# A reconfigurable high-gain metal-graphene printed dipole antenna for Wi-Fi and LTE applications

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**Research Article**

**Keywords:** Printed Dipole antenna, Graphene, Reconfigurable, Wi Fi, LTE

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# A reconfigurable high-gain metal-graphene printed dipole antenna for Wi-Fi and LTE applications

**Roghaye Ebadzadeh[1], Pejman Mohammadi[1] and Mahdi Zavvari[1]**

**Abstract** –This study presents the design and construction of a reconfigurable c-shaped dipole antenna for Wi-Fi and LTE bands. It consists of two nested c-shape resonators located inside each of the wings of the c-dipole patch antennas. The mentioned resonators have been used due to their inductive and capacitive effects. The reconfigurable property of the proposed antenna has been achieved with two graphene layers which are deposited on two gaps over the patch antennas. The graphene layers adjust the return loss of the proposed antenna into the desired band. These graphene layers are examined with different chemical potentials so that the antenna return loss changes over the. The simulation and measurement results show that the gain of the antenna is higher than 5dB for both LTE and Wi-Fi applications. A good agreement is recognized between the measured and simulation results.

**Keywords**: Printed Dipole antenna, Graphene, Reconfigurable, Wi-Fi, LTE

## 1. Introduction

Given the new applications of radio systems, designing the most effective antenna seems to be indispensable. The Wi-Fi can be regarded as the most popular technology in the field of wireless local area networks that allows high-speed internet or network connections using radio waves [1]. The Long term evolution (LTE) covers three bands, where the lower band includes frequency range of (698–966 MHz), the middle band in the range of (1.427–2.69 GHz) and higher band in the range of (3.4–3.8 GHz) [2]. Graphene has been constructed as two-dimensional material in 2004, which has attracted increasing attention in recent years due it's exotic properties such as high mobility carrier, low resistivity, high conductivity, chemical stability, mechanical flexibility, and so on [3], [4].

According to the development of knowledge regarding radio systems in wireless communications, there have been many studies about graphene antennas [5]. Presently, the use of nanomaterials such as graphene in designing antennas, including the antennas with small dimensions, the electrically tunable, reconfigurable, and beamforming have grasped the attention of many researchers. Graphene can be used directly as a radiation element, or for tuning the radiation properties of the element [6].

However, the radiation efficiency of the graphene is usually limited due to its significant loss [7]. To improve the radiation efficiency, hybrid metal-graphene structures have been proposed [7], [8], [9], [10].

In some other structures, graphene is used to improve the radiation of antennas. In this case, graphene is used as a coating of radiation metal, thereby improving its radiation pattern and efficiency [11].

The concept of reconfigurable antenna denotes the changes in frequency characteristics, radiation patterns, or polarization of the antenna that can be implemented without changing the physical size and

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dimensions of the antenna using these techniques [12]. The antenna structure of graphene could be flexible and lightweight [13], [14]. Graphene has the property that, it exhibits different resonance frequencies when the applied chemical potential is changed. Also, changing the resistance of the grapheme in different DC-bias, changes the input impedance of the antenna, thus shifting the resonance frequency of the antenna. In the proposed manuscript the aforementioned property of graphene is applied to the metal-graphene antenna for achieving reconfigurable structure.

Performance analysis of the hybrid metal-graphene frequency reconfigurable antenna in the microwave regime has been proposed by Alvarez et al [15]. In the mentioned study, the performance of the use of graphene in the frequency of reconfigurable antenna has been evaluated using the simulation of two metal-graphene antennas for Wi-Fi and LTE applications. Accordingly, graphene is not only another choice to an RF switch, however, it can also be used for fabricating the radiating antenna itself [15].

In [16] a planar antenna with voltage-controlled frequency tuning based on few-layer graphene was proposed. They showed that by using the pad of few-layer graphene flakes at the input of shorted microstrip stubs, it is possible to obtain the optimized voltage-controlled tunable patch antenna.

In the present study, at first, the c-dipole antenna was designed with two nested c-shape resonators located inside each of the wings of the c-dipole antenna under non-graphene condition. To feed the c-dipole antenna, a microstrip integrated balun [17], [18] was used on the backside of the Rogers 4003 substrate. The integrated balun is used for impedance matching of the antenna with coaxial cable. In the next step, the graphene was added to the dipole antenna. The antenna simulation and measurement results with and without graphene are provided and also the simulation results with different chemical potentials are illustrated. Some features of the proposed antenna are compared with those of similar antennas.

## 2. Design of Reconfiguration Antenna

The geometric structure of the proposed antenna is presented in Fig.1.The top view (Fig.1a) of the structure includes two nested c-shape resonators which are located inside each of the wings of the c-dipole patch antenna. Two narrow strips of graphene are used to connect the resonators.

The overall size of the proposed c-dipole antenna is 49×90×0.8 mm3. An integrated balun in the form of a Γ-shape microstrip line is printed on the backside of the substrate (Fig.1b). The proposed antenna can operate at 1-4 GHz. This operating bandwidth covers Wi-Fi and LTE. The coaxial cable is connected to the antenna's feed line through a ground plane that is perpendicular to an antenna and located underneath it. The parametric values of the proposed antenna are summarized in Table.1. The proposed antenna was etched on the Rogers4003 substrate with a thickness of 0.8mm a dielectric constant of 3.55, and a loss tangent of 0.0027. In the proposed design, a temperature of 300 K, graphene thickness of 10nm, chemical potential coefficient of 0.2, and a relaxation time of 1 hour were applied.

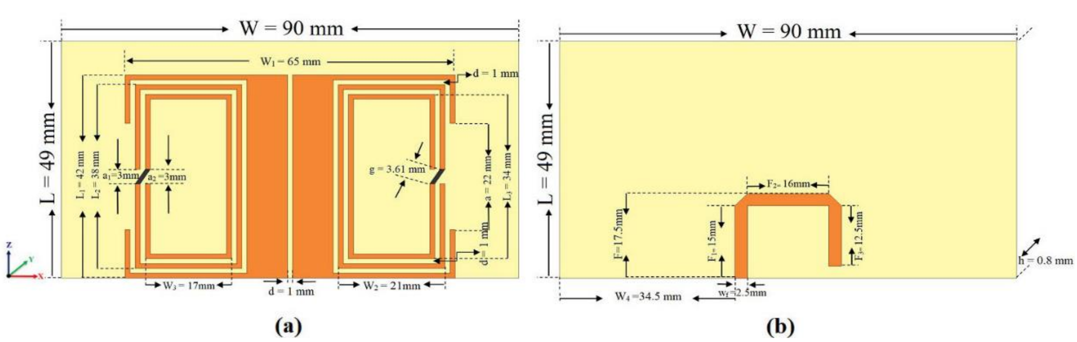



**Fig. 1.** The proposed antenna (a) front view, (b) back view.

**Table1:** The optimized parameters of the proposed antenna.

| Parameter | Value | Parameter | Value | Parameter | Value |
|---|---|---|---|---|---|
| W | 90 | $L_1$ | 42 | $L_2$ | 38 |
| L | 49 | $W_2$ | 21 | $L_3$ | 34 |
| $W_1$ | 65 | $W_3$ | 17 | a | 22 |
| h | 0.8 | $F_1$ | 15 | $a_1$ | 3 |
| $w_f$ | 2.5 | $F_2$ | 16 | $a_2$ | 3 |
| g | 3.61 | $F_3$ | 12.5 | d | 1 |
| F | 17.5 | $W_4$ | 34.5 | | |

The c-shaped resonators and the equivalent circuit model [19] are shown in Fig.2. The c-shaped resonator acts as a parallel LC circuit near the resonance frequency. The graphene can be represented by the equivalent resistance in.

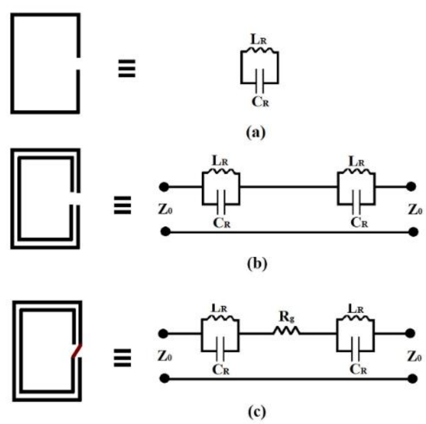



**Fig. 2.** (a) The c-shaped resonator and the equivalent circuit model, (b) Two c-shaped resonators and the equivalent circuit model without graphene, (c) with graphene

## 3. Results and Discussion of the Antenna

Graphene strips in the proposed antenna firstly have been used for adjusting the return loss, then by changing the chemical potential of it the reconfigurable property of the antenna has been achieved. Therefore, the simulation of the proposed antenna with and without graphene is investigated separately. Two proposed antennas are compared in terms of return loss, gain, and pattern. The simulation and measurement results obtained from the CST software and the N5242A network analyzer respectively.

