STRUCTURE ENHANCEMENTS OF PIFA FOR 3G MOBILE DEVICES

Tran Thi Huong*, Nguyen Thanh Hang**

The University of Danang, University of Science and Technology;
**tranhuong@dut.edu.vn, **sun411moon@gmail.com*

Abstract - The paper presents the monopole antenna's structure, L antenna's structure, F antenna's structure and shows developments toward antenna's structure enhancement. Thus, the paper presents a method to enhance the structure of planar inverted F antenna (PIFA) by meandering and folding techniques for the monopole antenna placed on FR4 dielectric. The proposed PIFA antenna has a compact size (21×14.5×3 mm3). In addition, this antenna offers enough wide bandwidth 380 MHz (VSWR ≤ 2), which covers 3G band. The authors use the simulation program HFSS of Ansoft to compute the antenna parameters such as input impedance, VSWR, bandwidth and the peak gain. The results from stimulation program show the enhancement of PIFA's structure to verify its applicability for the 3G devices.

Key words - 3G device; monopole antenna; L antenna; inverted F antenna; compact antenna.

1. Introduction

Nowadays, portable devices become more and more popular with people in the world. They are very useful in communicating and receiving information. The demand for mobile devices is accelerated with small size, thin and light weight as well as convenience. In view of satisfying the above demand, it is necessary to miniaturize its components. Especially, the antenna size must be miniaturized to put the entire antennas into the devices.

Many studies and suggestions of typical antenna structures for portable devices have been published. D. Bonefacic [1] proposed a design for a micro-strip antenna that works on central frequency of 2 GHz and has very small size (30×12.9×5 mm^3); however, the bandwidth of the proposed antenna is too narrow (26 MHz). Y. Kim [2] proposed a folded loop antenna system for new future handsets. K. Skrivervik [3] proposed an antenna with smaller size (23×14×5 mm^3) which can be applied for the 3G mobile devices. N. Q. Dinh [4] proposed a method to miniaturize antenna structure for the 3G mobile device (23×14×5 mm^3) and then [5] the optimum design of PIFA for the 3G mobile device with the size (21×14.5×4 mm^3) and the bandwidth (272 MHz).

In this paper, the authors use Ansoft HFSS to analyze PIFA antenna placed on a metallic plane that represents for a mobile device with surveyed bandwidth from 1.8 GHz to 2.3 GHz (cover 3G band: 1.9 GHz - 2.17 GHz). Therefore, it is possible to adapt suitable method of miniaturized of antenna structure and design a compact antenna 21×14.5×3 mm^3, whose sizes are smaller than antennas in the reference [5]. However, its height is only 3 mm but its bandwidth and other technical parameters are still ensured and it is possible for this antenna structure to place into mobile devices.

Besides, in order to match antenna input impedance with the feeder and to ensure its bandwidth must be wide enough to cover the 3G band of Vietnam, the proposed antenna structure is optimized. Finally, the antenna parameters such as input impedance, VSWR and peak gain are calculated to validate the applicability of the proposed antenna in a wide band of 1.8 GHz – 2.3 GHz for 3G devices.

2. The Proposed Antenna Atructure

2.1. *The Monopole, L, F Antenna Structure*

2.1.1. The monopole antenna

Consider the standard monopole antenna structure, in practical, monopole antenna's length satisfies a quarter wavelength. With the central frequency f = 2 GHz and the speed of light c = 3.10^8 m/s, a quarter wavelength is 37.5 mm. It means that its length equals 37.5 mm. Due to the limited ground plane size in the stimulation, antenna's length was modified by l = 33 mm. The overall dimension of the antenna has been determined with w = 1 mm (width) and t = 0.1 mm (thickness) placed on a metallic plane (copper) (80×40×0.1 mm^3).

