Two-sided Inverted F Antenna with LTE, GSM, WLAN, WiMax Frequency Bands for Mobile Phones

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Abstract— A small-size double-sided threelayers inverted-F antenna suitable to be printed on the system circuit board for LTE 700 MHz, GSM 900/1800 MHz, WLAN 2400/5200/5800 MHz and WiMax 3500/5500 MHz is presented With mender microstrip line disperses on double-sided and coupled each other to produce enough bandwidth of low-band and multi-band of high-band, but also makes the size of the radiation side of the proposed antenna is $40 \times 13\,\mathrm{mm}^2$. Including the ground plane, the total antenna size is $0.8\,\mathrm{mm} \times 87\,\mathrm{mm} \times 40\,\mathrm{mm}$ of the FR4 substrate. This size and performance of this proposed antenna are suitable to the mobile phone.

1. INTRODUCTION

In recent years, with the rapid development of wireless communication industry, has also led to advances in mobile communications technology. The LTE (Long Term Evolution) 3GPP is the start of the latest technology in recent years, which improve and enhance the 3G air acess technology, and by using OFDM and MIMO wireless network evolution as its core technology to provide fast-level bit rate of broadband up/down link of communication, which is operated in the low-frequency band 746–787 MHz. The communication system of mobile devices further comprises other necessary wireless systems, such as WLAN, Bluetooth, etc., so that the operation of multi-wireless communication systems has become a basic requirement, the antenna design must respond to such a request.

[1, 2] had proposed the antenna design using the meandering structure coupling method to make low-frequency operation in GSM, these two documents can only operate in GSM low frequency, however, no contains WiMAX 3500/5500 band and LTE700 bands. Other authors had proposed using the PIFA structure and including the radiation conductors structure [3], a coupling short circuit antenna structure [4], the ground plane extending parasitic capacitance technology [5], and fed into a compact coupling structure, such that the antenna can generate a multi-band and operating in GSM 850/900 WLAN 2400/5200/5800, WiMax 3500/5500 MHz. However, these paper [3–5] still cannot meet the application of LTE frequency bands and more bands, [6] proposed a coupling fed PIFA structure on the plate allowing this antenna operating in GSM 1800/1900, UMTS/LTE 2300/2500 MHz frequency bands, but it's size of $15 \times 48\,\mathrm{mm}^2$ is larger.

[7, 8] proposed the loop antenna structure that can generate multi-band and operate in GSM/DCS/PCS/UMTS, but cannot meet the application LTE700 band. [9–11] using the coupled fed and distributed coupled antenna structure to achieve broadband operation, can produce LTE/WLAN bands, but was unable to provide GSM band applications. [12] proposed a slot antenna having two different lengths of a quarter wavelength and a half wavelength slot grooves, raising band covers 704–960, 1710–2690 MHz, but there is no WiMAX 3500/5500 frequency bands.

This paper presents an eight-band antenna covering LTE 700 (746–787 MHz), GSM 900/1800 (890–960/1710–1880 MHz), WLAN 2400/5200/5800 (2400–2483/5150–5350/5725–5875 MHz) and WiMax 3500/5500 (3500–3600/5250–5850 MHz), the size of the antenna radiation terminal $40 \times 13 \times 0.8\,\mathrm{mm}^3$, comprising a ground plane of the overall size of $87 \times 40 \times 0.8\,\mathrm{mm}^3$. This antenna is easy to manufacture and to fulfill the requirements of low cost and miniaturization, using a $50\,\Omega$ coaxial cable as the fed line, to be suitable for embedded antenna of mobile phone application in size.

2. ANTENNA DESIGN

This paper presents an eight-band, double-side inverted-F antenna is suitable for LTE, GSM, WLAN, WiMax applications. The structure diagram and dimension of this proposed antenna are shown in Figure 1. This antenna is designed on FR4 substrate with total size of $0.8 \times 87 \times 40\,\mathrm{mm}^3$, the dimension of radiating end part of antenna is $13 \times 40\,\mathrm{mm}^2$. Figure 1(a) is a front of the antenna, the double-layer inverted F and microstrip meander line structure, main for generating

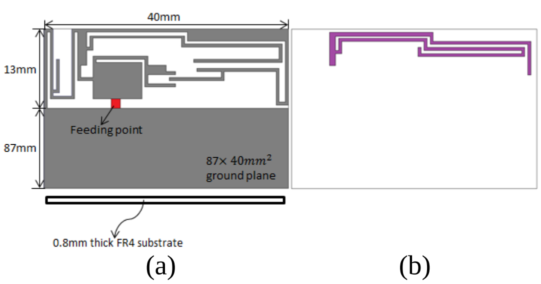

Figure 1: Structure of proposed antenna. (a) Front part. (b) Back part.

