



Use of Graphene as a Patch Material in comparison to the copper and other Carbon Nanomaterials

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Abstract: We have designed two patch antennas namely rectangular and circular (FEKO is used as simulation tool). Single-Walled Carbon Nanotube (SWCNT), Multiwalled Carbon Nanotubes (MWCNT), Copper and Graphene are used as patch material. Property of Electrical conductivity is used to differentiate among patch materials. Antenna parameters vary depending on the patch material. Rectangular patch antenna resonates at 2.44 GHz for multiwalled CNT and 2.46 GHz for Carbon and Graphene patch antennas. Simulations results are obtained and compared to analyse the performance of rectangular patch antenna when different patch materials are used. Similar procedure is repeated for Circular Patch Antenna and also for freq 5.8 GHz. By analyzing all the simulated results, it is concluded that **Graphene patch antennas** show **overall excellent performance** (by virtue of having higher electrical conductivity) **as compared to SWCNT, MWCNT and Copper patch antennas**. Copper patch antennas also have good simulated results and performance is slightly less good as compared to Graphene. The reason is that Graphene has slightly higher conductivity than Copper.

Keywords: Patch Antenna, Carbon Nanotubes, Graphene, Conductivity

1. Introduction

The electronic and materials properties of **Carbon Nanotubes (CNT)** and **Graphene** are remarkable. Depending on their structure, carbon Nanotubes are either single walled or multiwalled. Both properties are appealing for applications in the field of electronics or for the refinement of materials. The youngest synthetic carbon allotrope is two-dimensional graphene, representing a single graphite sheet [1]. Recently, single graphene layers were prepared successfully by means of a simple mechanical exfoliation of graphite using Scotch tape [1]. During the last years, graphene has gained increasing attention in the device community. The progress in the development of graphene transistors is breathtaking and graphene based devices are now considered as an option for a post-Si electronics. Recently it has been proposed that a graphene based Patch Antenna will be able to radiate electromagnetic waves in the terahertz band (0.1-10.0 THz) [2]. There have been several papers published demonstrating or explaining applications of CNT-polymers as patch antenna for various applications [3, 4]. Nowadays, with the rapid development of modern wireless communications, there has been increasing demand for various portable wireless communication devices to provide more flexible applications. Patch antennas can be used for achieving frequency bands for wireless applications. All this prompted us to do work on patch antennas taking CNT and Graphene as patch material and compare their performance with conventionally used copper patch antennas.

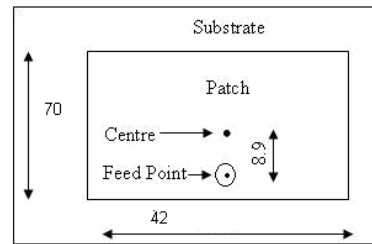
Table 1. Properties of Different Materials

	Copper	SWCNT	MWCNT	Graphene
Conductivity(S/m)	5.96×10^7 [5]	10^2 [6,7]	10^3 [7,8]	10^8 [9,10]
Melting Point (K)	1356	3800(graphite)		
Tensile Strength (GPa)	0.22	22.2+ 2.2	11-63	
Thermal Conductivity ($\times 10^{-3}$ W/m-K)	0.385	1.75- 5.8	3	3-5
Temp. Coeff. of resistance($\times 10^{-3}$ /K)	4	< 1.1	-1.37	-1.47
Mean Free Path @ room temperature	40	10^3	2.5×10^4	10^3
Maximum Current Density(A/c.m ²)	10^7	10^9	10^9	10^8

Rectangular Patch Antenna

At 2.4GHz:

