Filtering Antenna Array based to Graphene-Assembled Films for 5G Applications

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***Abstract*—A filtering antenna array based on graphene assembled film (GAF) operating in 3.5 GHz is presented in this paper. The GAF has a conductivity of 10^6 S/m and a thickness of 25 μm with excellent ductility and flexibility. Split-Ring Resonator (SRR) is loaded on side of the feeder to provide filtering characteristics for the upper band of the GAF antenna. Meanwhile, a H-shaped slot is etched the ground below the feeder to suppress the lower band. The gain of the proposed 1×2 GAF antenna array can arrive at 5.36 dBi at the working frequency. In addition, the -10dB impedance bandwidth of GAF antenna array covers the range of 3.45 GHz-3.6 GHz with the good sideband suppression of 20dB. All the results show that GAF filtering antenna array has the important application potential for 5G mobile communications.**

***Index Terms*—filtering antenna array, graphene assembled film, flexibility, sideband suppression, 5G mobile communications.**

I. Introduction

The beam and directionality of antenna array can be adjusted by different excitation and arrangement of antenna element [1]. Filtering antenna is favored by academia and industry for its simultaneous filtering and radiation functions [2]. Therefore, high gain and filtering characteristics can be achieved by designing filter antenna array [3].

Graphene has been used in the design and research of antenna design since its discovery. Conventional graphene sheets have many applications in the terahertz band, such as multi-functional reflective polarizers, absorber, terahertz dipole antennas, reconfigurable antennas [4, 5], due to the conductivity of graphene sheet is adjustable in the terahertz band. But graphene is used relatively sparingly in the microwave band, mostly as loss resistor in amplitude-modulation devices, which indicates the high surface resistance of graphene sheet in microwave band [6]. In recent years, graphene film has become a substitute for microwave devices [7-11].

In this paper, a 2 elements filtering antenna array based on GAF is presented and can be applied to 5G mobile communication. The peak gain and sideband suppression of the GAF filtering antenna array are reached 5.36 dBi and 20 dB.

II. Antenna Array Element Design

A. Filtering Antenna Element Configuration

Fig. 1 depicts the configuration of the proposed filtering antenna element. Both the radiator and the ground are GAF, whose conductivity is as high as 1.1×10^6 S/m. The substrate of the antenna is Rogers 5880 with dielectric constant of 2.2, thickness of 0.508 mm and dimension of 68mm×50mm. The adoption of flexible substrate and GAF make the proposed antenna flexible and conformal. The antenna adopts a rectangular patch with the size of 12 mm×12 mm, which fed by a rectangular slot. The antenna is fed by a 50 Ω microstrip line with SRR, which enhance inhibition at the upper band. The middle-slot-fed method is introduced to improve impedance matching performance. Notching a H-shaped slot on the ground under the feeding line to provide filtering response at the lower band.

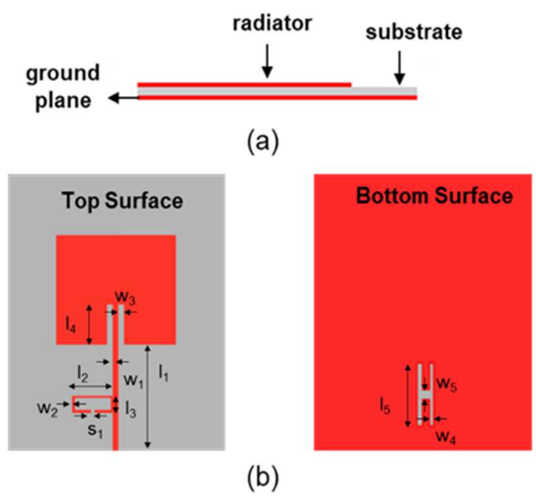

Fig. 1. Topology of the proposed GAF filtering antenna. (a)side view. (b)top view and bottom view. The optimized dimension parameters are as follows (unit: mm) l_1=26.11, w_1=1.58, l_2=11.1, l_3=4.5, s_1=1, w_2=0.7, w_3=1.5, l_4=10.5, w_4=1.2, l_5=11, w_5=1.8.

B. Working Mechanism

To better understand how the filtering antenna element works, Fig.2 shows three patch antennas. The Physical dimension l_{SRR} of the SRR can be calculated by equation (1). The microstrip line with etched H-slot on the ground like a resonant circuit, which combines the parallel LC resonant circuit with the characteristic impedance of the microstrip line. The length of the H slot and the gap spacing have a certain influence on the inductance value and capacitance.

$$l_{SRR} = c/2\sqrt{\varepsilon_{re} f}. \qquad (1)$$

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The simulated S-parameter and realized gain of the three antennas are shown in Fig. 3. It can be seen that three antennas are resonant at 3.5 GHz. Antenna II has a wider bandwidth than antenna I, and antenna III and antenna II have similar bandwidth. In addition, compared with antenna I, antenna II has excellent filtering performance at the upper band, and there is a radiation zero at 3.1 GHz. Antenna III has a significant suppression at the lower band of antenna II.

