# Design of Dual-Band Printed-Dipole Array Antenna with Omni-directional Radiation Behaviour

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***Abstract –*** In this paper, we present a compact array of 4 printed dipole antennas with ground plane, operating at 2.7 GHz and 5.2 GHz, designed for base station applications. First, the elementary printed dipole antenna, selected for its small size and good performances, is described. However, this kind of structures cannot cover two bands at the same time, which justify our proposal of a 4-elemnts network. Next, the 4-elements array is simulated, optimized, and measured to proof its performances with good agreement between the measurements and simulations. The measured gain of the 4-dipoles array is 4.21 dBi and 6.15 dBi for both operating frequencies 2.7 GHz and 5.2 GHz, respectively.

***Index Terms –*** Dual-band array, horizontal polarization, Omnidirectional radiation pattern, printed dipole.

## I. INTRODUCTION

The last few years have seen the emergence of a wide variety of wireless networks, and a new need has arisen: that of being permanently connected to a network wherever you are [1]. We then see the appearance of many types of networks: telephony networks, broadband broadcasting, local or very extensive via terrestrial or space communications. Thus, the development of these wireless networks requires technological advances in electronic components, computer software, coding techniques and antennas. Indeed, the antenna is one of the key points of wireless networks since this element is the last link in the chain allowing transmission and reception of the signal and therefore of the information contained therein [2-7]. The base station antenna must be adapted to each link according to the desired coverage. The antenna must not only cover standard but must also keep a compact size and good efficiency. Different types of antennas can be used such as patch antennas, dielectric resonator antennas and dipole antennas.

The printed dipole is one of the most used antenna structures in wireless communication systems, thanks to its advantages (low cost, low profile, easy to integrate with other electronics and omnidirectional radiation pattern) with several designs presented in the literature [8]. For a dipole, a natural resonance appears when the dimension of the antenna is close to half the wavelength. The size of the dipole antenna can be reduced with the ground plane effect. According to image theory [9], the ground plane creates an image of the antenna; the combination of the antenna and its image plays an identical role to that of a dipole. Nowadays we are also seeing more and more multi-standard wireless communication devices, especially with the evolution of technologies like 4G, LTE, 5G, which requires multi-band antennas for good coverage at multi-operating frequencies. Some techniques used to design these types of antenna have also been described in the literature. Among these techniques, we mention the addition of slots [10,11] and parasites [12,13]. To meet this growing need to integrate several standards and new applications in the same device, new concepts of miniature and multi-frequency antennas are the subject of much research. Several techniques identified in the literature to achieve significant directivities with compact antennas. These techniques include adding a reflector [14,15], Huygens sources [16,17], integrating charges [18], using parasitic elements within the Alford loop antennas [3] or antenna arrays [19,20].

Antenna networks represent one of the methods for obtaining miniature structures. This technique is based on the combination of radiation of multiple compact sources to increase the directivity of the network. Optimizing the network factor by controlling the coupling phenomena makes it possible to increase the

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directivity. In [20], a 4 × 4 array of compact wideband dual-polarized printed dipole antenna for 5G base station application was presented with a dimension of 200 mm × 200 mm. A rectangular-shaped reflector is also used to enhance the stability of its radiation patterns over the operating frequencies. It achieves a 22% size reduction compared to the conventional printed half-wavelength cross-dipole. A dual-broadband printed dipole antenna for 2G/3G/4G base station applications is proposed in [21]. The dimension of the antenna is 144mm×132mm× 2mm. The gains are about 4-5 dBi and 5-6 dBi for both resonance frequencies.