### 3.1 Return loss

The simulation results of the proposed antenna are provided in Fig.3. According to this figure, the antenna with graphene covers more frequency in Wi-Fi and LTE application. The measurement setup of the proposed antenna is presented in Fig.4.The simulations and measurements of the S11 for the proposed antenna without and with graphene are provided in Fig.5 and Fig.6, respectively.

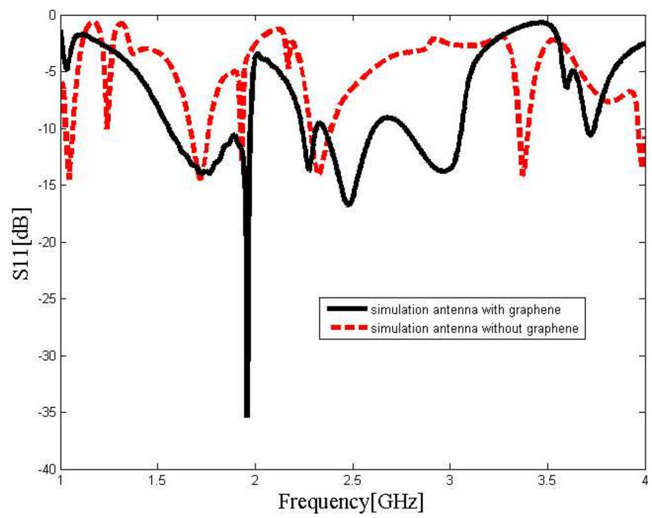
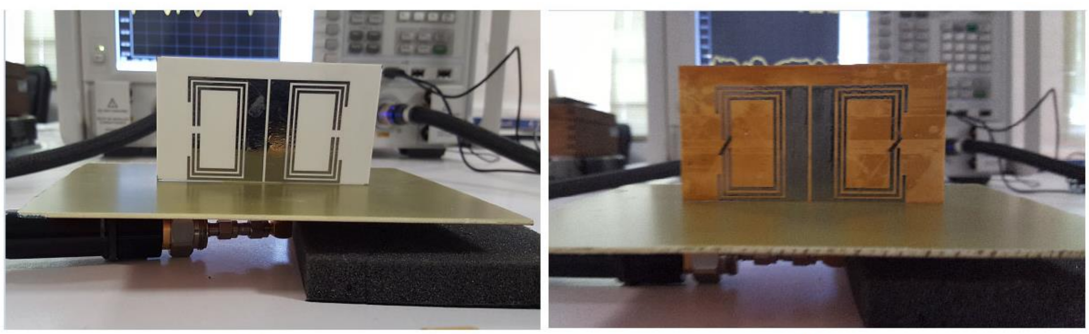



**Fig. 3.** The simulation results of S11 for the proposed antenna.



(a) (b)

**Fig 4.** The measurement setup of the proposed antenna (a) without graphene, (b) with graphene.

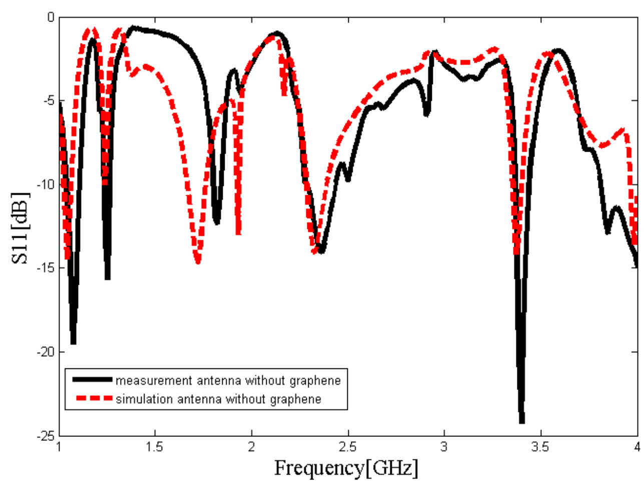



**Fig 5.** The simulation and measurement results of S11 for the proposed antenna without graphene.

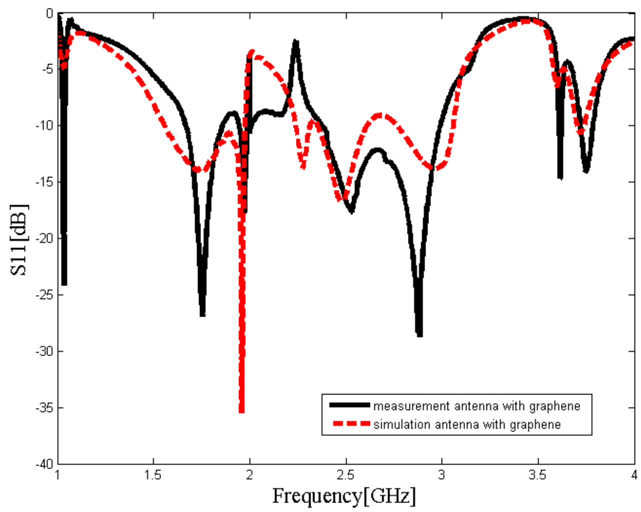



**Fig6.** The simulation and measurement results of S11 for the proposed antenna with graphene.

By changing the chemical potential of the graphene antenna, the resonant frequency changes, attaining frequency reconfiguration is shown in Fig.7.

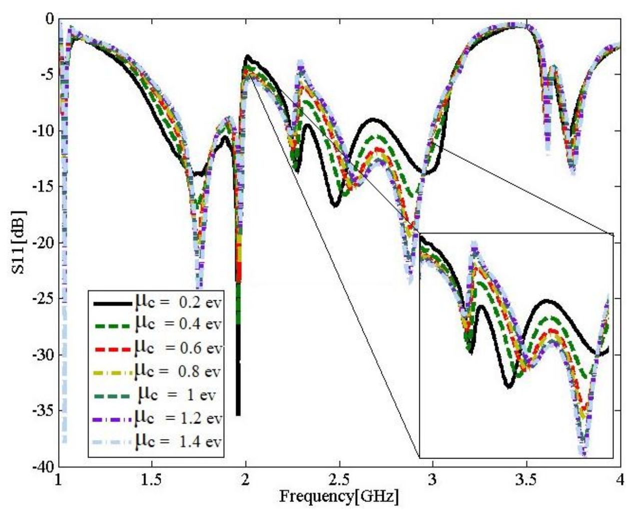



**Fig. 7.** The simulation results of S11 versus frequency for different chemical potentials.

Fig. 8 shows the simulation results of S11 versus frequency, for different values of the graphene resistance. As expected, changing the equivalent resistance of the graphene changes the input impedance of the antenna, thus shifting the resonance frequency of the antenna. As shown in Fig. 8, the antenna operates at the frequency of 2.4 GHz when the graphene resistance is R=1000 Ω and decreases to 2.29 GHz when the graphene resistance is R=100 Ω. The resulting overall frequency shift is 110 MHz.

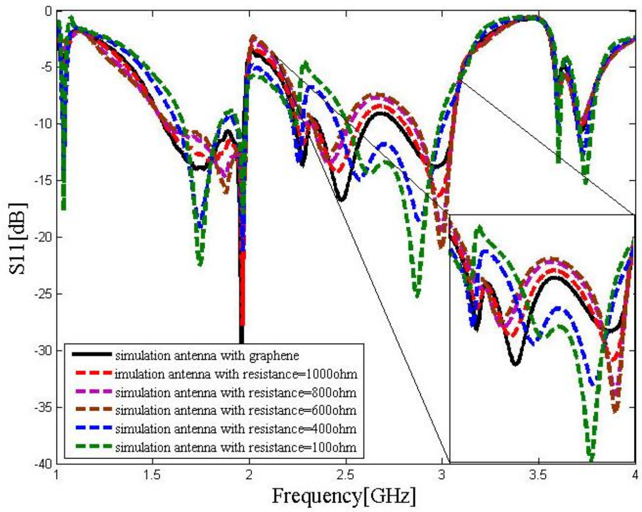



**Fig. 8.** The simulation results of S11 versus frequency, for different values of the graphene equivalent resistance.

### 3.2. Gain

The measurement and simulation gains of the antenna are presented in Fig.9. The measurement gains of the antenna with graphene are 5 dB, 6.1 dB, 5.2 dB, 7.1dB, and 6.5 dB at 1.1GHz,1.8 GHz, 2.4 GHz, 2.8 GHz, and 3.6 GHz respectively. The measurement gains of the antenna without graphene are 3 dB, 5 dB, 6.1 dB, 6.9 dB, and 6.5 dB at 1.1GHz, 1.3GHz, 1.8 GHz, 2.3 GHz, and 3.3 GHz respectively.

