DESIGN AND SIMULATION OF PLANAR INVERTED-F ANTENNA ARRAY FOR LTE2500 APPLICATIONS

Tran Thi Bich Ngoc[1,*], Tran Van Tho[1], Le Thanh Toi[2]

[1]*Ho Chi Minh City University of Transport*

[2]*Ho Chi Minh City University of Food Industry*

*Email: *btranthi22@gmail.com*

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ABSTRACT

Planar inverted-F antenna (PIFA) is a most commonly used antenna especially in mobile communication because of its simplicity and low cost, though it suffers bandwidth limitations. In this paper, a study of Planar Inverted - F Antenna (PIFA) and its array is presented. The arrays two by two (2 × 2), four by two (4 × 2), four by four (4 × 4), eight by two (8 × 2) PIFA and dipole antenna array were simulated using MATLAB. The performance of the designed antenna was discussed on the results (return-loss, bandwidth, directivity, radiation pattern) and compared with the its array in term directivity and radiation pattern.

Keywords: Planar inverted-F antenna (PIFA), PIFA array, dipole antenna array.

1. INTRODUCTION

Wireless communication (voice calls, video calls, internet, video conferencing etc.) has become an important and integral part of human beings. Many improvements are taking place to give a better and faster wireless communication system. Lots of mobile devices have been invented. However, the miniaturized devices in wireless communication are required. The most important and essential component/device needed for wireless communication system is an antenna, which transmits/receives an electromagnetic wave. Modern wireless mobile devices are demanded smaller and slimmer day by day and thus, antenna also is needed smaller. On the other hand, these mobile devices are performing different wireless applications and so different antennas for different applications cannot be afforded.

Therefore, these wireless mobile devices, which used at wide range of frequency, require the antenna having smaller size and lighter weight. In the past few years, new designs based on planar inverted-F antennas (PIFA) have been used for handheld wireless devices because of its low-profile geometry [1-6]. The antenna is resonant at a quarter-wavelength (thus reducing the required space needed on the phone), and also typically has good specific absorption rate (SAR) properties. First PIFA appeared in the IEEE literature by the year 1987 [7]. Their operation can be understood by considering their development from two well-known antennas, namely the quarter-wavelength monopole and the rectangular microtrip patch antenna. This antenna resembles an inverted F, which explains the PIFA name. The Planar Inverted-F Antenna is popular because it has a low profile and an omnidirectional pattern. Additionally, the PIFA offers very high radiation efficiency and sufficient bandwidth in a compact antenna. Gradually the performance of PIFA was studied and compared with that of a monopole and helical antenna (as external antennas) or microstrip antennas (as internal antennas) as they are the other popular alternatives to be used in a handheld device. Several PIFA structures have been developed in the past to cover various communication frequency bands. These antennas are generally designed for various wireless applications such as: WLAN, LTE, WiMax, mobile phone applications, wireless applications [4-6, 8-10].

The radiation pattern of a single element is relatively wide, and each element provides low values of directivity. In many applications, it is necessary to design antennas with very directive characteristics to meet the demands of long distance communication, that cannot be achieved with a single element. Antenna arrays, formed by multielements, are used to scan the beam of an antenna system, increase the directivity, and perform various other functions which would be difficult with any one single element. There are a plethora of antenna arrays used for personal, commercial, and military applications utilizing different elements including dipoles, loops, apertures, microstrips, horns, reflectors, and so on [11, 12].

This work is concerned with: (1) Design of a single PIFA for LTE2500, and (2) Simulated results of dipole antenna arrays and the proposed PIFA arrays.

2. ANTENNA CONFIGURATION

The PIFA consists of a ground plane, radiating patch, shorting pin or wall and feed. It exhibits high gain and omnidirectional radiation pattern. Also, it provides a wider bandwidth which is enough for mobile phone operations.

In general, the operating frequency of a PIFA [13] is given by

$$f_o = \frac{c}{4(W+L)} \tag{1}$$

where c is the speed of light, W and L are the width and length of the radiating element, and f_o is the operating frequency.

Hassan Tariq Chattha *et al* [14] gave a new empirical equation for the prediction of the resonant frequency, which involves all the parameters that significantly affect the resonant frequency of the PIFA.

