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A Novel Design of Antenna for the 3G Mobile Devices

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Abstract

This paper proposes a novel structure of the inverted F antenna based on meandering and folding methods for the monopole antenna placed on FR4 dielectric plate. The proposed antenna has compact size (21 mm × 14 mm × 3.2 mm). Moreover, this antenna still offers enough wide bandwidth (VSWR ≤ 2), which covers 3G bandwidth. Using the simulation program to optimize antenna structure and calculate the antenna parameters in order to verify its applicability for the 3G mobile devices.

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1. Introduction

Nowadays, with the rapid growth of wireless means of communication, there is a growing demand for mobile devices that are small, thin, attractive, lightweight, and curvy. To satisfy the above demand, it is necessary to miniaturize mobile device's components. Especially, antenna, an essential part, is miniaturized in order to put into the device.

Many studies and suggestions about typical antenna structure for portable devices have been published recently. D. Bonefacic [1] proposed a design for a micro-strip antenna that works on central frequency of 2.0 GHz and has very small size (30 mm × 12.9 mm × 5 mm) but the bandwidth of the proposed antenna is too narrow (26 MHz). Y. Kim [2] proposed a folded loop antenna system for new future handsets. M. Karaboikis [3] proposed a dual-printed inverted F antenna structure for terminal devices. K. Sarabandi [4] proposed a method of miniaturized size antenna as small as $0.05\lambda \times 0.05\lambda$. M. Akbari [5] presented an approach to optimize the antenna structure by creating a planar inverted F antenna (PIFA). However, the overall size of the proposed antennas in the references is still quite large; therefore it is difficult for the mobile device to miniaturize its size for applications in MIMO system. In order to overcome the said shortcomings, in the reference document [6], an antenna with smaller size (23 mm × 14 mm × 5 mm) is proposed which can be applied for 3G mobile devices.

In this paper, the authors use Ansoft HFSS software to miniaturize antenna structure for the 3G mobile devices based on meandering and folding methods for the monopole antenna, which is developed from the inverted F antenna. Next, we analyze the inverted F antenna placed on a metallic plane representing a mobile device. Then, it is possible to propose a method to miniaturizing antenna structure and to design a compact antenna with dimensions of 21 mm × 15 mm × 3.2 mm, which is smaller than antennas in the reference [6]. Although its height is only 3.2 mm but its bandwidth and other technical parameters are still ensured. This antenna structure can be placed into thin mobile devices.

In order to match the antenna input impedance with the feeder and to ensure its bandwidth must be wide enough to cover the 3G bandwidth, the antenna structure is optimized. Finally, the antenna parameters such as input impedance, VSWR, radiation pattern are calculated to validate the applicability of the proposed antenna in 3G devices.

2. The proposed antenna structure for 3G mobile devices

2.1. Main requirements of antennas for 3G mobile devices

When design an antenna for the mobile devices, bandwidth and the requirements of antenna compact dimensions must be taken into account. Normally, the 3G mobile devices have the length, width and thickness of 110 mm, 60 mm, and 12 mm, respectively. Currently, the 3G mobile systems in Vietnam use frequencies from 1.9 GHz to 2.17 GHz. Thus, the design antenna for 3G mobile devices has to ensure the requirements on compact size, bandwidth and several following parameters:

- The antenna size must be small enough to be placed in a mobile device, its height is less than 5 mm, its length and its width are less than 40 mm;
- The input impedance of the antenna can reach 50 Ω at the central frequency (to match perfectly with the feeder);
- VSWR ≤ 2;
- The bandwidth of the antenna is large enough: (≥ 10%, ≥ 200 MHz).

2.2. A method of miniaturizing antenna structure

Let's consider the inverted F antenna placed on a metallic plane (using copper), with dimensions of 86 mm × 40 mm × 0.1 mm, that represents a mobile device, with surveyed bandwidth from 1.8 GHz to 2.2 GHz. A FR4 dielectric plate is placed between the antenna and the metallic plane. In Fig. 1, the dimension of the FR4 dielectric plate is 40 mm × 15 mm × 3.2 mm. In order to miniaturize the size of the initial inverted F antenna, it is possible to apply meandering, folding and slotting methods [7] and apply dielectric substance FR4 to form its structure. In addition, in order to ensure the antenna input impedance, it is needed to change the current in the antenna by varying the distance between the feeding point and the grounding point and adding U, L shape strip-lines, rectangular strip-lines.

