz) and X-band (7.35–7.8 GHz).

Moreover, to show the practical performance of the antenna, the radiation patterns in far field of the \( E \)-plane and the \( H \)-plane at 3.28, 4.43 and 9.5 GHz are displayed in Fig. 4. Due to the influence of the test environment, the radiation patterns are not as good as it was simulated. Results show that the antenna has a meaningful radiation pattern which is acceptable according to the practical requirement. The radiation pattern of the \( H \)-plane is nearly omnidirectional and the radiation pattern of the \( E \)-plane is like that of the dipole.

Besides, the realised gain of the antenna is plotted in Fig. 5. The gain keeps a stable trend to increase gradually against the frequency except the sharp decrease at the notched bands which clearly show the function of the slots.

**4 Conclusion**

In this Letter, a triple notched band antenna with new design is proposed and analysed. Band notched characteristics could be tuned easily by adjusting parameters of the slots. Measured results show it has a wide bandwidth from 3.1 to 13.5 GHz except the selected notched bands of 3.35–3.8, 5.1–5.9 and 7.35–7.8 GHz. The unique structure and simple notched ways make it a good choice for UWB application.

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