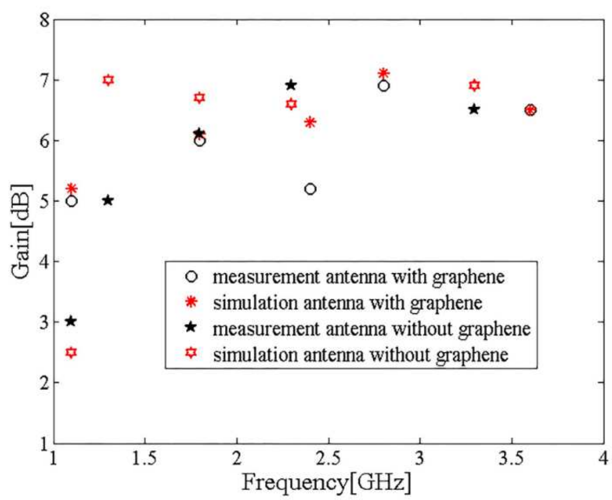



**Fig. 9.** The simulation and measurement results of the gain for the proposed antennas.

### 3.3. Radiation Pattern

The measurement and simulation results of the radiation pattern for the proposed antenna without and with graphene are summarized in Fig.10 and Fig.11 respectively. As it is seen in Fig 11, by adding the graphene, the radiation pattern changes slightly, also the radiation pattern has an almost homogeneous pattern on frequencies of 1.3GHz, 1.8GHz, 2.3GHz, 2.4GHz, 2.8GHz, 3.3GHz and, 3.6 GHz in the E plane as it is expected for this antenna.

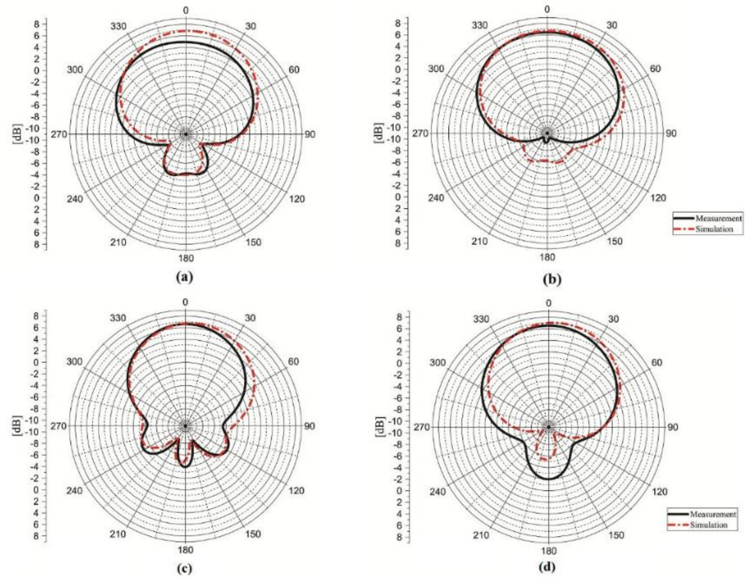


**Fig. 10.** Measurement and Simulation results of the radiation pattern of the antenna without graphene. (a) 1.3GHz, (b)1.8GHz, (c)2.3GHz, (d)3.3GHz.

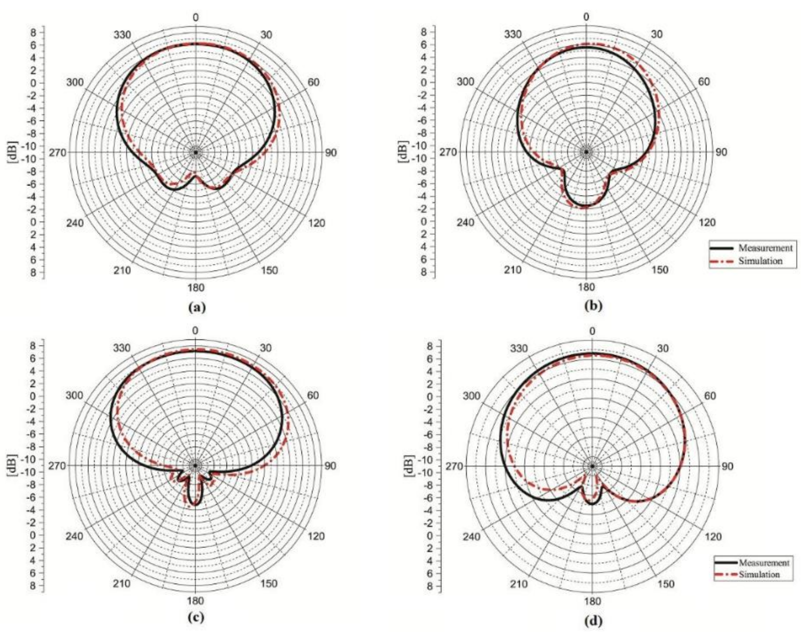


**Fig. 11.** Measurement and Simulation results of the radiation pattern of the antenna with graphene. (a) 1.8GHz, (b)2.4GHz, (c)2.8GHz, (d)3.6GHz.

### 3.4. Surface current

Fig.12 shows the current distribution for the proposed antenna at two-state without and with graphene at 2.5 GHz. As it is expected the current distribution is stronger when the graphene is set to the existed state, Fig. 12b, the current is allowed to flow, through the strips. However, when the graphene is set to the nonexistence state, Fig. 9a, the currents are not flow through the strips but are diverted around them. This makes the currents travel longer paths, which is equivalent to increasing inductance effect and therefore the antenna resonance is found at a lower frequency.

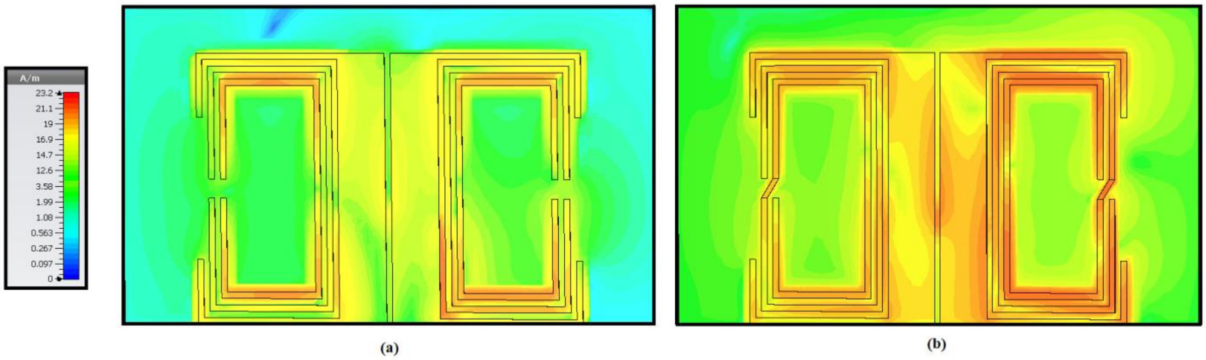



**Fig. 12.** Surface current distribution antenna (a) without graphene (b) with graphene.

### 3.5. Comparisons

Table.2 presents a comparison of the proposed antenna with similar antennas [15], [16]. In order to have an exact comparison, we try to do it with a graphene-metal-based antenna. In [15] two different structures are used for Wi-Fi and LTE. The first structure for Wi-Fi consists of a central rectangular patch with two graphenes added on the sides and the second structure for LTE consists of a microstrip patch antenna with inset notches on the edges, where graphene strips are added in those spaces. The structure in [16] consists of the microstrip line, patch, graphene, stub, and shorting via. The gain of the proposed antenna is higher than both similar antennas, and also its structure is simple in comparison with them.