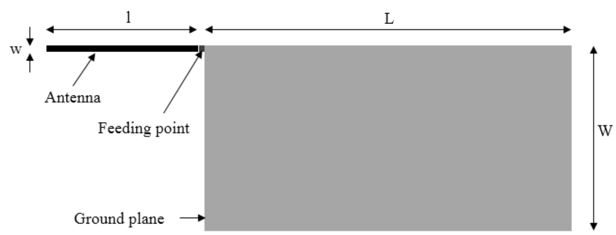


Figure 1a. *Monopole antenna*

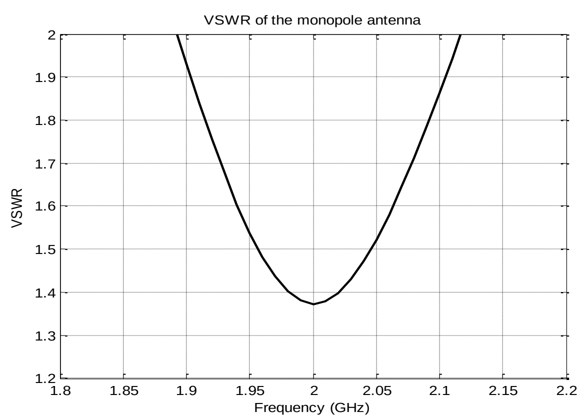


Figure 1b. *VSWR of the monopole antenna*

As can be seen from Figure 1b, the bandwidth of monopole antenna is 230 MHz (from 1.89 GHz to 2.12 GHz) and VSWR ≤ 2; however, antenna's size is so long. Next, to decrease the length of this antenna, it is folded into L antenna.

2.1.2. The L antenna

Consider the L antena with l_1 = 28 mm (lenghth), l_2 = 5 mm, w = 1 mm (width) and t = 0.1 mm (thickness) placed on a metallic plane (copper) (80×40×0.1 mm^3).

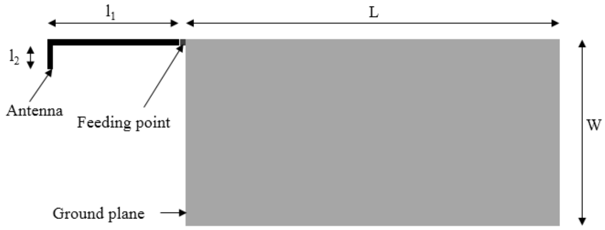


Figure 2a. *L antenna*

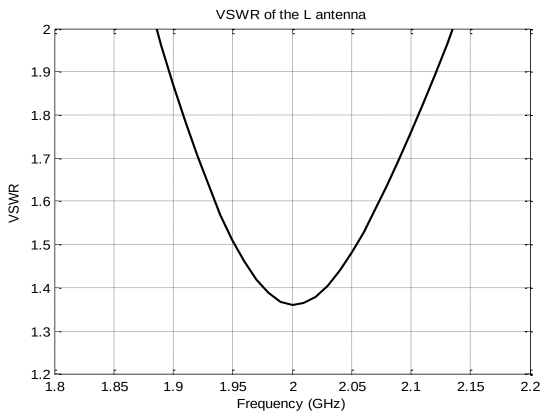


Figure 2b. *VSWR of the L antenna*

As can be seen from Figure 2b, the bandwidth of L antenna is 250 MHz (from 1.88 GHz to 2.13 GHz), VSWR ≤ 2 and L antenna size is smaller than previous monopole antenna. Next, this antenna is folded into F antenna to decrease the length.

2.1.3. The F antenna

Consider the F antenna with l_1 = 26.5 mm (lenghth), l_2 = 6 mm, l_3 = 4 mm và l_4 = 16 mm, w = 1 mm (width) and t = 0.1 mm (thickness) placed on a metallic plane (copper) (80×40×0.1 mm^3).

