

Research Article

Novel Miniaturized Octaband Antenna for LTE Smart Handset Applications

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A novel octaband LTE mobile phone antenna is presented, which has a compact size with the overall dimension of $35\text{ mm} \times 9\text{ mm} \times 3\text{ mm}$. The miniaturized octaband antenna is implemented by a simple prototype of three parts which include a folded monopole as feeding element, main radiator element, and parasitic radiator element. The main and parasitic radiator elements are excited by the folded monopole feeding element coupling and shorting to the handset ground plane. A wide bandwidth in low-frequency bands covering from 747 MHz to 960 MHz (LTE Band13/GSM850/GSM900) is contributed by both main and parasitic radiator elements. In addition, the folded monopole is designed to resonate at 2530 MHz, and the coupling between the feeding element and main radiator element is designed to resonate at 1840 MHz. Subsequently, the wide bandwidth in high-frequency bands covering from 1710 MHz to 2690 MHz (DCS1800/PCS1900/WCDMA2100/LTE2300/LTE2500) is contributed by both structures. The antenna has the total efficiency up to 30% in low bands and up to 75% in high bands, respectively. At the same time, the proposed miniaturized octaband LTE mobile phone antenna is fabricated and tested to verify the design.

1. Introduction

Nowadays, with the rapid development of wireless communication technology, there is a great demand for high-performance, multifunction, slight, and thin wireless terminal products. Therefore, it gives rise to a challenging demand for miniaturized, low-profile, broadband, high-efficiency, highly integrated, and low-cost antennas [1–6]. With the development and promotion of the LTE standards, the smart mobile phones will be popular and widely used, and the design of new LTE antenna has been becoming a research hotspot. It is worth noting that the LTE mobile antennas should have wideband characteristics covering the working frequency bands of 2G, 3G, and 4G, which further increase the difficulty of cell phone antenna design [4–7]. Some kinds of miniaturized LTE handset antennas are proposed in [8–14]. Simultaneously, some design methods of decreasing antenna dimension and improving antenna performance were adopted [9–16]. An electrically small, wideband, and 4G handset antenna printed on a ceramic material with a high relative permittivity of 6.45 is reported in [9], where

the dimension of the antenna is $35\text{ mm} \times 11\text{ mm} \times 5\text{ mm}$. But the material with high relative permittivity may lead to some undesired loss and the increase of cost. It is demonstrated that meander-line is suitable for miniaturizing dimension of the LTE handset antenna [10–13]. A planar printed antenna with folded monopole and folded shorting strip to cover the frequency bands of 698–960 MHz and 1710–2690 MHz is reported in [10], and the whole dimension of the antenna is $64\text{ mm} \times 15\text{ mm}$. The antenna with dimension of $40\text{ mm} \times 15\text{ mm} \times 3\text{ mm}$ is presented in [11], which has three wide operating bands 698–960 MHz, 1710–2690 MHz, and 5150–5825 MHz. Integrating lumped components into the antenna is another way to achieve miniaturization [8, 12–15]. A series chip capacitor (C) of 1.2 pF and a series chip inductor of 5.6 nH were used as matching circuit in the front of the antenna in [12] and a wide frequency band from 704 to 960 MHz and 1710 to 2690 MHz can be obtained. The area of the antenna is $34.5\text{ mm} \times 10\text{ mm}$, but the antenna is mounted along an edge and at a corner of the device ground plane of size $150 \times 200\text{ mm}^2$, which is a reasonable size for the tablet computer with a 10 in display panel. Table 1 gives

TABLE 1: Comparison of the dimension, working bandwidth, and radiation efficiency of the antennas reported in references.

