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A NOVEL DESIGN OF LTE SMART MOBILE ANTENNA WITH MULTIBAND OPERATION

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Abstract—An LTE smart mobile antenna with multiband operation is proposed to work in the bands of LTE, GSM, DCS, PCS, PHS, UMTS, Bluetooth, and WLAN. Compared with those reported in the literature, the proposed antenna features a simple and straightforward design procedure, which is composed of three easy steps. Firstly, A three-dimensional meandering monopole antenna is constructed along the edge of a rectangular PCB to act as the main radiator, resulting in the bands of LTE, DCS, and PCS, PHS, and UMTS. Secondly, a shorted stub is fabricated to excite the GSM band, and also to improve the impedance matching in the bands of LTE and GSM. Finally, the second shorted stub is added to radiate in the band of WLAN. The numerical results show that the -6 dB return-loss bandwidths are from 0.7 GHz to 0.985 GHz (0.285 GHz, 34%) in the lower band and from 1.64 GHz to 2.535 GHz (0.895 GHz, 43%) in the higher band. The corresponding measured data are from 0.7 GHz to 1.03 GHz (0.33 GHz, 38%) in the lower band and from 1.64 GHz to 2.55 GHz (0.91 GHz, 43%) in the higher band. The measured antenna gains are about 2 to 3 dBi in the lower and higher bands, respectively.

1. INTRODUCTION

Over the past 10 years, mobile devices, such as laptop computers, tablet computers, and smart phones, have become more and more popular due mainly to their easy access to information on the Internet. For users' convenience, there is an obvious trend toward integrating

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many functions and communications into a mobile device, thus resulting in studies [1–3] for designing multiband antenna. Recently, the band of Long Term Evolution (LTE) has attracted much attention, because it is promising in the 4G communication due to larger amount and higher speed of transmission. Therefore, there has been much research focusing on the application of LTE operation on smart phones, laptop computers, and tablet computers [4–17]. However, it is difficult to design an antenna for the LTE700 band using conventional dipole or monopole antennas, since the low frequency operation leads to a longer current path. To reduce the space and make the antenna applicable on the mobile device, the meandering design is widely adopted by many researchers. These designs have the common feature that an additional patch is constructed on one side of the ground plane of a portable device. However, too many design parameters have to be fine tuned in order to achieve multi-band operation, making the design procedure difficult to optimize and implement.

The purpose of this paper is to propose an LTE smart mobile antenna with multiband operation, with special emphasis on a simple and straightforward design procedure, and then the difficulties mentioned above can be overcome. The proposed antenna will simultaneously meet all the following communication standards: LTE700 (698 MHz–806 MHz), LTE800 (790 MHz–862 MHz), GSM (880 MHz–960 MHz), DCS (1.71 GHz–1.88 GHz), PHS (1.88 GHz–1.93 GHz), PCS (1.85 GHz–1.99 GHz), UMTS (1.92 GHz–2.17 GHz), Bluetooth (2.4 GHz–2.4385 GHz), and WLAN (2.4 GHz–2.484 GHz). The design procedure comprises three easy steps. First, a meandering monopole antenna is constructed on the extended region of the PCB to act as the main radiator, resulting in the bands of LTE, DCS, and PCS, PHS, and UMTS. Then, adjusting the coupling between the monopole antenna and the shorted stub, the GSM band is added and the impedance matching in the bands of LTE and GSM is improved. Finally, an additional shorted stub is constructed to radiate in the WLAN band. The organization of the rest of the paper is as follows. Section 2 begins with the antenna configuration and design parameters, and then three simple design steps for the proposed antenna will be introduced. Section 3 will give both measured and simulated results of return loss, radiation pattern, and antenna gain. In Section 4, a detailed parametric study for various design parameters will be performed, and then a brief conclusion will be given in Section 5.