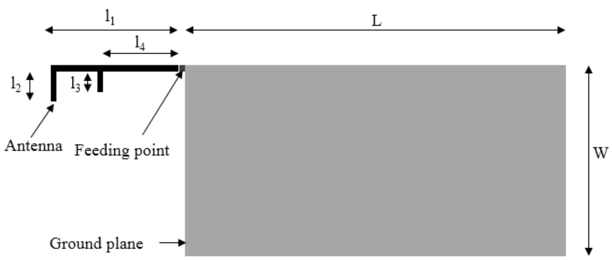


Figure 3a. *F antenna*

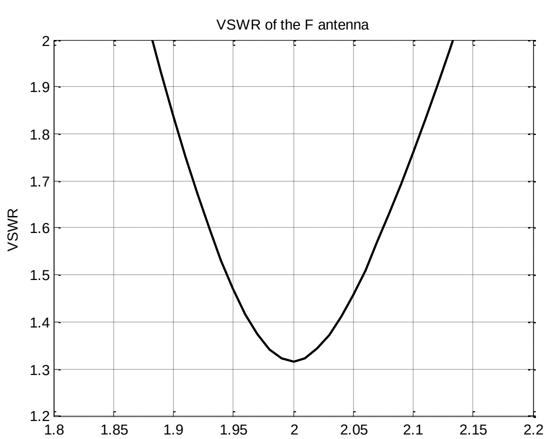


Figure 3b. *VSWR and input impedance of the F antenna*

As can be seen from Figure 3b, the bandwidth of F antenna is 250 MHz (from 1.88 GHz to 2.13 GHz), VSWR ≤ 2 and F antenna size is smaller than the monopole antenna and L antenna above.

2.2. ***Main Requirements of Antenna for 3G Mobile Devices***

When design an antenna for the mobile device should take the working frequency bandwidth and the requirement on antenna compact size 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 system of Vietnam works on 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, working 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).
- 1 ≤ VSWR ≤ 2.
- The bandwidth of the antenna is large enough: ≥ 10%, ≥ 200 MHz.

2.3. ***A Method of Miniaturized Antenna Structure***

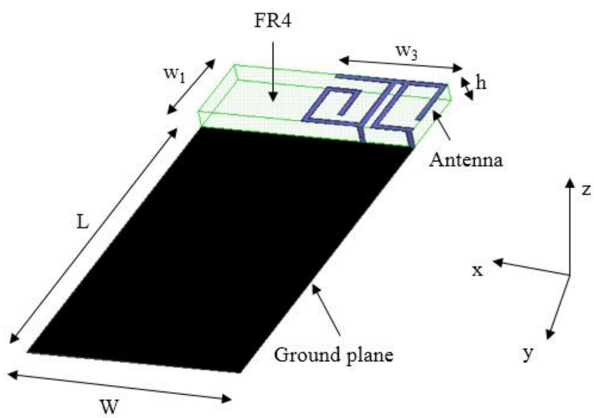
Consider the Inverted F antenna placed on a metallic plane (using copper), with length L (70 mm) and width W (40 mm), that presents for a mobile device.

In order to miniaturize size of the initial inverted antenna, it is possible to apply bending, folding and slotting methods and apply dielectric substance FR4 to solid its structure. Furthermore, so as to ensure the antenna input impedance, it is needed to change current in the antenna by varying the distance between the feeding point and the connection point and adding U, L shape strip-lines. These strip-lines will change the current distribution on the antenna, this in turn will change the antenna input impedance matching with the feeder. Moreover, the optimized antenna expands bandwidth and ensures more compact size.

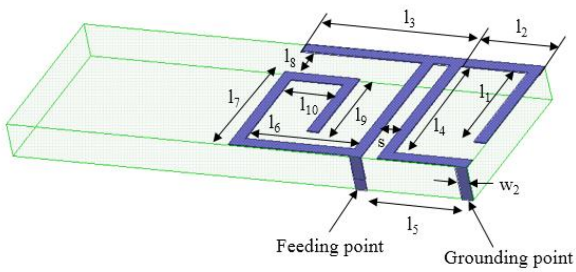
2.4. ***The Proposed Antenna Structure***

Antenna is fixed on a FR4 dielectric plate (ε = 4.4, $tan\delta$ = 0.02). The size of the FR4 dielectric plane is 40×14.5×3 mm^3. The whole antenna ad FR4 dielectric plate are placed at the above of the metallic plane measuring 70×40×0.1 mm^3 (Figure 4a).