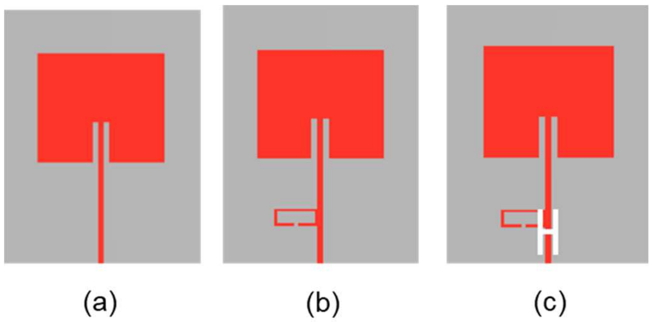

Fig. 2. Configuration of three antennas. (a) antenna I: a conventional middle-slot-fed square patch antenna. (b) antenna II: SRR added at feeder of antenna I. (c) antenna III: H-shaped slot etched at the ground of antenna II.

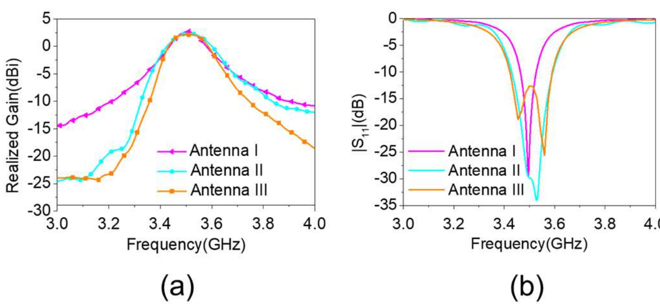

Fig. 3. Simulated S-parameter and realized gain of three antennas.

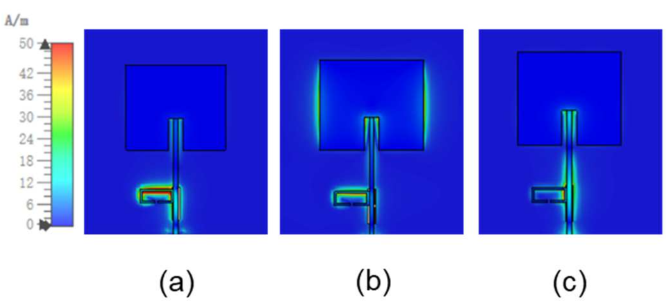

Fig. 4. Surface current distributions. (a)3 GHz. (b)3.5 GHz. (d)4 GHz.

In Fig.4, we have plotted the current distributions of the proposed antenna element at three frequencies. At 3 GHz, the surface current of the SRR is mainly concentrated in the SRR, while the patch has no current. At 3.5 GHz, the current of the device is mainly concentrated on one side of the device, thus achieving a good heat dissipation effect. At 4 GHz, the current is mainly distributed on the feeder. Therefore, at 3 GHz and 4 GHz, the filtering antenna has radiation zeros.

C. Results

The antenna element measured in Figure 5 has -10 dB impedance bandwidth of 4.86% (3.42 GHz - 3.59 GHz) with an impedance bandwidth of -10 dB, a peak gain of 2.63 dBi, and a sideband rejection of 27 dB and 21 dB at 3 GHz and 4 GHz, respectively. It can be seen from Fig. 6 that the standard radiation pattern of the proposed antenna element is more similar to the conventional rectangular patch antenna in the x-o-z plane and the y-o-z plane, showing its good radiation performance. The simulation results are basically consistent with the measured results.

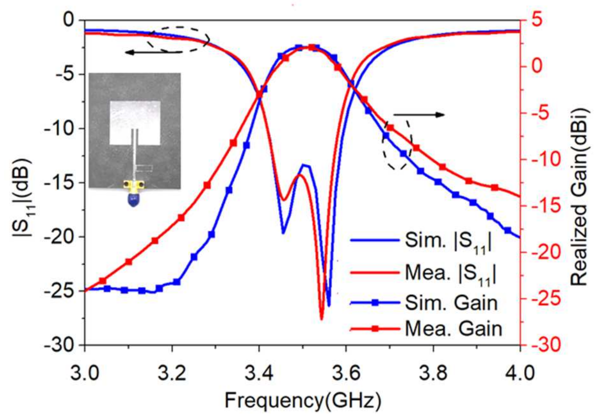

Fig. 5. Simulated and measured S-parameter and realized gain of antenna element.