The modified equation is as follows:

$$f_o = \frac{c}{3W + 5.6L + 3.7h - 3W_f - 3.7W_s - 4.3L_b - 2.5L_s} \tag{2}$$

Where Ls: distance between the shorting plate and the edge of top plateground plane dimensions are $Lg \times Wg$.

W_f : width of the feeding plate.

W_s : width of the shorting plate.

L_b: horizontal distance between the feeding plate and the edge of the top plate.

h : height of top plate.

Based on these results (1) (2), the proposed geometry of the PIFA element is shown in Figure 1 (dimensions in mm). For the design of proposed single-band PIFA, size of ground plane has been taken as 39 mm × 39 mm.

The dimensions of the initial patch have been calculated by using following equation for resonant frequency of 2.625 GHz. Figure 1 shows a simple PIFA dimensions are top plate L = 25 mm, W = 20 mm, h = 3.3 mm, W_s = 2 mm and feed position is arranged from the top and shorting plate junction.

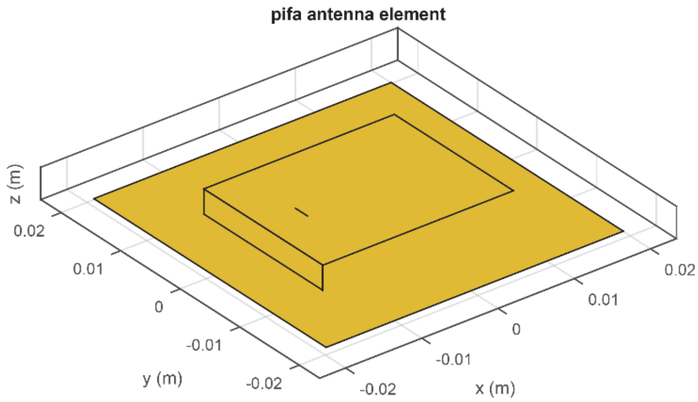

Figure 1. Geometry of the simulated PIFA

Impedance matching is very important parameter for any antenna. Max matching means max power transfer or low return-loss. Good advantage with PIFA is that the matching of antenna, is achieved by positioning of the single feed with in the shaped top plate. It is found that PIFA characteristics are affected by feed position [15].

Ten different feed positions were simulated and compared. The results show when the distance is larger, return-loss has increased. Therefore, the feed position most optimized that was chosen, for the proposed design was 5 mm, since it produced good performance in terms of return-loss and resonant frequencies are shown in Figure 2.

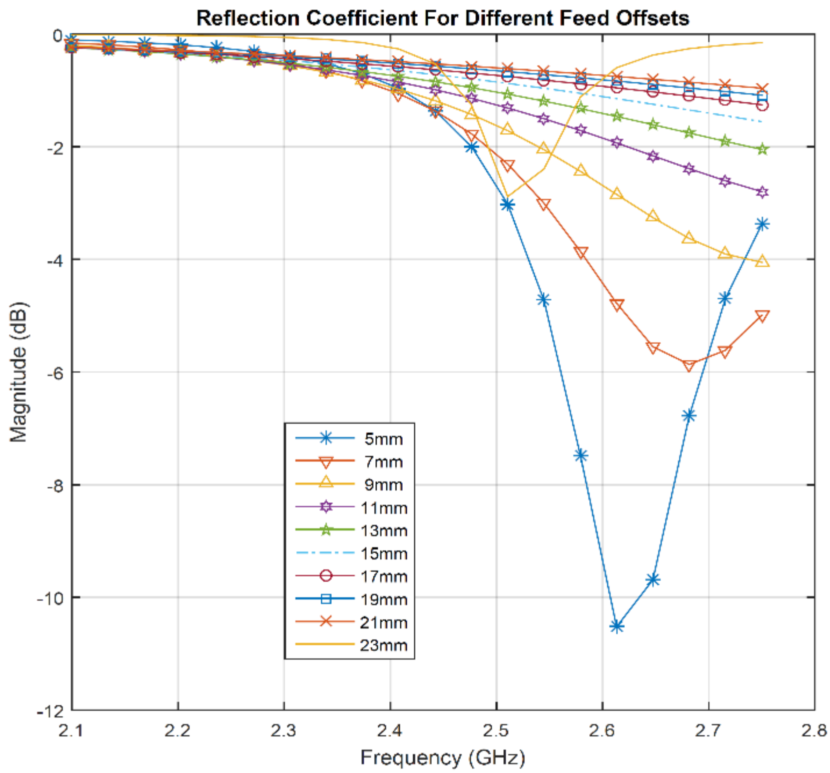

Figure 2. Return loss for different feed positions

3. RESULTS AND DISCUSSION

The simulations are performed in MatLab2015a to optimize the shape parameters of the antenna and to arrange different array antenna.

