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Comparison Using Simulation of Carbon allotropes Based Nanostrip Antenna

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Abstract

Graphene-enabled wireless communications constitute a novel paradigm which enables wireless communications at the nano scale. There is the problem of limited capability of nano-scale antennas fabricated from traditional metallic components. With antennas made from conventional materials like copper, communication between low-power nano machines would be virtually impossible. But by taking advantage of the unique electronic properties of graphene, nano devices can be connected forming a network of nano devices. This research work carry out performance analysis of carbon-based nano patch antenna. Use of graphene and graphite as a patch material of nano patch antenna shows a better performance compared to copper patch nano antenna. Dependency of operating frequency of graphene patch nano antenna on its patch length is modeled and validated with simulation results. Also the effects slot in patch of graphene patch nano antenna is observed and increment in the bandwidth of antenna is achieved.

Keywords: *Graphene, Nano patch antenna, Operating frequency, Slots*

1. INTRODUCTION

The Nanotechnology is enabling the development of devices in a scale ranging from one to a few hundred nanometers. Coordination and information sharing among these nano-devices will lead towards the development of future nano networks, boosting the range of applications of nanotechnology in the biomedical, environmental and military fields. Despite the major progress in nano-device design and fabrication, it is still not clear how these atomically precise machines will communicate. Recently, the advancements in graphene-based electron-ics have opened the door to electromagnetic communications in the nano scale [1] [2]. It would be unfeasible to simply reduce traditional metallic antennas to nano sizes, because they would require tremendously high frequencies to operate. Consequently, it would require a lot of power to operate them. Furthermore, electrons in these traditional metals are not very mobile at nano sizes and the necessary electromagnetic waves would not form. However, these limitations would not be an issue with graphene's unique capabilities. A flake of graphene has the potential to hold a series of metal electrodes. Consequently, it would be possible to develop an antenna from this material [3]. Graphene has a unique structure, wherein,

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electrons are able to move with minimal resistance [4]. This enables electricity to move at a much faster speed than in metal, which is used for current antennas. Furthermore, as the electrons oscillate, they create an electromagnetic wave atop the graphene layer, referred to as the surface plasmon polariton wave. This would enable the antenna to operate at the lower end of the terahertz frequency, which would be more efficient than the current copper based antennas. Based on the honeycomb lattice of carbon atoms, graphene-based nano-antennas can radiate electromagnetic wave, which is also referred to as the Surface Plasmon Polariton wave (SPP) at the terahertz band [5].

2. METHODOLOGY

2.1. Design of of Carbon-based Nano Antenna

Nano patch antennas with different patch material is designed using High Frequency Structure Simulator soft-ware. Various carbon allotropes are used for patch material of the antenna. The carbon allotropes used are graphene and graphite. Design Specification of the Nano Antenna: Length of Patch (L): 120nm Width of Patch (W):160nm Thickness of Patch (t):5nm Thickness of Substrate (h):10nm Permittivity of Substrate Material: 3.58 Operating Frequency of the Antenna (fr):600THz Design Procedure of Nano Antenna using HFSS

Draw patch, ground plane and substrate with the specified dimensions and properties and assign materials for patch and substrate with specified value of conductivity, relative permittivity and relative permeability similarly Assigning boundaries select the bottom face of the substrate and assign the perfect electric boundary to it. Assign the Radiation boundary to the top and bottom air boxes, assign perfect electric boundary to the rectangular patch.. Assigning Excitation: Assign wave port excitation to the rectangle on the XZ plane and set-up a solution, set up an adaptive solution at 600 THz, with 20 passes and delta as .001 and set up a sweep solution from 200-900 THz with a step size of 0.25.

2.2. Performance Comparison of Carbon-based Nano Antenna

After designing nano patch antenna of different patch materials (grapheme, graphite and copper), its performance measure is carried out using High Frequency Structural Simulator (HFSS). The major parameters for the performance measure of the antennas are antenna gain, VSWR, S parameter. Finally, the performance comparison of the nano patch antenna is carried out based on the parameters measured.

3. RESULT AND DISCUSSION

The Graphene is used as patch of the nanostrip antenna. The carrier mobility measured in graphene devices is extremely high, which leads it to be feasible candidates for nano patch antenna. Simulation of graphene patch nano antenna gives various results e.g. gain, VSWR, S11 parameter.It gives the graphical representation of the radiation property i.e. gain of the antenna as a function of space. The maximum gain of the antenna is observed to be 1.5339 dB. In case of microstrip patch antenna, antenna gain is generally found up to 7 dB. Due to antenna dimension of nano size, the antenna gain of the nano antenna is also decreased. So the result observed is acceptable. Antenna gain at different azimuth angle (θ) for elevation angle (Φ) of 900 in case of graphene patch nanostrip antenna. The value of voltage standing wave ratio (VSWR) for graphene patch nanostrip antenna is found to be 1.8. The resonant frequency of the antenna is calculated from an S-parameter measurement gives the S11 value of -9.4 dB. The minimum return loss (equivalent to maximum power delivered) occurs at 610 THz. So the frequency of operation of the antenna is 610 THz.

