COMPARATIVE ANALYSIS OF COPPER AND GRAPHENE BASED MICROSTRIP PATCH ANTENNAS

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***Abstract*—Recently, the research on graphene based microstrip patch antennas have made great progress. Hence a comparative study of copper and graphene based rectangular microstrip fed patch antennas is presented in this paper. Both single and 2×2 array microstrip patch antennas are designed. The considered performance parameters of the designed antenna are return loss, VSWR, bandwidth, gain, and directivity at a targeted resonance frequency of 2.45 GHz. Based on the results and analysis, it is noted that the graphene based single rectangular patch antenna shows higher performance than the copper based single rectangular patch antenna. And also graphene based 2×2 patch antenna array gives improved return loss, VSWR, bandwidth and gain than the copper based 2×2 patch antenna array.**

Keywords: *Graphene, Rectangular patch, Antenna array, Antenna parameters, Computer Simulation Technology (CST)soft ware.*

1. INTRODUCTION

Graphene is a single layer of carbon packed in a hexagonal (honeycomb) lattice, with a carbon-carbon separation of 0.142 nm [1]. Graphene-based materials have some sole properties, such as mechanical properties [2], electrical properties [3], thermal properties [4], rheological properties, microwave adsorption, environmental and toxicological impacts, effect of preparation, and gas barrier properties [5]. These materials are mostly used in biological applications, especially related to toxicity, and in other applications like electrically-conductive adhesives and selective photoredox reactions [6]. The rectangular patch is the fundamental and mass commonly used microstrip antenna. Dual characteristics, dual frequency operation,frequency agility, circular polarizations, broad band width, beam scanning, feed line flexibility can be easily gained from these patch antenna. Due to its planar configuration and ease of implementation with microstrip technology, the microstrip patch antenna has been highly studied and is often used for an array element. For rectenna or telemedicine application antenna is operating at 2.45 GHz. For WPT systems, the most preferable frequency is 2.45GHz because it obtains the highest transmission efficiency of over 90% [7]. Antenna array is necessary for those applications. A microstrip antenna is characterized by its width, length, gain, input impedance, and radiation patterns. Graphene can increase the performances of microstrip patch antenna. This paper presents comparative analysis between copper and graphene based rectangular patch antennas. Graphene increases antenna performance for both single and 2×2 array antenna.

We can use those materials which have the dielectric constant in the range of $2.2 \leq \varepsilon r \leq 12$ as substrate material. The proposed antennas have designed and simulated using the CST Microwave Studio Suite.

2. ANTENNA MODELING

There are several methods for analyzing of microstrip patch antenna:

- i Transmission Line model.
- ii Cavity model.
- iii Method of Moments (MoM)

Among these three models the study uses Transmission Line model particularly. To design the antenna model following equations are used [8].

1. To Find the Antenna Width (W) [8]:

$$w = \frac{v_o}{2 f_r \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \tag{1}$$

Where, ε_r = Dielectric constant of substrate.

f_r = Resonant frequency.

2. To find the effective dielectric constant [8]:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \tag{2}$$

Where, h= Height or thickness of the dielectric.

W = Width of patch.

3. To find the fringing length (ΔL) [8]:

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \quad (3)$$

4. To find the actual length L the width and length of the Ground [8]. The input impedance is usually 50Ω.

$$L = \frac{v_o}{2 f_r \sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (4)$$

5. The length of inset (f_i) [8]:

$$f_i = 10^{-4}\left(0.01699 \times \varepsilon_r^7 + 0.13761 \times \varepsilon_r^6 - 6.1783 \times \varepsilon_r^5 + 93.187 \times \varepsilon_r^4 - 682.69 \times \varepsilon_r^3\right) \quad (5)$$

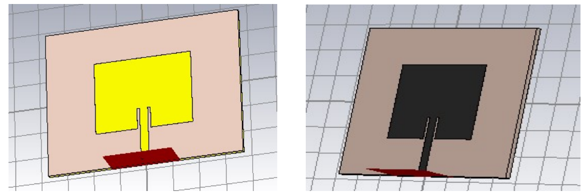
6. The gap between the patch and the inset-fed(Gpf) usually 1mm [8].