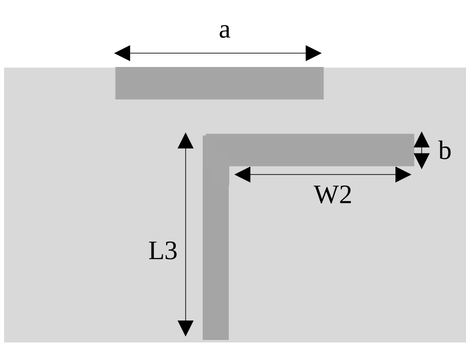
In this paper, a compact network that can operate on two different frequencies is presented as summarised in Table 1. The proposed antenna employs an array structure which allows to obtain compactness and high directivity and therefore ease of integration in base stations. First, we describe the elementary dipole which will serve as the basis for the realization of the network. In the second part, we present the design and realization of the network composed of 4 dipoles. Finally, we propose a realistic application of the network for a compact base-station. The simulation has been done using HFSS ANSYS and the measurements are made in a near field anechoic chamber (Starlab from MVG).

Table 1: Summary of the dimension and the gain of the dipole antenna of the literature

| References | Application | Dimension ($mm^2$) | Maximum Gain (dBi) |
|---|---|---|---|
| [19] | 5G | 200 ×200 | 6 |
| [20] | 2G/3G/4G | 144 × 132 | 6 |
| This work | 4G/5G | 90 × 90 | 6.15 |

## II. ELEMENTARY SOURCE

The elementary antenna consists on a printed dipole as shown in Fig. 1 [2]. The design parameters of the structure were optimized to operate at 2.7 GHz and 5.2 GHz. The printed dipole is made of two identical arms of length W2 and width b, printed on both sides of a Neltec NY9220 substrate of size 33 × 55 mm, thickness h = 0.8 mm, and relative permittivity $\varepsilon_r = 2.2$.

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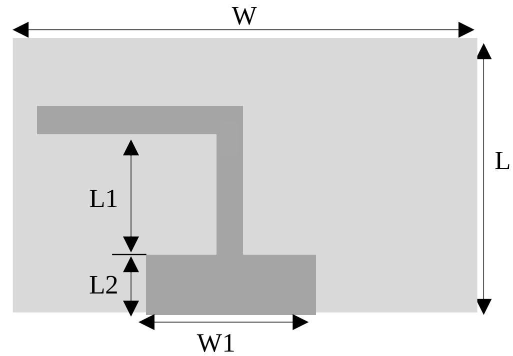


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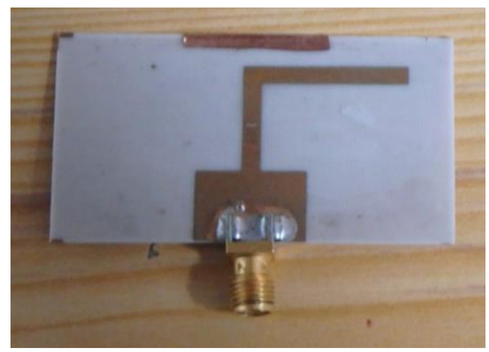

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Fig. 1. Schema of the elementary printed dipole: (a) front view and (b) back view. (c) Photograph of the proposed antenna.

The two arms of the dipole of length approximately λ/2 are placed at λ/4 from of a small rectangular ground plane where the SMA connector is soldered. A parasitic strip of length λ/2 is placed at a distance of 2 mm from the dipole to operate at 5.2 GHz. Table 1 presents the dipole antenna dimensions. These dimensions were optimized to get good impedance matching, by using HFSS software.

Table 2: The elementary printed dipole antenna dimensions

| Parameters | Values (mm) | Parameters | Values (mm) |
|---|---|---|---|
| W | 55 | a | 20 |
| L | 33 | b | 2 |
| L1 | 12 | W1 | 8 |
| L2 | 4 | h | 0.8 |
| L3 | 18 | W2 | 20 |

Both simulated and measured reflection coefficients of the antenna are shown in Fig. 2.

The simulated return loss of the dipole antenna shows a first resonating band which extends from 2.7 GHz to 3.4 GHz and a second one from 5.2 GHz to 5.4 GHz. However, the same performance was obtained in simulation with a small frequency shift towards low frequencies, this may be due to the rapid realization of the prototype with copper ribbon.