**Table2:** Comparisons between this work and other antennas.

| Reference | $\varepsilon_r$ of the substrate | Frequency(GHz) | Size ($mm^3$) | Gain(dB) |
|---|---|---|---|---|
| [15] WIFI application | Polystyrene (PS),2.4 | 2.4,3.6,5 | 23×14.7×2.1 | -3.4,1.3,5.2 |
| [15] LTE application | Polystyrene (PS),2.4 | 1.8,2.1,2.6,3.6 | 39×22×2.1 | -1.6,-0.7,-3.3,3.9 |
| [16] | Taconic RF35,3.5 | 5-5.2 | 20×15×1.52 | 2.38 |
| This work | Rogers 4003,3.55 | 1.1,1.8.2.4,2.8,3.6 | 90×49×0.8 | 5,6.1,5.2,7.1,6.5 |

## 4. Conclusion

The new design and topology of a reconfigurable metal-graphene dipole antenna are proposed. In order to show the role of graphene two structures are designed and fabricated. The comparison results with similar antennas indicated that the proposed antenna not only has a simple structure but also shows a higher gain. The reconfigurable ability of graphene with different chemical-potential is exhibited. The measurement return loss and radiation properties verify that it is suitable for Wi-Fi and LTE applications.

## ACKNOWLEDGMENTS

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### Declarations

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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# Figures

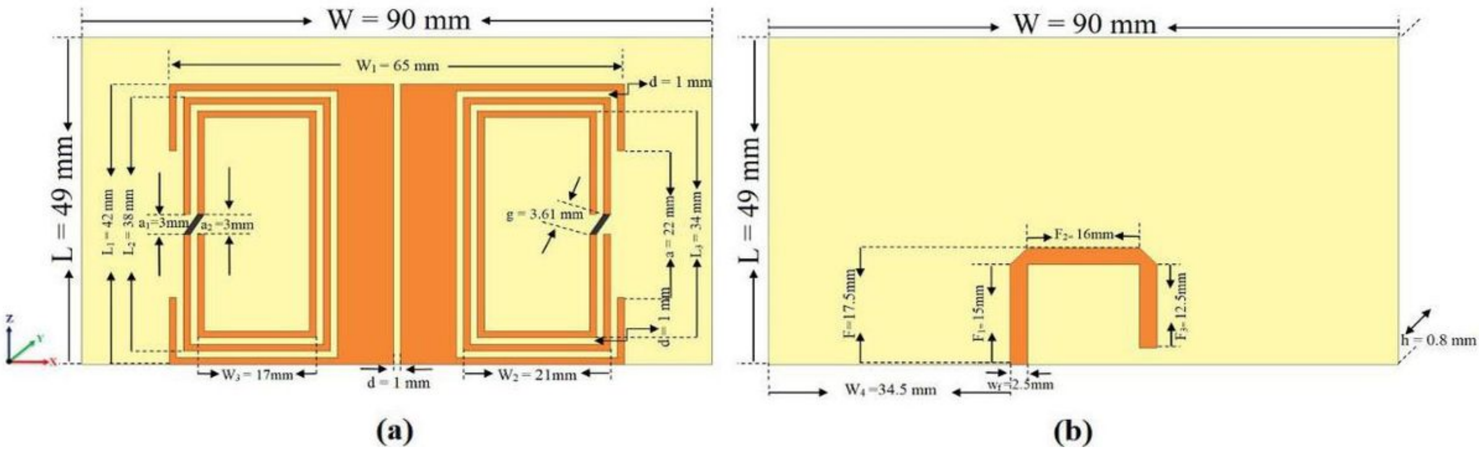



Figure 1

The proposed antenna (a) front view, (b) back view.

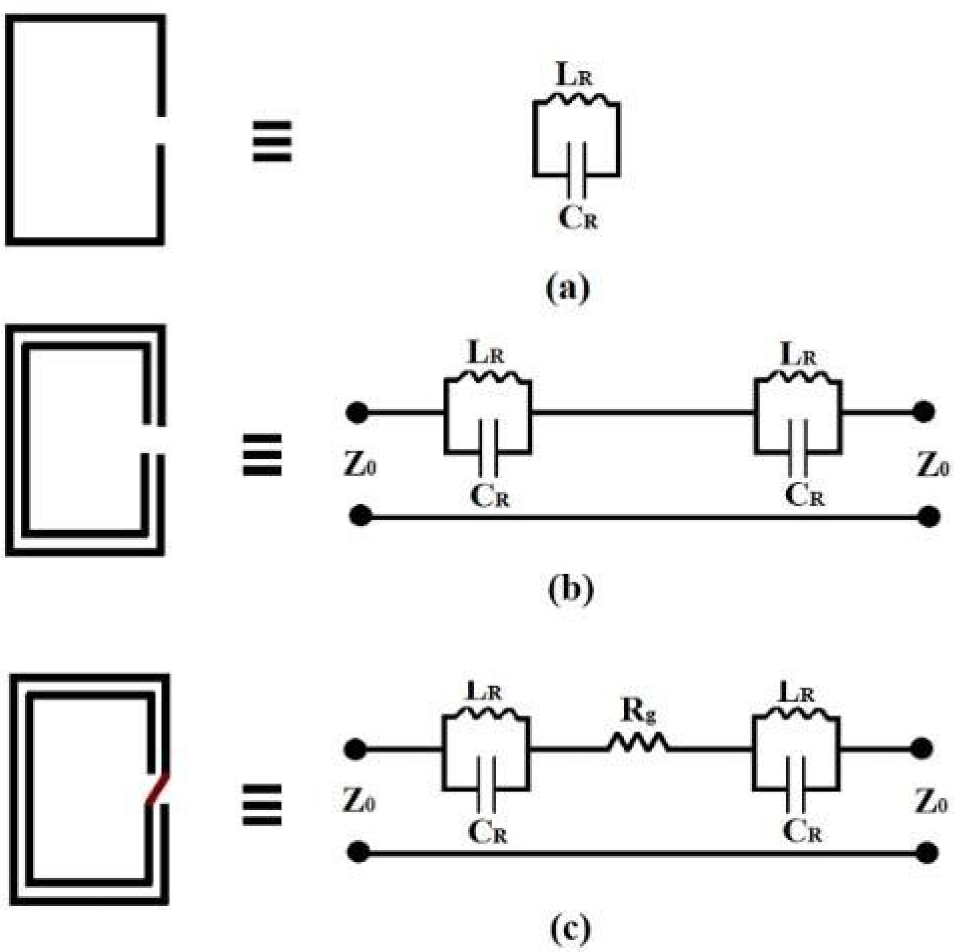
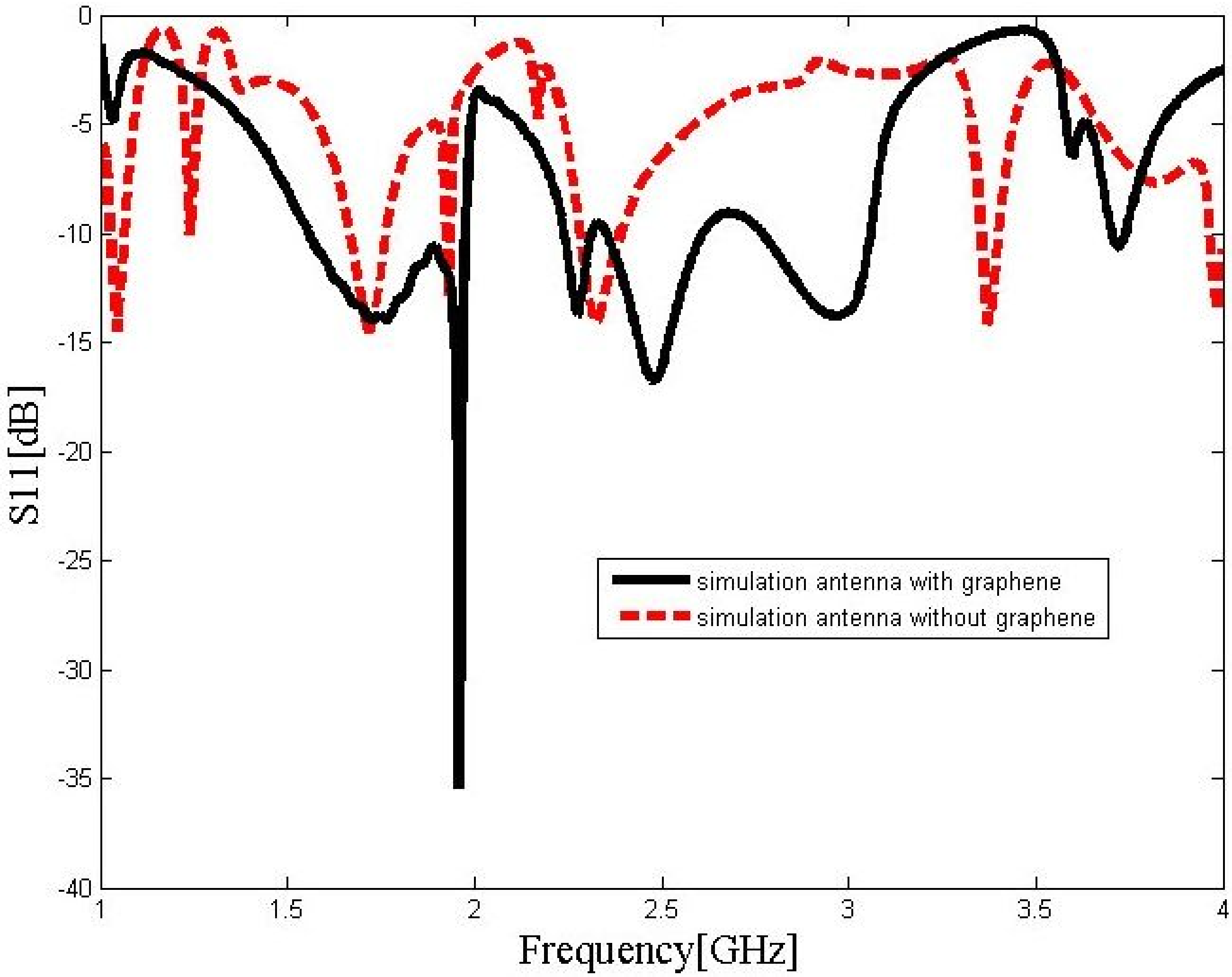