References	Dimension of substrate (mm ³)	Dimension of antenna (mm ³)	Frequency (MHz)	Radiation efficiency
[3]	100 × 60 × 0.8	9.5 × 60 × 3	698–960, 1710–2690	52–75% (L) 53–78% (H)
[6]	122 × 46 × 1	11 × 46 × 7	698–960, 1710–2690	55.3–71.3% (L) 32.5–98.1% (H)
[7]	115 × 40 × 1	15 × 40 × 1	685–1345, 1685–2985	50–70% (L) 50–82% (H)
[8]	110 × 55 × 1	12 × 55 × 4	809–975, 1675–2703	24%–44% (L) 40%–78% (H)
[12]	150 × 200 × 0.8	10 × 34.5 × 0.8	704–960, 1710–2690	40%–62% (L) 64%–92% (H)

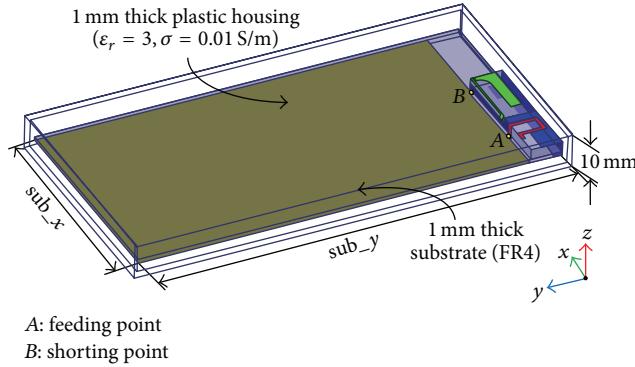


FIGURE 1: Overall structure of the proposed octaband LTE handset antenna.

the comparison of the dimension, working bandwidth, and radiation efficiency of the reported references.

Among these presented small-size LTE antennas, the methods of mender-line, lumped components, and high relative permittivity are applied to achieve the characteristics of miniature, low-profile, and high performance. In this paper, a new miniaturized octaband antenna for LTE smart mobile phone is introduced. The proposed antenna consists of three parts: the folded monopole feeding element, main radiator shorting element, and the parasitic radiator shorting element. It has a compact size with the overall dimension of 9 mm × 35 mm × 3 mm. Additionally, the parasitic radiator element is loaded with a lumped inductance of 4.7 nH, which can reduce the length of the antenna with good matching. Wide octaband operating bands covering the LTE Band13/GSM850/GSM900/DCS1800/PCS1900/WCDMA2100/LTE2300/LTE2500 (747–960 MHz, 1710–2690 MHz) can be obtained. The paper is arranged as follows. Section 2 will introduce the geometry and configuration of the proposed miniaturized LTE antenna. The operating mechanism of the proposed antenna is analyzed in Section 3. Moreover, the miniaturized LTE antenna is fabricated and measured. The measured and simulated results indicate the good performance of the proposed antenna. Finally, a conclusion is given in Section 4.

2. Antenna Design

The overall structure of the proposed new miniaturized octaband LTE handset is shown in Figure 1. The total dimension of the substrate is 60 mm × 120 mm, which is suitable for the actual smart handset platform. The 1 mm thick FR4 substrate with relative permittivity 4.4 and loss tangent 0.024 is used as the system circuit board. The proposed antenna is mounted on a 3 mm thick antenna holder that is also made of FR4 material. Note that a plastic casing made of a 1 mm thick plastic plate with relative permittivity 3.0 and loss tangent 0.02 encloses the system circuit board to simulate the practical mobile phone casing [7]. Figure 2 shows 3D view of the proposed octaband handset antenna and the detailed 2D topology. Note that the red dash-lines shown in Figure 2(b) represent the bending lines. The proposed antenna has a compact size with an overall volume of 35 mm × 9 mm × 3 mm, which is smaller than the proposed antennas in Table 1.

The proposed antenna has a simple structure. Table 2 shows the structural parameters in detail. It consists of a folded monopole feeding element, a main radiator element, and a parasitic radiator element. The folded monopole operates at upper band about 2530 MHz. The main and parasitic radiator elements are excited by the folded monopole feeding element coupling and shorting to the handset ground plane.