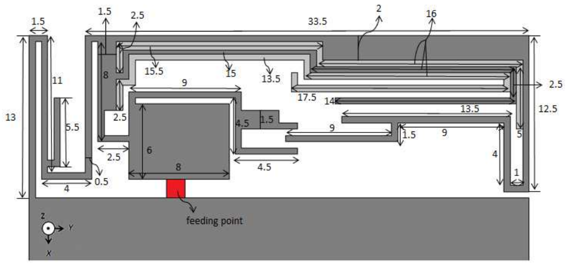

Figure 2: The detail size of proposed antenna.

the low frequency band of LTE and the high frequency bands. Figure 1(b) is the back of the antenna, a microstrip meander line structure as an induction capacitor, for expanding GSM frequency bandwidth.

Figure 2 presents a detail structure and size of the radiation part of proposed antenna, feed line with length and width is 1.5 mm respectively. Figure 4 shows the marked current flow path to illustrate the resonating wave length of corresponding frequency. There are three layers of inverted F antenna structure to generate eight band oscillations, the longest layer is ABC and AL, the second is ANOP and AL, the shortest is AE and AL.

The path ABC is the longest length corresponding to the wavelength $0.23\lambda_g$ (75 mm) of LTE 700 MHz. The path ANOP is the second longest corresponding the wavelength $0.25\lambda_g$ (57.8 mm) of GSM 900 MHz. The path ANOP couples the high order resonating frequency GSM 1800 to the meandering micro strip line on the back part. The path ADE generates the WiFi 2400/5200 MHz bandwidth. The path AM generates the WiMax 3500 MHz bandwidth. This three layers inverted F antenna is transformed from the monopole antenna can reduce the size of antenna and generates eight band resonators. This antenna designed for the FR4 glass fiber with thickness of 0.8 mm, the relative dielectric constant (Relative Permittivity) of 4.4 and a constant loss tangent (loss tangent) is 0.0245. The size of radiation area is $40 \times 13\,\mathrm{mm}^2$. The ground contact area of $40 \times 87\,\mathrm{mm}^2$ can be used as a mobile phone board, without affecting the antenna function, in general, this antenna is suitable for a LTE mobile phone system.

3. RESULTS AND DISCUSSION

Simulation result of return loss of the proposed antenna shown in Figure 3, frequency band was defined with condition of the reflection loss is greater than 6 dB. There are eight frequency bands, low-frequency operating at 746–796 MHz, 860–1000 MHz, 1760–1880 MHz, high-frequency operating at 2390–2499 MHz, 3480–3708 MHz, 5120–5957 MHz. These frequency bands can be applied to four kinds of wireless communication systems, such as LTE 700, GSM 900/1800, WLAN 2400/5200/5800, WiMax 3500/5500.

Through these current distribution paths shown in Figure 4 can verify the design resonance effect. The current distribution from the end point A to the B rightmost and point C of Figure 4(a) shows the $0.23\lambda_g$ (75 mm) wavelength of LTE 700 MHz. The current distribution on meandering path ANOP corresponds to the wavelenth $0.25\lambda_g$ (57.8 mm) of GSM 900. Two current distribution

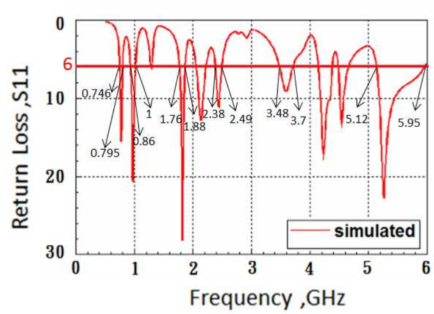

Figure 3: Simulated return losses of the proposed antenna.