2. ANTENNA CONFIGURATION AND DESIGN

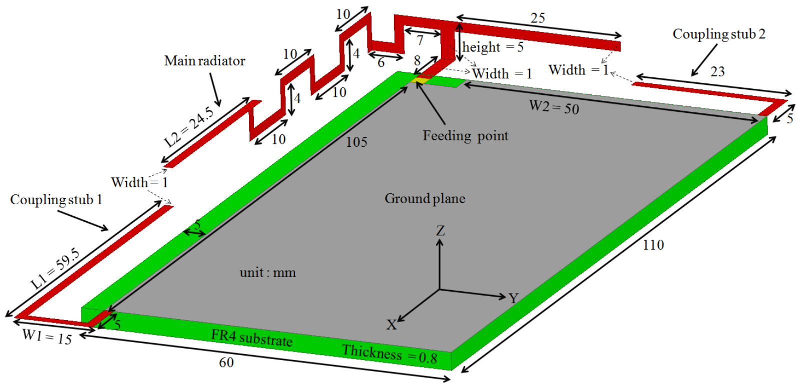
2.1. Antenna Configuration

Figure 1 shows the configuration of the proposed LTE smart mobile antenna with multiband operation. This proposed antenna is fabricated on a low-cost FR4 substrate with dielectric constant $\varepsilon_r = 4.26$, loss tangent $\tan\delta = 0.02$, and thickness $h = 0.8\,\text{mm}$. Etched on the FR4 substrate is a ground plane, where many system devices for mobile phone can be located and constructed. Three pieces of conductors are constructed for radiation: main radiator, coupling stubs 1 and 2. A 50-ohm coaxial cable is adopted to feed RF power to the main radiator. The inner conductor of the cable is soldered to the main radiator, while the outer conductor of the cable is connected to the ground plane. The Ansys HFSS high frequency simulator based on the finite element method is used as the simulation tool. After the optimization process, the final dimensions used for fabrication are indicated in Fig. 1, and the photo of the fabricated antenna is shown in Fig. 2. From Fig. 1(a), the main radiator, coupling stubs 1, and 2 extend 5 to 8 mm from the dielectric to the air region, so that the bandwidth can be broadened. It should be noted that the height of the antenna is only 5 mm, making it a good candidate for the mobile device.

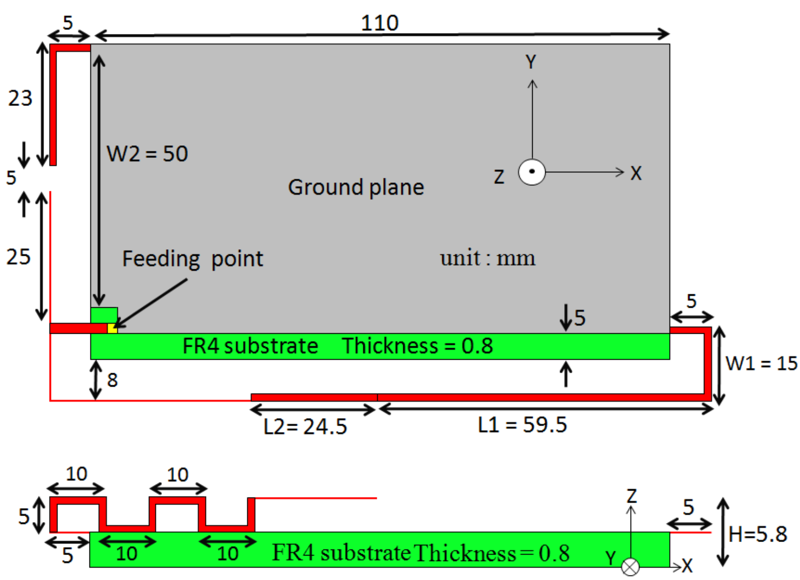
2.2. Antenna Design

In this subsection, a simple design algorithm of the proposed antenna will be detailed in three easy steps. As shown in Fig. 1(a), the first step is to construct the main radiator along the edge of a rectangular PCB, which is based on an inverted-L antenna. The basic idea of an inverted-L antenna is to provide the low and high frequency bands using the longer and shorter sections, respectively. However, the longer section is about 100 mm, which is a quarter wavelength for the LTE band. To overcome the disadvantage of the inherent larger size of an LTE antenna due to the lower frequency of this band, a three-dimensional meandering monopole antenna is used as main radiator. It should be noted that the meandering structure seems to be a better choice among many methods to reduce the antenna size. Moreover, this structure provide additional advantages of wider bandwidth and easier matching process. Fig. 3 shows the variation of simulated return loss with frequency for three consecutive steps. Obviously, the bands of LTE, DCS, and PCS, PHS, and UMTS are excited after step 1. The second step is to fabricate a shorted stub (see Fig. 1(a)). It can be shown from Fig. 3 that the step 2 serves to excite the GSM band

and also to improve the impedance matching in the bands of LTE and GSM. The final step is to add the second shorted stub (see Fig. 1(a)). Fig. 3 shows that the step 3 results in the addition of WLAN band with little influence on the other bands. For convenience, the eight bands excited by the proposed antenna are classified into two groups:



(a)



(b)

Figure 1. Configuration of an LTE smart mobile antenna with multiband operation: (a) three-dimensional view, (b) planar view.

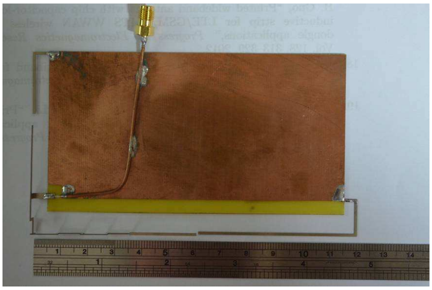


Figure 2. Photograph of an LTE smart mobile antenna with multiband operation.