3.1. Return-loss

The return-loss characteristics of the proposed antenna are shown in Figure 2 (feed offset was in 5mm). The impedance bandwidth of antenna designs is from 2.1 GHz to 2.7 GHz covering LTE2300 (2300-2400 MHz), WLAN (2.4-2.484 GHz) and LTE2500 (2500-2690 MHz) bands. Obviously, resonance is better at 2.625 GHz frequency (LTE2500). This is because of proper impedance matching at this frequency. For getting the impedance bandwidth we are taking -10,84 dB as the reference return loss, which is acceptable for mobile phone applications.

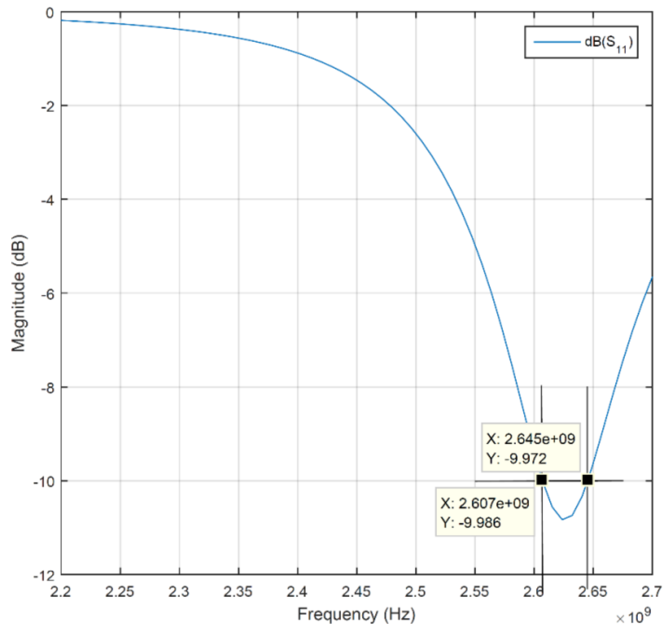

Figure 3. Reflection coefficient for designed PIFA.

Figure 3 shows that this antenna can meet a 10 dB bandwidth at the LTE band. The impedance bandwidth is obtained at the 10 dB return-loss, where the lower and upper frequency is 2.607 GHz and 2.645 GHz, respectively. Therefore, the difference between the upper and lower frequency of this proposed PIFA is equivalent to the impedance bandwidth which is 0.038 GHz. Hence, the value of impedance bandwidth with respect to the resonance frequency, 2.625 GHz is 1.4% [12].

3.2. Radiation pattern of a single PIFA

Figure 4 shows the simulated radiation pattern of a single PIFA with directivity of 3.4 dB. The 3D plot is showed in Figure 4a. The azimuth (*y*-z plane) and the elevation (*x*-*y* plane) radiation patterns are shown in Figures 4b, 4c. It can be seen from these plots of Figure 4 that the antenna is a good radiator with almost omnidirectional radiation which supports multiple standards.