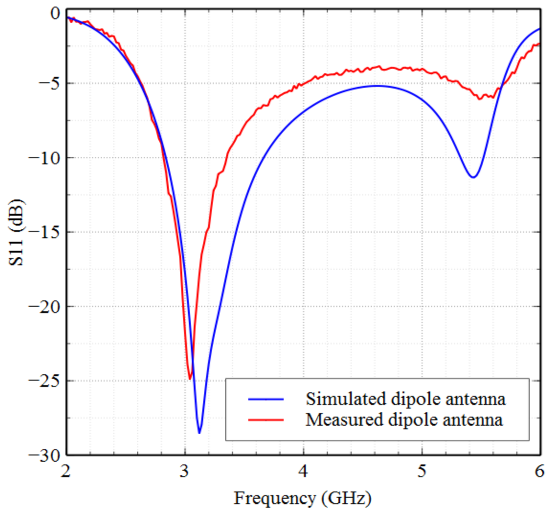



Fig. 2. Measured and simulated $|S_{11}|$ values of the dipole antenna versus the source frequency.

The radiation patterns were measured at resonance frequencies 2.7 GHz and 5.2 GHz, at the IETR institute, buy using the STARLAB MVG anechoic room facilities. At the resonance frequency, the radiation pattern is omnidirectional in the x-z plane with null along the dipole y-axis as shown in Fig. 3. The maximum simulated realized gain is about 2.75 dBi while the measurements show a gain of 2.7dBi.

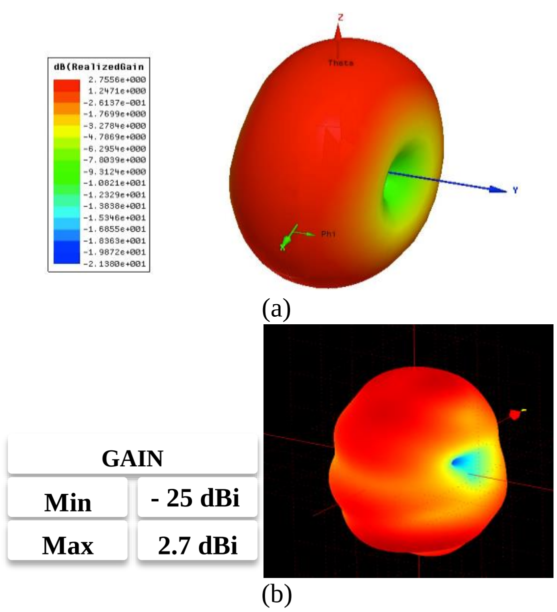



Fig. 3. 3D-radiation pattern at the resonance frequency 2.7 GHz: (a) simulation and (b) measurement.

As shown in Fig. 4 with the red simulated curve, ripples of ± 0.8 dBi in the H-plane are observed, much larger than in the blue measured curve.