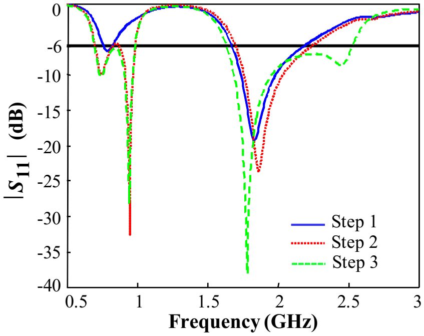


Figure 3. Simulated return loss of the proposed antenna in three design steps.

a lower band (including LTE700, LTE800, and GSM), and a upper band (including DCS, PHS, PCS, UMTS, Bluetooth, and WLAN). It should be reemphasized that the present design allows an easier implementation of an octo-band operation antenna than those using an additional patch [1–17].

3. RESULTS

3.1. Reflection Coefficient

The return losses are measured by network analyzer: R&S ZVB 20, and the radiation patterns are measured in anechonic chamber with size $7\,\mathrm{m} \times 4\,\mathrm{m} \times 4\,\mathrm{m}$. The variation of return loss with frequency is shown in Fig. 4. The measured data are in good agreement with the simulated ones. Taking -6 dB as reference value, the frequency ranges and impedance bandwidth of the proposed antenna are summarized in Table 1 for comparison. It is common practice to take -6 dB as reference for multiband mobile antenna [3, 8], which is also adopted in this work. The experimental results show that the reflection coefficient is below -6 dB between 0.7 to 1.03 GHz with a bandwidth of 0.330 GHz (38%) in the lower band, and between 1.64 to 2.55 GHz with a bandwidth of 0.91 GHz (43%) in the upper band. In addition, the corresponding simulated data are between 0.7 to 0.985 GHz with a bandwidth of 0.285 GHz (34%) in the lower band, and between 1.64 to 2.535 GHz with a bandwidth of 0.895 GHz (43%) in the upper band.

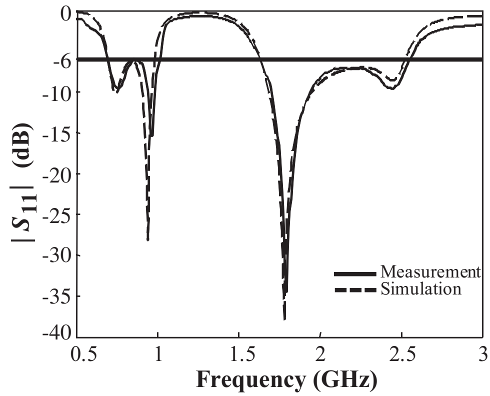


Figure 4. Measured and simulated return loss of the proposed antenna.

Table 1. Summary of the frequency ranges and bandwidths of the proposed antenna.

	f (GHz)	bandwidth (%)
Simulation	0.700–0.985	0.285 GHz (34%)
	1.640–2.535	0.895 GHz (43%)
Measurement	0.700–1.030	0.330 GHz (38%)
	1.640–2.550	0.910 GHz (43%)

3.2. Radiation Patterns

The radiation patterns at 0.7, 0.8, 0.9, 1.7, 1.8, 1.9, 2.1, and 2.45 GHz are shown in Figs. 5, 6, 7, 8, 9, 10, 11, and 12, respectively. These figures show that the proposed antenna exhibits good radiation performances over the eight operating bands. The radiation patterns at lower frequencies (see Figs. 5, 6, and 7) all exhibit omni-directional characteristic in the y-z plane, because the low-frequency radiation results mainly from the ground plane, which is located along x-axis. However, Not only the ground plane but also the main radiator and two coupling stubs have contributions to high-frequency radiation (Figs. 8–12), leading to more disordered radiation patterns, which do not obey omni-directional characteristic in the x-y, y-z, or x-z planes.

3.3. Antenna Gains

The measured gains in y-z, x-z, and x-y planes are shown in Figs. 13, 14, and 15, respectively. For y-z plane (see Fig. 13), the measured