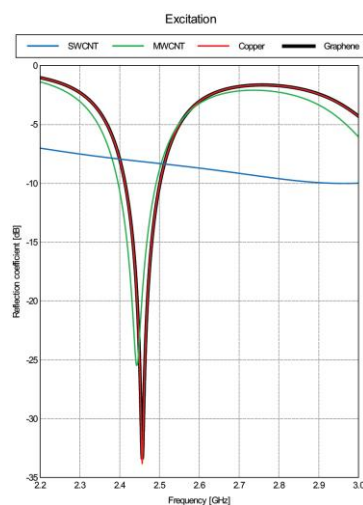
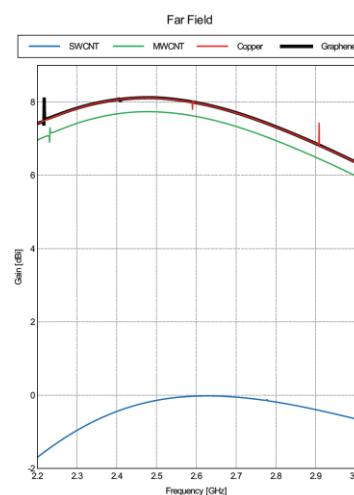
We have designed a rectangular patch antenna using Transmission Line Model. Length, Width and Thickness of Patch are 70mm ,42 mm and 0.5 mm respectively. Feed Distance is 8.9 mm from centre. Height of Substrate is 4.87 mm and permittivity of substrate is assumed 1.6. Substrate is assumed of infinite dimensions. Design is simulated using FEKO simulator for different patch materials- SWCNT, MWCNT, Copper and Graphene.

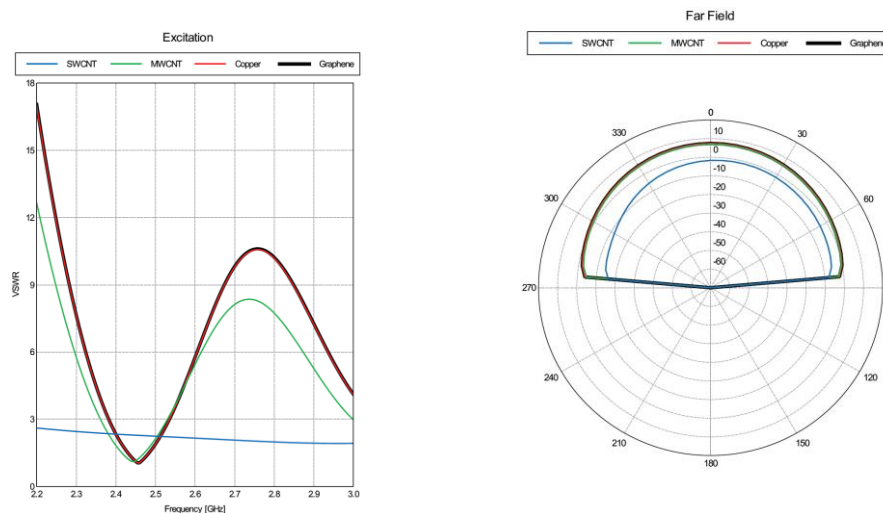
Figure 1. Top view of Rectangular Patch Antenna

The different antenna parameter such as gain, return loss, VSWR and radiation pattern were determined. Return loss should be less than -10 dB for the acceptable operation. The simulated result shows resonant mode at frequency 2.44 GHz for MWCNT and 2.46GHz for Carbon and Graphene patch antennas. Total 10 dB impedance bandwidth of the proposed Patch antenna is 95.481 MHz for MWCNT, 87.780 MHz for copper and 87.655MHz for Graphene with respect to central frequency 2.46 GHz. The simulated result for return loss in dB is shown in figure 2. The figure 3 showing the relation between gain and frequency of the proposed structure. We have obtained maximum gain 8.2 dB for Graphene. Simulated gain is 8.1 dB for copper and 7.7 dB for MWCNT. VSWR should be less than 2 for satisfactory performance of antenna. Performance of antenna in terms of VSWR is similar in case of MWCNT, Copper and Graphene. The radiation pattern is the graphical representation of the maximum radiated power in a particular direction. A stable radiation patterns have been obtained across operating frequencies. It is almost same for MWCNT, Copper and Graphene. A summary of results for rectangular patch antenna is shown in tabular form. It gives a quick insight about performance of antenna in terms of various parameters. A comparison is shown here among SWCNT patch antenna, MWCNT patch antenna, Copper patch antenna and Graphene patch antenna.