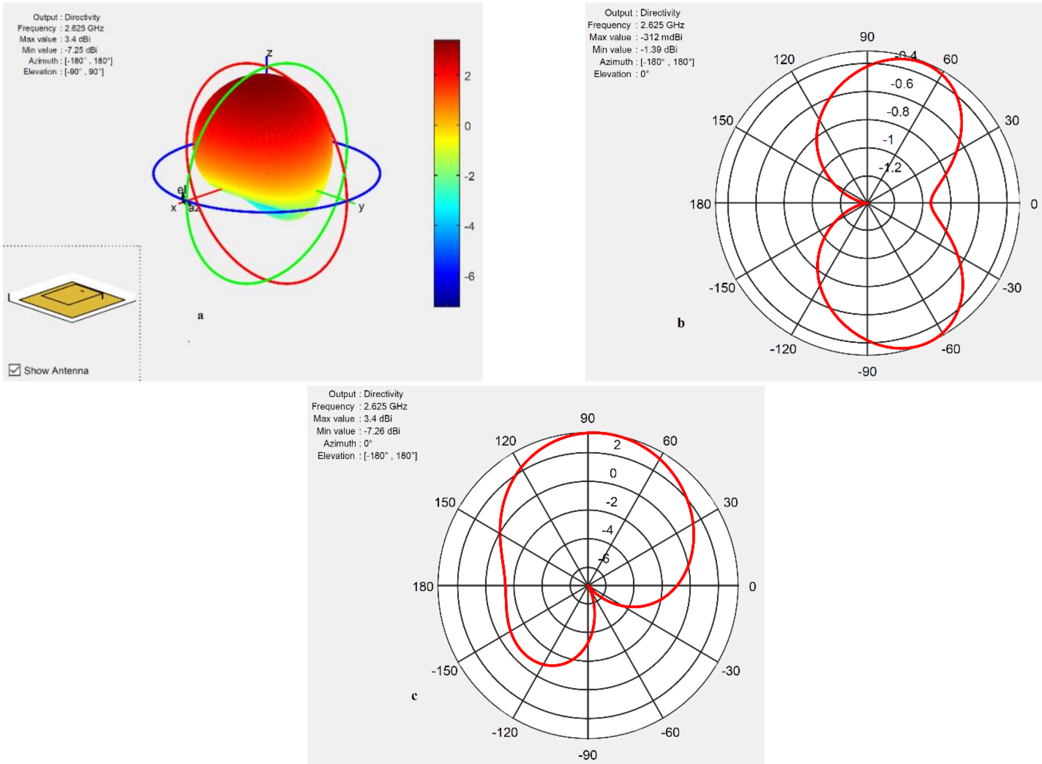

Figure 4 . The simulated radiation patterns of single PIFA
(a. 3D polar plot; b. The azimuth (*y*-z plane) radiation pattern; c. the elevation (*x*-*y* plane) radiation pattern)

3.3. Antenna arrays

The dipole is one of the most widely used antennas for wireless mobile communication systems [16-18]. Therefore, in this paper dipole anten arrays and the proposed PIFA arrays have been presented. Consider a antenna array whose elements reside on a $n \times m$ rectangular grid. To ensure that there was no grating lobe, the element spacing was chosen to be half of the wavelength at the operating frequency. Assume that the speed of light was 3.10^8 m/s. The element spacing was the same for both arrays. Figures 5-12 show the radiation pattern for simulation of PIFA arrays and dipole antenna arrays with 2 × 2, 4 × 2, 8 × 2, 4 × 4 elements. The results can be seen these plots are almost the same type of radiation patterns between PIFA arrays and dipole array antenna.

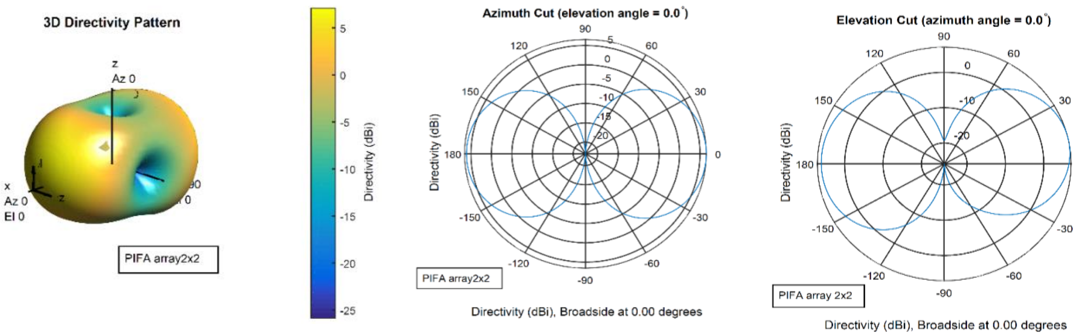

Figure 5. Radiation patterns of PIFA array antenna 2 × 2 (*From left to right*: 3D polar plot; the elevation (*x-y* plane) radiation pattern; the azimuth (*y*-z plane) radiation pattern).