To create the graphene material in the simulation environment thickness, chemical potential, relaxation time, and temperature of graphene are taken as 10 nm, 0.2 eV, 0.1ps, and 300 k respectively [9]. Graphene material is used both in ground plane and patch. For our array design, to match the impedance quarter wavelength transformer is used. Quarter-wavelength transformer matches the 100 Ω to 50 Ω transmission line [8].

Table I. Design parameters of optimized rectangular single and 2×2 microstrip patch antenna array.

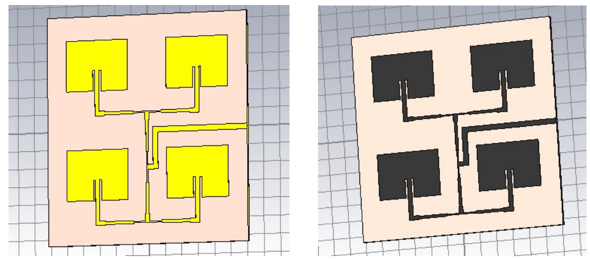
Parameters	Rectangular single patch Value(mm)	Rectangular 2×2 Array Value(mm)
Patch width,W	37	37.5
Patch length, L	28.25	28.25
Inset length,Fi	8.075	11.5
Inset gap,Gpf	1	1.2
Substrate length,Lg	57	127.5
Substrate width,Wg	74	121.95
Substrate thickness,h	1.6	1.6
Metal thickness,Mt	0.035	0.035
Resonant frequency, f_r	2.45 GHz	2.45 GHz

FR-4 (lossy) substrate with relative dielectric constant of 4.3 is used to design all antennas. The Widths of 50 Ω, 70.71Ω and 100Ω transmission lines are 3.09mm, 1.64mm, 0.72mm. Fig.1(a)-1(b) show rectangular single patch and Fig. 2(a)-(b) show rectangular 2×2 array antenna.



(a) (b)

Fig. 1. Rectangular microstrip patch single antenna (a) Copper based (b) Graphene based.



(a) (b)

Fig. 2. Rectangular microstrip patch 2×2 array antenna (a) Copper based (b) Graphene based

3. COMPARATIVE RESULT ANALYSIS

The comparison between copper based and graphene based antennas has been classified into four main areas: return losses, VSWR, gain and bandwidth.

A. Simulation results of copper and graphene based rectangular single patch antenna

- *Return loss:*

Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high. A high return loss is desirable and results in a lower insertion loss. Taking the ratio of reflected to incident power results in a negative sign for return loss [8].

From Fig. 3 and 4, it is clear that graphene based PA offer more negative return loss.

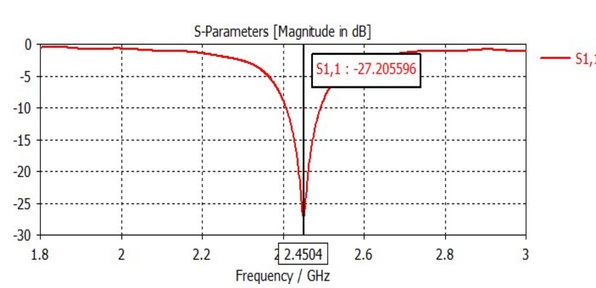


Fig. 3. Return loss for copper based single antenna

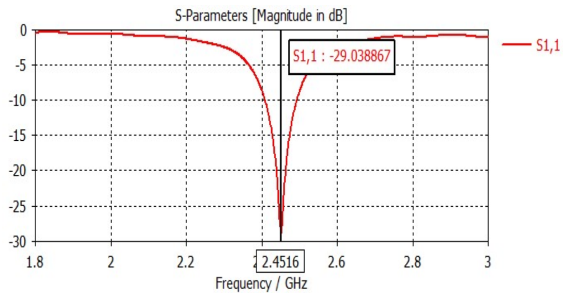


Fig. 4. Return loss for graphene based single antenna

- *VSWR:*

VSWR stands for voltage standing wave ratio. It is defined as the ratio between the maximum value of standing wave voltage to its minimum value. The minimum VSWR for an antenna would be 1 [8]. From Fig. 5 and 6, it is observed that both PA have almost same VSWR.