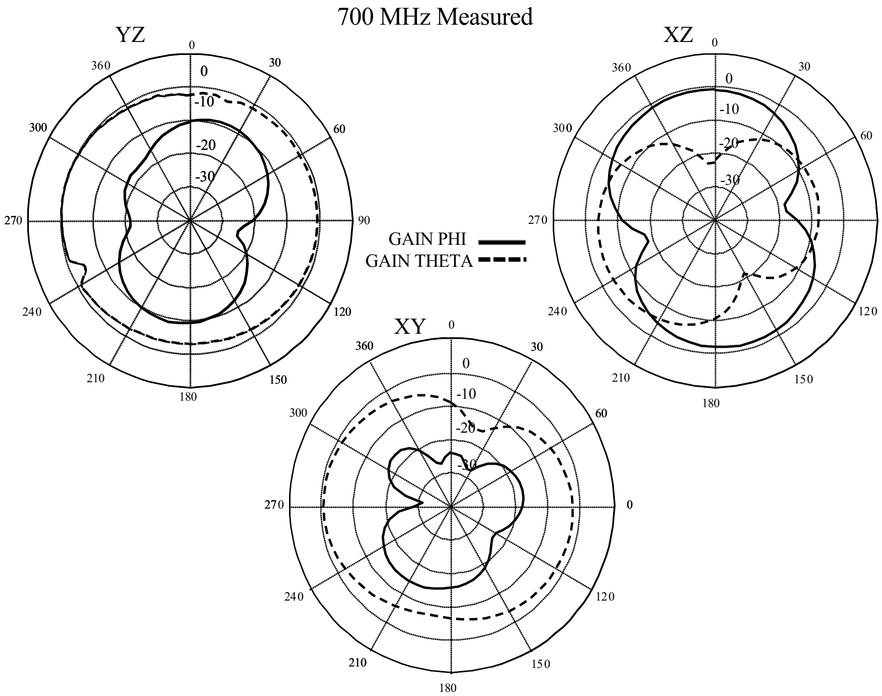
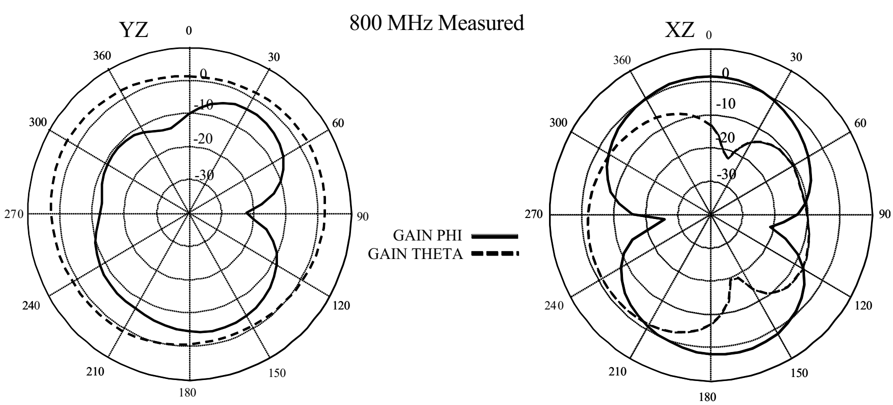


Figure 5. Measured radiation patterns at 700 MHz with the same parameters as indicated in Fig. 1(a).



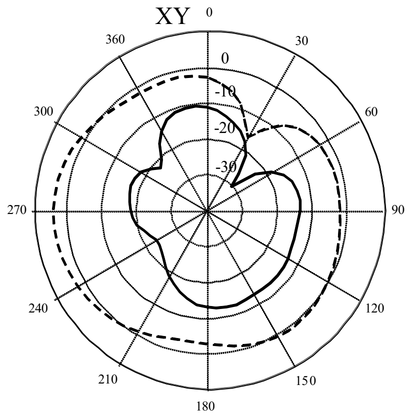


Figure 6. Measured radiation patterns at 800 MHz with the same parameters as indicated in Fig. 1(a).

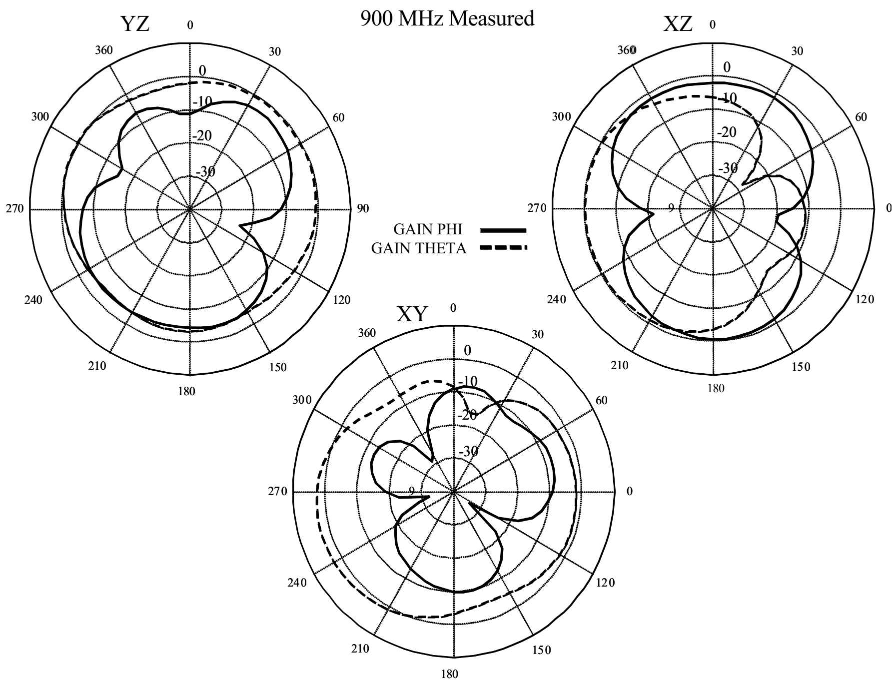


Figure 7. Measured radiation patterns at 900 MHz with the same parameters as indicated in Fig. 1(a).