Compared with the initial inverted F antenna structure, the proposed antenna has a U-shape strip-line with the parameter of s and two rectangular strip-lines with the parameters of $l_1 \times l_2$ and $l_6 \times l_7$, as shown Fig. 2. Adding these strip-lines will change the current distribution on the antenna. This in turn will change the antenna input impedance and therefore help the impedance matching with the feeder. Moreover, the optimized antenna will expand the bandwidth and ensure more compact size.

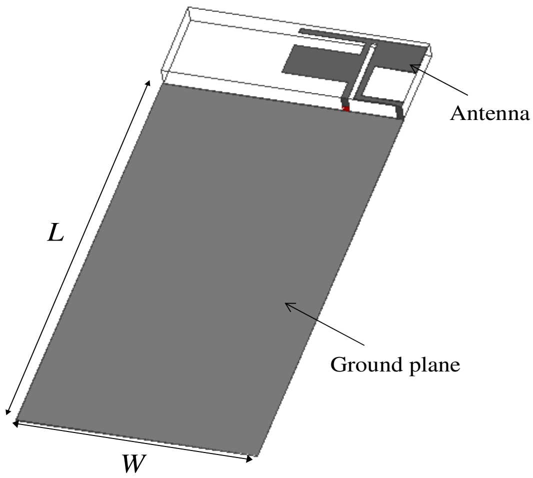


Fig. 1. The antenna structure.

After many experiments, an optimized antenna structure is chosen. The size of the optimized antenna elements is shown in Table I.

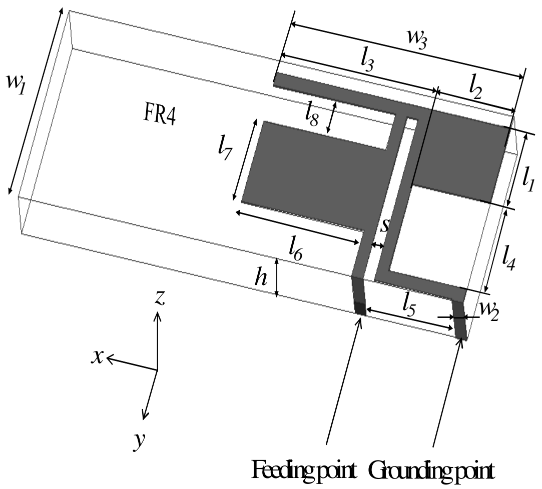


Fig. 2. The structure of proposed antenna.

Antenna is connected with the metallic plane by 2 points, the feeding point and the grounding point. This antenna structure consists of copper strip-lines of width w_2 = 1 mm, thickness is 0.1 mm. The overall dimensions of the antenna are chosen with 21 mm (length), 14 mm (width), and 3.2 mm (height). A gap between the feeding point and the grounding point is l_5 = 9 mm. Except for the strip-lines are connected to the metallic plane, other strip-lines are fixed on the dielectric FR4 plate and parallel to the ground.

To choose the optimal parameters of antenna as shown in Table I, we examine of the effect of antenna size parameters to VSWR.

2.3. Impact of VSWR when changing antenna size parameters

2.3.1. Impact of VSWR when changing l_3

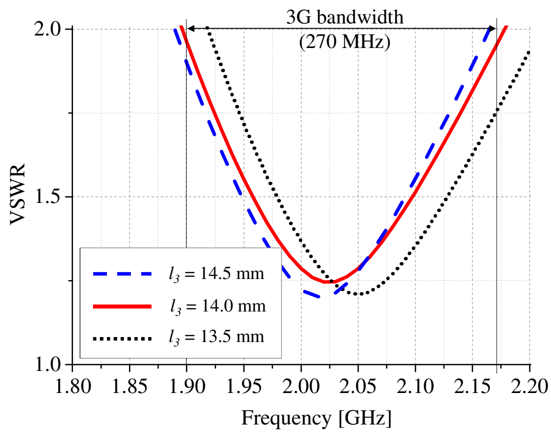


Fig. 3. The effect of l_3 to VSWR.

The results of calculating the dependence of parameter l_3 on the VSWR is represented in Fig. 3. For VSWR ≤ 2, when increasing the length l_3, the electrical length of monopole antenna increases so that resonance frequency and bandwidth of antenna decrease. In contrast, when reducing the length l_3, the bandwidth of antenna increases but it does not cover the bandwidth of 3G mobile devices. As a result, in order to have bandwidth of antenna cover the working bandwidth of 3G mobile devices, it is necessary to select parameter l_3 = 14.0 mm.