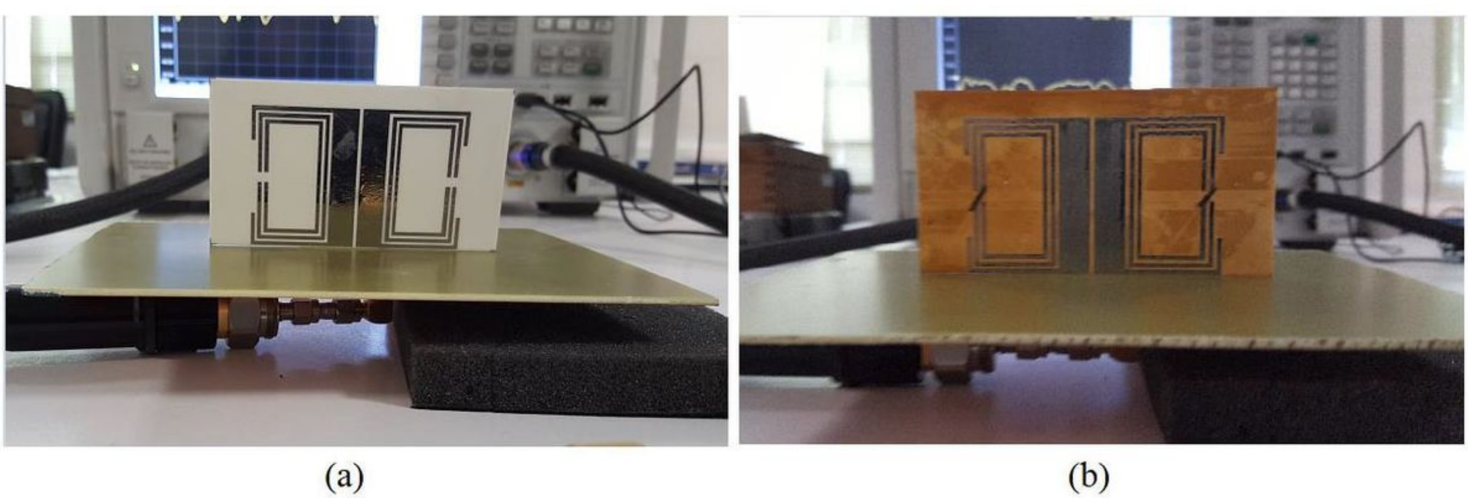

Figure 2

(a) The c shaped resonator and the equivalent circuit model, (b) Two c shaped resonators and the equivalent circuit model without graphene, (c) with graphene




## Figure 3

The simulation results of S11 for the proposed antenna.




## Figure 4

The measurement setup of the proposed antenna (a) without graphene, (b) with graphene.

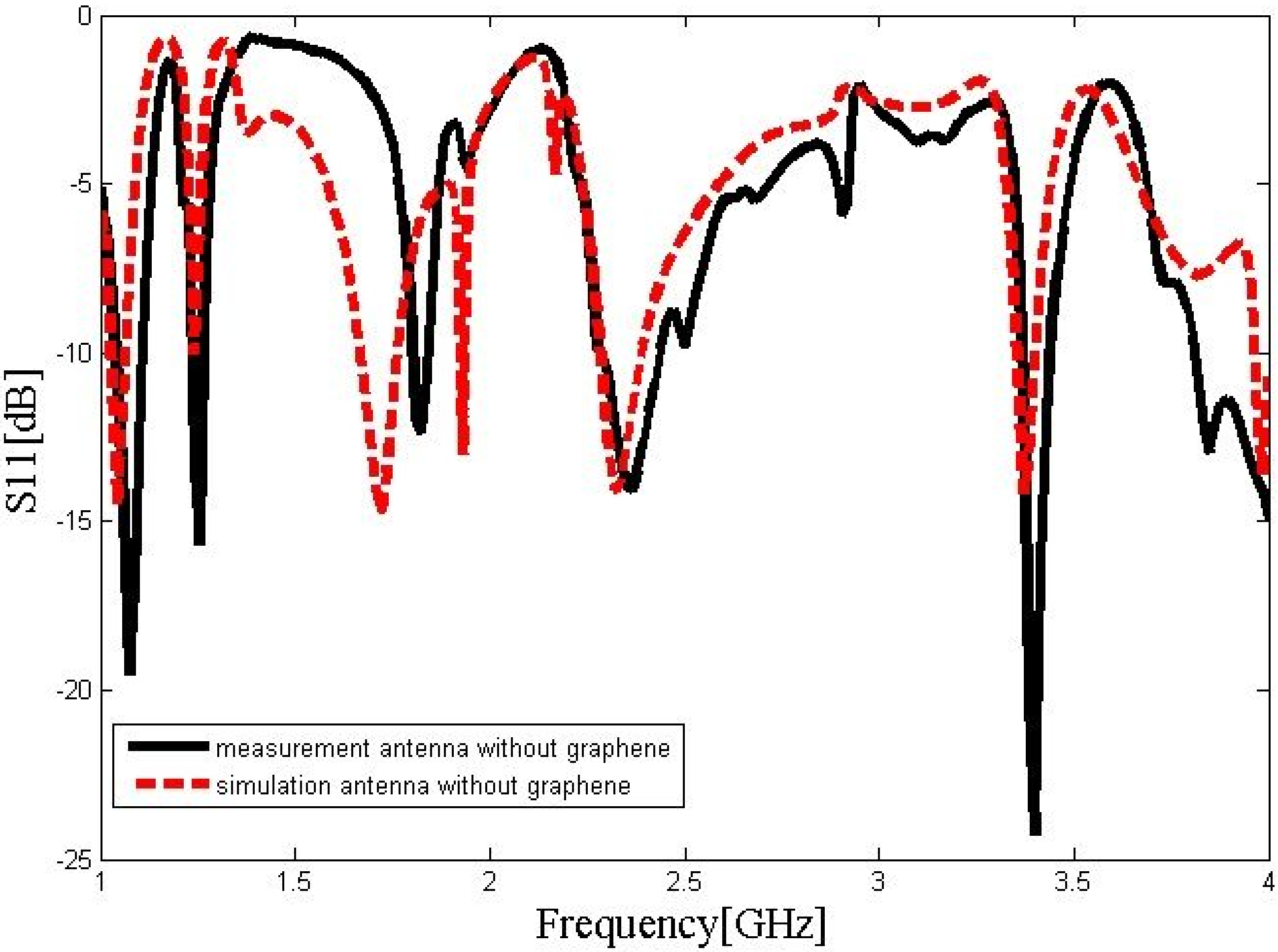



**Figure 5**

The simulation and measurement results of S11 for the proposed antenna without graphene.