Table 2. Results for Rectangular patch antenna at 2.4GHz

S.No.	Parameter	SWCNT	MWCNT	Copper	Graphene
1	Resonant Frequency (GHz)	-----	2.44	2.46	2.46
2	Gain (dB)	-0.1	7.7	8.1	8.2
3	Reflection Coefficient (dB)	-10	-26	-34	-33
4	Bandwidth (MHz)	-----	95.481	87.780	87.655
5	VSWR	1.92	1.2	1.4	1.1

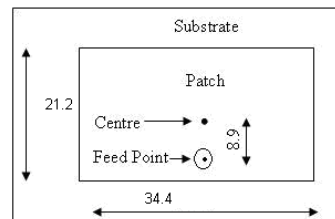
Figure 2.Return Loss**Figure 4. VSWR****Figure 3. Gain****Figure 5. RadiationPattern**



At 5.8 GHz:

We have designed a rectangular patch antenna using Transmission Line Model. Length, Width and Thickness of Patch are 34.4 mm, 21.2 mm and 0.5 mm respectively. Feed Distance is 8.9 mm from centre. Height of Substrate is 2.87 mm and permittivity of substrate is assumed 1.6. Substrate is assumed of infinite dimensions. Design is simulated using FEKO simulator for different patch materials- SWCNT, MWCNT, Copper and Graphene.

Figure 6. Top view of Rectangular Patch Antenna



The different antenna parameters such as gain, return loss, VSWR and radiation pattern were determined. Return loss should be less than -10 dB for the acceptable operation. The simulated result shows resonant mode at frequency 5.77 GHz for MWCNT and 5.79 GHz AND 5.80 for Carbon and Graphene patch antennas and the frequency bands ranges from 5.54 GHz to 5.89 GHz in general. Total 10 dB impedance bandwidth of the proposed Patch antenna is 264.105 MHz for MWCNT, 243.335 MHz for copper and 243.043 MHz for Graphene with respect to central frequency 5.8 GHz. We have obtained maximum gain 8.39 dBi for Graphene. Simulated gain is 8.38 dBi for copper and 8.05 dBi for MWCNT. VSWR should be less than 2 for satisfactory performance of antenna. Performance of antenna in terms of VSWR is similar in case of MWCNT, Copper and Graphene. A stable radiation patterns have been obtained across operating frequencies. It is almost same for MWCNT, Copper and Graphene.

Table 3. Results for Rectangular patch antenna at 5.8 GHz

S.No.	Parameter	SWCNT	MWCNT	Copper	Graphene
1	Resonant Frequency (GHz)	-----	5.77	5.79	5.80
2	Gain (dBi)	2.8	8.05	8.38	8.39
3	Reflection Coefficient (dB)	-6.85	-28	-21.5	-21.5
4	Bandwidth (MHz)	-----	264.105	243.335	243.043
5	VSWR	2.63	1.1	1.2	1.2

