Progress In Electromagnetics Research Letters, Vol. 50, 55–60, 2014

A Multiband Four-Antenna System for the Mobile Phones Applications

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Abstract—A multiband four-antenna system with high isolation for the mobile phone applications is presented in this paper. The four antennas consisting of a main antenna and three auxiliary antennas are located on a $135 \times 65 \times 0.8\,\text{mm}^3$ FR4 epoxy board. The main antenna is an improved monopole antenna which can cover LTE700/2300/2500, GSM850/900/1800/1900/UMTS, and 2.4-GHz WLAN bands. Three identical auxiliary antennas with a size of $40 \times 6 \times 0.8\,\text{mm}^3$ are located vertically in the sides and bottom of the circuit board, respectively. By adopting three slots in each radiating patch of the auxiliary antennas, they can successfully cover 704–746 MHz and 1880–2690 MHz band with S_{11} less than -6 dB. The isolation among the four antennas is better than 13 dB. The measured efficiency of the main antenna in the operation band can reach 40%, and the efficiency of auxiliary antennas can reach 25% at upper frequency band and about 10%–20% at 704–746 MHz band.

1. INTRODUCTION

The MIMO (Multiple-Input-Multiple-Output) technology has proved to be an efficient way for obtaining higher capacity and higher transmission speed. So far, most of the multi-antenna mobile terminals published operate only at relatively high frequency band, such as at 2.4 GHz/5.15 GHz WLAN (Wireless Local Area Network) bands [1–3]. Recently, for achieving LTE MIMO operation, two LTE antennas are designed to be used in the mobile communication devices [4–6]. Furthermore, the increase of the MIMO antennas is helpful for the improvement of the channel capacity of the system. In [7], the authors used three folded monopole antennas to cover 2300–2690 MHz band. In [8], four-element antenna working in the UMTS band is presented. It is well known that the lower the operating frequency is, the larger the antenna will be. Since so limited space mobile phone can offer, it will be challengeable for the engineers to finish the design of four antennas in one terminal working on the LTE700 (704–787 MHz) band.

In this paper, a multiband four-antenna system with high isolation for the mobile phones applications is proposed. The main antenna can cover the LTE700/2300/2500 (698–787/2300–2400/2500–2690 MHz), GSM850/900/1800/1900/UMTS (824–894/880–960/1710–1880/1850–1990/1920–2170 MHz), and 2.4 GHz WLAN (2400–2484 MHz) bands. The three auxiliary antennas are fabricated on an FR4 epoxy board with the same size of $40 \times 6 \times 0.8\,\text{mm}^3$. They can cover both the 1880–2690 MHz band and 704–746 MHz band by adding slots to the radiating patch. The measured results show that the isolation between the antennas is higher than 13 dB. The measured efficiency of the main antenna reaches more than 40% in the whole working frequency band. The efficiency of the auxiliary antennas can reach 25% at higher frequency band and 10%–20% at lower frequency band.

Received 29 September 2014, Accepted 17 November 2014, Scheduled 26 November 2014
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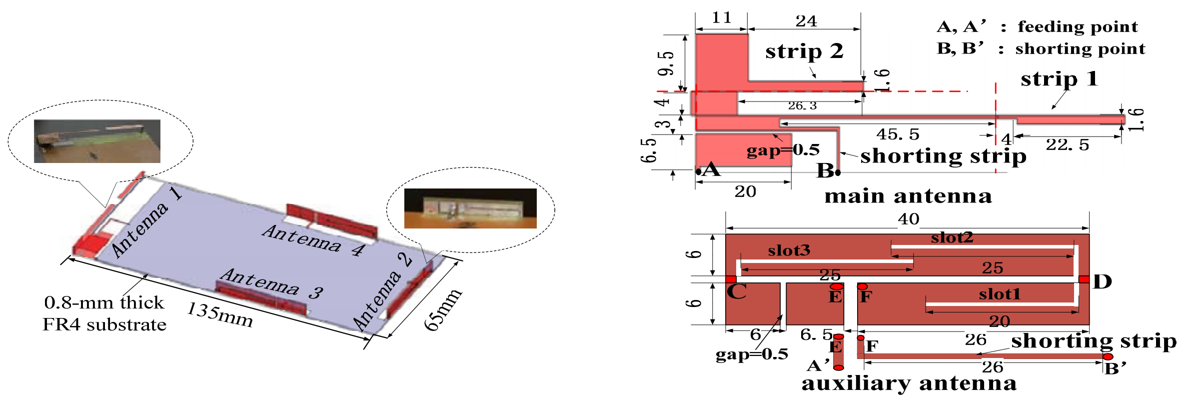
2. ANTENNA DESIGN

