Proceedings of IOE Graduate Conference, 2016
pp. 65–70

Performance Analysis of Carbon Based Nano Antenna

Shambhu Singh Bist [1], Surendra Shrestha [2]

[1,2] *Department of Electronics and Computer Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal*
Corresponding Emails: [1] bistshambhu433@gmail.com, [2] surendra@ioe.edu.np

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 slots in the 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

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 nanonetworks, boosting the range of applications of nanotechnology in the biomédical, 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 electronics 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, electrons are able to move with minimal resistance[4][5]. 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[6].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[7][8].

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 software. 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:

1. Draw patch, ground plane and substrate with the specified dimensions and properties.
2. Assign materials for patch and substrate with specified value of conductivity, relative permittivity and relative permeability.
3. Assigning Boundaries
   (a) Select the bottom face of the substrate and assign the perfect electric boundary to it.
   (b) Assign the Radiation boundary to the top and bottom air boxes.
   (c) Assign perfect electric boundary to the rectangular patch.
4. Assigning Excitation: Assign wave port excitation to the rectangle on the XZ plane.
5. Set-up a Solution.
   (a) Set up an Adaptive solution at 600 THz, with 20 passes and delta as .001
   (b) 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 (graphene,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

3.1 Graphene Patch Nano Antenna

Graphene was used as patch of the nano 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.

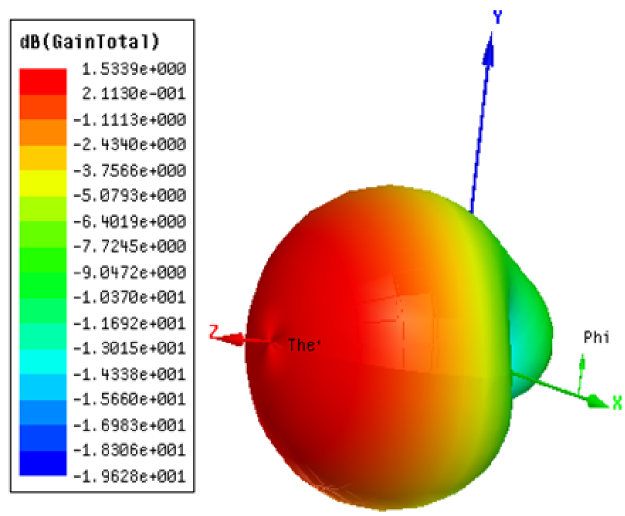

Figure 1: Radiation Pattern of Graphene Patch Nano Antenna

The figure 1 shows radiation pattern of graphene patch nano antenna. 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 upto 7dB. Due to antenna dimension of nano size, the antenna gain of the nano antenna is also dereased. So the result observed is acceptable.

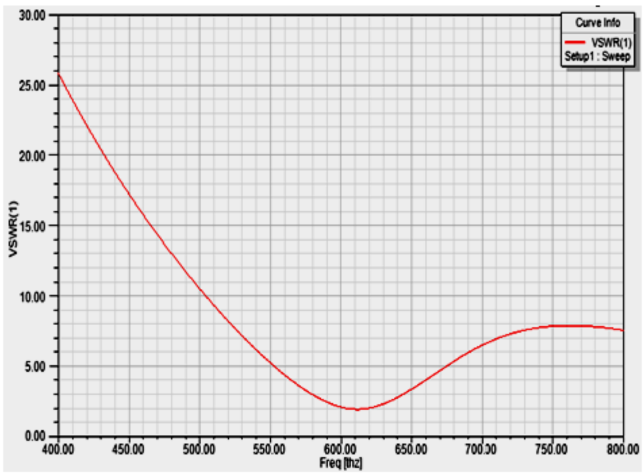

Figure 2: VSWR curve for Graphene Patch Nano Antenna

As shown in the figure 2 the value of voltage standing wave ratio (VSWR) for graphene patch nano antenna is found to be 1.8. The resonant frequency of the antenna is calculated from an S-parameter measurement of the graph, which gives the S11 value of -9.5 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.

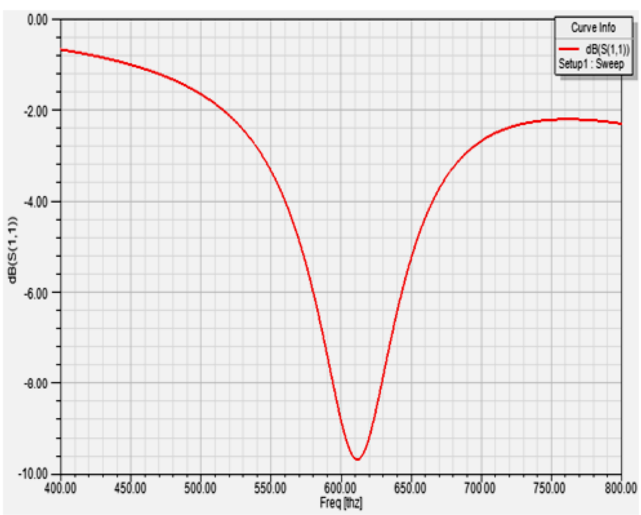

Figure 3: S11 Parameter for Graphene Patch Nano Antenna

3.2 Graphite Patch Nano Antenna

The figure 5 shows radiation pattern of graphite patch nano antenna. 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 1.5218 dB, which is comparable to that of graphene patch nano antenna.