antenna total gains are about 2, 4, and 1.5 dBi in the lower band, the upper band from 1.7 to 2 GHz, and the upper band from 2 to 2.55 GHz, respectively. However, For x-z plane (see Fig. 14), the measured

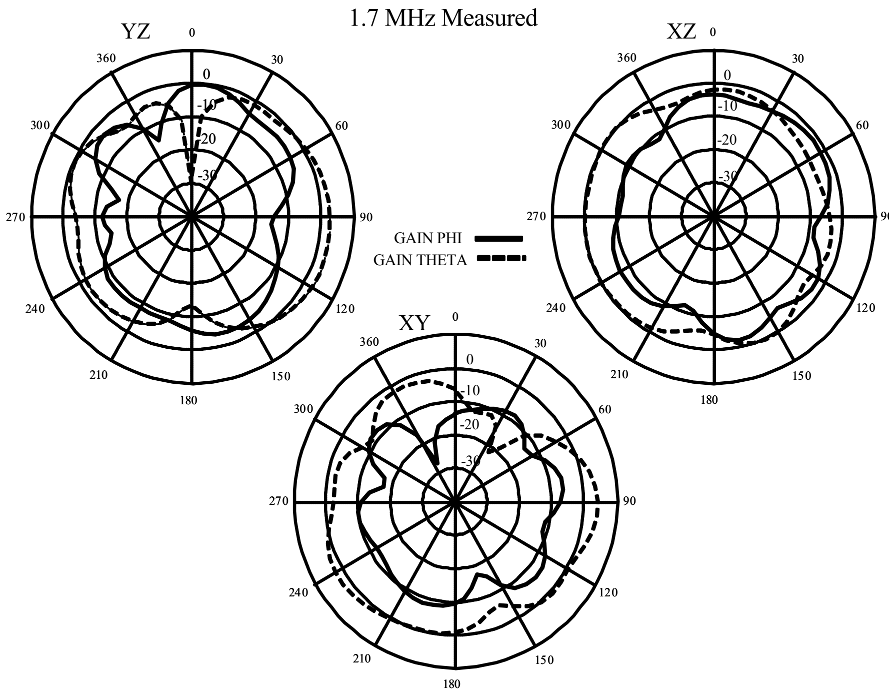
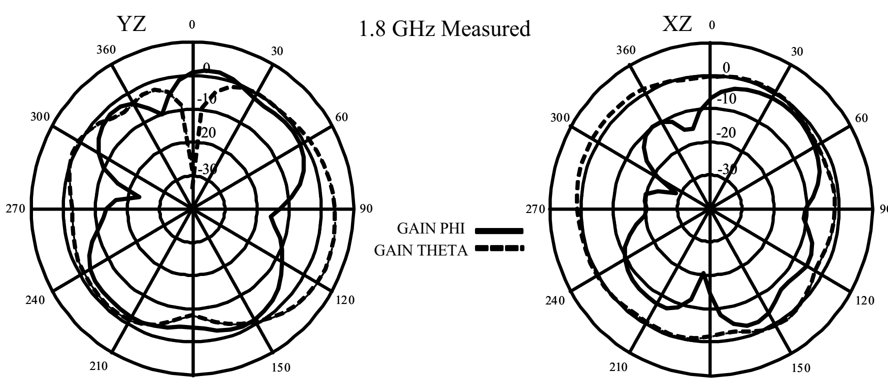


Figure 8. Measured radiation patterns at 1.7 GHz with the same parameters as indicated in Fig. 1(a).



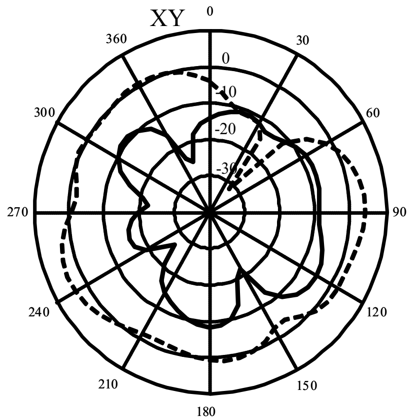


Figure 9. Measured radiation patterns at 1.8 GHz with the same parameters as indicated in Fig. 1(a).