2.3.2. Impact of VSWR when changing l_5

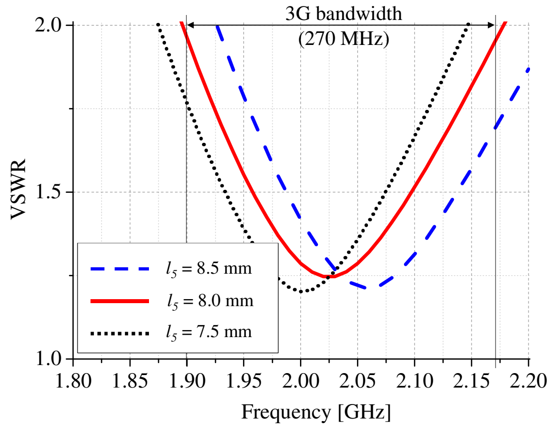


Fig. 4. The effect of l_5 to VSWR.

The results of calculating the dependence of parameter l_5 on the VSWR is represented in Fig. 4. For VSWR ≤ 2, when increasing the length l_5, the distance between the feeding point and the grounding point increases, therefore current in the antenna changes. This makes resonance frequency and bandwidth of antenna increase. In contrast, when reducing the length l_5, the bandwidth of antenna decreases. However, in both cases, bandwidth of antenna does not cover the bandwidth of 3G mobile devices. Therefore, parameter l_5 must be selected with optimal value is 8.0 mm.

2.3.3. Impact of VSWR when changing l_6

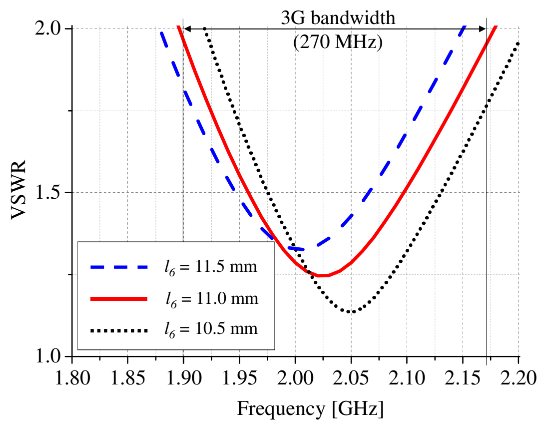


Fig. 5. The effect of l_6 to VSWR.

In Fig. 5, similar to the parameter l_3, when increasing the length l_6, the electrical length of monopole antenna increases, therefore resonance frequency and bandwidth of antenna decrease. In contrast, when reducing the length l_6, the bandwidth of antenna increases but it does not cover the bandwidth of 3G mobile devices (with VSWR ≤ 2). Therefore, parameter l_6 must be selected with optimal value is 11.0 mm.

2.3.4. Impact of VSWR when changing l_8

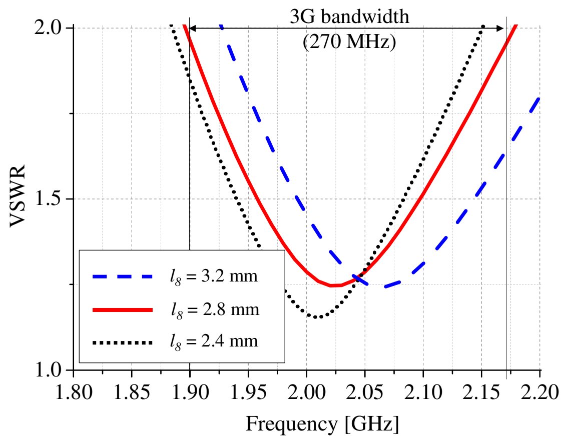


Fig. 6. The effect of l_8 to VSWR.

The results of calculating the dependence of parameter l_8 on the VSWR is represented in Fig. 6. Similar to other parameters, when changing the length of l_8 compared with the optimal value, the bandwidth of antenna (with VSWR ≤ 2) does not cover the bandwidth of 3G mobile devices. Therefore, parameter l_8 must be selected with optimal value is 2.8 mm.

Similarly, when analyzing the effects of changing other parameters to VSWR, the optimal dimensions of the antenna are chosen, as shown in Table I.