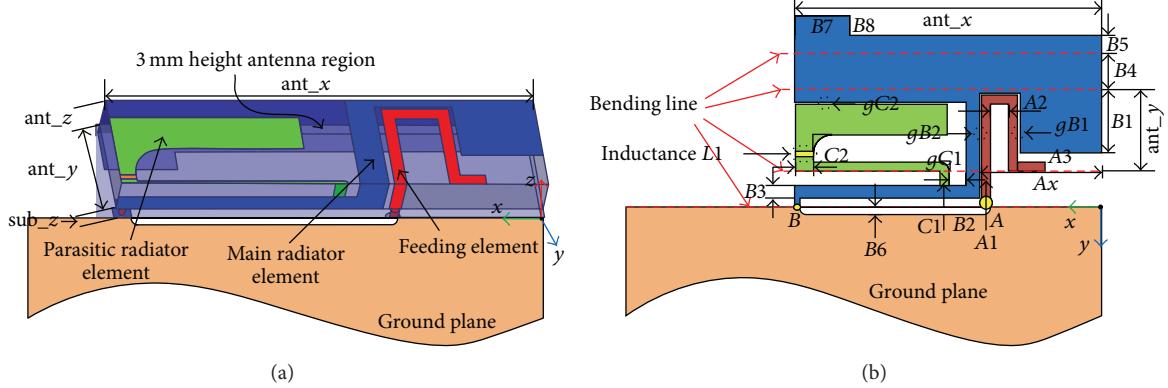


FIGURE 2: Configuration of the proposed octaband handset antenna, (a) 3-dimensional view and (b) 2-dimensional view (red dash-lines represent the bending lines).

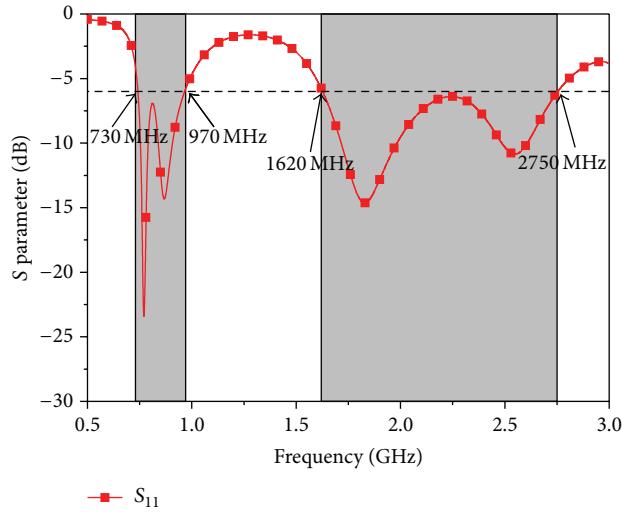


FIGURE 3: Simulated S parameter for proposed antenna.

TABLE 2: Detailed structural parameters of the proposed antenna (unit: mm).

ant_x	ant_y	ant_z	Ax	A1	A2	A3
35	9	3	12.6	1	3.5	2
$gB1$	$B1$	$gB2$	$B2$	$B3$	$B4$	$B5$
0.35	5.95	0.5	2.35	1.5	4	2
$B6$	$B7$	$B8$	$C1$	$gC1$	$C2$	$gC2$
0.7	6	2	1	1	1.35	0.6

The sub_z is referred to as the thickness of substrate, that is, 1 mm. The main radiator element can be excited by the capacitive coupling and generate a resonant mode at about 770 MHz, and the parasitic radiator element is also excited about 860 MHz. A lumped inductor (4.7 nH) is embedded in the parasitic radiator element to further reduce the size. A similar concept of using a short driven element coupled to a parasitic element was proposed for achieving operation at 2G and 3G bands in [17]. More importantly, the etched slit on the ground plane and the shorting strip with