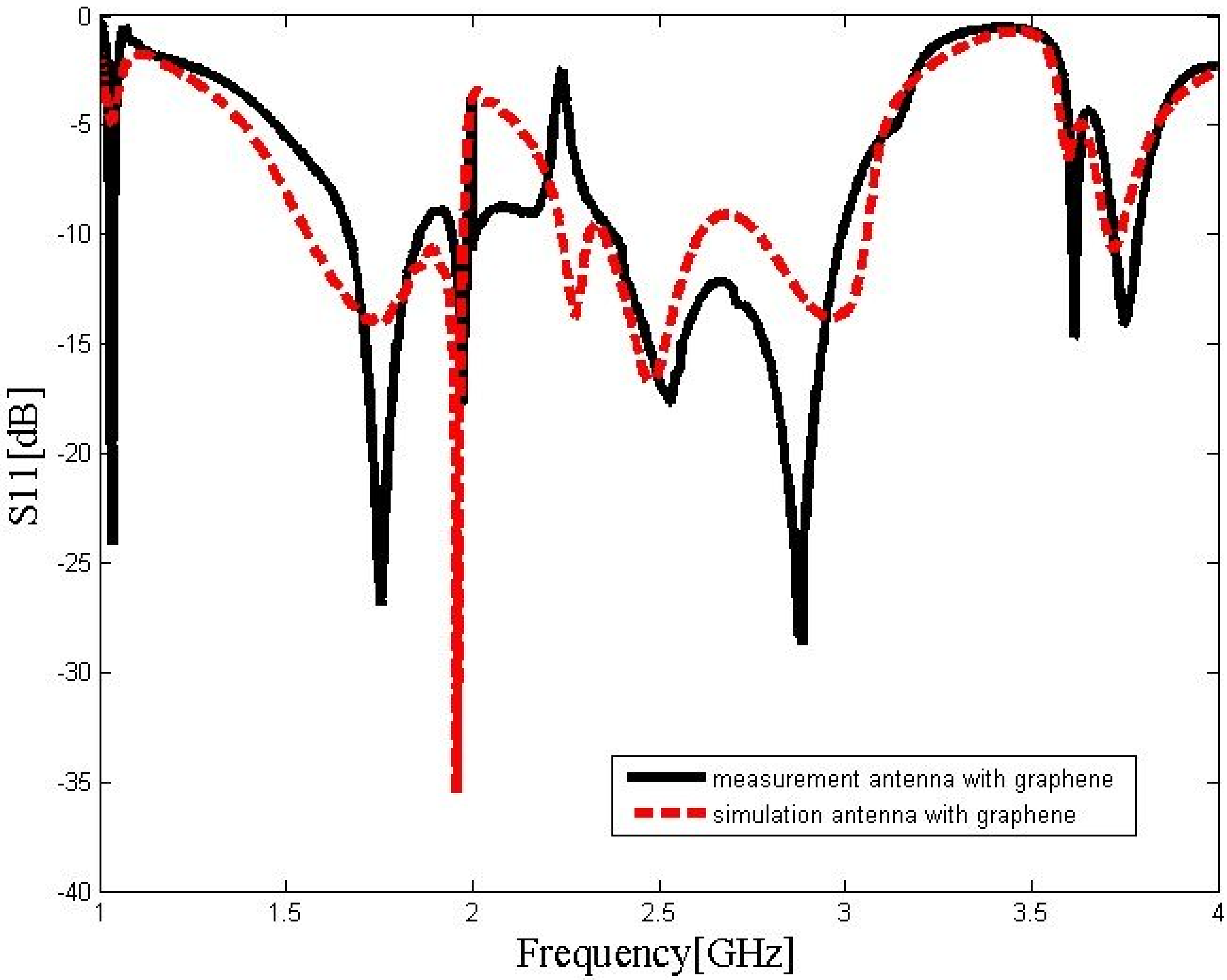



**Figure 6**

The simulation and measurement results of S11 for the proposed antenna with graphene.

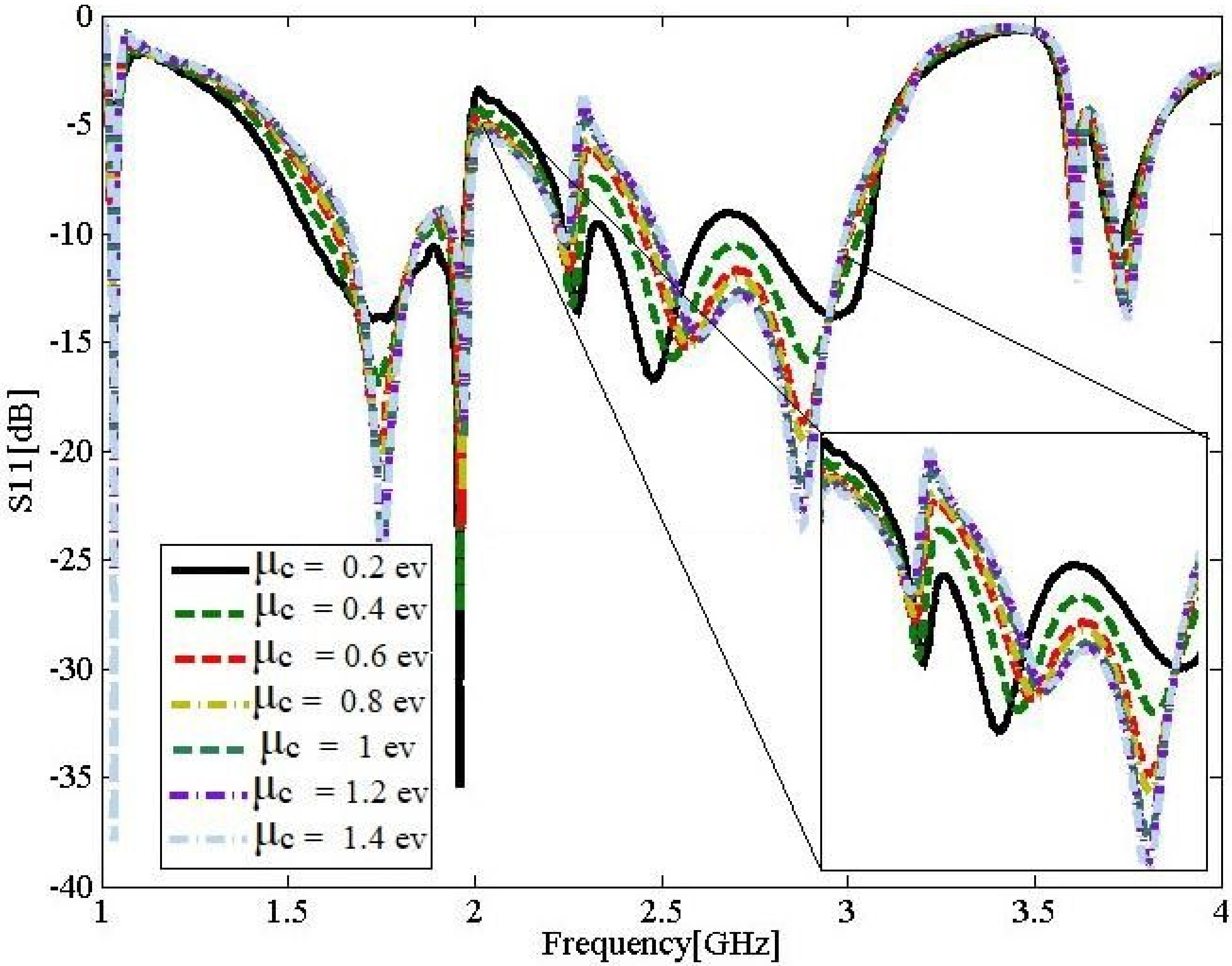



**Figure 7**

The simulation results of S11 versus frequency for different chemical potentials.

