A SIW Horn Antenna with Dynamically Tunable Graphene-Based Attenuator

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***Abstract*—In this paper, a novel substrate integrated waveguide (SIW) H-plane horn antenna with dynamically tunable graphene-based attenuator is first presented. The antenna is composed of the H-plane horn aperture, the matching transition and the graphene-based attenuator. By using external voltage, the surface impedance of graphene sheets can be changed dynamically. Correspondingly, the gain of antenna can be tuned from 3.045dB to -14.12dB at 17.7GHz. So the switchable horn antenna is in working state with the larger gain and no-working state with the lower gain by changing biased voltage.**

Keywords—horn antenna; dynamically tunable gain; graphene; working state; no-working state

I. INTRODUCTION

Recently, the application of graphene in antennas has made enormous progress because of the extraordinary electronic, mechanical and optical character of graphene [1-2]. For example, multilayer graphene, graphene ink and graphene-containing composite are proposed to substitute for radiation metal of antenna [3-4]. One of the most interesting features of graphene at microwave frequency is the possibility to electronically modify its conductivity. This feature can be used to design reconfigurable antennas, such as frequency reconfigurable antennas and polarization reconfigurable antennas [5].

In this paper, a novel switchable horn antenna with dynamically tunable graphene-based attenuator is proposed. The antenna is composed of the H-plane horn, the matching transition and two graphene sandwich structures. The transition is designed to match a H-plane SIW horn antenna built in a thin substrate [6]. The graphene sandwich structures (GSS) are spread on the substrate near the microstrip line along the direction of propagation to dissipate electromagnetic field. The GSS is a mutually gated graphene capacitor using two monolayer graphene and an ionic liquid electrolyte (diethylmethyl (2-methoxyethyl) ammonium bis (trifluoromethylsulfonyl) imide, [deme][Tf2N]) sandwiched between them[7]. The surface impedance of GSS can be dynamically changed with biased voltage, hence the gain of the horn antenna can also be changed.

The rest of this paper is structured in the following way. The detailed structure and working principle are provided in section II. The performance of antenna with different critical parameters of graphene sheets is analysed in section III. Eventually, the conclusion of this paper is displayed in section IV.

II. ANTENNA DESIGN AND CONFIGURATION

The geometry of the proposed antenna is shown in Fig.1. The overall size of the antenna is $103.9\times52\times1.575mm^3$. It consists of four main parts: 1) the microstrip-to-SIW transition, 2) the SIW H-plane horn, 3) the matching transition, and 4) two graphene sandwich structures. All the four parts are integrated in a single substrate with a thickness of 1.575mm. The relative dielectric constant of the substrate is 3.2.

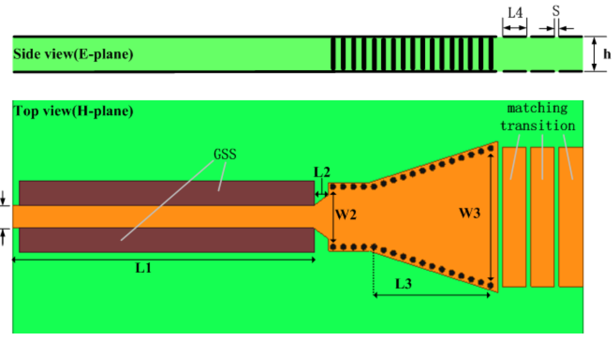

Fig.1. Configuration of the graphene-based horn antenna(L1=60mm, L2=2.427mm, L3=19.849mm, L4=4.3mm, W1=3.8mm, W2=9mm, W3=22.1mm, S=0.2mm, h=1.575mm)

The taper of the microstrip-to-SIW transition is used to transform the quasi-TEM mode of the microstrip line into the TE_{10} mode in the SIW [8]. The three matching transitions are designed to overcome the dismatch of SIW horn antenna when the substrate thickness is much smaller than the wavelength (thickness<λ_0/10) [9]. The GSS is employed to dissipate the EM filed on the edge of the signal strip. Since the surface impedance of GSS can be dynamically changed from 520Ω/□ to 3000Ω/□ with bias voltage increasing from 0V to 4V, then the gain of the antenna can also be changed correspondingly. So the switchable horn antenna has the working state with the larger gain and the no-working state with the lower gain by changing biased voltage.

III. Result and Discussion

To derive the performance of antenna, HFSS is employed here to implement the full wave simulation. Fig.2 exhibits the Δgain of the antenna when the graphene is tuned from 520Ω/□ to 3000Ω/□ versus the changing L1 which determines the length of GSSs. It can be seen from fig.2 that Δgain increases with increasing L1. The largest gain is 3.045dB, the lowest gain is -14.12dB and Δgain =17.165dB when L1=60mm. So the horn antenna can be regarded as a switchable antenna which has working state and no-working state.