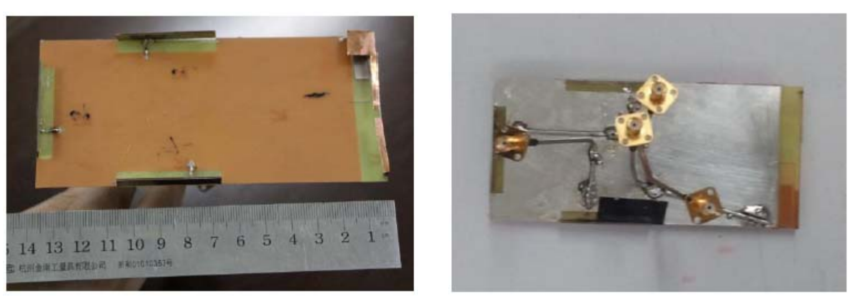
The geometry of the proposed antenna system is shown in Fig. 1(a). An improved monopole antenna is designed as the main antenna. The different current paths provided by the two parasitic strips of the antenna, and the distributed LC matching circuit formed by a coupling feed and a shorting strip ensure that the main antenna has a good performance of multiband work. It is printed on the no-ground region at the top of the system ground plane. Three identical auxiliary antennas with size of $40 \times 6 \times 0.8\,\text{mm}^3$ are, respectively, located vertically on the left, right and the bottom of the circuit board. The antenna is directly fed on the rectangular patch by feeding strip at point E. The shorting strip with a size of $26 \times 0.3\,\text{mm}^2$ is connected to the parasitic radiating patch at point F. Points C and D are metallic vias which connect the parts of the parasitic patch at two sides of the FR4 board. The auxiliary antennas are vertical to the edge of the cell phone circuit board, and they require a no-ground portion of $40 \times 5\,\text{mm}^2$. By adopting three narrow slots on the obverse and reverse of the FR4 substrate, the auxiliary antenna can achieve another resonance at lower frequency (near 700 MHz) to cover the LTE band. The dimensions of the main and auxiliary antennas are specified in Fig. 1(b).



(a) (b)

Figure 1. (a) General view of the proposed mobile antenna, (b) dimensions of the main and the auxiliary antenna (unit: mm).

The proposed antenna system is fabricated, and the photograph is shown in Fig. 2.



(a) (b)

Figure 2. The photograph of the proposed antenna. (a) Front view, (b) back view.

3. RESULTS AND ANTENNA PERFORMANCE

Figure 3 shows the measured return losses of the main and auxiliary antennas. It can be seen that the main antenna (*Antenna 1*) can cover the 704–960 and 1710–2690 MHz bands, and the auxiliary antennas

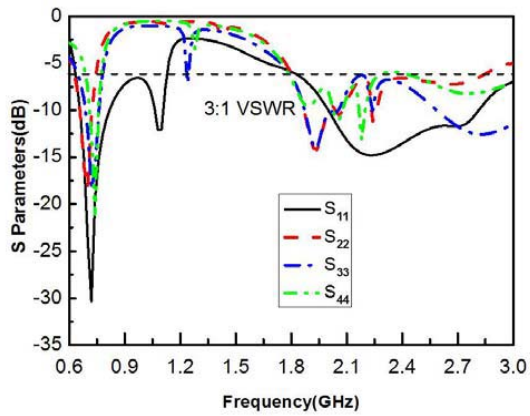


Figure 3. Measured return losses of the main and auxiliary antennas.