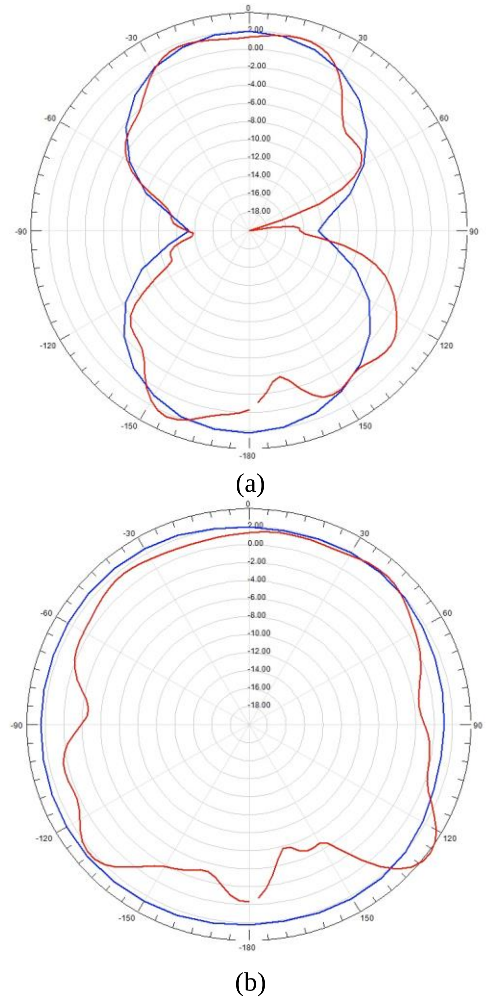


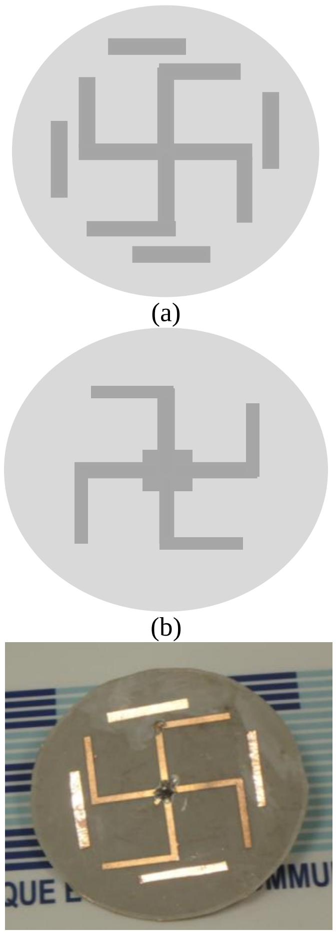

Fig. 4. Simulated and measured gain: (a) E-plane and (b) H-plane at 2.7 GHz (simulation in red and measurements in blue).

## III. DIPOLE ARRAY

### A. Dipole array design

Antenna networks represent one of the methods for obtaining miniature and directive structures. This technique is based on the combination of radiation from multiple compact sources to increase the directivity of the network [22]. Optimizing the network factor by mastering the coupling phenomena [23] makes it possible to increase the directivity. For this reason, a complete network of a 4-dipole array is designed as shown in Fig. 5.

The 4 dipoles with their parasitic elements are positioned at the 4 corners of a 60-mm diameter circular substrate. The power is supplied to the center of the network with an SMA-connector welded on a small ground plane. The dipoles are positioned approximately at 12 mm from the small ground plane, which corresponds substantially to λ/4.




(c)

Fig. 5. Structure of proposed 4-dipole array: (a) front view and (b) back view. (c) Photograph of the manufactured prototype.

### B. Reflection coefficient

Figure 6 shows the reflection coefficient of the 4-dipole array. There is a good agreement between the measurements and the simulation. The resonance frequency of the low band is located at 2600 MHz with a bandwidth of -10 dB between 2550 and 2700 MHz. For the higher band, the resonance frequency is at 5200 MHz with a bandwidth of -10 dB between 5100 MHz and 5520 MHz.

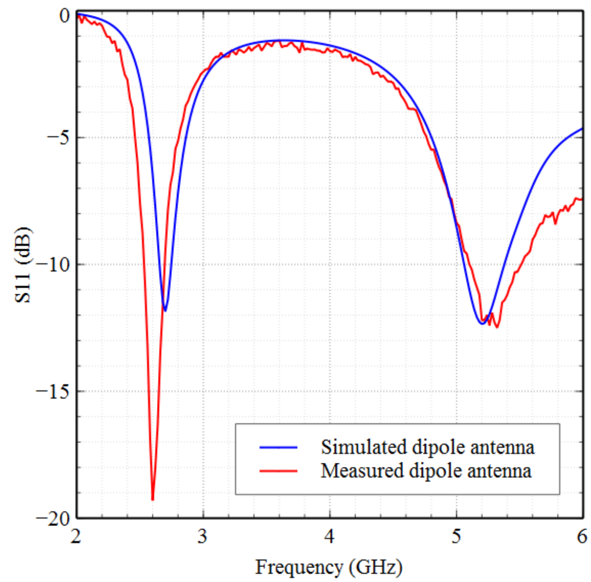
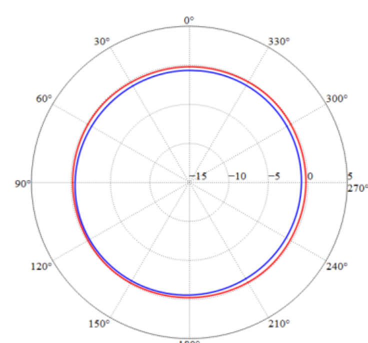



Fig. 6. Simulated and measured $|S_{11}|$ values of the 4 dipoles array versus the source frequency.