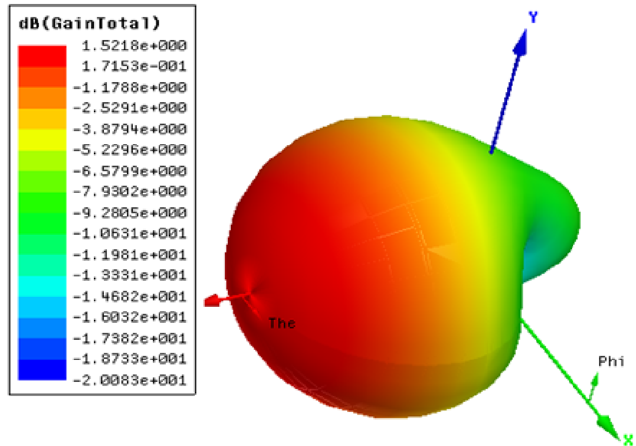

Figure 4: Radiation Pattern of Graphite Patch Nano Antenna

As shown in the figure 5 the value of VSWR for graphite patch nano antenna is found to be 1.9. The resonant frequency of the antenna is calculated from an S-parameter measurement of the graph, which 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 again.

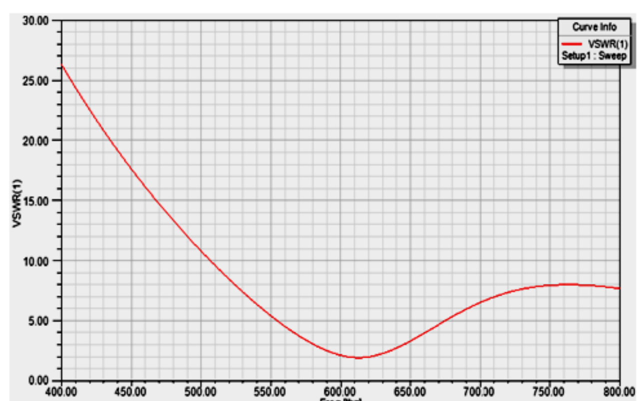

Figure 5: VSWR Curve for Graphite Patch Nano Antenna

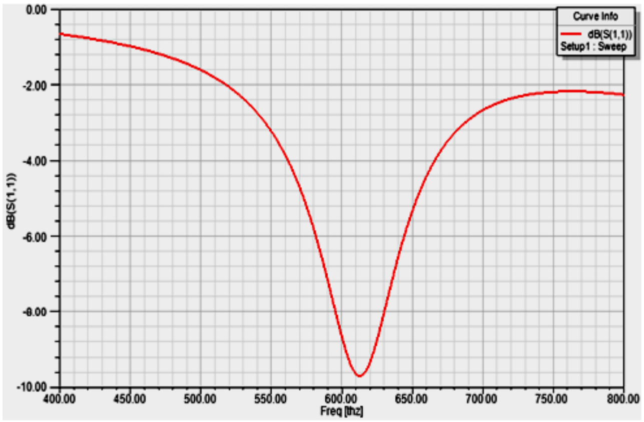

Figure 6: S11 Parameter of Graphite Patch Nano Antenna

3.3 Copper Patch Nano Antenna

The figure 7 shows radiation pattern of copper patch nano antenna. The maximum gain of the antenna is observed to be 1.4807 dB, which is lower than that of graphene and graphite patch nano antenna.

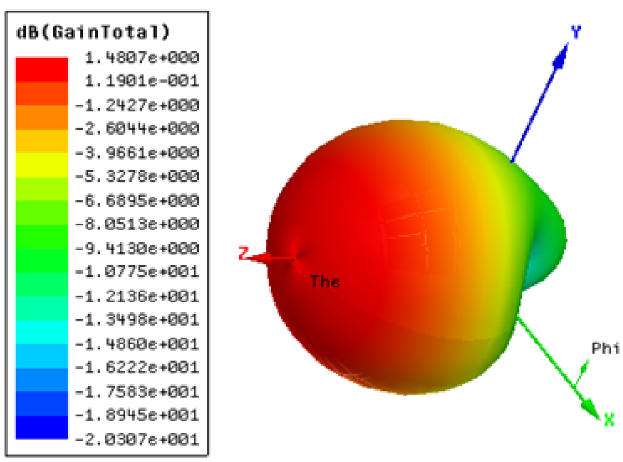

Figure 7: Radiation Pattern of Copper Patch Nano Antenna

As shown in the graph the value of VSWR for copper patch nano antenna is found to be 2. The resonant frequency of the antenna is calculated from an S-parameter measurement of the graph, which gives the S11 value of -9.6 dB . The minimum return loss (equivalent to maximum power delivered) occurs at 610 THz. So the frequency of operation of the antenna is 612 THz.