the truncated corners are adopted to achieve a good impedance matching. And the etched ground plane can be regarded as a part of the antenna in order to realize the miniaturization. Therefore, a wide bandwidth covering lower frequency bands from 747 MHz to 960 MHz (LTE Band13/GSM850/GSM900) can be obtained. The strong capacitive coupling between the folded monopole and the main radiator element can generate a resonant mode at about 1840 MHz, which combines with the high resonant mode contributed by the folded monopole at 2530 MHz to produce wide high-frequency bands from 1710 to 2690 MHz (covering DCS1800/PCS1900/WCDMA2100/LTE2300/LTE2500). Therefore, the proposed antenna can cover the octaband operation in the 747–960 MHz and 1710–2690 MHz.

3. Results and Discussion

Figure 3 shows the simulated S parameter of the proposed antenna by using Ansys HFSS software based on finite-element full-wave analysis. It is clearly shown that a wide low-frequency band from 747 MHz to 960 MHz can be

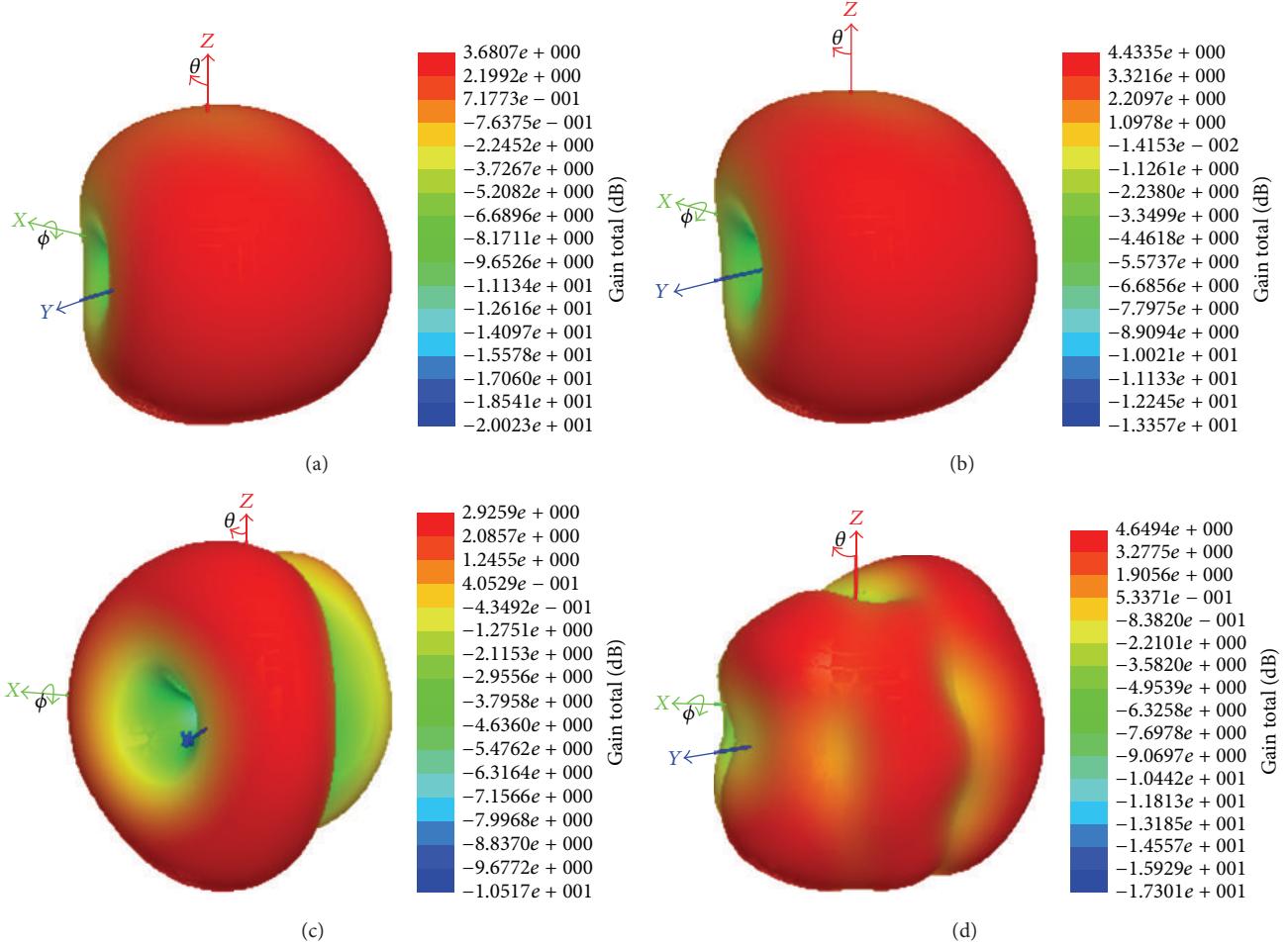


