Graphene Film Based Dual-band Antenna for 5G Mobile Communications

Rongguo Song[1,2], Chunyu Liu[1,2], Ran Fang[2], Daping He[2]* and Zhi Wu[1,2]*
[1] School of Information Engineering, Wuhan University of Technology, Wuhan, 430070, China
[2] Hubei Engineering Research Center of RF-Microwave Technology and Application, Wuhan, 430070, China
hedaping@whut.edu.cn, z.p.wu@whut.edu.cn

***Abstract*—This paper presents a 5G mobile communication dual-band antenna based on graphene film. The graphene film has a high conductivity of 1.1×10^6 S/m. The new antenna has an excellent return loss of -30.02 dB and -26.09 dB at 3.5 GHz and 4.9 GHz, respectively. The -10 dB bandwidth of the antenna is 3.31 GHz to 3.81 GHz and 4.67 GHz to 5.03 GHz. In addition, the simulation results agree well with the measured results.**

Keywords—graphene; dual-band antenna; 5G;

I. Introduction

5G is defined as the next generation mobile communication. High data rates, high efficiency, miniaturization, lightweight, huge system capacity and massive device connectivity are required to match the demand of 5G wireless communication [1]. Dual-band antenna with the advantages of simple structure, small size and easy integration has been widely used in satellite communications, mobile communications base stations and mobile phones, automotive equipment and other fields [2]. In the past, metal materials such as copper, alloy material quality are used to manufacture the antennas and other RF and microwave devices, which are easy to corrode, environmentally polluting, heavy, expensive and complex production process. Therefore, it is urgent to find a substitute for metal materials to prepare RF and microwave devices.

In recent years, carbon based materials, such as graphene, graphite and carbon nanotubes are used widely due to its excellent advantages of light weight, mechanical reliability, flexibility, chemical reliability and anti-corrosion. Due to their good performances, various carbon based materials are used to make RF and microwave devices [3, 4]. However, the conductivity of carbon-based materials is far less than that of metal materials, which leads to unsatisfactory performance of carbon-based materials devices.

In this paper, we propose a graphene film based dual-band monopole antenna (GDMA) for 5G mobile communications. The graphene film with the thickness of ~25 µm has the conductivity of 1.1×10^6 S/m and density of only 1.8 g/cm^3. The operate frequency of GDMA is 3.5 GHz and 4.9 GHz, which coincides with 5G mobile communication frequency band of 3.3 GHz - 3.6 GHz and 4.8 GHz - 5.0 GHz at sub-6 GHz bands [5]. The GDMA has an excellent |S_{11}| of -30.02 dB and -26.09 dB at 3.5 GHz and 4.9 GHz, respectively. The -10 dB bandwidth of the GDMA is 3.31 GHz to 3.81 GHz and 4.67 GHz to 5.03 GHz, which cover all bands of 5G at sub-6 GHz. Light-weight and stable graphene antenna will be of great significance in the field of mobile communication.

II. The Antenna Configuration And Design

Fig. 1 shows configuration of the proposed graphene film based dual-band monopole antenna with the resonant frequency of 3.5 GHz and 4.9 GHz, which are the sub-6GHz bands for 5G wireless communications. The GDMA is built on the FR-4 substrate with a relatively permittivity of 4.3, a thickness of 1.6 mm and loss tangent of 0.02. The overall size of the substrate is $L \times W$. The width and height of GDMA patch are w_1 and w_2, l_1 and l_2, respectively. The GDMA has an incomplete ground with a height of l_0.

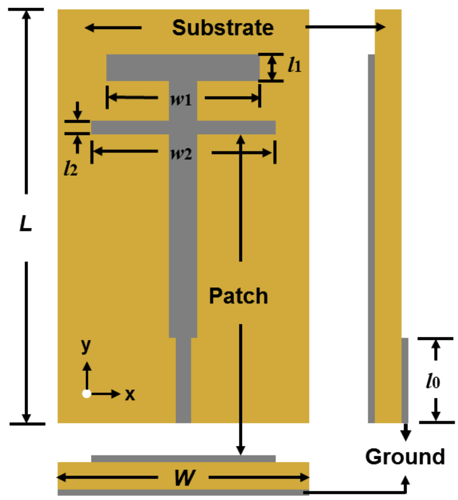

Figure 1. The schematic diagram of GDMA

The parameters of patch and ground affect the performance of GDMA. To analyze the effect of the size of antenna patch on resonant frequency and impedance matching, |S_{11}| response of the GDMA for different values of l_1, l_2, w_1 and w_2 are described in Fig. 2. It can be observed from these figures that the variation of the patch size have significant affects for resonant frequency and impedance matching of GDMA. As

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shown in Fig. 3, the GDMA with a varied l_0 has completely different $|S_{11}|$. The ground plane has a regulatory effect on impedance matching networks. The details of the optimized parameters are shown in the Table 1.