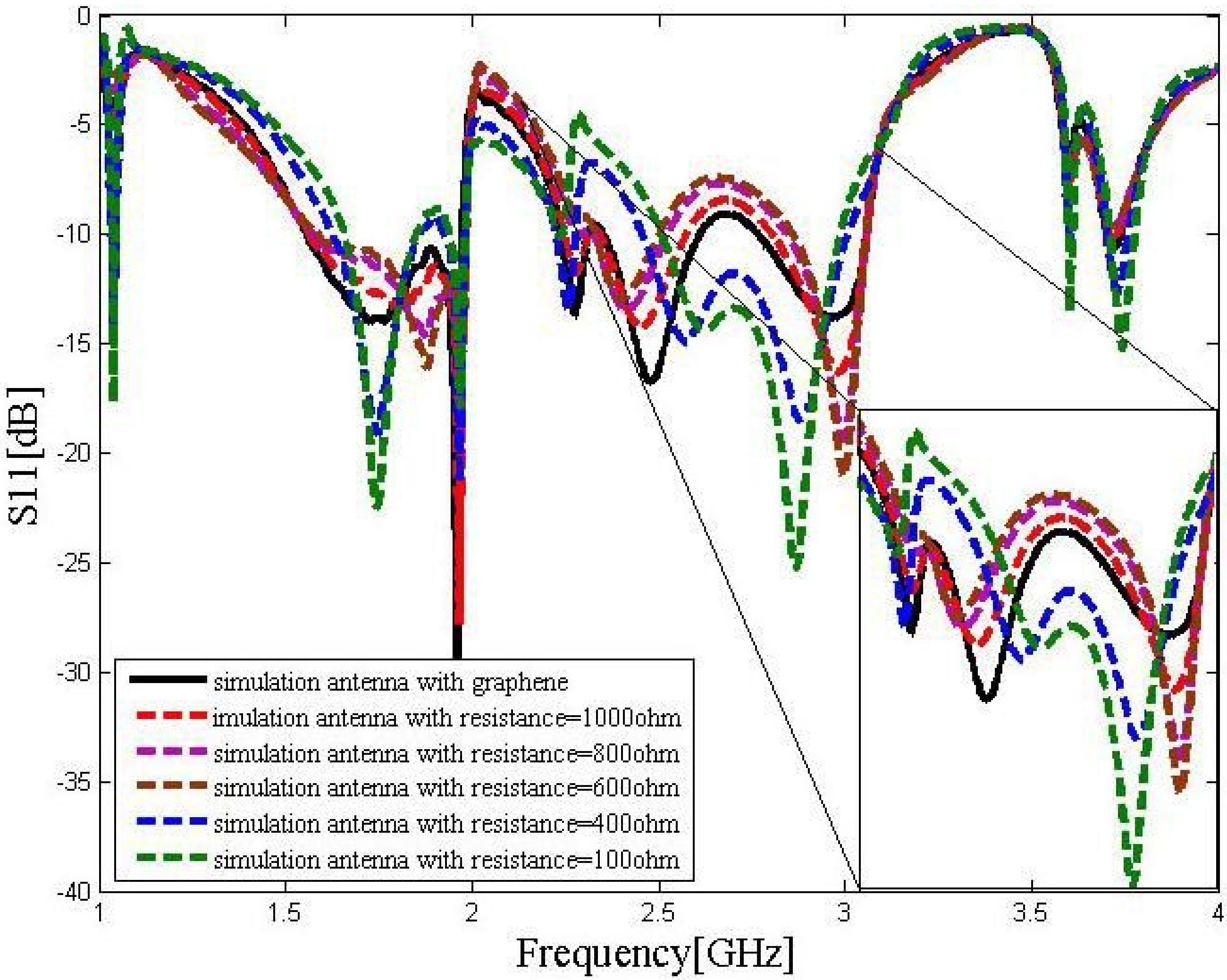



**Figure 8**

The simulation results of S11 versus frequency, for different values of the graphene equivalent resistance.

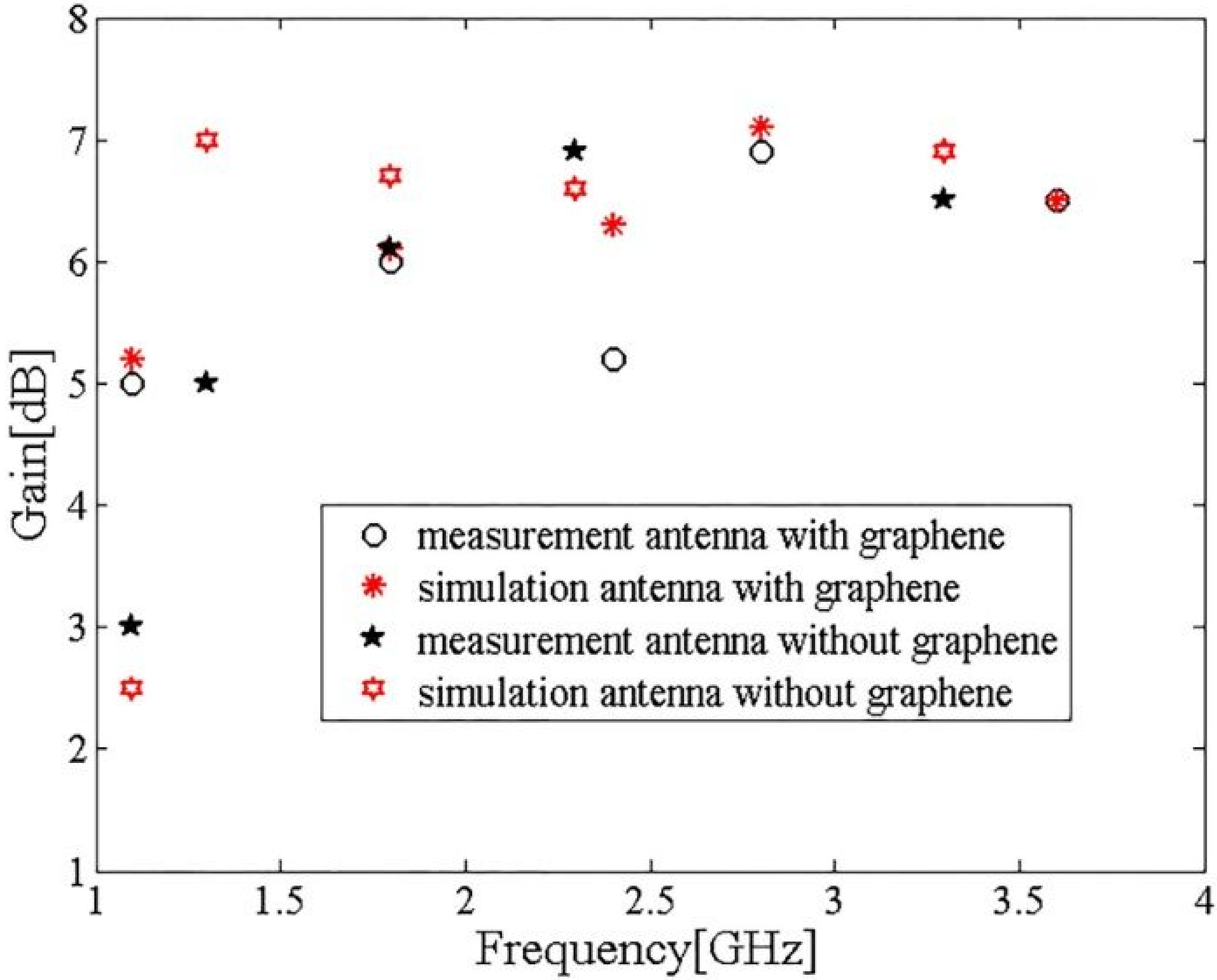
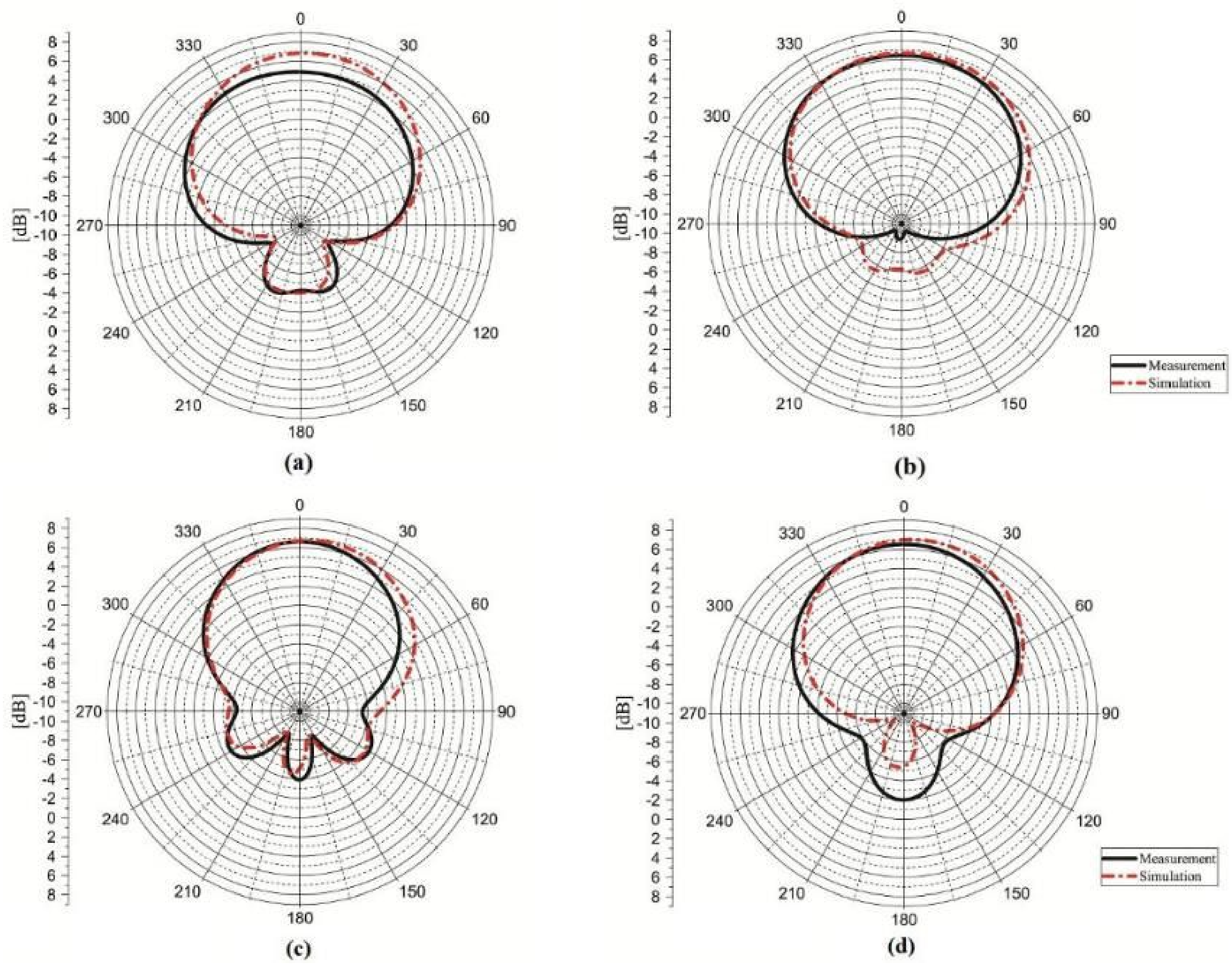