Figure 7. Return Loss

Figure 8. Gain

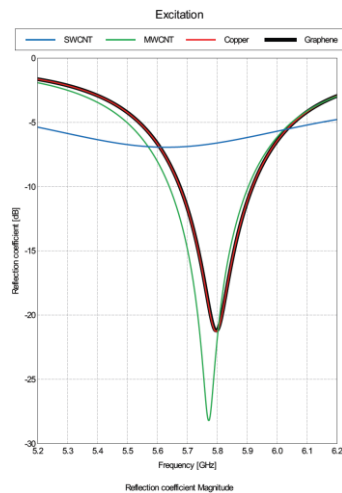


Figure 9. VSWR

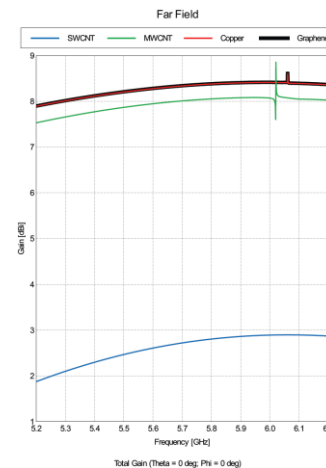
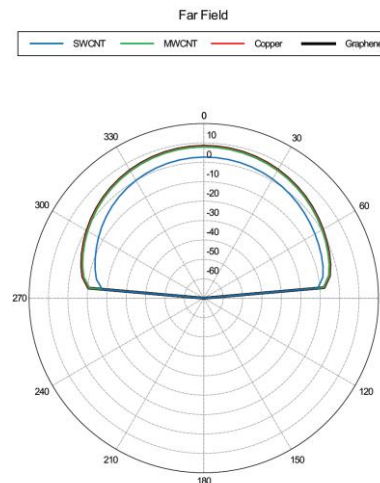
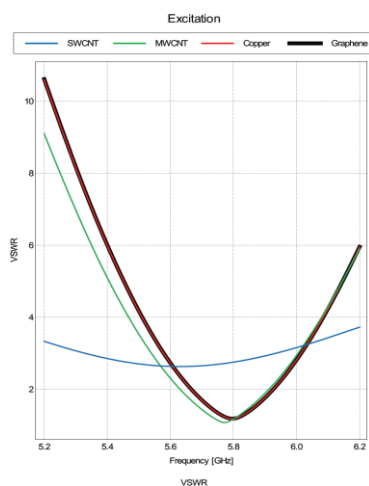


Figure 10. RadiationPattern

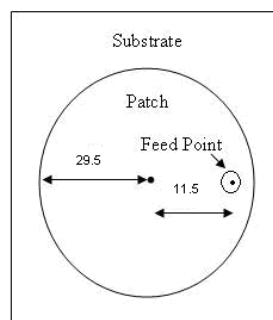


Circular Patch Antenna

At 2.4GHz:

Diameter and Thickness of Patch are 29.5mm and 0.5 mm respectively. Height and Permittivity of Substrate are 4.87 mm and 1.3 respectively. Feed Distance from Centre is 11.5 mm.

Figure 11.Top view of Circular Patch Antenna



From simulated result, resonant mode for MWCNT, Copper and Graphene can be seen at 2.41 GHz frequency. Resonant frequency for SWCNT is nothing. The proposed structure is providing maximum impedance bandwidth (129.934 GHz) in case of MWCNT AND 125.298,125.230 copper and grapheme at central frequency 2.41 and 2.42 GHz. Respectively The proposed structure is providing the maximum gain 8.75 dB at

2.41 GHz frequency for Graphene. Simulated gain is 0.45 dB, 8.48dB and 8.74dB for SWCNT, MWCNT and Copper respectively.

A summary of results for circular patch antenna is shown in table 4.

Table 4. Results for Circular patch antenna at 2.4GHz

S.No.	Parameter	SWCNT	MWCNT	Copper	Graphene
1	Resonant Frequency (GHz)	-----	2.41	2.42	2.41
2	Gain (dBi)	0.45	8.48	8.74	8.75
3	Reflection Coefficient (dB)	-6.5	-32	-42	-41
4	Bandwidth (GHz)	-----	129.934	125.298	125.230
5	VSWR	2.24	1.1	1.1	1.3