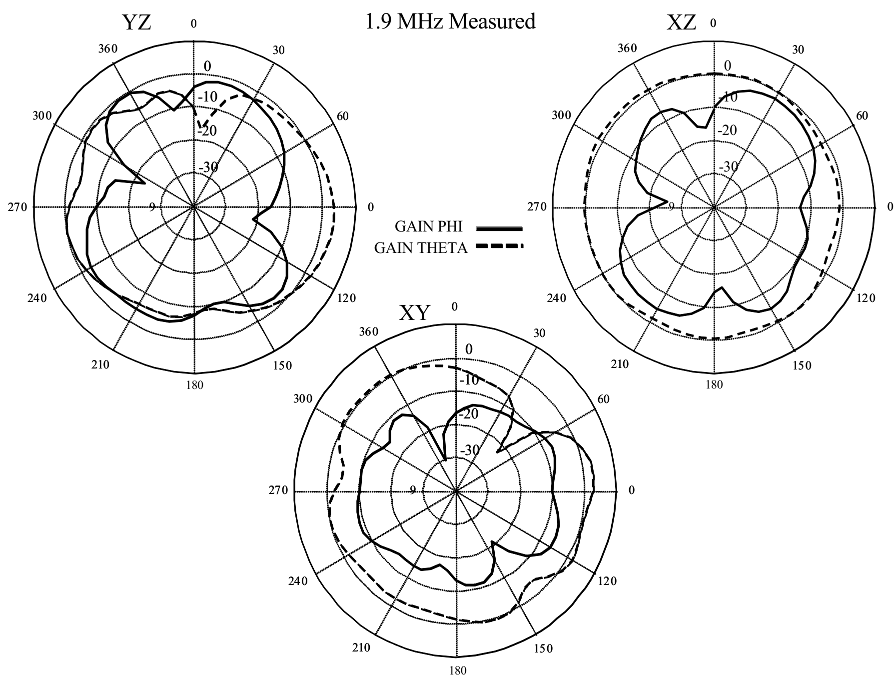


Figure 10. Measured radiation patterns at 1.9 GHz with the same parameters as indicated in Fig. 1(a).

antenna total gains are about 2 dBi in the lower and upper bands. In addition, the antenna total gains in the x-y plane (see Fig. 15) show similar characteristic as in the y-z plane (see Fig. 13).

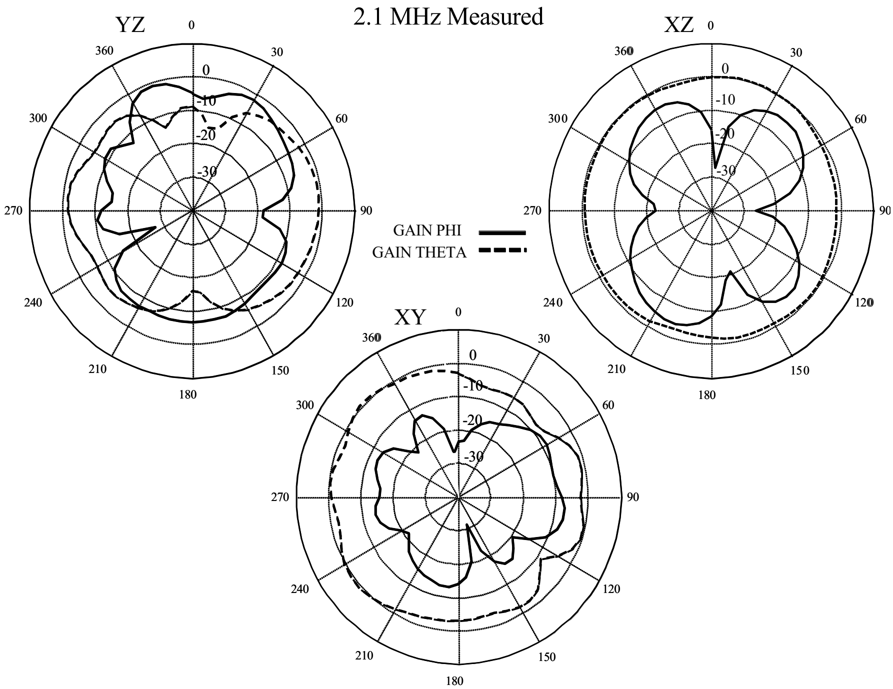
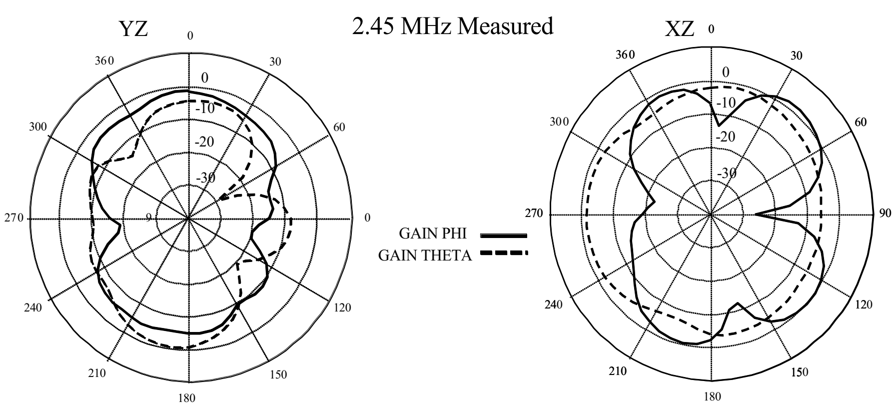


Figure 11. Measured radiation patterns at 2.1 GHz with the same parameters as indicated in Fig. 1(a).



