Graphene film based Inverted-F Antenna for 5G Mobile Communications

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Abstract—**This paper presents an inverted-F antenna based on graphene film for 5G mobile communications. The graphene film has a high conductivity of 1.1×10^6 S/m. The graphene film based inverted-F antenna with the resonant frequency of 3.48 GHz has excellent performance, which the $|S_{11}|$ is -43.2 dB and the bandwidth is from 3.08 GHz to 4.65 GHz.**

Keywords—5G, graphene film, inverted-F antenna;

I. INTRODUCTION

During the past few decades, the Mobile data traffic has experienced explosive development, in order to adapt to the rapidly growing market demand, the fifth generation mobile communication net work (5G) is becoming a focus issue. Antenna plays a significant part in the field of wireless signal transmission and reception; it has to match the requirement of 5G frequency band, which is 3.3 GHz to 3.6 GHz [1].

Nowadays, most of the materials used to make antennas are precious metal materials such as cooper, alloy material quality[2, 3], which are heavy, expensive and complex production process. Using metal materials to make antenna can also cause the problem of heat dissipation. Hence, it is essential for us to find out a material to replace the metal in antenna design.

For the past few years, with the progress in the preparation of carbon based materials, graphene, carbon nanotubes and graphite are widely used in electronic fields [4, 5]. Carbon based materials have various great characteristics, such as light weight, flexibility, mechanical reliability, portability, optical properties, and reliability in harsh environments. However, the conductivity of carbon-based materials cannot meet the design requirements of the antenna. Consequently, despite the many advantages of using carbon-based materials, there are few carbon-based antennas.

Inverted-F antenna is a kind of deformation structure of monopole antenna, which has the advantages of small size, simple structure, easy matching and low production cost. Therefore, it is supposed to be used in short-range wireless communications such as Bluetooth and IEEE 802.a/b/g [6].However, it has some weakness, such as insufficient gain, narrow effective bandwidth and high return loss.

In this paper, we report an inverted F antenna that use of graphene film instead of metal to design and fabricated. The graphene film conductivity is as high as 1.1 × 10^6 S/m. The resonant frequency of graphene inverted-F antenna (GIFA) is 3.48GHz with the $|S_{11}|$ of -43.2 dB, and the bandwidth is from 3.08 GHz to 4.65 GHz, which meets the requirement of 5G frequency band. This will be of great significance to modern mobile communications.

II. ANTENNA DESIGN

Inverted-F antenna is developed on the basis of monopole antenna and inverted-L antenna. The structure of GIFA is shown in Fig. 1. The antenna is designed on FR-4 substrate with a thickness of 1.6 mm, relatively permittivity of 4.4, loss tangent of 0.02.

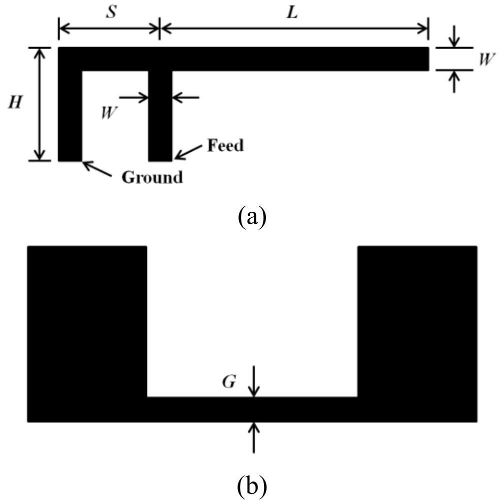

Fig. 1. The structure of GIFA. (a) Patch; (b) Ground

There are three structure parameters significantly affect the performance of GIFA, which are the length of antenna arm (*L*), height of feeder (*H*), height of ground (*G*).

III. SIMULATION AND RESULTS

In this part, each structure parameter that affects the performance of GIFA is calculated by using CST Microwave Studio.