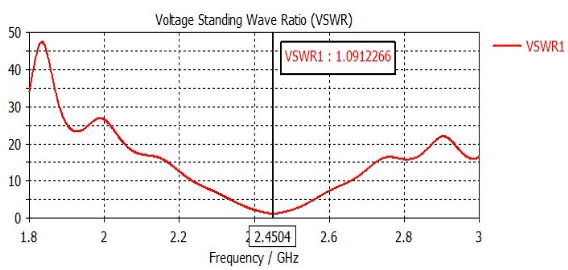


Fig. 5. VSWR for copper based single antenna

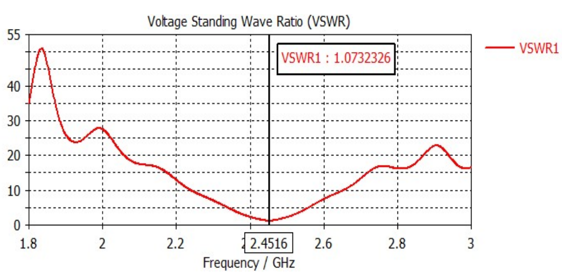


Fig. 6. VSWR for graphene based single antenna

C. Farfield pattern :

Fig. 7 and 8, show the farfield pattern of both Copper and Graphene based single patch antennas.

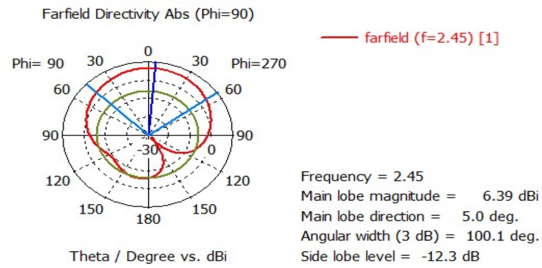


Fig. 7. Polar plot for copper based single antenna

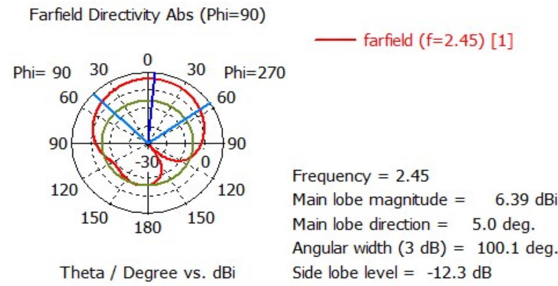


Fig. 8. Polar plot for graphene based single antenna

B. Simulation results of copper and graphene based rectangular patch 2×2 array antenna

A. Return loss:

From Fig. 9 and 10, it is clear that graphene based 2×2 array antenna offers more negative return loss about -39.69 dB.

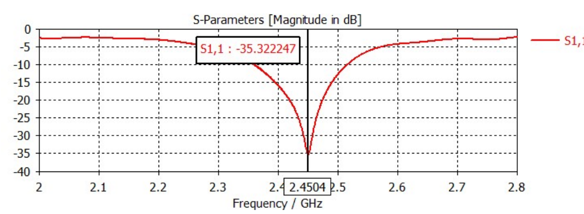


Fig. 9. Return loss for copper based 2×2 array antenna

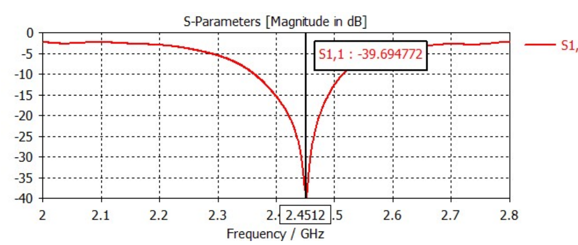


Fig. 10. Return loss for graphene based 2×2 array antenna

B. VSWR:

From Fig. 11 and 12, it is clear that graphene based 2×2 array antenna offers better VSWR which is 1.0209.