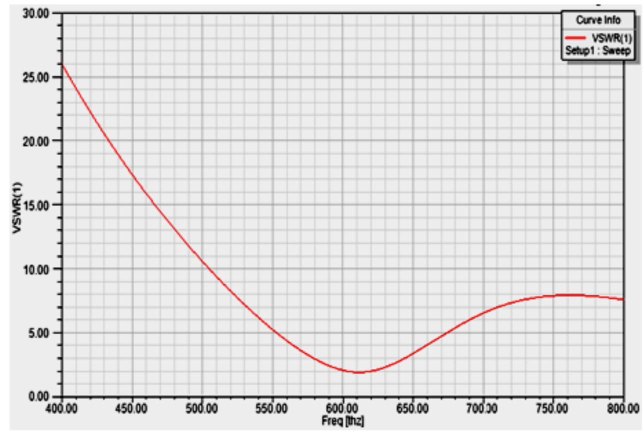

Figure 8: VSWR Curve of Copper Patch Nano Antenna

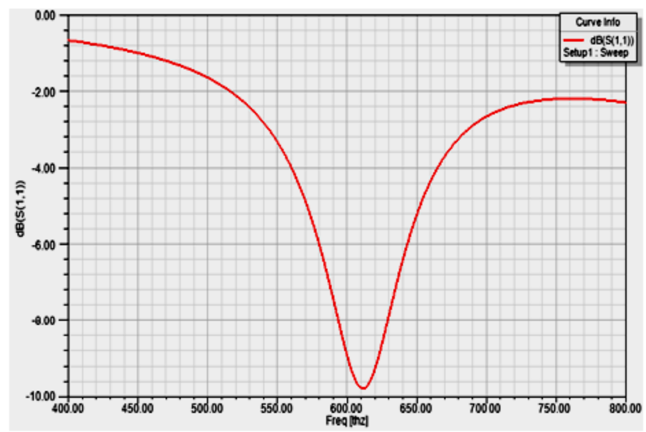

Figure 9: S11 Parameter of Copper Patch Nano Antenna

3.4 Dependency of Operating Frequency on Patch Length

The operating frequency of a nano 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 can be given by the equation:

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

Where,
L = length of patch
δL = Increment in patch length
ε_0 = Permittivity of free space

ε_{eff} = Effective Permittivity of substrate
μ_0 = Permeability of free space

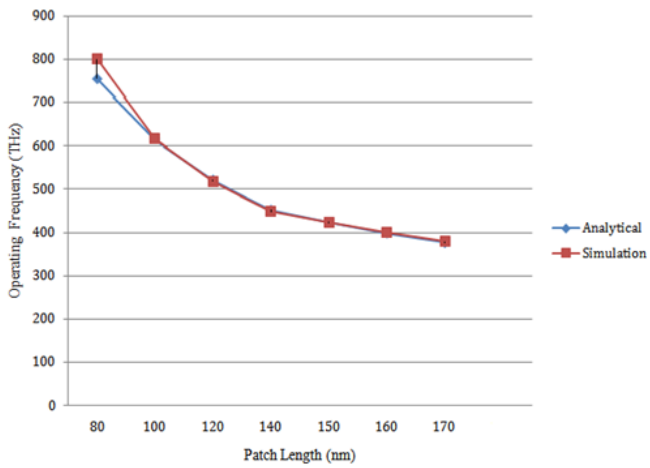

Figure 10: Dependency of Operating Frequency on Patch Length

3.5 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. The operating frequency of the antenna is shifted to its lower value due to the presense 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 presense of slot.

