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Graphene Metamaterials Array Based Reconfigurable Antenna

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***Abstract* - This work investigates applications of graphene in reconfigurable antennas. A reconfigurable graphene metamaterials array is designed and characterized, and further applied to design reconfigurable hybrid antenna. Simulation results have proved reconfigurable antenna radiation pattern. This work proves graphene is promising in designing flexible antenna system with both high radiation efficiency and tunability.**

***Index Terms* — Graphene; Metamaterials; Reconfigurable antenna.**

1. Introduction

Recently, the two dimensional (2D) material graphene has attracted much research interest in microwave and optical applications such as tunable cloaks, metasurface etc. for the tunability of its conductivity [1]-[3]. Due to limited availability of large-size and high-quality graphene, microwave band graphene applications are quite limited currently, except for some absorber applications [4-7]. Besides, the loss of single-layer graphene in microwave band is large [8], hindering its applications as radiation material. In previous studies, graphene has ever been investigated as radiation units of tunable antennas, while only low radiation efficiency can be obtained [9]. Even though the most recent development of graphene research has experimentally proved successful microwave radiation, graphene ink based antenna has no reconfiguration [10-11].

Since the development of chemical vapour deposition (CVD) technology brings large-size and economical graphene sheet, the applications of graphene in microwave band is no longer limited by sizes. In this work, we develop a hybrid method to combine graphene with metamaterials array for reconfigurable antenna application. In microwave region, graphene can be modelled as 2D sheet with tunable complex surface impedance under various chemical potentials (μ_c). As seen in our previous work, when $\mu_c=0eV$, surface impedance of the graphene is around 2.3kΩ. The sheet resistance changes to 420Ω and 100Ω when chemical potential is tuned to 0.2 and 0.8eV, respectively [6,7]. As graphene can be tuned continuously with external voltage, the sheet resistance can be achieved at any value between 100Ω to 2.3kΩ, and the corresponding external DC needed to tune the graphene can be found in ref [6,7]. Here in this paper, we use these typical values to design and characterize graphene metamaterials based components.

2. Reconfigurable antenna based on graphene metamaterials array

To investigate the applications of graphene in reconfigurable metamaterials, a SRR structure is used as in Fig.1. Two graphene sheets are placed in both slots of the SRR unit. The response of the array under TE/TM incident waves are simulated in CST MWS, and the S_{11} is given also in Fig.1. From the figure, when incidence is TE polarized, the S_{11} keeps the same, no matter how the sheet resistance of graphene changes, indicating that the array is insensitive to TE waves.

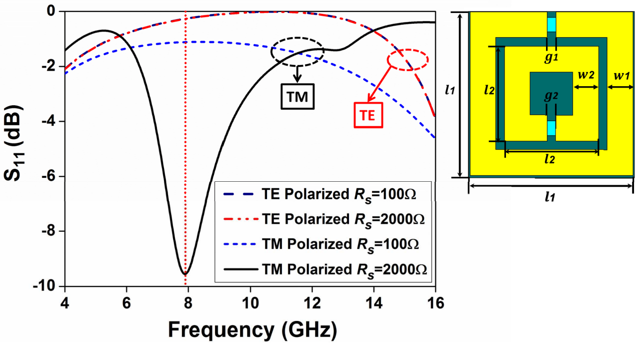

Fig.1 Unit cell of graphene based metamaterial array, and performances of array under TE/TM incidence polarizations, as well as different sheet resistance. The sizes of graphene sheets in gap are both 0.3mm×0.5mm, and the supporting dielectric has dielectric constant of ϵ_r=3, and height of $h=0.6mm$,and $g_1 = g_2 = 0.3mm$ $l_1 = 5.7mm$, $l_2 = 3.3mm$, $w_1 = w_2 = 0.9mm$.

However, when the wave is TM polarized, the performances vary with graphene property. When graphene is tuned to $Rs = 2000\Omega$, with no external voltage applied, the array has resonance of -9.55dB on its S_{11} at around 7.89GHz, revealing little reflection. In contrast, when the graphene is tuned to $Rs = 100\Omega$, the reflection is -1.1dB, providing a high reflection. This property means the graphene based array has tunable reflection under external voltage control, which poses possibility of designing reconfigurable arrays based on graphene metamaterials.

The above section has proved the tunable reflection based on graphene metamaterials array. This property is further used to design reconfigurable antennas. In the left insertion of following Fig.2, a typical dipole antenna is designed and its reflection is given. The dipole antenna is designed to work at same frequency band of array in Fig.1, and it has dimensions of: l_a=8.05mm, g=1mm, $w = 0.5mm$. From the

S_{11}, the dipole antenna works at around 7.89GHz with -30dB resonance, same with working frequency of array in Fig.1.