FIGURE 4: Simulated three-dimensional radiation patterns of proposed antenna, (a) 770 MHz, (b) 860 MHz, (c) 1840 MHz, and (d) 2530 MHz.

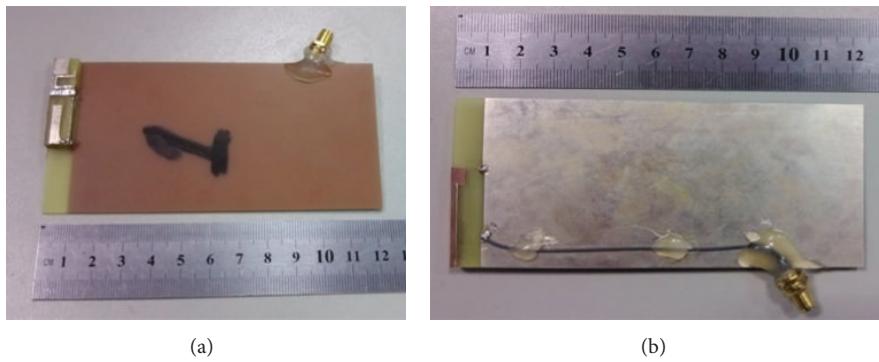


FIGURE 5: Prototype of the fabricated LTE handset antenna, (a) front view and (b) back view.

obtained based on the definition of $-6 \text{ dB } S_{11}$ in the handset application. This allows the antenna to cover the LTE Band13/GSM850/GSM900 operation. Simultaneously, a wide high-frequency band from 1710 to 2690 MHz can be achieved. Therefore, the octaband operation of the LTE Band13/GSM 850/GSM900/DCS1800/PCS1900/WCDMA2100/LTE 2300/LTE2500 can be obtained for the proposed antenna.

The simulated three-dimensional radiation patterns of the proposed antenna are shown in Figure 4 and the characteristics of omnidirectional radiation can be achieved.

The proposed octaband miniaturized LTE antenna prototype was fabricated and tested, as shown in Figure 5. The simulated results were obtained by the Ansys HFSS and the measured results were tested by an Agilent 8719ES



FIGURE 6: Test environment of LTE handset antenna in microwave anechoic chamber.