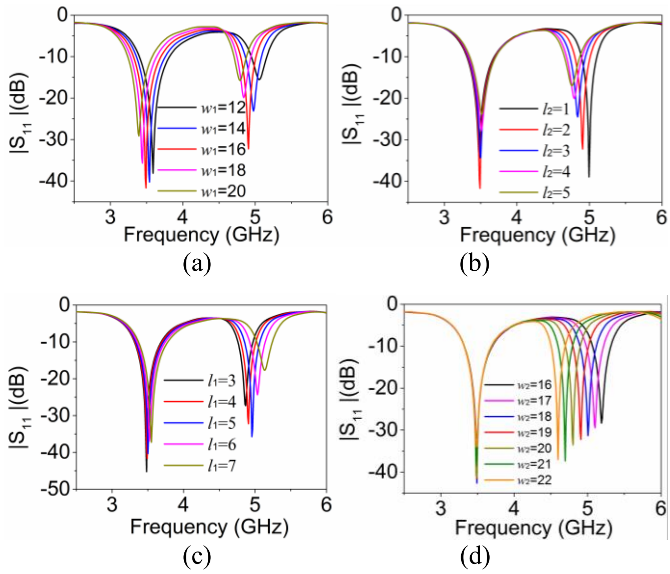


Figure 2. Effect on $|S_{11}|$ due to variation of patch size in mm. (a) l_1, (b) l_2, (c) w_1 and (d) w_2

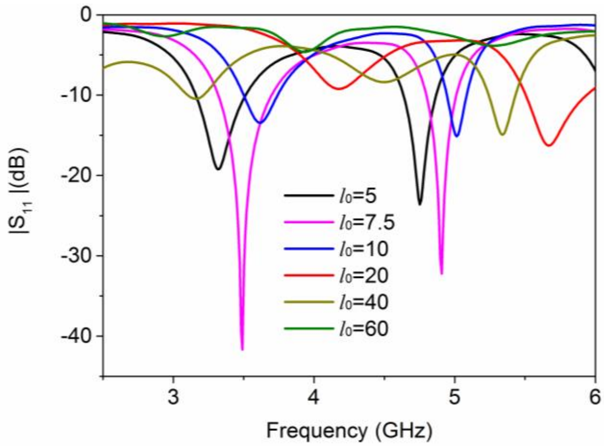


Figure 3. Effect on $|S_{11}|$ due to variation of l_0 in mm

TABLE I The optimized parameters of GDMA

Parameter	value (mm)
L	65
W	36
l_0	7.5
l_1	4
l_2	2
w_1	16
w_2	19

III. Simulation And Measurement Results

According to the optimized parameters, the GDMA model is simulated. Fig. 4 shows the simulated $|S_{11}|$ of GDMA. The resonant frequency of GDMA is 3.5 GHz and 4.9 GHz with the reflection coefficient of -41.67 dB and -32.23 dB, respectively. The simulated -10 dB bandwidth of the GDMA is 3.32 GHz to 3.69 GHz and 4.79 GHz to 5.01 GHz.

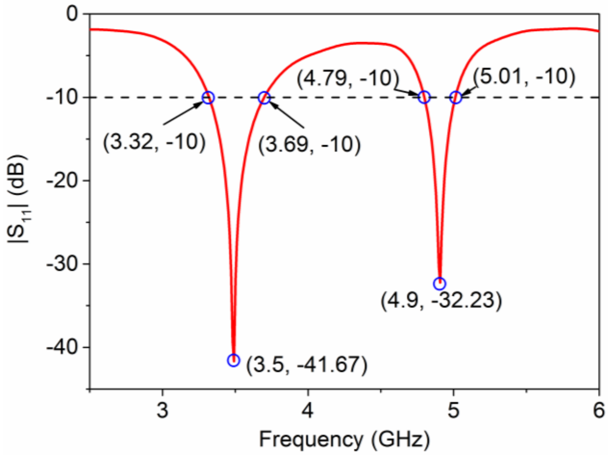


Figure 4. The simulated $|S_{11}|$ of GDMA

Fig. 5 shows the simulated 3D radiation pattern of the GDMA at 3.5 GHz and 4.9 GHz, respectively. The pattern shows that the gain of GDMA at 3.5 GHz and 4.9 GHz is 3.88 dBi and 3.78 dBi, respectively.

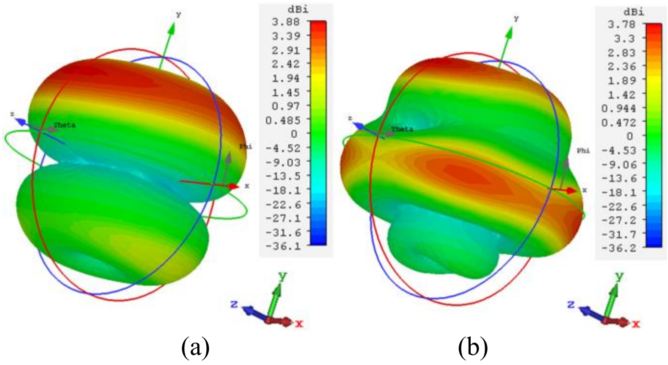
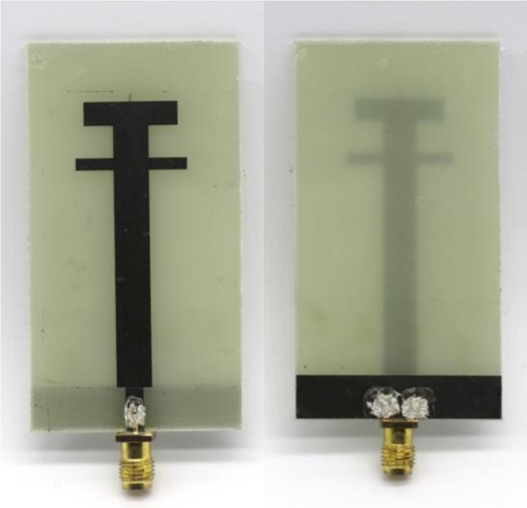