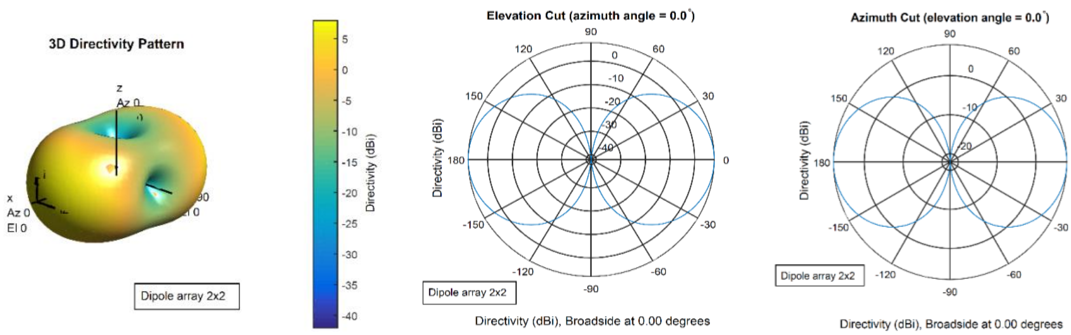

Figure 6. Radiation patterns of dipole array antenna 2 × 2 (*From left to right*: 3D polar plot; the elevation (*x-y* plane) radiation pattern; the azimuth (*y*-z plane) radiation pattern).

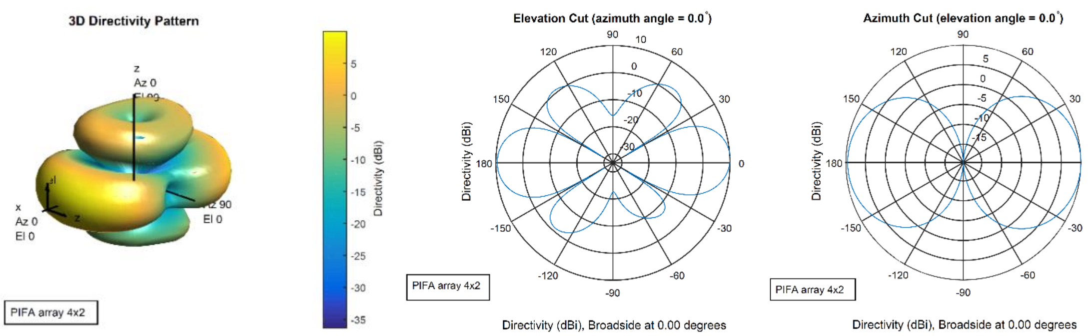

Figure 7. Radiation pattern of PIFA array antenna 4 × 2 (*From left to right*: 3D polar plot; the elevation (*x-y* plane) radiation pattern; the azimuth (*y*-z plane) radiation pattern).

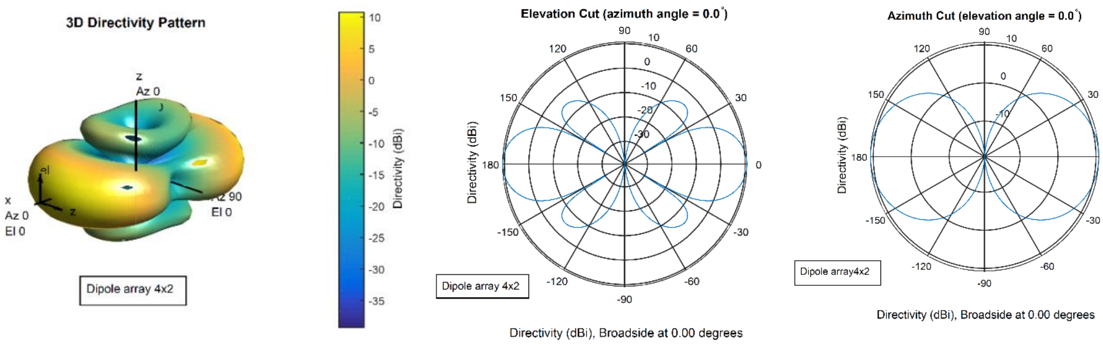

Figure 8. Radiation pattern of dipole antenna array 4 × 2 (*From left to right*: 3D polar plot; the elevation (*x*-*y* plane) radiation pattern; the azimuth (*y*-z plane) radiation pattern).