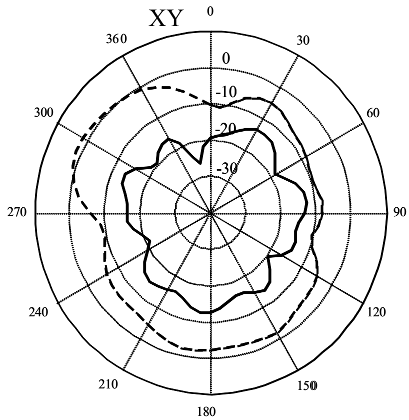


Figure 12. Measured radiation patterns at 2.45 GHz with the same parameters as indicated in Fig. 1(a).

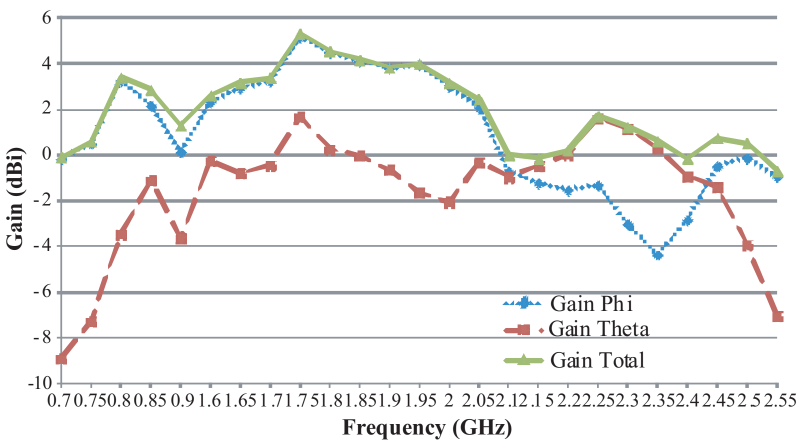


Figure 13. Measured gains in the y-z plane.

4. PARAMETRIC STUDY AND ANALYSIS

Having shown the good performances of the proposed antenna, it would be interesting to investigate the influence of the structure parameters on the return loss. Taking L_1 as a variable and the other parameters kept the same as indicated in Fig. 1, the simulated return losses against frequency with different values of L_1 are shown in Fig. 16. Similarly, the simulated return losses with different parameters of L_2, W_1, and

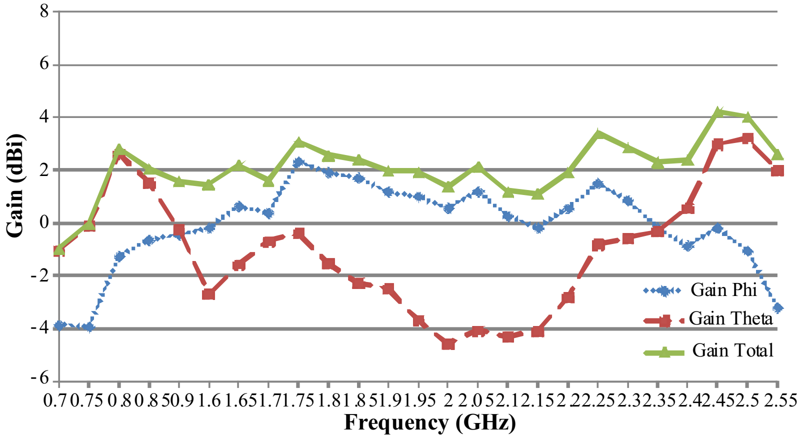


Figure 14. Measured gains in the x-z plane.

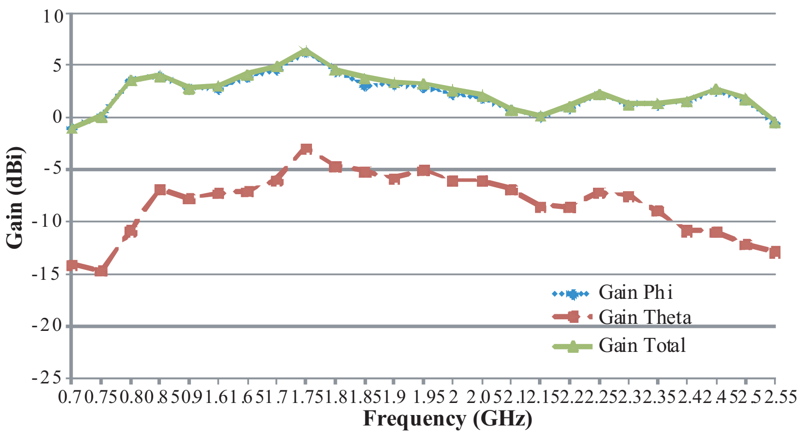


Figure 15. Measured gains in the x-y plane.