A. The length of antenna arm (L)

The resonant frequency of GIFA is determined by the length of the antenna arm (*L*). Fig. 2 shows the simulated $|S_{11}|$ of GIFA with different L from 6.6mm to 16.6mm. The resonant frequency of GIFA at different *L* is shown in Table 1. As *L* increases, the resonant frequency of the GIFA decreases. When *L* is 11.6 mm, the resonant frequency of the GIFA is 3.5 GHz.

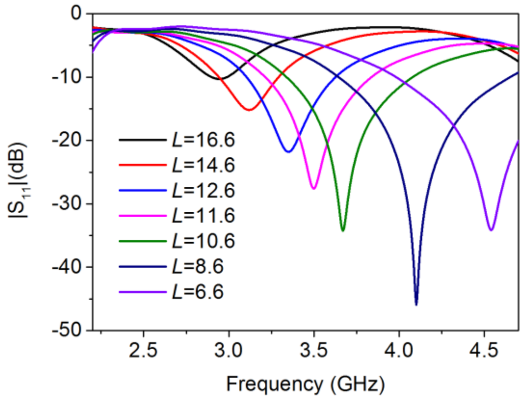

Fig. 2. The $|S_{11}|$ of GIFA with different arm length

Table 1 The result of scanning parameter *L*

L (mm)	Resonant frequency (GHZ)
6.6	2.945
8.6	3.120
10.6	3.350
11.6	3.500
12.6	3.670
14.6	4.100
16.6	4.540

B. The height of feeder (H)

The $|S_{11}|$ from 2.5 GHz to 4.5 GHz of GIFA with different feeder heights is shown in Fig. 3. Table 2 shows the $|S_{11}|$ of GIFA with different *H* at 3.5 GHz. Feeder height affects the impedance matching of antenna. When *H* is 14.1mm, the GIFA has the best $|S_{11}|$, which is -27.6 dB.

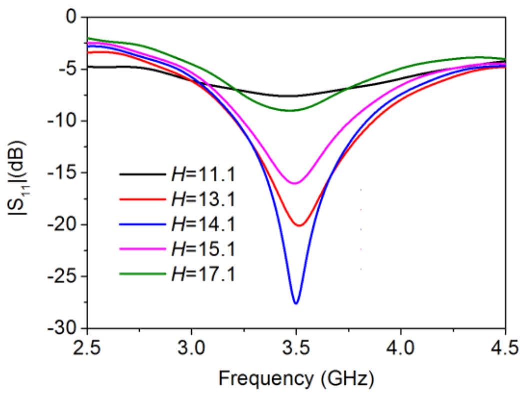

Fig. 3. The $|S_{11}|$ of GIFA with different feeder height

Table 2 The result of scanning parameter *L*

H (mm)	$|S_{11}|$ (dB)
11.1	-7.609
13.1	-20.104
14.1	-27.608
15.1	-16.029
17.1	-9.010

C. The height of ground (G)

The ground height has a great influence for the performance of GIFA. Fig. 4 and Table 3 show the $|S_{11}|$ and bandwidth of IFA with different ground height. The GIFA has the -10dB bandwidth of 3.22 GHz to 3.84 GHz, which can fully meet the requirement of 5G low frequency band.

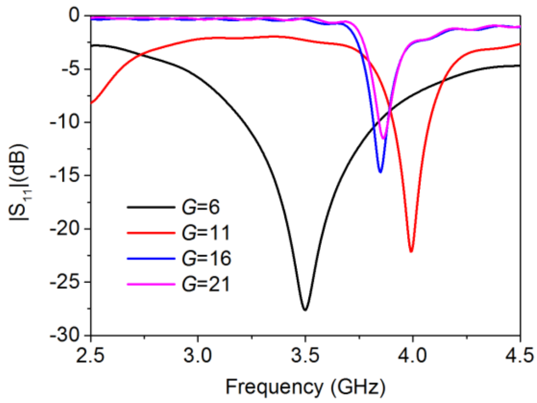

Fig. 4. The $|S_{11}|$ of GIFA with different ground height

Table 3 The result of scanning parameter *G*

G (mm)	-10dB Bandwidth (GHz)
6	3.22~3.84
11	3.91~4.08
16	3.82~3.88
21	3.84~3.88

The optimized parameters are shown in Table 4.