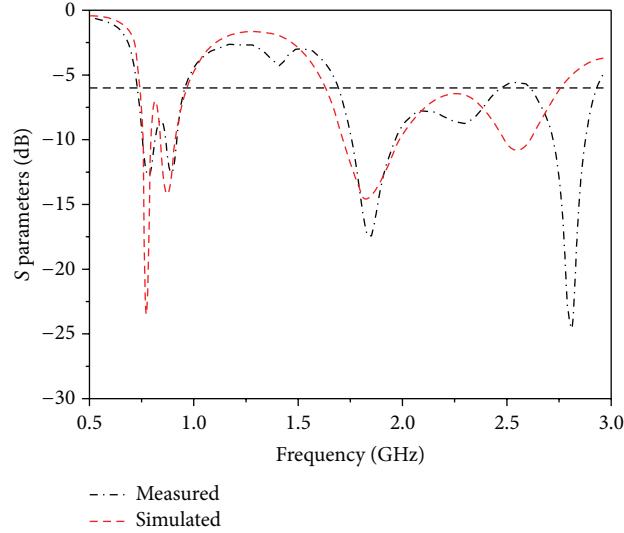
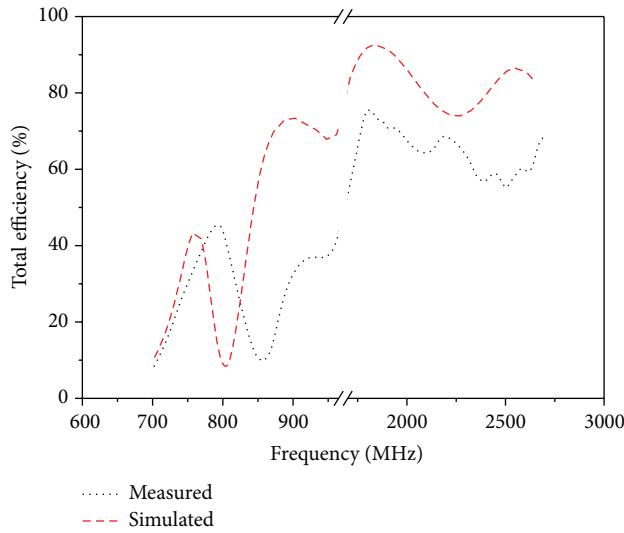
FIGURE 7: Comparison of simulated and measured S₁₁.

FIGURE 8: Comparison of simulated and measured total antenna efficiency.

vector network analyzer in a microwave anechoic chamber. Test environment of LTE handset antenna is shown in Figure 6. Figure 7 shows the comparison of the simulated and measured S₁₁ of the antenna, and the good agreements are obtained between the measured and simulated results.

It is noteworthy that an additional resonance is produced at 2750 MHz, possibly because of the strong capacitive coupling of the radiation strips. The measured total antenna efficiency and three-dimensional radiation patterns of the proposed antenna are shown in Figures 8 and 9, respectively. It can