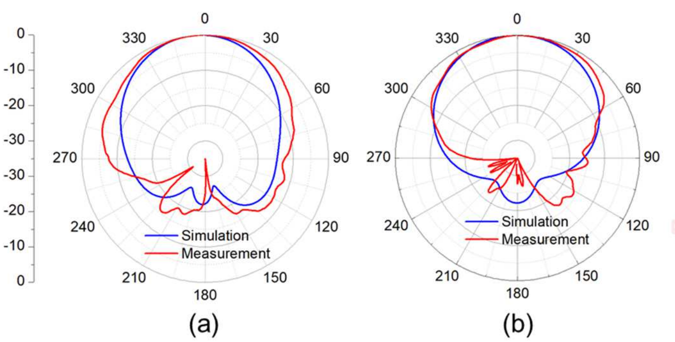

Fig. 6. Simulated and measured normalized radiation patterns of proposed antenna element. (a)x-o-z plane. (b)y-o-z plane.

III. Filtering Antenna Array

Based on the above filtering antenna element, this paper designs a 1x2 element array to achieve high gain requirements, and its structure is shown in Fig.7. Three SRRs are added to the feeding line of the array, and one H-shaped grooves and two "]-[" shaped grooves are engraved on the ground of the antenna array. The harmonic of 3.2 GHz can be suppressed well by changing the H-shaped slot to "]-[" shaped slot.

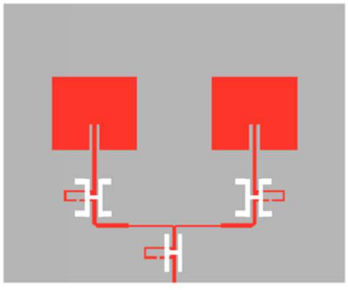

Fig. 7. Structure of 1×2 filtering antenna array.

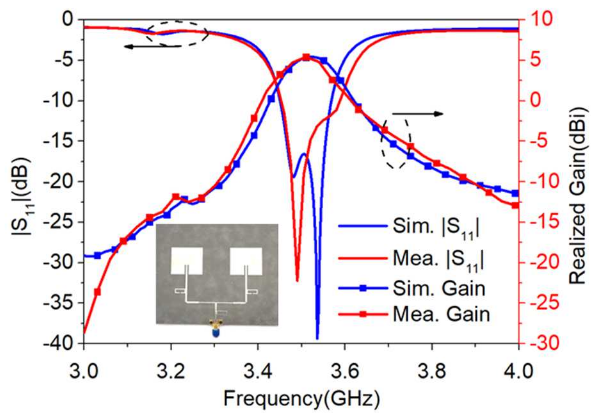

Fig. 8. Simulated S-parameter and realized gain of 1×2 filtering antenna array.

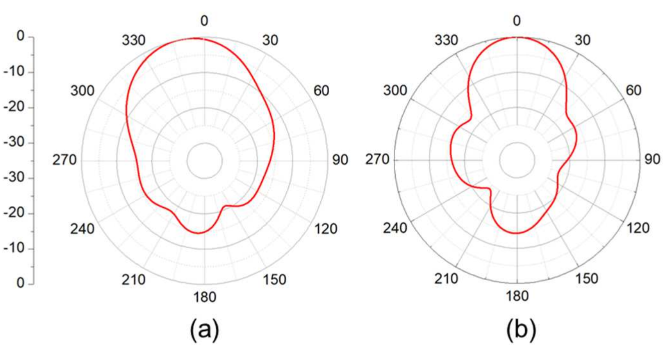

Fig. 9. Simulated normalized radiation patterns of 1×2 filtering antenna array. (a)x-o-z plane. (b)y-o-z plane.

As can be seen from Fig. 8, the GAF filtering antenna array was fabricated and measured. The measured -10dB impedance bandwidth is 4.3% (3.45 GHz-3.6 GHz), peak gain is 5.36 dBi, and sideband suppression reached 29 dB and 20dB at 3 GHz and 4 GHz, respectively. In addition, the simulated radiation pattern is shown in Fig. 9 and the half power beam width of is 49° and 37° for the x-o-z and y-o-z planes, respectively.

IV. Conclusion

In conclusion, a filtering antenna element based on GAF is presented and applied to 1×2 array. The proposed filtering antenna array works at 3.5GHz of 5GHz mobile communication, with peak gain of 5.36 dBi and -10 dB impedance bandwidth of 4.3%. Meanwhile, the sideband suppression of the GAF filtering antenna array is satisfactory, more than 20 dB. Consequently, a good filtering performance and radiative characteristics of the designed GAF filtering antenna array are accomplished.

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