Table 4 The Antenna Dimension Parameters

Parameter	Detail (mm)
L	11.6
H	14.1
G	6
S	7.45
W	3.1

According to the optimized parameter results, the model of GIFA simulated by CST is shown in Fig. 5. Fig. 6 shows the performance of GIFA. The $|S_{11}|$ of IFA at resonance frequency 3.5 GHz is -27.61 dB, and the bandwidth of -10 dB is 3.21 GHz-3.83 GHz.

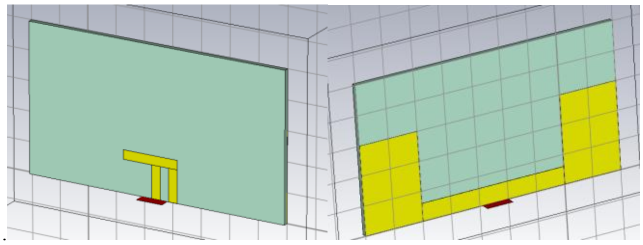

Fig. 5. The model of GIFA

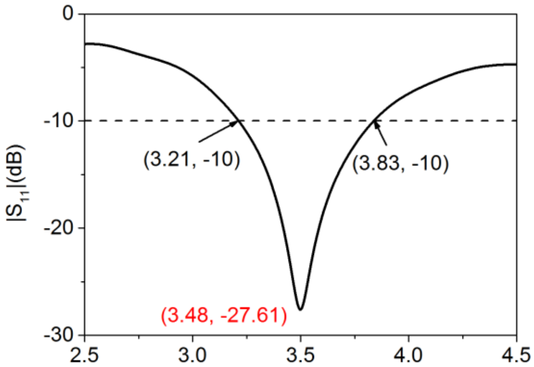

Fig. 6. Simulated $|S_{11}|$ of GIFA

After simulation, the GIFA is fabricate using high conductivity graphene film by laser engraving method, as shown in fig. 7.

Fig. 8 shows the measured $|S_{11}|$ of GIFA. The resonance frequency of GIFA is 3.48 GHz with the $|S_{11}|$ of -43.2dB. The -10dB bandwidth is from 3.08 GHz to 4.65 GHz. The measured performances are better than the simulation results.

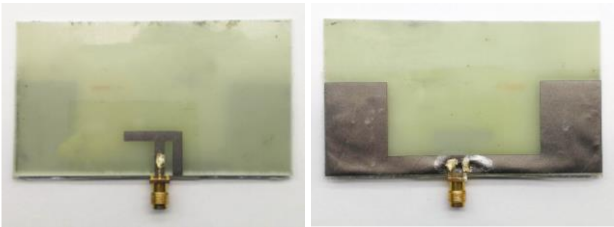

Fig. 7. The digital photo of GIFA

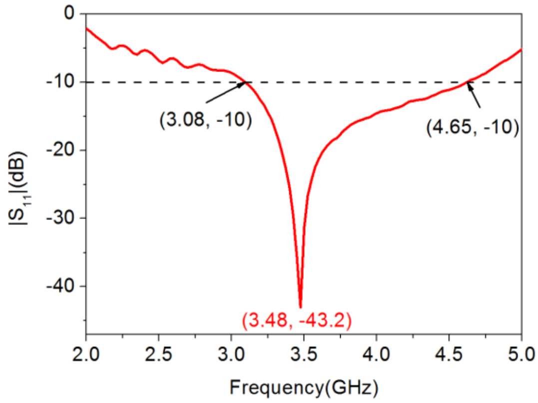

Fig. 8. Measured $|S_{11}|$ of GIFA

IV. Conclusions

In this paper, a graphene film based inverted-F antenna is designed and fabricated. From the result of measurement, the graphene antenna has an excellent $|S_{11}|$ of -43.2 dB at resonance frequency of 3.48 GHz. The bandwidth is from 3.08 GHz to 4.65 GHz, which meets the requirement of 5G frequency band. Therefore, the high conductivity graphene film can replace metal as the main material to make antennas for 5G applications.

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