A broadband and tri-band L-shaped slot antenna for 2G/3G/LTE/WiMAX/WLAN applications

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Abstract: A compact broadband and tri-band slot antenna is proposed. The antenna is composed of a L-shaped slot embedded in a ground plane, a T-shaped microstrip feed line and two rectangular slits etched in the ground plane. The L-shaped slot fed by the T-shaped microstrip line is introduce to generate broad impedance bandwidth, while the two slits are used to divide the one broad band into three frequency bands. The design step of the antenna is presented. Measured results show that the antenna is successfully designed to cover the frequency band from 1.71 to 2.9 GHz for 2G/3G/LTE systems, 3.3–3.8 GHz for WiMAX system and 5–6 GHz for WLAN system.

Keywords: slot antenna, wideband antenna, multiband antenna

Classification: Antennas and Propagation

References

1 Introduction

With the rapid development of wireless communication technology, there are coexisting many different wireless communication systems such as 2G, 3G, LTE, WiMAX and WLAN communication standards. In order to minimize size and cost, it is desirable to integrate as many systems such as possible into a single wireless device. For this reason, multiband antennas have attracted much attention and many multiband antenna have been presented. A dual-band monopole antenna [1] composed of inverted L-shaped and fork strips and a rectangular slot is proposed for LTE and WLAN used. In [2], a slot antenna using a single split-ring resonator to generate multiple lower-order resonances, but the antenna only can cover 1.65 GHz, 1.93 GHz and 2.20 GHz bands. In [3], a F-shaped slot antenna is introduce to generate quad-band operation which can cover 2.28–2.66, 3.35–3.65, 5.07–5.3, and 5.75–5.85 GHz for WiMAX and WLAN systems. A rectangular slot antenna embedded with inverted T-shaped stubs and E-shaped stubs has been proposed in [4] to generate four operating bands, which can cover the frequency bands from 1.575 to 1.665 GHz, 2.4–2.545 GHz, 3.27–3.97 GHz and 5.17–5.93 GHz for GPS/WiMAX/WLAN application. However, the overall size of the antenna is a bit of large.

In this Letter, a novel broadband and tri-band L-shaped slot antenna for 2G/3G/LTE/WiMAX/WLAN application is proposed. The antenna consists of a L-shaped slot and two rectangular slits embedded in the ground plane on top side of the substrate, and a T-shaped microstrip feed line on other side. By properly selecting dimensions of the L-shaped slot and T-shaped stub, a broad impedance matching from 1.71–6 GHz can be achieved. By inserting two slits near the L-shaped slot, three operating bands are successfully obtained. The antenna has small size of 35.5 mm × 50 mm.

2 Antenna design

Fig. 1(a) shows the geometry of the broadband slot antenna which is printed on a 0.762 mm thick substrate with relative permittivity of 3.5. The antenna is formed by a ground plane, an open-ended L-shaped slot embedded in the ground plane on the top side of the substrate and a T-shaped feed stub printed in middle of the bottom side of the substrate. The length of the L-shaped slot L2 is set to be approximately a quarter guided wavelength at the first resonant frequency (1.8 GHz in this design). The part of the T-shaped stub with length of Lf1 is 50 ohm microstrip line.

The length L1 and width w2 of the slot are both important parameters for the impedance matching. Fig. 2(a) shows the simulated return loss of the antenna as a function of L1. The impedance matching of high frequency range is enhanced, while the impedance matching for the lower frequency band become worse as L1 increased from 5.8 mm to 26 mm. Optimized values for L1 is found to be 26 mm for the excellent impedance matching of the whole band. Fig. 2(b) shows the impedance matching varied slot width w2. The return loss is improved from −7 dB to −12 dB when w2 increases from 2 mm to 5.8 mm. The optimal value for the width w2 of the slot is 5.8 mm.
The T-shaped stub is another important element for the impedance matching of the antenna. The effect on the return loss by the length $L_{f2}$ of the T-shaped stub is demonstrated in Fig. 2(c), and an optimized value for $L_{f2}$ is found to be 7.5 mm. The effect on the return loss by the width $w_{f2}$ of the T-shaped stub is demonstrated in Fig. 2(d). As shown in the picture, the wider width $w_{f2}$ has better impedance matching. Good impedance matching is achieved for $w_{f2} = 11.8$ mm.