W_2 are shown in Figs. 17, 18, and 19, respectively. The increase of the L_1 parameter results in the decrease of the lower band (see Fig. 16), while the increase of the L_2 parameter gives rise to the decrease only in the front lower band (see Fig. 17). On the other hand, the increase of the W_1 parameter leads to the decrease only in the latter lower band (see Fig. 18). Fig. 19 shows that the larger the W_2 parameter, the better impedance matching in the upper band with a shift toward higher frequency.

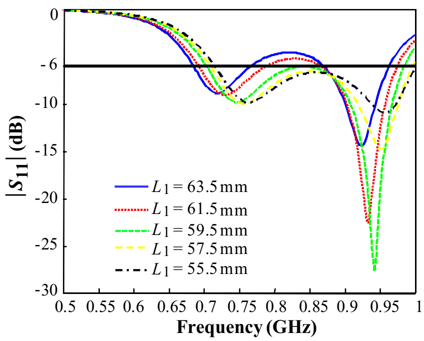


Figure 16. Simulated return losses against frequency for different L_1.

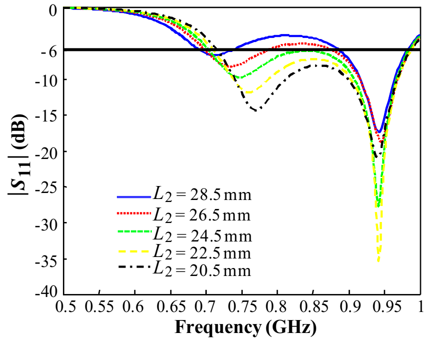


Figure 17. Simulated return losses against frequency for different L_2.

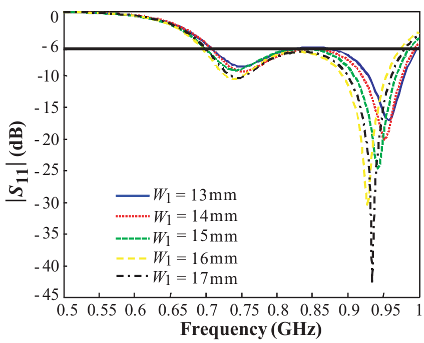


Figure 18. Simulated return losses against frequency for different W_1.

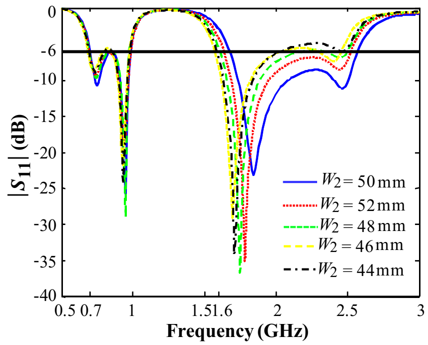


Figure 19. Simulated return losses against frequency for different W_2.

5. CONCLUSIONS

An LTE smart mobile antenna with multiband operation has been proposed to support eight frequency bands with LTE, GSM, DCS, PCS, PHS, UMTS, Bluetooth, and WLAN. This paper puts special focus on developing a simple design, and three easy-to-implement steps go as follows. The main radiator made by a three-dimensional meandering monopole antenna is first built along the perimeter of the grounded plane in order to cover the operating bands of LTE, DCS, and PCS, PHS, and UMTS. A shorted stub is then fabricated along the perimeter for two purposed: exciting the GSM band and also improving the impedance matching in the bands of LTE and GSM. The second shorted stub is finally added to be responsible for providing the WLAN band. Extensive parametric studies are conducted and the measured results show that the -6 dB return-loss bandwidths are from 0.7 GHz to 1.03 GHz (0.33 GHz, 38%) in the lower band and from 1.64 GHz to 2.55 GHz (0.91 GHz, 43%) in the higher band. In addition, the proposed antenna exhibits good radiation performances over the eight operating bands, and the measured antenna gains are about 2 and 3 dBi in the lower and higher bands, respectively. The previous published studies for multiband antenna often adopt an additional patch constructed on one side of the ground plane of a portable device, leading to a more complicated process for adjusting parameters. In this work, an easy-to-implement design is proposed for octo-band operation. Based on the design concept, a more compact and more wideband antenna will be of great interest in the near future.

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