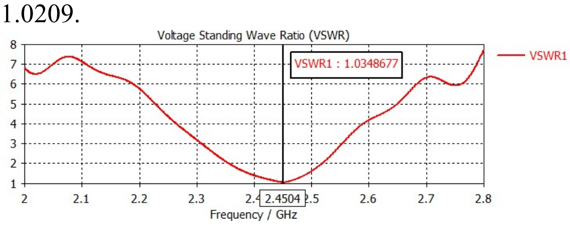


Fig. 11. VSWR for copper based 2×2 array antenna

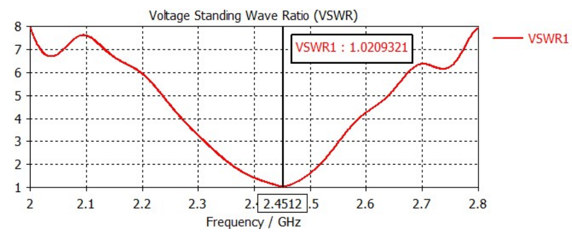


Fig. 12. VSWR for graphene based 2×2 array antenna

C. Farfield pattern :

Fig. 13 and 14 shows the farfield pattern of both Copper and Graphene based 2×2 array antennas.

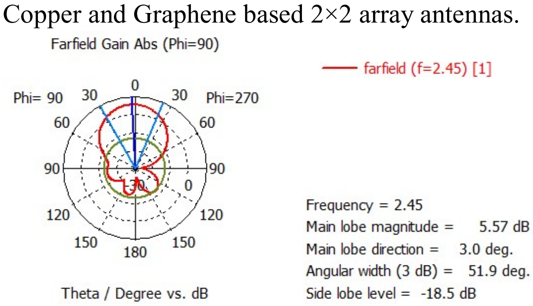


Fig. 13. Polar plot for copper based 2×2 array antenna

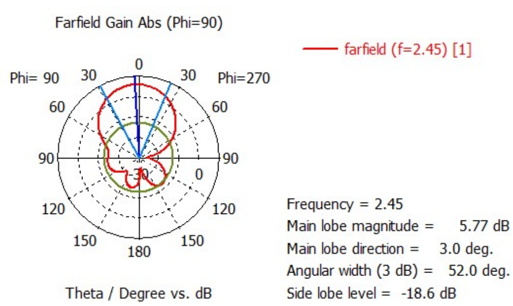


Fig. 14. Polar plot for graphene based 2×2 array antenna

4. RESULT AND DISCUSSIONS

From the Table III, it is seen that graphene based single antenna has better results compared to copper based antenna. More negative values of Return loss provide the better result and the graphene based antenna has more negative return loss. Closer the value of 1 is better for the VSWR, and graphene based antenna has the better VSWR, gain and more bandwidth.

Table III. Comparison between Rectangular copper and graphene based single patch antenna

Parameter	**Copper based**	**Graphene based**
Return loss	-27.2077dB	-29.0388 dB
VSWR	1.0912	1.0732
Bandwidth	81.2 MHz	85 MHz
Directivity	6.388dBi	6.387dBi
Gain	3.003 dB	3.086dB

From the Table IV, it is seen that graphene based 2×2 array antenna has better results compared to copper based 2×2 array antenna. Graphene based array antenna has better return loss and VSWR, gain and more bandwidth. The directivity for both copper and graphene based antennas is almost same.

Table IV. Comparison between Rectangular copper and graphene based 2×2 array antenna

Parameter	Copper based	Graphene based
Return loss	-35.3222 dB	-39.6947 dB
VSWR	1.1009	1.0209dB
Bandwidth	143 MHz	170 MHz
Directivity	10.72dBi	10.73dBi
Gain	5.556 dB	5.753dB

4. CONCLUSION

In this research, single patch and 2×2 array antenna have investigated and successfully simulated. Both single and array Graphene based antenna show quite good results in the perspectives of return loss, VSWR, gain and bandwidth. So, grapheme material enhances the antenna performance considerably. Further we can increase array element with grapheme material. However, one drawback of graphene based antennas is their low radiation efficiency because graphene has very high surface resistance compared to metals at micro and mm-waves frequency, even with the possibility of doping and electric field biasing [10]. However the dynamic tunability of such grapheme based antennas with respect to chemical potential compensates for this low radiation efficiency.

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