Figure 5. The simulated radiation patterns of GDMA at (a) 3.5GHz and (b) 4.9GHz

After simulation, the GDMA is produced by laser engraving method with the cutting precision of 25 μm. The digital photo of GDMA is shown in Fig. 6. Fig. 6(a) and (b) is patch side and ground side, respectively. Fig. 7 shows the measured $|S_{11}|$, which indicate the GDMA resonant frequency is 3.5 GHz and 4.88 GHz. The reflection coefficient of GDMA at 3.5 GHz and 4.9 GHz is -30.02 dB and -26.09 dB. The measured -10 dB bandwidth of the GDMA is 3.31 GHz to 3.81 GHz and 4.67 GHz to 5.03 GHz. The Fig. 7 also indicates that the measured $|S_{11}|$ is similar to the simulated one, and has better bandwidth. Fig. 8 and Fig. 9 show the measured xoz plane and yoz plane radiation patterns at 3.5 GHz and 4.9 GHz, respectively. The measured results are in good agreement with the simulation results.



(a) (b)

Figure 6. Digital photos of GDMA. (a) patch and (b) ground

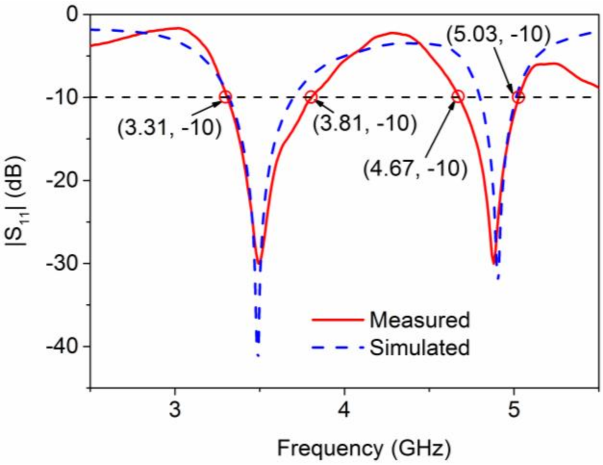
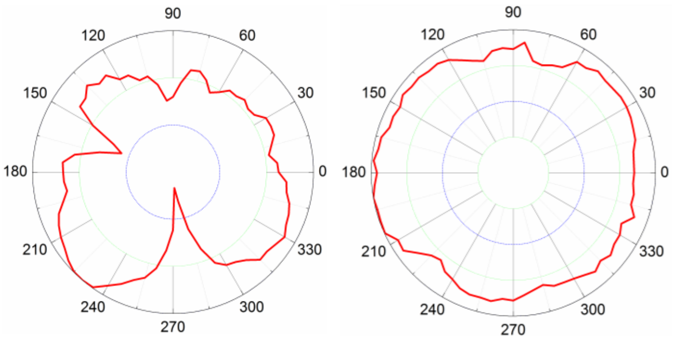
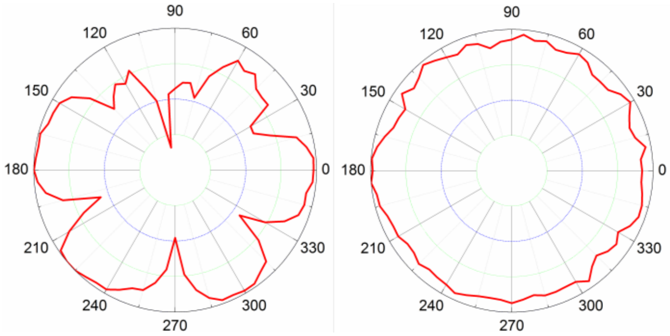


Figure 7. The $|S_{11}|$ of GDMA



(a) (b)

Figure 8. The measured radiation patterns of GDMA at 3.5GHz (a) xoz plane and (b) yoz plane



(a) (b)

Figure 9. The measured radiation patterns of GDMA at 4.9GHz (a) xoz plane and (b) yoz plane

IV. CONCLUSIONS

In this paper, a dual-band monopole antenna based on graphene film is proposed and studied. The proposed antenna is made of the graphene film with conductivity of 1.1×10^6 S/m by laser engraving method. The measured results are good agreement with the simulated results, including $|S_{11}|$, radiation patterns. Furthermore, the implemented antenna has batter bandwidth than simulated result. This new graphene film based dual-frequency microstrip antenna has great potential in 5G mobile communications.

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