**Figure 9**

The simulation and measurement results of the gain for the proposed antennas.




## Figure 10

Measurement and Simulation results of the radiation pattern of the antenna without graphene. (a) 1.3GHz, (b)1.8GHz, (c)2.3GHz, (d)3.3GHz.

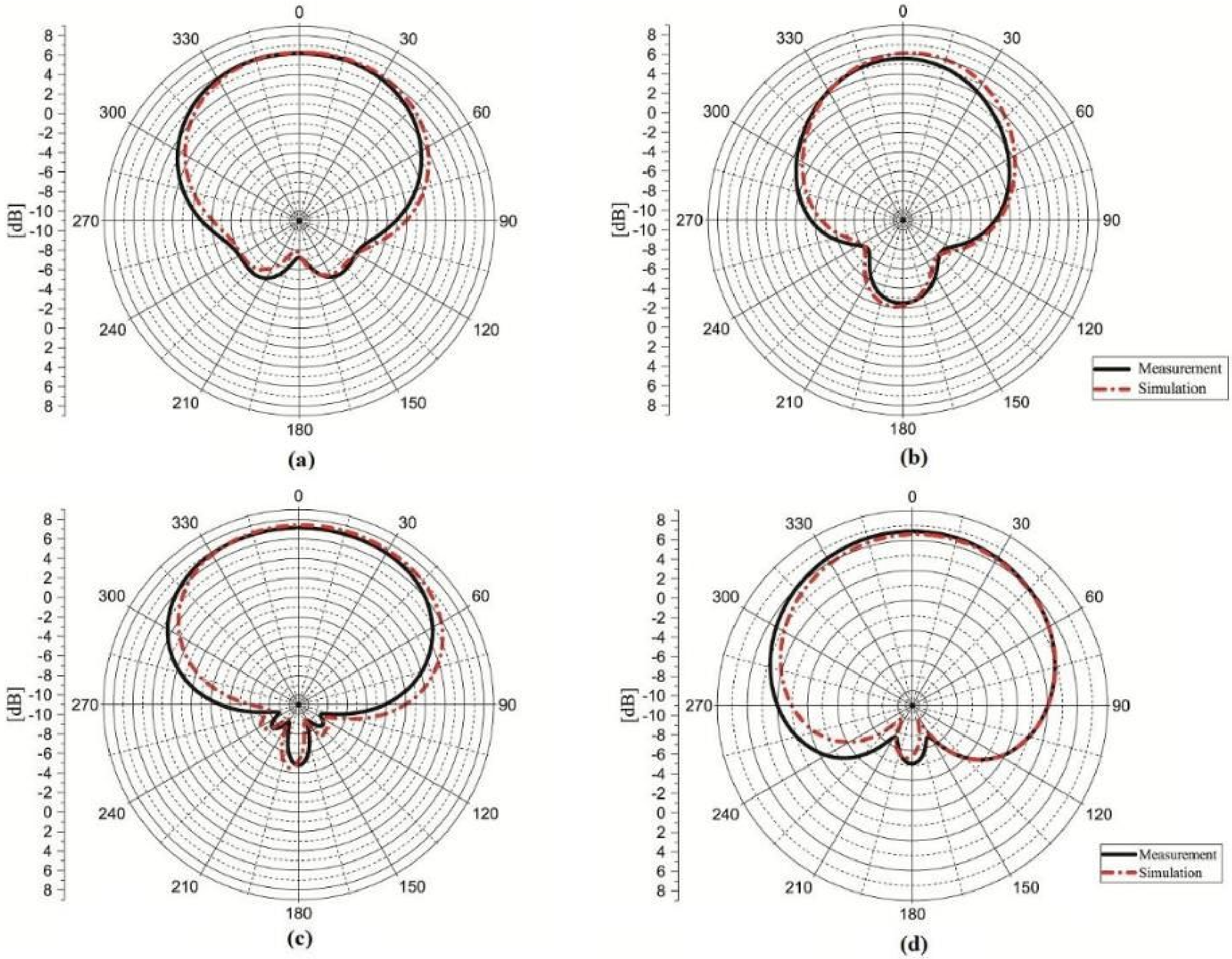



**Figure 11**

Measurement and Simulation results of the radiation pattern of the antenna with graphene. (a) 1.8GHz, (b)2.4GHz, (c)2.8GHz, (d)3.6GHz.

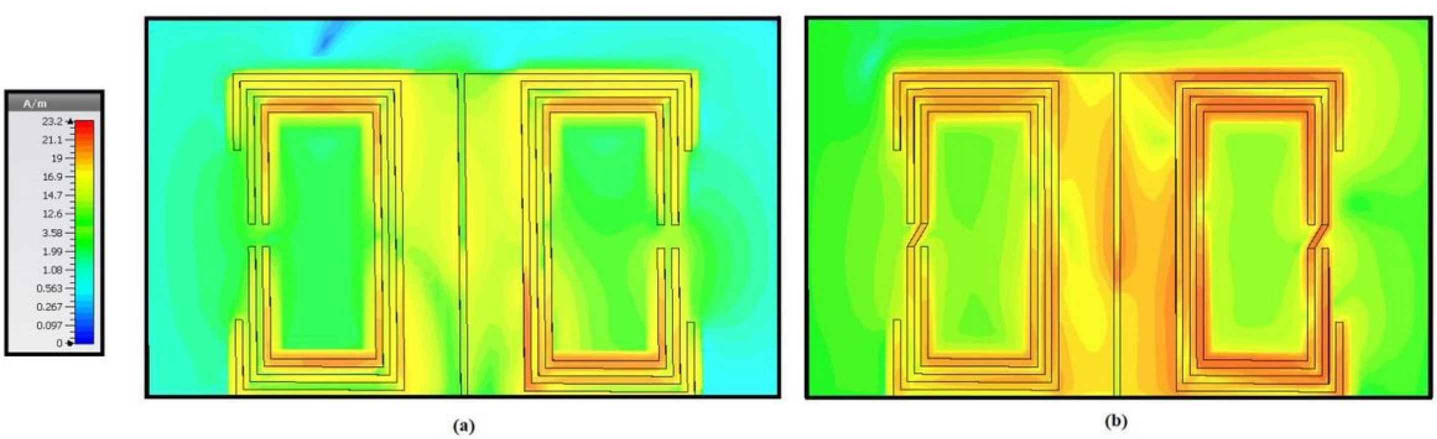



**Figure 12**

Surface current distribution antenna (a) without graphene (b) with graphene.