To form reconfigurable antenna, 4×4 units array is periodically placed and the designed dipole is placed above the array with distance of h_d=3*mm*.To reduce the influence of edge diffraction, four metal walls with height of 3mm are placed to form a rectangular surround. The configuration is shown in the right insertion of following Fig.2.

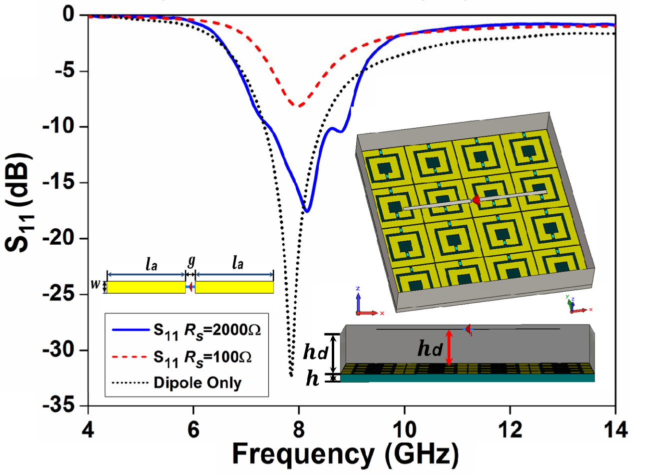

Fig.2 Reflections of dipole antenna (left insert), and the reconfigurable hybrid antenna (right insert), when sheet resistance of graphene is tuned to $Rs = 2000\Omega$ and $Rs = 100\Omega$.

The working performances of the hybrid antenna are simulated under various sheet resistance of graphene. As shown in Fig.2, when graphene has $Rs = 100\Omega$, the hybrid antenna resonates at 7.964GHz at -8.15dB. When it is tuned to 2000*Ω*, the resonance shifts to 8.15GHz, at -17.59dB. A small working frequency shift is obtained. However, frequency shift here is not the main concern. The radiation patterns of the hybrid antenna under these two cases are further studied to show its flexibility.

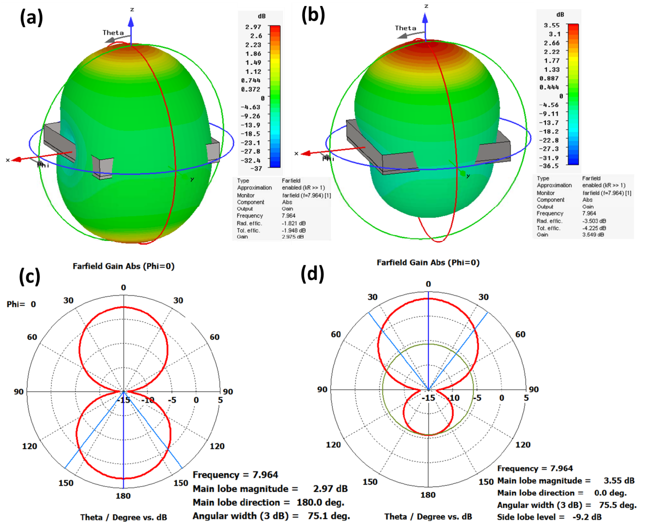

Fig.9 Radiation pattern reconfiguration of graphene metamaterials array based antenna system at 7.964GHz, when graphene sheet resistance is tuned. (a) 3D Radiation pattern, $Rs = 2000\Omega$.(b) 3D Radiation pattern, $Rs = 100\Omega$. (c) 2D Radiation pattern, $Rs = 2000\Omega$. (d) 2D Radiation pattern, $Rs = 100\Omega$.

The 3D radiation patterns at 7.964GHz are shown in Fig.3(a),(b), and corresponding 2D polar patterns are given in Fig.3(c),(d). From the 3D patterns in Fig.3(a), the main lobes of the hybrid antenna are in two directions in Z axis, while only one main lobe direction in Fig.3(b). The negative Z direction radiation is blocked by the array when $Rs = 100\Omega$. This effect can be more clearly seen in 2D radiation pattern in Fig.3(c),(d). When $Rs = 2000\Omega$, the two radiation lobes in Fig.3(c) are almost symmetric, while in (d), the back radiation lobe is below -5dB, while main lobe is 3.55dB, above 8dB difference.

3. Conclusion

In this paper, we have demonstrated applications of graphene in reconfigurable microwave applications. Typical SRR metamaterials unit is used to hybrid with graphene to form reconfigurable graphene metamaterials. The performances of the array show reconfiguration under voltage tuning, which is applied for reconfigurable hybrid antenna design. From the radiation pattern at working frequency under various tunings of graphene, the graphene based hybrid antenna shows flexibility on radiations.

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