Antenna associated with the metallic plane in 2 points such as the feeding point and the grounding point (the connection point to the metallic plane) (Figure 4b). This antenna consists of copper strip-lines of width w_2 (1 mm), thickness (0.1 mm). The overall dimension of the antenna has been determined with w_3 = 21 mm (length), w_1 = 14.5 mm (width) and h = 3 mm (height). A gap between the feeding point and the grounding point is l_5 = 8.2 mm. Except for the strip-lines are connected to the metallic plane, other strip-lines are fixed on the dielectric plate and parallel to the ground. The size of the proposed antenna elements is shown in Table 1. The proposed has L shapes which are formed by strip-lines $l_1 \times l_2$; $l_6 \times l_7$ and $l_9 \times l_{10}$ and U shape with the parameters of and $l_4 \times s$.



(4a)



(4b)

Figure 4. *Inverted F antenna placed on a metallic plane*

Table 1. *The size of the Inverted F antenna after optimization (mm)*

Parameters	Values	Parameters	Values
L	70	l_3	14.2
W	40	l_4	12.5
h	3	l_5	8.2
s	1.4	l_6	9.8
w_1	14.5	l_7	10.5
w_3	21	l_8	3
l_1	10.7	l_9	7.6
l_2	6.8	l_{10}	4.8

3. Simulated Results of the Proposed Antenna structure

Simulated results in the input impedance and VSWR of the proposed antenna are shown in Figure 5. The antenna input impedance can reach approximately 37 Ω at the resonant frequency of 2.04 GHz. The proposed antenna bandwidth is 380 MHz (from 1.83 GHz to 2.21 GHz) (18 % compared with the central frequency), VSWR $\leq$ 2. Therefore, the proposed antenna bandwidth covers the bandwidth for 3G devices (270 MHz). The results show that the proposed antenna structure has the widest bandwidth compared with the former designs.

The peak gain of the antenna within the surveyed bandwidth is shown in Figure 6. From the figure, the antenna gain is relatively equal and is greater than 3.6 dB in the whole working bandwidth of the 3G device. Simulated results show that the proposed antenna structure can be applied to antennas for 3G mobile devices.