Table I. The size of the proposed antenna (MM)

Parameters	Value	Parameters	Value	Parameters	Value
L	80	w_2	1	l_4	7
W	40	w_3	21	l_5	8
h	3.2	l_1	6	l_6	11
s	1	l_2	7	l_7	6.5
w_1	15	l_3	14	l_8	2.8

2.4. Simulated results of the proposed antenna

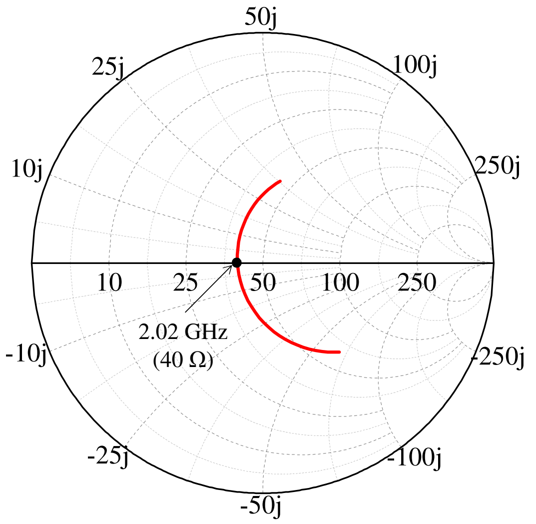


Fig. 7. Input impedance of the proposed antenna.

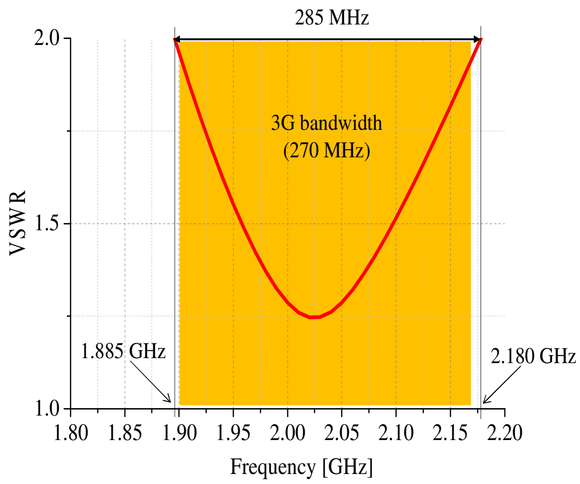
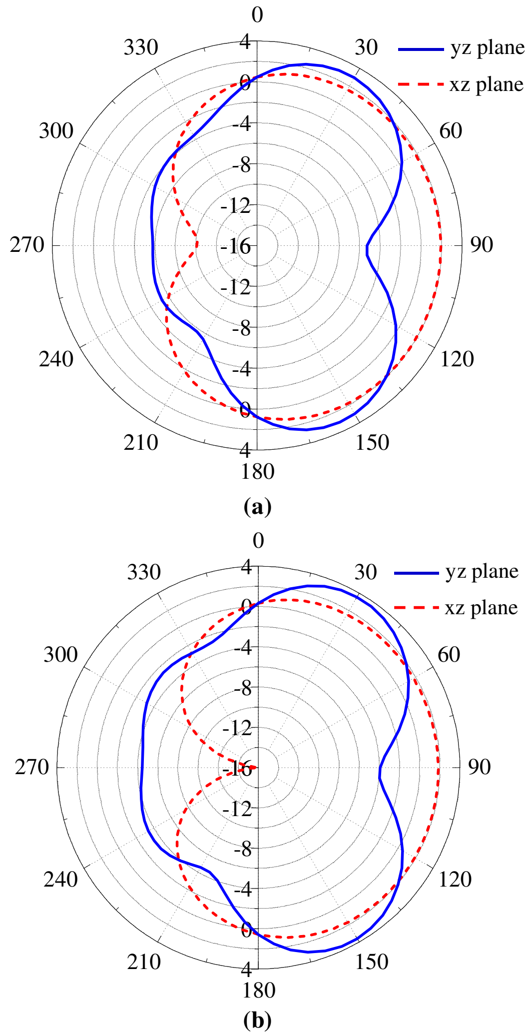
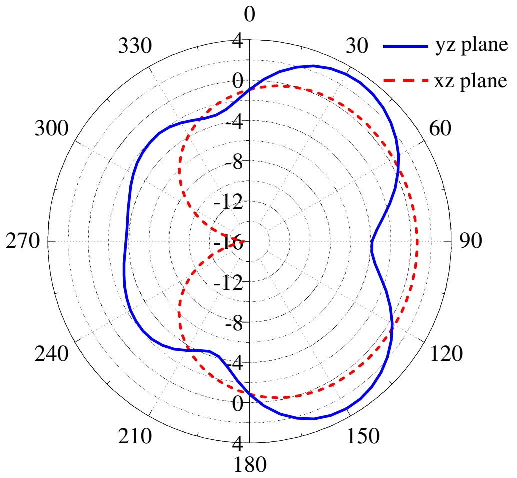


Fig. 8. VSWR of the proposed antenna.