Graphite patch nanostrip antenna S11 gives the graphical representation of the radiation property i.e. gain of the antenna as a function of space. The maximum gain of the antenna is observed to be 1.5218 dB, which is comparable to that of graphene patch nanostrip antenna. Total gain at different azimuth angle (θ) for elevation angle (Φ) of 90 degree for graphite patch nanostrip antenna. The value of VSWR for graphite patch nanostrip antenna is found to be 1.9.The resonant frequency of the antenna is calculated from an S-parameter measurement. The minimum return loss (equivalent to maximum power delivered) occurs at 610 THz. So the frequency of operation of the antenna is 610 THz again. Copper patch nanostrip antenna the maximum gain of the antenna is observed to be 1.4807 dB, which is lower than that of graphene and graphite patch nanostrip antenna. Gain at different azimuth angles for the elevation angle of 90 degree for copper patch nanostrip antenna.

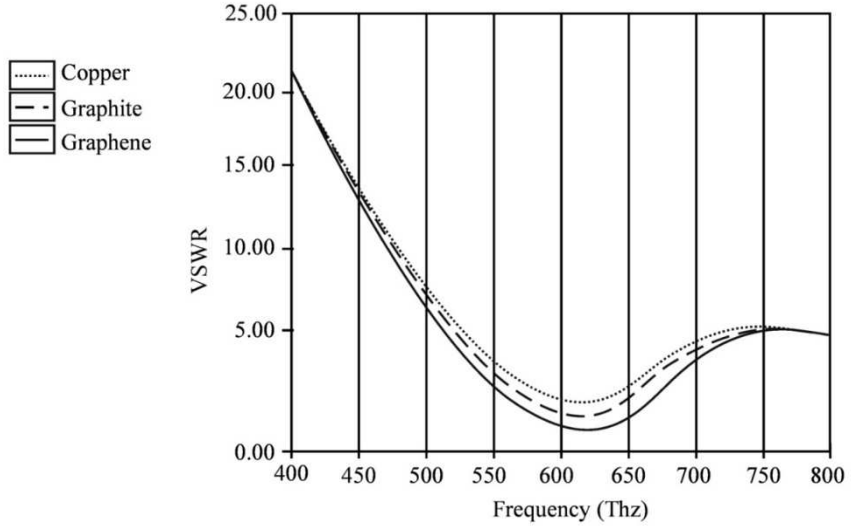


Figure 1. VSWR curve of carbon allotrophes

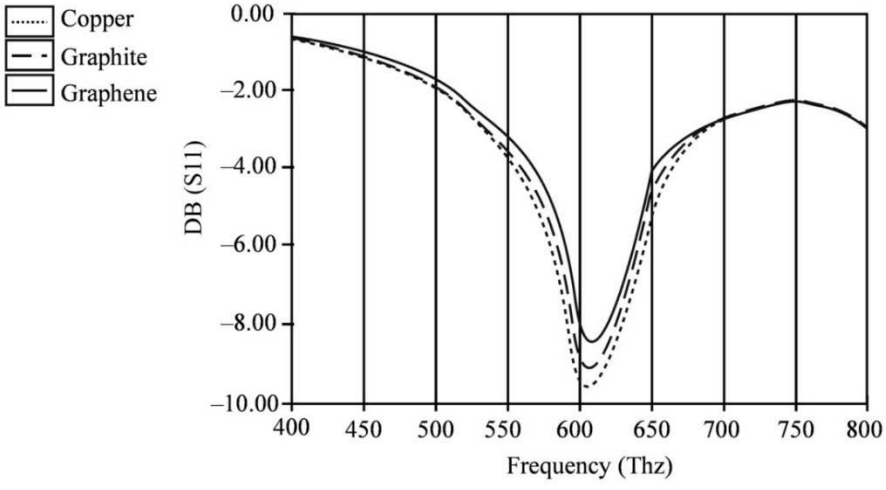


Figure 2. S11 Parameters carbon allotropes

The value of VSWR for copper patch nanostrip antenna is found to be 2. The minimum return loss (equivalent to maximum power delivered) occurs at 610 THz. So the frequency of operation of the antenna is 612 THz.

The antenna properties of various antennas are compared. The dimension of the antennas is kept same but only the patch material is varied. The material used for patch are graphene, graphite and copper. The best result is shown by the graphene patch antenna. Its gain is found to be 1.5339 dB, VSWR is found to be 1.8 and S11 parameter is found -9.4 dB. So, the best performance is found to be graphene patch nanostrip antenna.

Graphene patch nanostrip antenna Graphite patch nanostrip antenna and copper patch nanostrip antenna VSWR is founds to be 1.8, 1.9 and 2 respectively minimum ratio is good for performance analysis. So, the best performance is found to be graphene patch nanostrip antenna. Graphene patch nanostrip antenna Graphite patch nanostrip antenna and copper patch nanostrip antenna S11 parameters is founds to be -9.4 , -9.42 and -9.6 dB respectively minimum value is good for performance analysis. So, the best performance is found to be graphene patch nanostrip antenna.