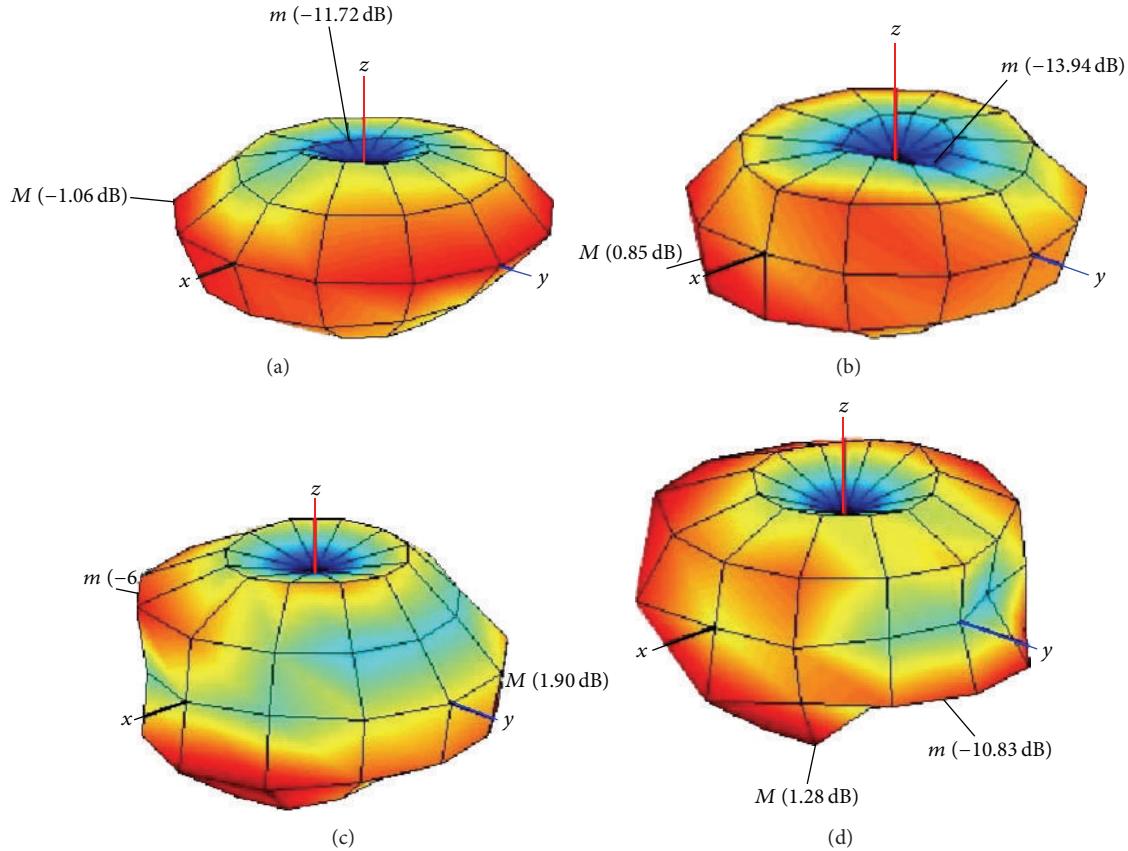


FIGURE 9: Measured three-dimensional radiation patterns of proposed antenna, (a) 767 MHz, (b) 885 MHz, (c) 1806 MHz, and (d) 2500 MHz.

be seen that the measured total efficiency of the antenna has some degradation and shift compared to the simulated results. The main reason is due to the material loss and fabrication errors. A surface-mount technology chip inductor of 4.7 nH (LQW15AN4N7B00D) was used, which is from Murata Manufacturing Co., Ltd. Because the inductor losses were not considered in the simulation, the measured results have some difference with the simulated results. Overall, the total efficiency of the proposed antenna is up to 75% in upper bands and up to 30% in lower bands. It can be seen from Figure 9 that the measured 3D radiation patterns of the antenna are close to omnidirectional radiation characteristics.

In order to analyze the characteristics of the proposed antenna in detail, the surface current distributions on the antenna and ground plane at the different operating frequencies are shown in Figure 10. It is clearly observed that the current is mainly distributed on the main radiator shorting element at 770 MHz, as shown in Figure 10(a), and on the parasitic radiator shorting element at 860 MHz, as shown in Figure 10(b). It can be seen that both main and parasitic radiator elements are excited to cover a broadband frequency range from 747 MHz to 960 MHz. The strong surface current on the folded monopole can be seen at 2530 MHz, as shown in Figure 10(d), which demonstrates that the mode is contributed by the folded monopole. Moreover,

the surface current between the folded monopole and the main radiator element is strengthened at 1840 MHz, as shown in Figure 10(c), which proves that the resonant mode is excited. Thus, a wide operating band from 1710 MHz to 2690 MHz can be obtained.

4. Conclusions

In this paper, a new miniaturized LTE handset antenna is designed, fabricated, and measured, which exhibits an octaband operation in LTE Band13/GSM850/GSM900/DCS1800/PCS1900/LTE2300/LTE2500 (747 MHz–960 MHz, 1710 MHz–2690 MHz) with high performance. It has a compact size with overall dimensions of $35 \text{ mm} \times 9 \text{ mm} \times 3 \text{ mm}$, which is smaller than the reported handset antenna. The antenna efficiency is generally larger than 30% in lower band and larger than 75% in upper band. It is worth pointing out that the proposed miniaturized octaband LTE antenna can be suitable for the application of next generation of wireless communications.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