### C. Gain and Directivity

The radiation patterns at the resonance frequencies are shown in Figs. 7, 8 and 9. Figures 7 and 8 show the simulated and measured 2-D radiation patterns of the proposed 4-dipoles array at 2.7 GHz and 5.2 GHz, in the E- plane and H- plane. The radiation patterns show good agreement between measurements and simulations for the two operating resonance frequencies. The structure has a directive radiation pattern with horizontal polarization.

At 2.7 GHz, we obtain a maximum gain of 2.5 dB in simulation and 2.4 dB in measurement. At the high operating frequency, we obtain 2.7 dB in simulation and 1.95 dB in measurement as shown in Figs. 7, 8 and 9.

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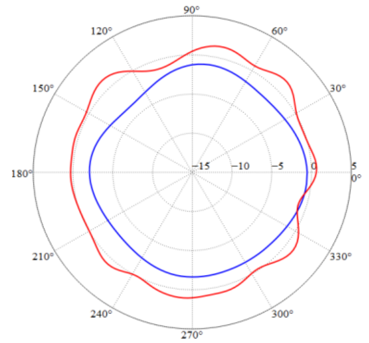


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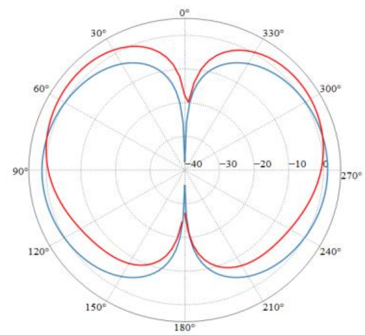
Fig. 7. Simulated and measured radiation patterns of the 4-dipoles array in the H-plane: (a) at 2.7 GHz and (b) at 5.2 GHz. (Simulation in red and measurements in blue).

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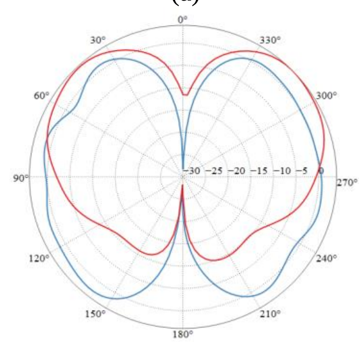


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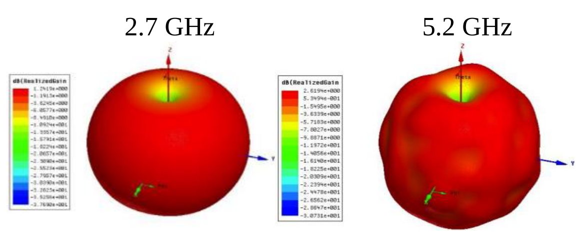
Fig. 8. Simulated and measured radiation patterns of the 4-dipole array in the E-plane: (a) at 2.7 GHz and (b) at 5.2 GHz. (Simulation in red and measurements in blue).

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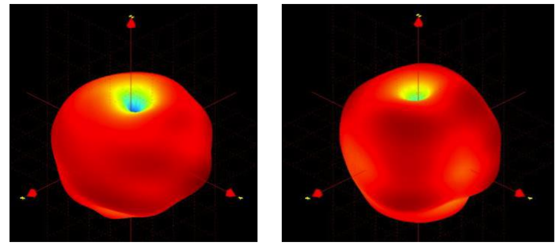


(b)

Fig. 9. 3D-radiation patterns at 2.7 GHz and 5.2 GHz: (a) simulation and (b) measurement.

Figure 10 shows the measured efficiency of the 4-dipole arrays. As we can see it about 88% for both resonance frequency of 2.7 GHz and 5.2 GHz.