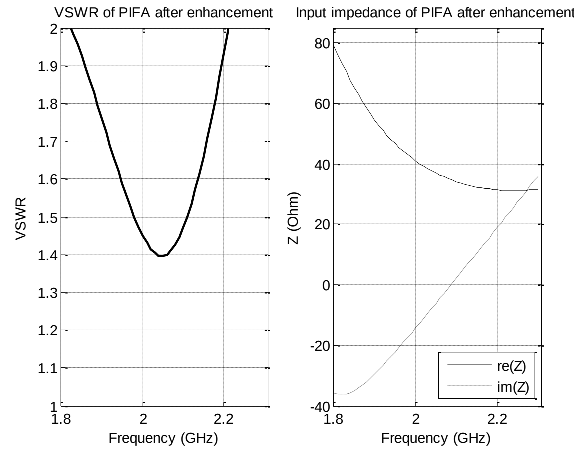


Figure 5. *VSWR and input impedence of the Inverted F antenna after enhancement*

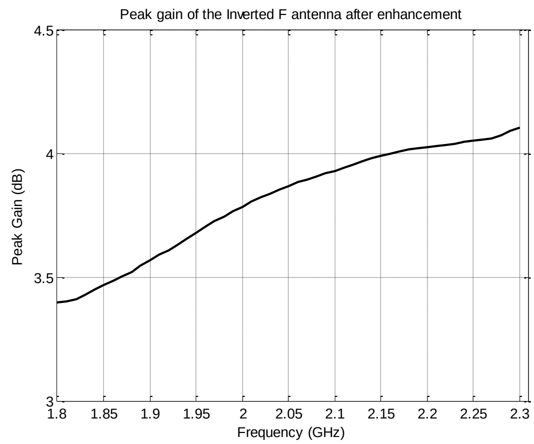


Figure 6. *Peak gain of the inverted F antenna after enhancement*

4. Results of Selecting Some Size Parameters of Antenna

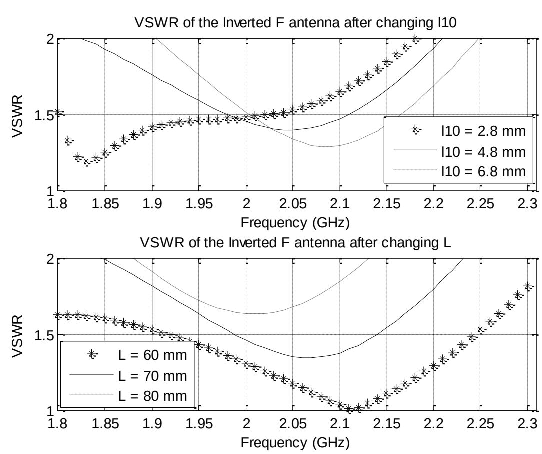


Figure 7. *VSWR of the inverted F antenna after changing l_{10} and L*

As can be seen from Figure 7, when changing l_{10} by 2.8 mm, 4.8 mm and 6.8 mm, respectively; When l_{10} is 6.8 mm, although VSWR $\leq$ 2, the bandwidth does not cover 3G band. When l_{10} is 2.8 mm, VSWR $\leq$ 2 but the resonant frequency is far from 2 GHz. Thus, it is necessary to select parameter l_{10} = 4.8 mm because this ensures covering the 3G band (VSWR $\leq$ 2). In practical, the ground plane size is extremely large. Nevertheless, it is essential to miniaturize the ground plane to put it into the mobile device. When changing *L* (the length of ground plane) by 60 mm, 70 mm and 80 mm, respectively; When *L* is 80 mm, the bandwidth does not cover 3G band despite VSWR ≤ 2. When *L* is 60 mm, VSWR ≤ 2 but the resonant frequency is far from 2 GHz. Therefore, it is necessary to select parameter *L* = 70 mm because this ensures covering the 3G band (VSWR ≤ 2).

5. Simulated Result in Comparison

In the reference [5], the proposed antenna has antenna size ($21\times14.5\times4$ mm^3); the bandwidth (272 MHz), the ground plane size ($80\times40\times0.1$ mm^3).

Figure 8 is VSWR of the PIFA in the reference [5] and VSWR of the proposed antenna in this paper. As can be shown, VSWR of the PIFA after enhancement in this paper is larger than the one in the reference [5] and covers the 3G band in Vietnam, 380 MHz and 272 MHz, respectively.

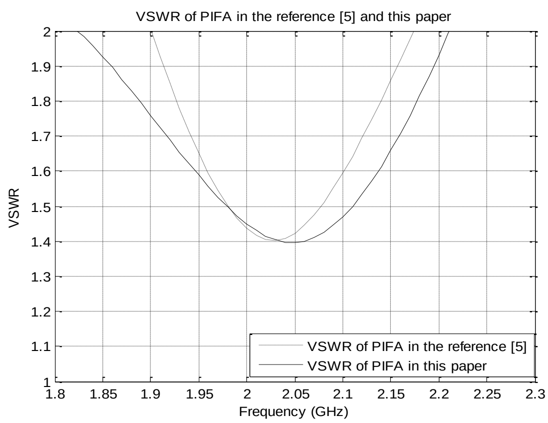


Figure 8. *VSWR of the Inverted F antenna in the reference [5] and in this paper*

6. Conclusion

This paper proposed an antenna structure for 3G devices by using planar inverted F antenna. Some achieved results are:

- Compact antenna structure ($21\times14.5\times3$ mm^3).
- Relatively wide bandwidth 380 MHz (18 %, VSWR ≤ 2), covers the 3G mobile bandwidth of Vietnam.
- Smaller ground plane ($70\times40\times0.1$ mm^3).
- Gain is relatively equal and is greater than 3.6 dBi in the whole bandwidth of the 3G mobile device.

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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