The design of the broadband slot antenna was simulated and optimized using Ansoft HFSS. The optimized design parameters and values are:

- $w = 35.5$ mm, $L = 50.0$ mm, $L_1 = 26.0$ mm, $w_1 = 6.2$ mm, $L_2 = 23.5$ mm, $w_2 = 5.8$ mm, $w_{f1} = 1.8$ mm, $L_{f1} = 13.8$ mm, $w_{f2} = 11.8$ mm, $L_{f2} = 7.5$ mm. The simulated results show that the broadband slot antenna covers 1.68 GHz to more than 6.4 GHz for return loss > 10 dB.

In order to generate multiband function, two rectangular slits with different lengths are introduce, as shown in Fig. 1(b). In this design, the length of slit 1 $L_{11}$ is set to be about a quarter guided wavelength at 3.15 GHz, which is used to generate a reject band at 3 GHz, while the length of slit 2 $L_{22}$ is set to be about a quarter guided wavelength at 4 GHz, which is used to generate a 4 GHz reject band. As a result, the broadband covering 1.68 GHz to 6.4 GHz is divided into three operating bands.

Fig. 2(e) illustrates return loss comparison of broadband slot antenna, antenna with slit 1 only, antenna with slit 2 only and the proposed tri-band antenna. As shown in Fig. 2(e), the 3 GHz reject band is generated by the slit 1, while the 4 GHz reject band is generated by the slit 2. Three operating bands are achieved by introducing the two slits. The optimized dimension of the slits are: $a_{11} = 1.0$ mm, $w_{11} = 0.8$ mm, $L_{11} = 16.3$ mm, $a_{22} = 0.4$ mm, $w_{22} = 0.4$ mm, $L_{22} = 12.5$ mm.

According to the above discussion for the tri-band antenna design, we propose to design the tri-band antenna using the following steps:
1) Design a broadband L-shaped slot antenna following the design process discussed above.

2) Embed a long open-ended rectangular slit below the L-shaped slot. The length of the long slit is selected to be quarter-wavelength of the lower center rejected resonant frequency. Then, embed a short open-ended rectangular slit upon the L-shaped slot. The length of the short slit is selected to be quarter-wavelength of the high center rejected resonant frequency.

3) Tune the parameters of the antenna properly to obtain the desirable tri-band operation.

With the use of the above steps, simulated result has shown that the operating bands of the antenna are 1.68–2.85 GHz, 3.24–3.89 GHz and 5.05–6.4 GHz.

**Fig. 2.** Simulated results
3 Measured results

Based on the design dimensions given above, the slot antenna was fabricated and measured. The photo of the fabricated antenna is shown in Fig. 3(a). The simulated and measured return loss of the proposed antenna is shown in Fig. 3(b). Experimental results show the proposed antenna covers 1.71–2.96 GHz, 3.22–3.85 GHz and 4.6–6.4 GHz frequency bands with 10 dB return loss. Good agreement can be observed between the simulated and measured results. The variation between measured and simulated results probably comes from fabrication tolerances and simulation accuracy of the software simulator.

![Photograph and measured results](image)

Fig. 3. Photograph and measured results
The measured H-plane and E-plane radiation patterns are illustrated in Fig. 3(c) and Fig. 3(d) respectively. The H-plane radiation patterns at 2.2 GHz, 3.5 GHz and 5.5 GHz are nearly omni-directional. Fig. 3(e) shows the measured gain of the proposed antenna. The gain is between 2.2–2.5 dBi, 3.2–3.45 dBi and 3.6–4.1 dBi in the 1.7–2.7 GHz, 3.3–3.8 GHz and 5.1–5.9 GHz operating bands respectively.

4 Conclusion

In this letter, a compact broadband and tri-band L-shaped slot antenna has been proposed and fabricated. The broadband and tri-band operation of the proposed antenna is achieved by inserting two open-ended slits into the L-shaped slot antenna. The antenna shows good radiation performance with acceptable gain over the desired frequency bands. The antenna is compact and planar, which make it suitable and attractive for the 2G, 3G, LTE, WiMAX and WLAN applications.