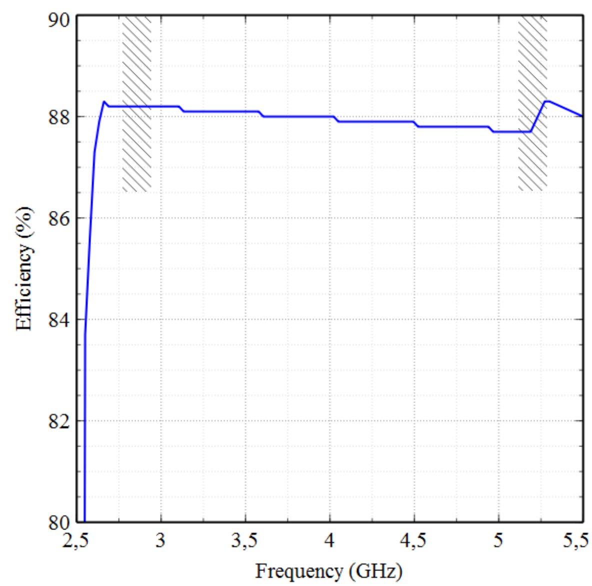



Fig. 10. Maximum measured efficiency of the 4-dipole arrays.

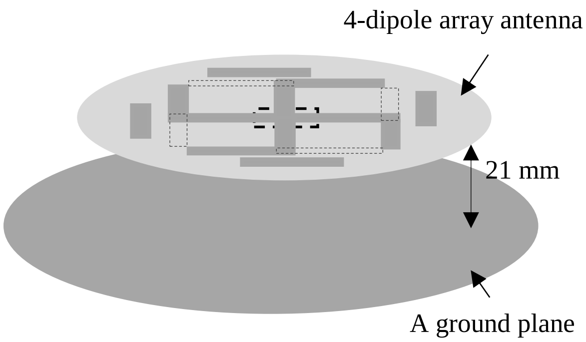
## IV. APPLICATION FOR COMPACT BASE STATION

The base station antennas have undergone several changes. The first versions were simple single-band antennas. The deployment of new standards has been accompanied by new frequency bands. The antennas have been multiband since that time [24].

In this section, we propose a 4-dipoles array structure with a ground plane to operate in a compact base station. The simulated and fabricated structure is shown in Fig. 11. A circular ground plane of 45 mm diameter is placed at 21 mm from the 4-dipoles array. In this way, a compact structure is obtained where the electronic part can thus be placed on the other side of the ground plane.

The measured reflection coefficient of the 4-dipoles array with a ground plane is in good agreement with the simulation results as we can see in Fig. 12 with a small frequency shift of 100 MHz. The bandwidth obtained in the low frequency band is 200 MHz between 2620 and 2820 MHz for an |S11| <-6 dB, whereas for the high frequency band, a bandwidth 820 MHz between 4860 and 5680 MHz is obtained.

The maximum measured gain of the 4-dipole array with a ground plane is shown in Fig. 13.

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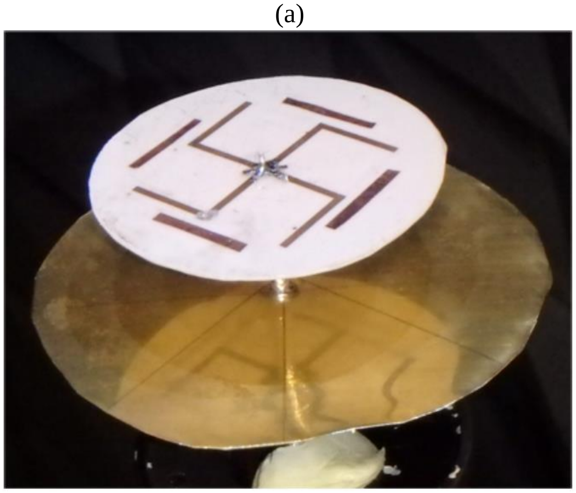


(b)

Fig. 11. Structure of the 4-dipoles array with ground plane: (a) simulated structure and (b) fabricated structure.