Figure12. Return Loss

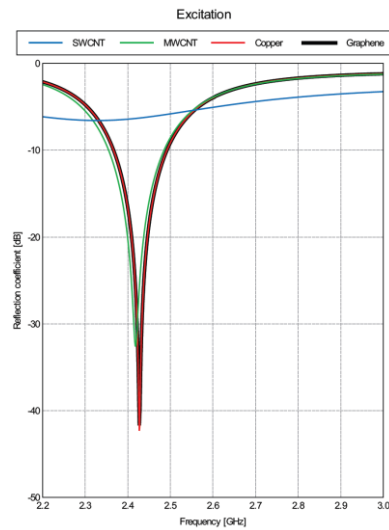


Figure13. Gain

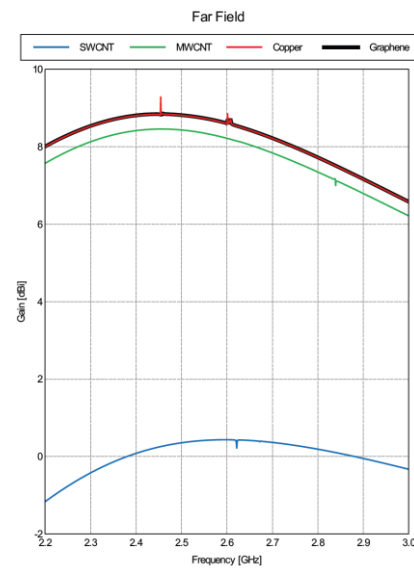


Figure14. VSWR

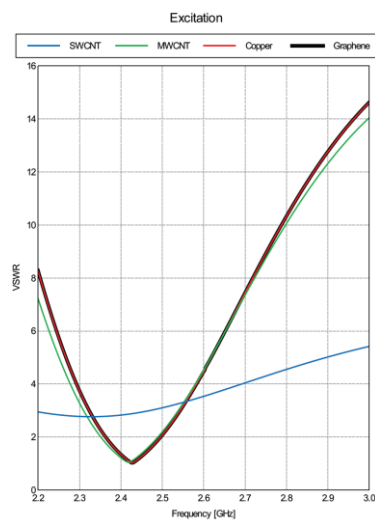
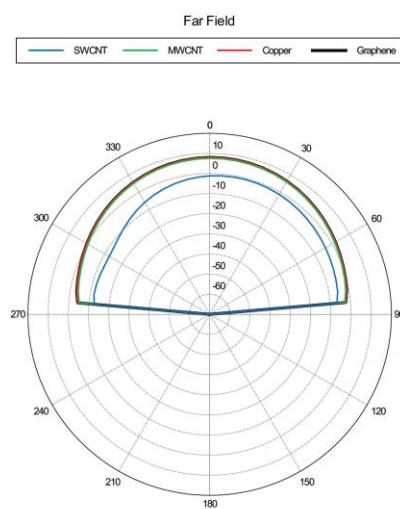
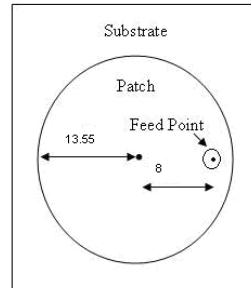


Figure15. RadiationPattern



At 5.8 GHz:

Diameter and Thickness of Patch are 13.55mm and 0.5 mm respectively. Height and Permittivity of Substrate are 2.87 mm and 1.1 respectively. Feed Distance from Centre is 8 mm.

Figure 16. Top view of Circular Patch Antenna

From simulated result, resonant mode for MWCNT, Copper and Graphene can be seen at 5.88 GHz frequency. Resonant frequency for SWCNT is nothing. The proposed structure is providing maximum impedance bandwidth (467.247 GHz) in case of MWCNT AND 450.214,449.973 copper and graphene at central frequency 5.77 and 5.80 GHz. respectively . The proposed structure is providing the maximum gain 9.37dB at 5.8 GHz frequency for Graphene. Simulated gain is 3.75 dB, 9.05 dB and 9.37dB for SWCNT, MWCNT and Copper respectively. VSWR should be less than 2 for satisfactory performance of antenna. Performance of antenna in terms of VSWR is similar in case of MWCNT, Copper and Graphene. A stable radiation patterns have been obtained in case of MWCNT, copper and Graphene. For SWCNT, radiation pattern is less satisfactory.