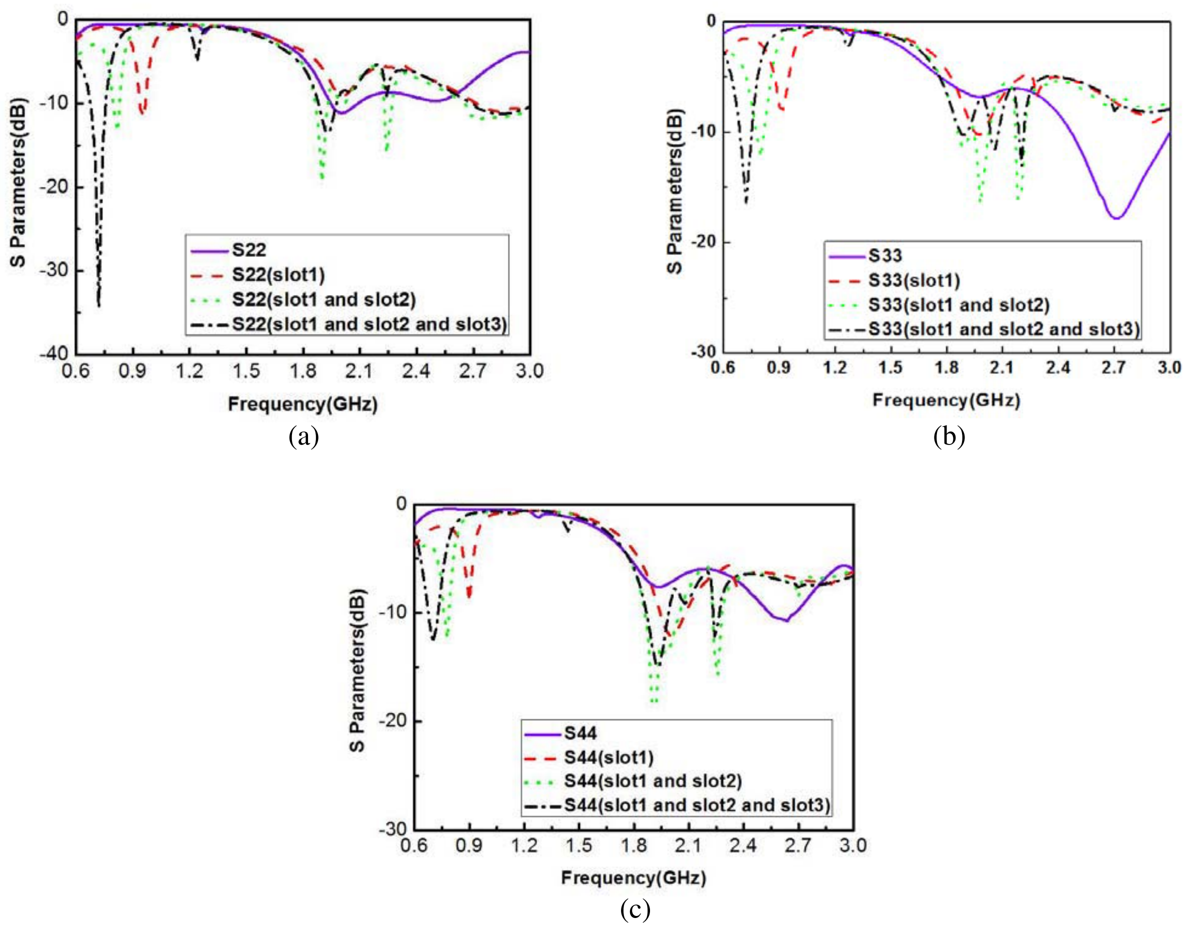


Figure 4. Simulated slotting effect on (a) auxiliary antenna 2, (b) auxiliary antenna 3, (c) auxiliary antenna 4.