The proposed structure has a gain which can reach 2.6 dB for the first resonance frequency and 4.03 dB for the second resonance frequency. The gain seems to increase with the frequency as it is known. It is depending more on the shape (size of the structure), whereas the efficiency is related to the loses in the antennas (metals and dielectric (substrate)).

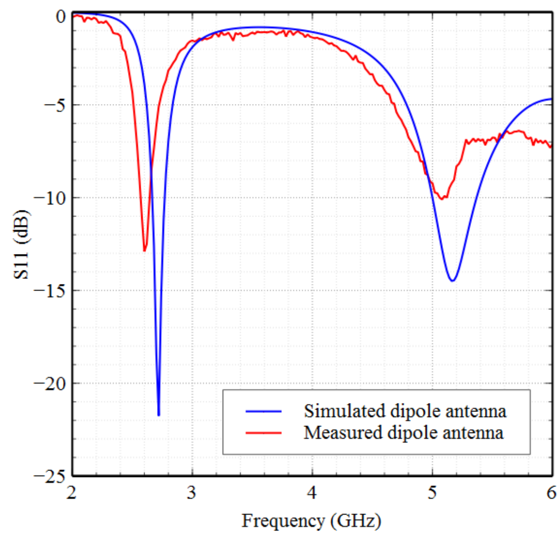



Fig. 12. Reflection coefficient of the 4-dipoles array with ground plane versus frequency.

Moreover, the prototype structure showed good measured efficiency which can reach 83% for both resonance frequencies as shown in Fig. 14. Figures 15, 16 and 17 show the 2-D and 3-D simulated and measured radiation patterns of the proposed structure in the H-plane at 2.7 GHz and 5.2 GHz. At both resonant frequencies, the radiation pattern of the 4-dipoles array with a ground plane is more directive in the orthogonal plane of the antenna and has a null along the dipole axis.

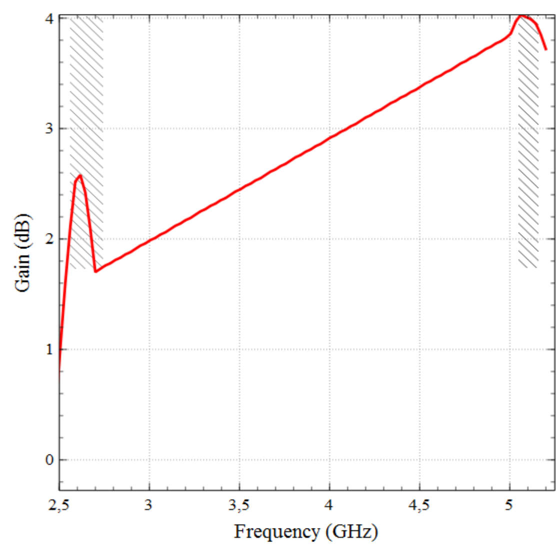



Fig. 13. Maximum measured gain of the proposed structure.

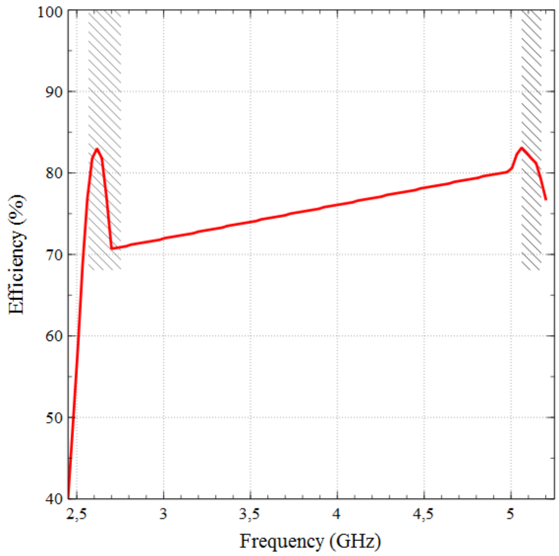
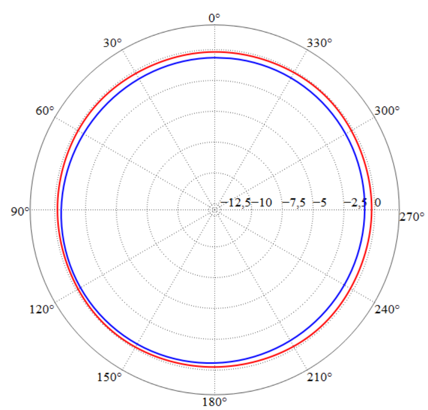



Fig. 14. Maximum measured efficiency of the proposed structure.