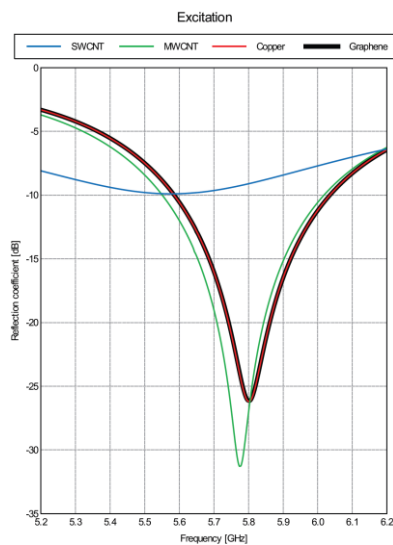
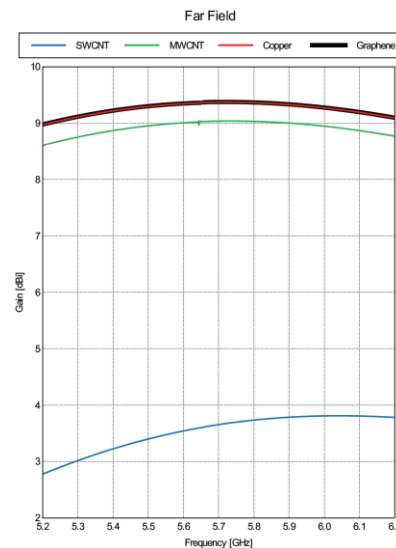
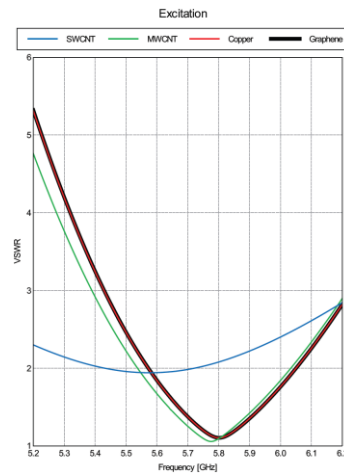
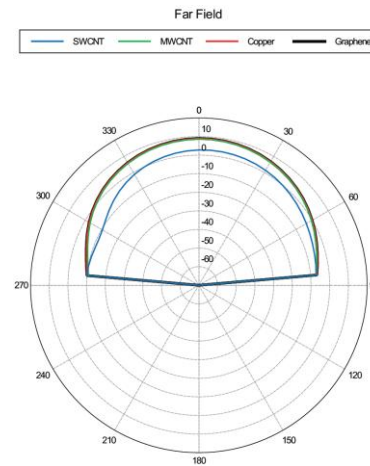
Figure17. Return Loss**Figure18. Gain**

Figure19. VSWR**Figure20. RadiationPattern**

A summary of results for circular patch antenna is shown in table 4.

Table 5. Results for Circular patch antenna at 5.8 GHz

S.No.	Parameter	SWCNT	MWCNT	Copper	Graphene
1	Resonant Frequency (GHz)	-----	5.77	5.80	5.80
2	Gain (dBi)	3.75	9.05	9.37	9.37
3	Reflection Coefficient (dB)	-9.9	-31	-26	-26
4	Bandwidth (GHz)	-----	467.247	450.214	449.973
5	VSWR	1.95	1.08	1.1	1.1

Conclusion

Patch antennas' performance is simulated over a large frequency range. Rectangular and circular patch antennas have resonant frequency 2.4 GHz, 5.8 GHz respectively. Every time we obtain highest gain for Graphene Patch antennas. Gain of copper patch antennas is slightly less than graphene patch antennas. Bandwidth performance is excellent both for graphene and copper patch antennas. Performance of copper and Graphene patch antennas in terms of reflection coefficient is almost same. Radiation pattern of Graphene, Copper and MWCNT patch antennas are almost same. Overall performance of SWCNT is poor and that of MWCNT is average. By analyzing all the simulated results, it is concluded that Graphene patch antennas show overall excellent performance as compared to SWCNT, MWCNT and Copper patch antennas. Copper patch antennas also have good simulated results and performance is slightly less good as compared to Graphene. The reason is that Graphene has slightly higher conductivity than Copper. It can be concluded that Graphene is the promising future candidate as patch material for patch antennas.

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