3.1 Dependency on Patch Length

The operating frequency of a nanostrip patch antenna can be adjusted by an appropriate choice of resonator length of patch. The dependency of operating frequency for a graphene patch nano antenna on resonator length of patch (keeping width and thickness of patch constant) at room temperature is given by the equation (1).

$$f_r = \frac{0.44}{(L + 2\delta L)\sqrt{\mu_0 \varepsilon_0 \varepsilon_{eff}}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where,

L is length of patch

W is width of patch

h is thickness of substrate

δ_L is fringing length extension, which is given by,

$$\delta L = 0.412 * h * \frac{(\varepsilon_{eff} + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{w}{h} + 0.8)} \dots\dots\dots\dots\dots\dots (2)$$

μ_0 is permeability of free space

ε_0 is permittivity of free space

ε_{eff} is effective permittivity of substrate, which is given by,

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-1/2} \dots\dots\dots\dots\dots\dots (3)$$

As given in the equation (1), the operating frequency calculation is improved by including scaling factor of 0.44 and by adding a "fringing length extension" δL to each edge of the patch length to get an "effective length". Also effective permittivity of substrate material is considered in the equation. The effective permittivity includes permittivity of substrate and air portion that is covered by fringing length of patch.

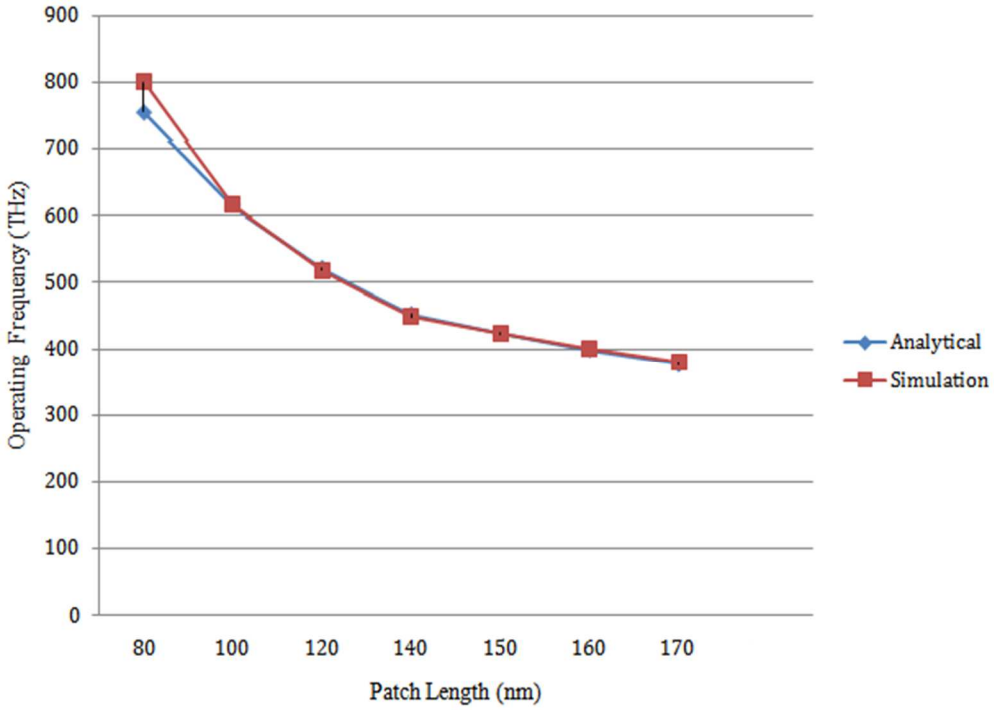


Figure 3. Dependency of operating frequency with respect to patch length

3.2 Effect of Slots on Antenna Performance

The effect of the slots on the antenna characteristics such as gain, return loss, VSWR is observed. Use of a slot on the patch's surface affects the radiation characteristics of patch antenna. Dimension of slot is: 20 nm by 20 nm by 5 nm. The operating frequency of the antenna is shifted to its lower value due to the presence of slot in the center. The operating frequency is decreased from 610 THz to 590 THz.Operating frequency can be adjusted by incorporating slot of various size. By using slot on rectangular patch a wide bandwidth is achieved. Broadening of antenna bandwidth is achieved because of using slots on patch's surface. But the gain of the antenna is decreased from the maximum gain of 1.53 dB to 1.07 dB due to the presence of slot.

4. CONCLUSION

Comparison using simulation carbon allotropes based nanostrip patch antenna is carried out in this research work. Antenna properties of graphene, graphite and copper patch nano an-tenna are compared and the best performance is given by graphene patch nano antenna. Antenna gain of graphene, graphite and copper patch nano antenna is found to be 1.5339 dB, 1.5218 dB and 1.4807 dB respectively. Dependency of operating frequency of graphene patch nano antenna on its patch length is modeled and validated with simulation results.

Also, performance of graphene slotted patch nano antenna is carried out and broadening of antenna bandwidth is observed.

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