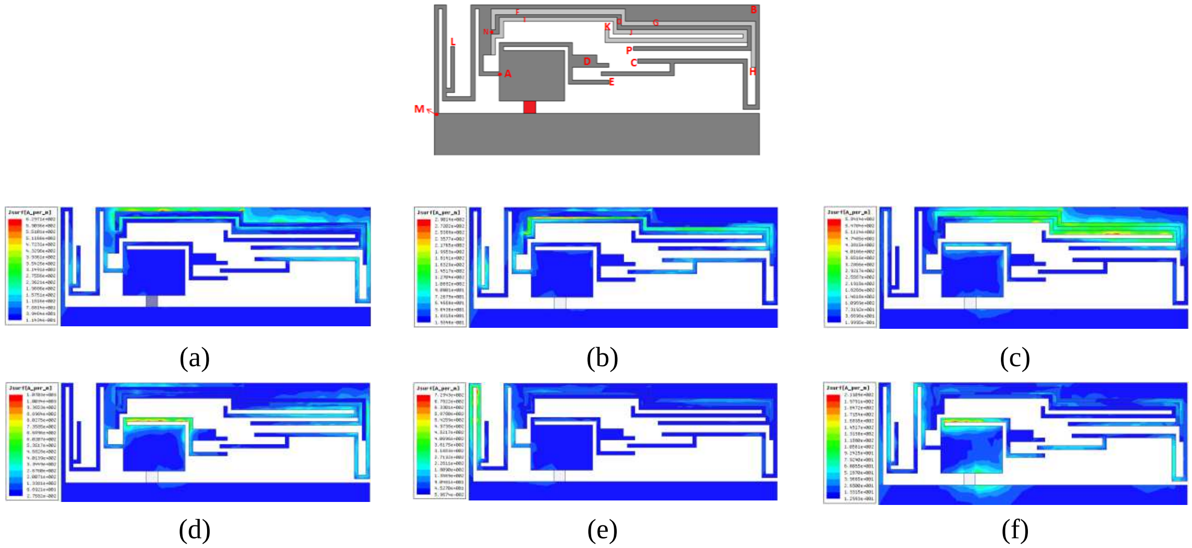

Figure 4: Current distributions at 5 oscillating frequencies of the proposed antenna, (a) 0.7 GHz, (b) 0.9 GHz, (c) 1.8 GHz, (d) 2.4 GHz, (e) 35 GHz, (f) 5.5 GHz.

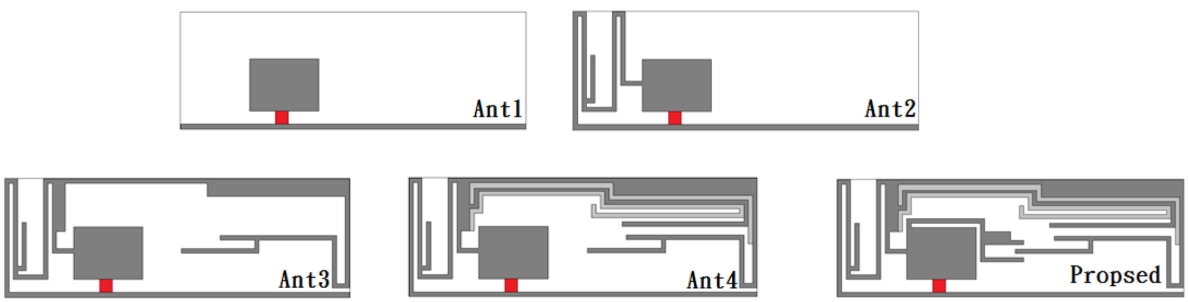

Figure 5: Design revolution of the proposed antenna.

paths at the back part, FH and IJK, were coupled from ANOP and oscillated at the relative wavelength $0.27\lambda_g$ (41 mm) GSM 1800. The current distribution path at DE corresponds to the wavelength of WLAN 2400 MHz. Finally, the current distribution path at AM corresponds to the wavelength of WiMax 3500 MHz.

Design revolution versions, Ant1∼4 and the proposed, of the proposed antenna are shown in Figure 5. These corresponding return losses are shown in Figure 6. Ant1 shows the square monopole antenna structure. Ant2 add a grounding mender microstrip line. Ant3 increases meandering microstrip line structure at the top and right hand of Ant2 and makes this antenna becomes an inverted F, enhancing the LTE 700 frequency band. Ant4 adds the parasitic meander microstrip line at back part to increase the frequency band and bandwidth. The proposed antenna architecture increases the strip arm to generate 2400 MHz, making the whole antenna to become a double-sided three-layer inverted F antenna design. Ant1 operated from 3.8 to 6 GHz, Ant2 increased 3.5 GHz resonant modes, Ant3 added 0.7 GHz bandwidth and 5.8 GHz higher frequency resonant modes. Ant4 increased in 0.9 GHz and 1.8 GHz resonance frequency band through a microstrip line coupling, it also provides 5.2 GHz high resonant modes. The proposed antenna increased the 2.4 GHz by adding the inner arm of the Ant4. So, by the double-side three-layer inverted F antenna structure to generate eight bands frequencies includes LTE 700, GSM 900/1800, WLAN 2400/5150/5500, WiMax 3500 for four different communication systems.