(*Antenna 2*, *Antenna 3*, *Antenna 4*) can cover the 704–746 and 1880–2690 MHz bands (VSWR $\leq 3:1$). The current paths of the three auxiliary antennas increase with the slots, which leads to the increase of the resonance of the antenna.

The return losses of three auxiliary antennas with different slots are simulated by Ansoft HFSS and shown in Figs. 4(a), (b), and (c). It can be observed that when only slot 1 exists, the tuning frequency appears around 980 MHz, and the addition of slot 2 will move the tuning frequency to 820 MHz, while the joint of slot 1, 2, and 3 enables the auxiliary antennas tuning at working frequency band (704–746 MHz). Due to the larger no-ground area of antenna 2 than antennas 3 and 4, it shows better performance.

Surface current on the ground at 720 MHz is shown in Fig. 5. As can be seen, the surface current on the ground around antenna 4 is stronger than that around antenna 3. This is because compared with antenna 4, the feeding point of antenna 3 is farther away from the main antenna (Antenna 1).

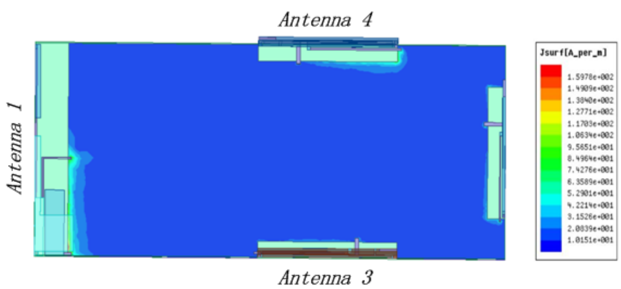


Figure 5. Surface current on the ground at 720 MHz.

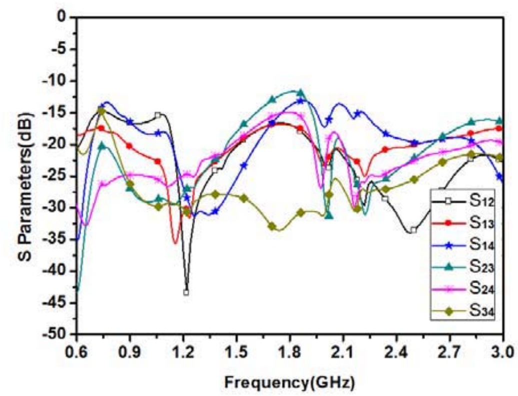


Figure 6. Measured isolations of the four antennas.