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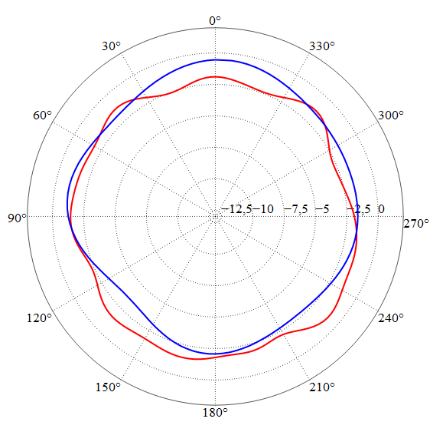
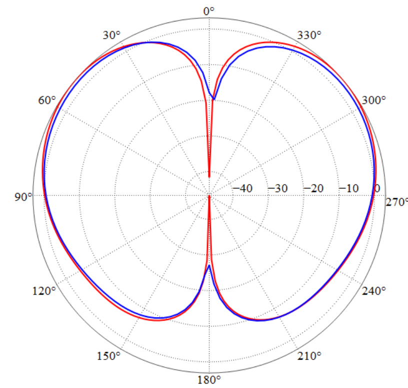



(b)

Fig.15. 2-D simulated and measured gain of the 4-dipoles array with ground plane in the E-plane: (a) 2.7 GHz and (b) 5.2 GHz. (simulation in red and measurements in blue).

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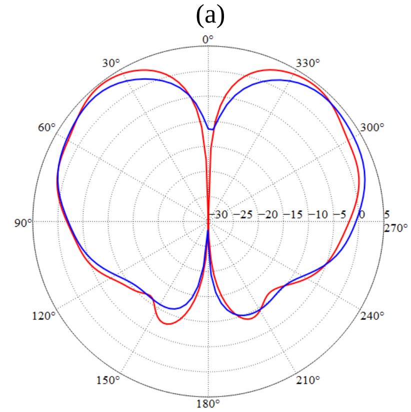


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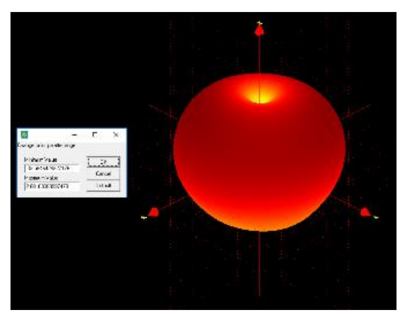
Fig. 16. 2-D simulated and measured gain of 4-dipoles array with ground plane in the H-plane: (a) 2.7 GHz and (b) 5.2 GHz. (simulation in red and measurements in blue).



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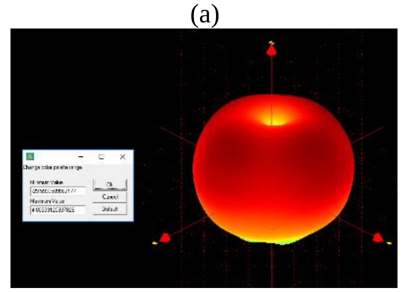

(b)

Fig. 17. 3-D measured gain of 4-dipoles array with a ground plane at: (a) 2.7 GHz and (b) 5.2 GHz.

## V. CONCLUSION

In this paper, we have designed a 4-dipoles antenna array based on the printed dipole structure. The proposed compact array, operating around 2.7 and 5.2 GHz, is characterized with omnidirectional radiation patterns, and high efficiency (about 88%). These good radiation properties allow it to be a potential candidate for compact-antenna used in wireless base stations used in satellite telecommunications.

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