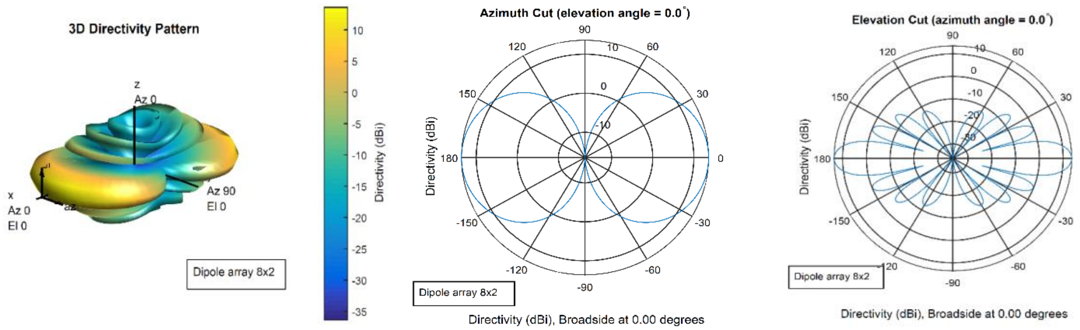

Figure 9. Radiation pattern of dipole array antenna 8 × 2 (*From left to right*: 3D polar plot; the elevation (*x*-*y* plane) radiation pattern; the azimuth (*y*-z plane) radiation pattern).

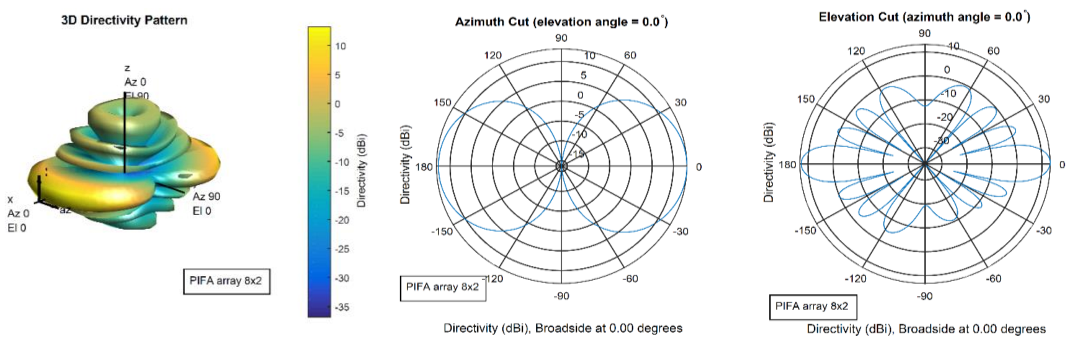

Figure 10. Radiation pattern of PIFA array antenna 8 × 2 (*From left to right*: 3D polar plot; the elevation (*x*-*y* plane) radiation pattern; the azimuth (*y*-z plane) radiation pattern).

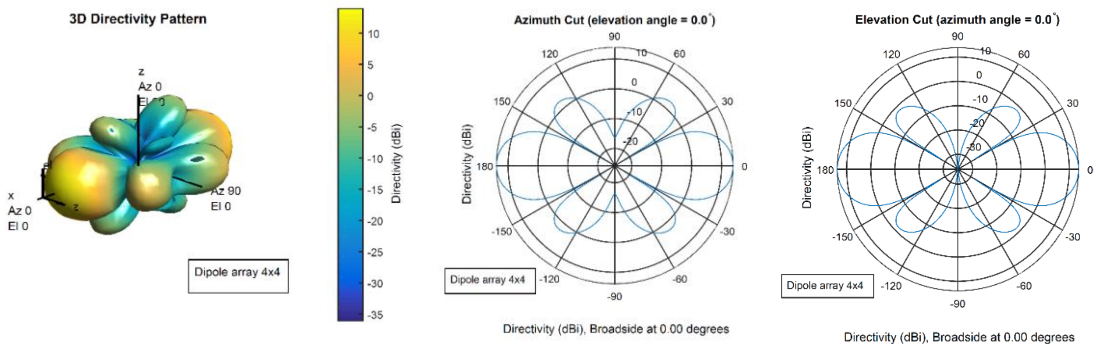

Figure 11. Radiation pattern of dipole array antenna 4 × 4 (*From left to right*: 3D polar plot; the elevation (*x-y* plane) radiation pattern; the azimuth (*y*-z plane) radiation pattern).