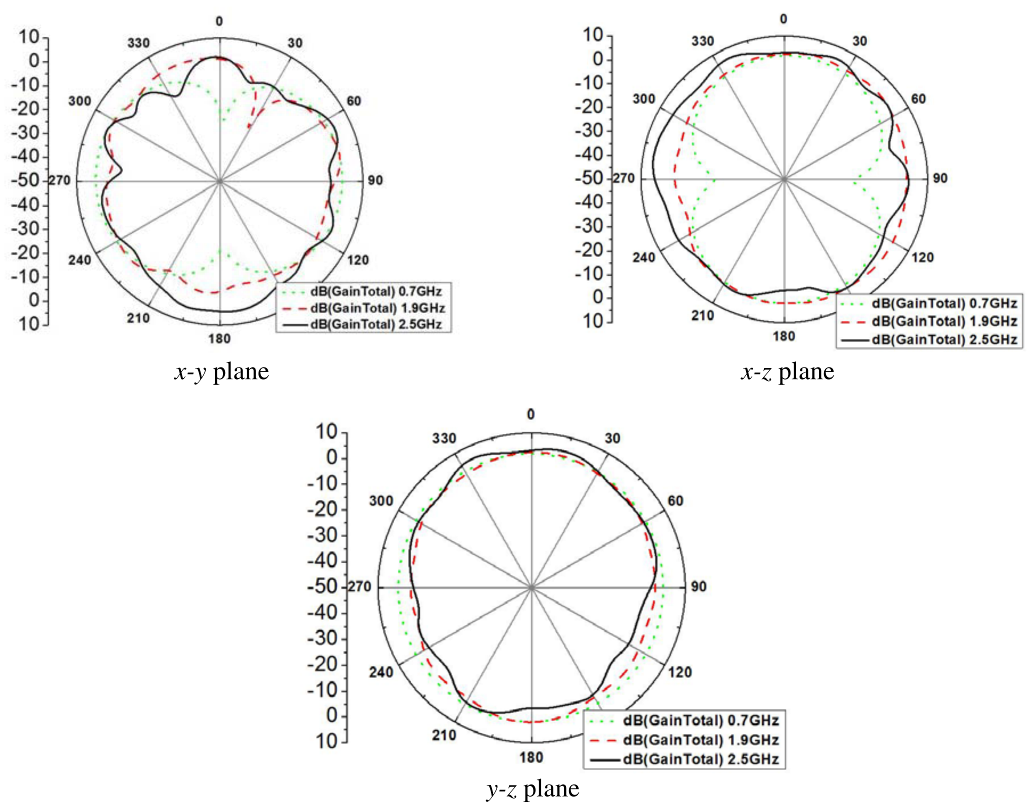


Figure 7. Simulated radiation patterns of the proposed antenna.

As a result, the isolation between antennas 4 and 1 is worse than that between antennas 3 and 1. Nevertheless, the isolations between the four antennas behave well. As shown in Fig. 6, the couplings between the three auxiliary antennas (S_{23}, S_{24} and S_{34}) are below -13 dB. The couplings between the main antenna and the auxiliary antennas (S_{12}, S_{13} and S_{14}) are below -15 dB at 700–3000 MHz band.

Figure 7 presents the simulated radiation pattern of the proposed antenna. It can be seen clearly that the antenna has a good omnidirectional radiation in x-y plane, x-z plane, and y-z plane at 700, 1900, and 2500 MHz, respectively.

The passive antenna test was implemented in the microwave anechoic chamber to observe the efficiency of the antenna. Both the dielectric loss and cable loss are considered. Fig. 8 shows the measured efficiencies of the four antennas respectively. For the main antenna, the measured efficiency is mostly higher than 40% in the frequency bands of 640–1000 and 1600–2690 MHz, and the maximum value is 72%. The measured efficiencies of the three auxiliary antennas are about the same, which are higher than 25% in the higher frequency band (1880–2690 MHz) and only 10%–20% in the lower frequency band (704–746 MHz).

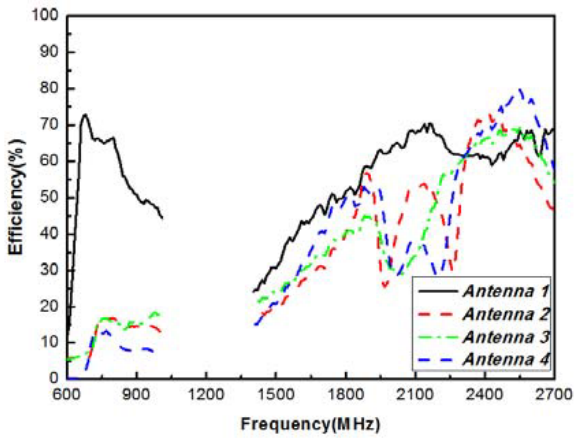


Figure 8. Measured efficiencies of the proposed antennas.

4. CONCLUSION

A multiband four-antenna system with high isolation for the mobile phones applications has been proposed. The main antenna can successfully cover LTE700/2300/2500, GSM850/900/1800/1900/UMTS, and 2.4 GHz WLAN bands. By adding slots to the three identical auxiliary antennas, they can work in both the 704–746 MHz and 1880–2690 MHz bands with a small occupied space. The measured isolation between any two antennas of the four antennas is greater than 13 dB in the whole working frequency band. The measured efficiency of the main antenna reaches 40%. For the auxiliary antennas, the efficiency reaches 25% in higher frequency band, and a little lower efficiency about 15% is got in the 704–746 MHz band.

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