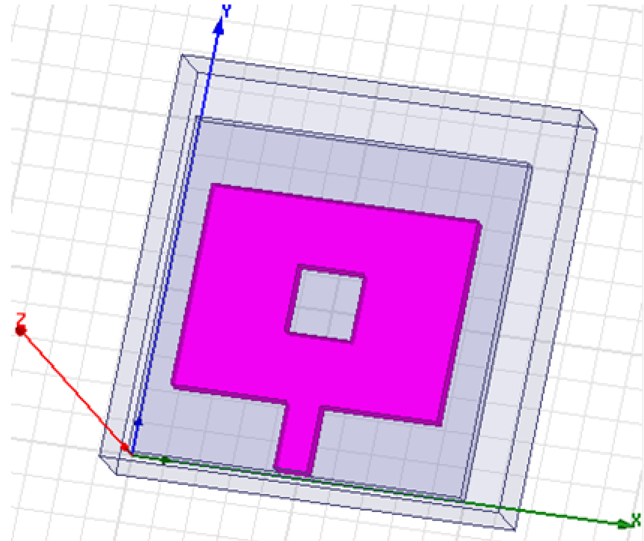

Figure 11: Graphene Patch Nano Antenna with Rectangular Slot in Center

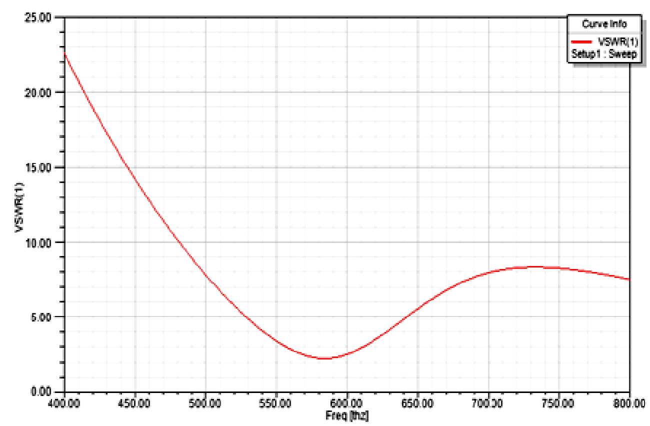

Figure 12: VSWR of Graphene Patch Nano Antenna with Rectangular Slot in Center

4. Conclusion

Performance analysis of carbon-based nano patch antenna is carried out in this research work. Antenna properties of graphene, graphite and copper patch nano antenna 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. Dependancy of operating frequency of graphene patch nano antenna on its patch length is modeled and validated with simulation results. Also, performance of graphene sloted patch nano antenna is carried out and broadening of antenna bandwidth is observed.

5. Acknowledgments

We would like to express our deepest appreciation to all those who provided me the possibility to complete this thesis work. It would not have possible without the kind support and help of many individuals. We are very much thankful to the Department of Electronics and Computer Engineering, Institute of Engineering for accepting my thesis on "Performance Analysis of Carbon Based Nano Antenna". Furthermore, we would also like to acknowledge with much appreciation to the Department of Science and Humanities for providing me laboratory access. Thank also goes to the staff of Nepal Academy of Science and Technology for supporting us technically. Finally, we would like to express our heartfelt thanks to our families and friends who always encouraged and supported us.

References

[1] Xuan Wang, Linjie Zhi, and Klaus Müllen. Transparent, conductive graphene electrodes for dye-sensitized solar cells. *Nano letters*, 8(1):323–327, 2008.

[2] LA Falkovsky and SS Pershoguba. Optical far-infrared properties of a graphene monolayer and multilayer. *Physical Review B*, 76(15):153410, 2007.

[3] LA Falkovsky and AA Varlamov. Space-time dispersion of graphene conductivity. *The European Physical Journal B*, 56(4):281–284, 2007.

[4] Fábio Hipolito, AJ Chaves, RM Ribeiro, MI Vasilevskiy, Vitor M Pereira, and NMR Peres. Enhanced optical dichroism of graphene nanoribbons. *Physical Review B*, 86(11):115430, 2012.

[5] Ignacio Llatser Martí, Christian Kremers, Alberto Cabellos Aparicio, Josep Miquel Jornet, Eduardo José Alarcón Cot, and Dmitry N Chigrin. Scattering of terahertz radiation on a graphene-based nano-antenna. In *The Fourth international workshop on theoretical and computational nanophotonics: TaCoNa-Photonics 2011*, pages 144–146. American Institute of Physics (AIP), 2011.

[6] Ignacio Llatser, Christian Kremers, Albert Cabellos-Aparicio, Josep Miquel Jornet, Eduard Alarcón, and Dmitry N Chigrin. Graphene-based nano-patch antenna for terahertz radiation. *Photonics and Nanostructures-Fundamentals and Applications*, 10(4):353–358, 2012.

[7] Josep Miquel Jornet and Ian F Akyildiz. Graphene-based nano-antennas for electromagnetic nanocommunications in the terahertz band. In *Proceedings of the Fourth European Conference on Antennas and Propagation*, pages 1–5. IEEE, 2010.

[8] Josep Miquel Jornet and Ian F Akyildiz. Graphene-based plasmonic nano-antenna for terahertz band communication in nanonetworks. *IEEE Journal on selected areas in communications*, 31(12):685–694, 2013.