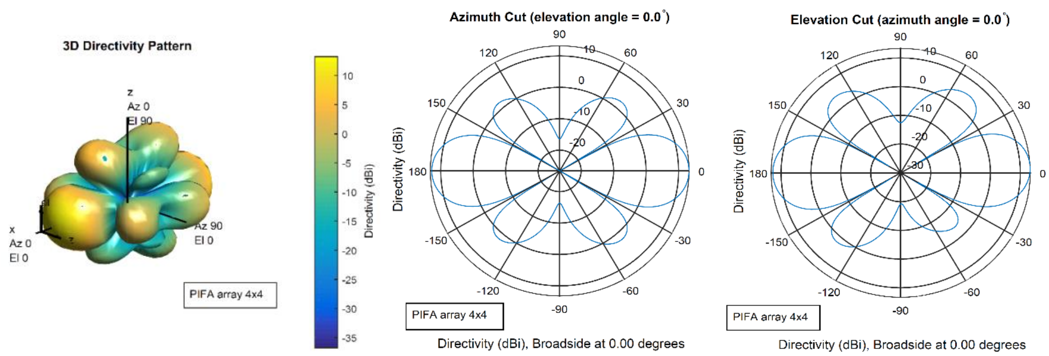

Figure 12. Radiation pattern of PIFA array antenna 4 × 4 (*From left to right*: 3D polar plot; the elevation (*x-y* plane) radiation pattern; the azimuth (*y*-z plane) radiation pattern).

Table 1. Comparison directivity (dB) between PIFA antenna array and dipole antenna array

Type / Size	PIFA array antenna	Dipole array antennas
2 × 2	7.06	8.318
4 × 2	10.2	10.9
4 × 4	13.41	13.42
8 × 2	13.18	13.47

Table 1 shows the simulated results in term directivity. As shown in the table the results obtained from PIFA array antennas are very close to those obtained from dipole array antennas.

It is clear from Table 1 that maximum value of directivity, for both arrays (PIFA array antenna, dipole array antenna), is increasing as the number of elements is increased, which is expected [11, 19] .

The radiation patterns in both array designs are in broadside direction. Small side lobes appear in 2 × 2, 4 × 2, 4 × 4, 8 × 2 array types. The side lobe level is increasing as the number of elements is increased as shown in radiation pattern Figures 6-12, which agreed in theory of antenna array [11, 12]. Finally, the designed PIFA arrays generated more intensity or focus (their value are written in Table 1) than single PIFA antenna (its directivity 3.4 dB). Therefore, it can be concluded that the array design antenna can be chosen or PIFA or dipole.

4. CONCLUSION

This paper presents the design of novel single band planar inverted-F antenna for LTE mobile application. The PIFA antenna resonates at 2.625 GHz with -10.84 dB return loss. The size of the antenna is 39 mm × 39 mm, and it can be easily integrated in mobile handsets. In other hand, effect of PIFA parameter change and feed position 5 mm was chosen for optimal PIFA. Radiation patterns of dipole array antennas and PIFA array antennas in size 2 × 2; 4 × 2; 8 × 2; 4 × 4 have been shown the same type at resonance frequency of proposed antenna. In future, the design will be able to fabricate and take comparison with this paper's simulation results.

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TÓM TẮT

THIẾT KẾ VÀ MÔ PHỎNG HỆ THỐNG BỨC XẠ ANTEN VI DẢI PHẲNG DẠNG CHỮ F NGƯỢC ỨNG DỤNG TRONG LTE2500

Trần Thị Bích Ngọc[1,*], Trần Văn Thọ[1], Lê Thành Tới[2]
[1]*Trường Đại học Giao thông Vận tải TP.HCM*
[2]*Trường Đại học Công nghiệp Thực phẩm TP.HCM*
*Email: *btranthi22@gmail.com*

PIFA là một loại anten được sử dụng nhiều trong thông tin di động do nó có những ưu điểm như cấu trúc đơn giản, kích thước nhỏ, và nó có hạn chế về băng thông. Bài báo trình bày về thiết kế anten vi dải phẳng dạng chữ F ngược (PIFA) và các đặc tính anten đạt được. Các kết quả mô phỏng về giản đồ hướng và hệ số hướng tính của hệ thống bức xạ của PIFA được so sánh với hệ thống bức xạ của dipole với cách sắp xếp 2 × 2, 4 × 2, 8 × 2 và 4 × 4 các phần tử.

Từ khóa: Anten vi dải phẳng dạng chữ F ngược (PIFA), hệ thống bức xạ của PIFA, hệ thống bức xạ của dipole.