Simulated 3D total power radiation patterns of each band are shown in Figure 7, four radiation patterns of each band from left to right are seen from different directions, the front, back, top and bottom. Observing graph types of radiation patterns, LTE 700 and WLAN 2400 are omnidirectional radiations, GSM 1800, WiMAX 3500 radiating in favor of the X-axis with the Y-axis. According to the radiating patterns directed to the back of PCB, it is a suitable antenna design mobile applications for meeting the requirement of SAR. Gain values of each band of the antenna presented

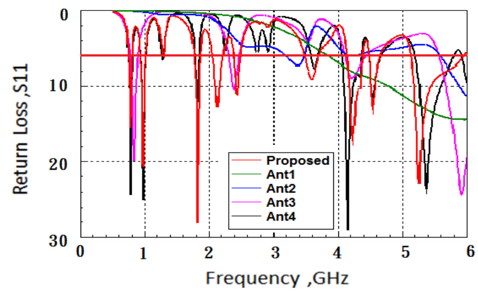

Figure 6: Return losses relative to architectures of Ant1∼4 and the proposed antenna.

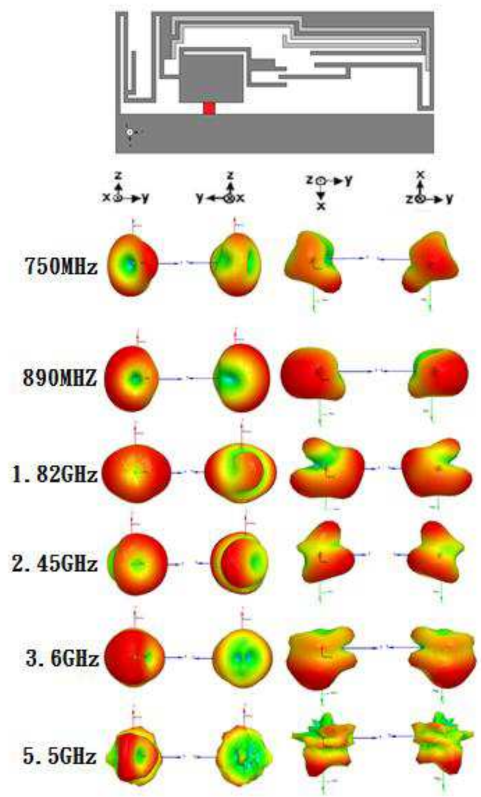

Figure 7: Radiation patterns at 6 oscillating frequencies of the proposed antenna.

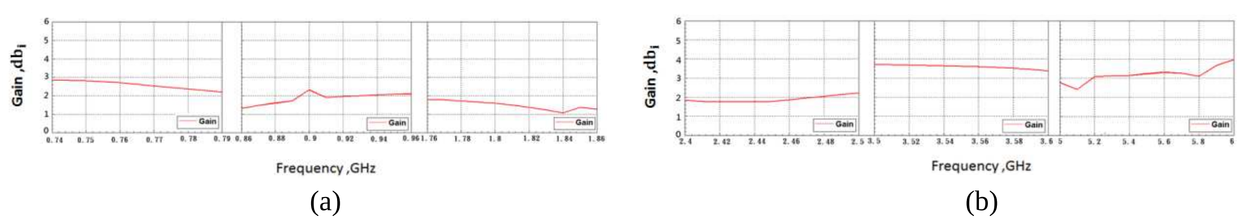

Figure 8: Antenna gain values at 6 oscillating frequencies, (a) 0.75, 0.89, and 1.82 GHz, (b) 2.45, 3.5, and 5.5 GHz of the proposed antenna.

in Figure 8, the low-frequency gain values stable at 1–2.8 dBi, the high frequency gain values is stabilized at 2.4–4 dBi.

4. CONCLUSIONS

This paper presents an eight bands antenna covering LTE 700, GSM 900/1800, WLAN 2400/5200/5800, WiMAX 3500/5500, with double-side three-layer inverted-F antenna which is transformed from the monopole antenna for minimizing the antenna size and generating eight bands. Besides, this combined antenna structure can generate good radiation patterns and gain values, under the minimal size of the radiation area is $40 \times 13\,\mathrm{mm}^2$. The ground plane of FR4 substrate size is $0.8\,\mathrm{mm} \times 87\,\mathrm{mm} \times 40\,\mathrm{mm}$. The overall antenna size and features are consistent and meets the need of the mobile phone with limited space and good performance.

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