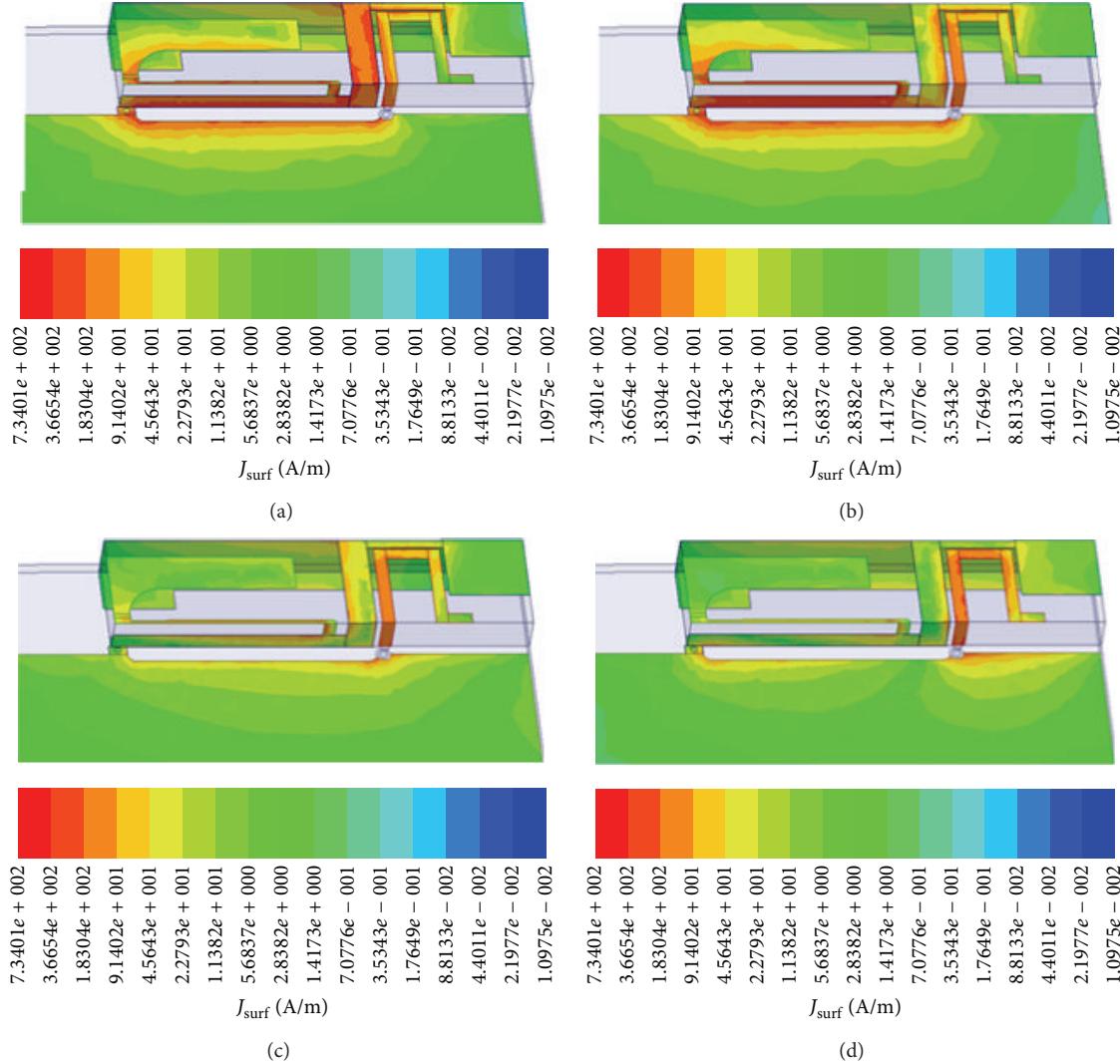


FIGURE 10: Characteristics of the current distribution on the antennas and ground plane, (a) 770 MHz, (b) 860 MHz, (c) 1840 MHz, and (d) 2530 MHz.

Acknowledgments

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