Simulated results in the input impedance and VSWR of the optimized antenna are shown in Fig. 7 and Fig. 8, respectively. The radiation pattern in the *xz* and *yz* planes for the frequencies of 1.90 GHz, 2.02 GHz and 2.17 GHz are plotted in Fig. 9.





(c)

Fig. 9. Antenna radiation pattern (a) $f = 1.90$ GHz, (b) $f = 2.02$ GHz, (c) $f = 2.17$ GHz.

In Fig. 7, the antenna input impedance can reach approximately 40 Ω at the resonant frequency of 2.02 GHz. In Fig. 8, the optimized antenna bandwidth is 285 MHz (14 % compared with the central frequency), VSWR ≤ 2. The results show that the proposed antenna structure has compact size (21 mm × 14 mm × 3.2 mm), relatively wide bandwidth and can be applied to antennas for 3G mobile devices.

In Fig. 9, the solid line is for the *yz* plane, dashed one is for the *xz* plane. The antenna radiation pattern is relatively equal in the whole bandwidth. The maximum gain can be achieved in the *yz* plane. At the central frequency of 2.02 GHz, antenna gain reaches its maximum of 3.92 dBi.

The peak gain of the antenna within the bandwidth is shown in Fig. 10. As can be seen, the antenna gain is relatively equal and is greater than 3.3 dBi in the whole bandwidth of the device.

Fig. 11 illustrates the distribution of current on the antenna surface. In Fig. 11, amperage is highest at the feeding point and then the amperage gradually decrease towards strip-line l_3 and rectangular strip-lines $l_2 \times l_1$, $l_6 \times l_7$.

Simulated results show that the proposed antenna structure can be applied well in 3G mobile devices.

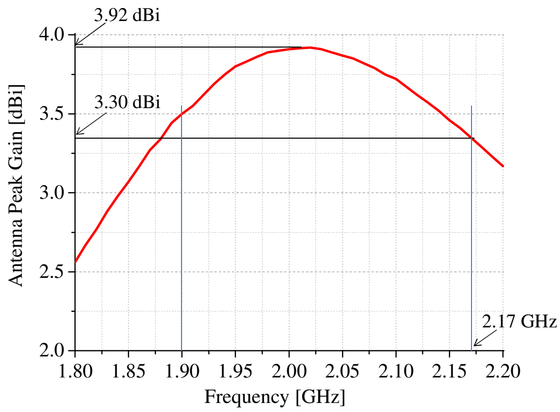


Fig. 10. Antenna maximum gain in yz plane.

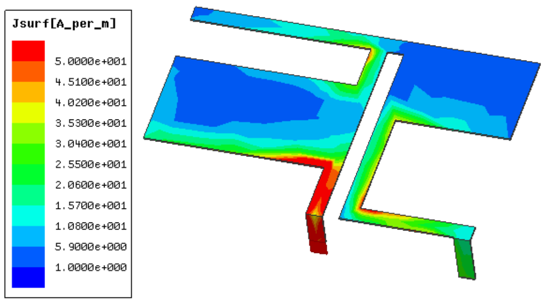


Fig. 11. Distribution of current on the proposed antenna.

3. Conclusions

This paper proposed a miniaturized antenna structure for 3G mobile devices based on meandering and folding methods for the monopole antennas using inverted F antenna. Some achieved results are:

i) Compact antenna structure of 21 mm × 14 mm × 3.2 mm is small enough to be placed in a mobile device;

ii) Relatively wide bandwidth 285 MHz (14 %, VSWR ≤ 2), covers the 3G mobile bandwidth;

iii) Antenna peak gain is relatively equal and is greater than 3.3 dBi in the whole bandwidth of the 3G mobile devices.

In the future, the authors continue to propose methods of miniaturized the antenna structure to reduce the antenna thickness while ensuring the bandwidth requirements and other technical parameters.

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