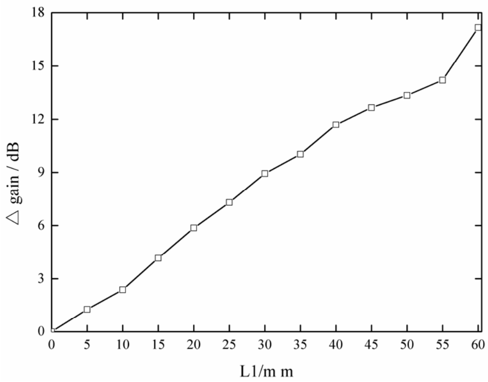

Fig.2. Δgain versus the length of graphene L1. The gain of antenna is simulated and calculated at 17.7GHz.

Fig.3 compares the simulated S_{11} of antenna with matching part and without matching part. It evidently manifests that the matching characteristic is efficiently improved with matching part. It can be observed form Fig.4 that S_{11}< -10dB over all operating frequency band from 10GHz to 20GHz. In fig.5(a), (b) and (c), the surface electric field magnitude increases clearly when the surface impedance Zg of GSSs increases from520Ω/□ to 3000Ω/□.

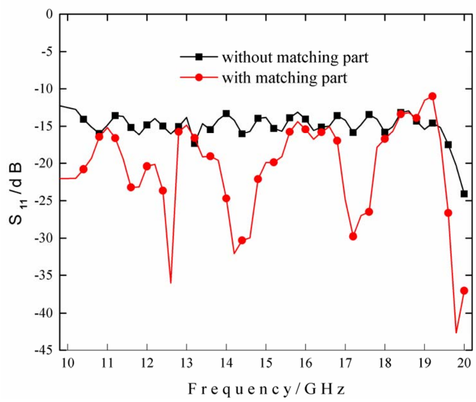

Fig.3. S_{11} of the Antenna with matching part and without matching part.

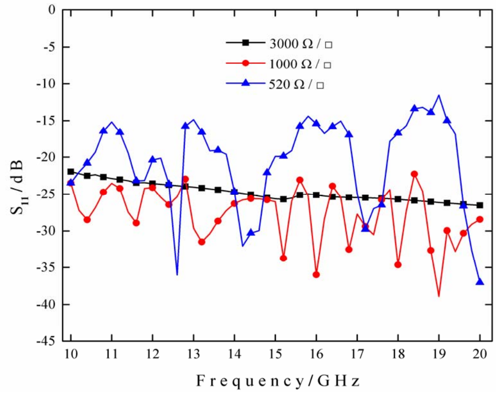

Fig.4. S_{11} of the antenna with different graphene surface impedance.

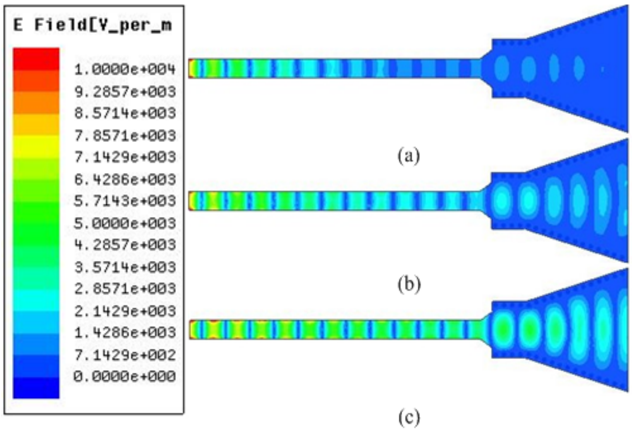

Fig.5. Electric field distribution of the antenna at 17.7 GHz with graphene surface impedance (a) Z_g =520Ω/□, (b) Z_g =1000Ω/□, (c) Z_g =3000Ω/□.

IV. Conclusion

A novel horn antenna with dynamically tunable gain is presented. The largest gain is 3.045dB, the lowest gain is -14.12dB and Δgain =17.165dB at 17.7GHz. Hence the switchable antenna has working state with relatively larger gain and no-working state with relatively lower gain when the surface impedance of GSSs be tuned from 520Ω/□ to 3000Ω/□ by changing biased voltage. The proposed antenna has potential for effective and wide utilization in various communication systems. The fabrication of this antenna is in progress.

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