International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 4, April - 2013

Design Of Carbon Nanotubes (CNT) Patch Antenna For WLAN Application

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Abstract

In this paper, we explore using carbon nanotube (CNT) composite material for WLAN antenna applications. We use composite material as the radiating element for a monopole antenna. An accurate electromagnetic model of the composite antenna is developed using Ansoft hfssv13 for numerical analysis. The return loss, radiation pattern and gain of the composite antenna are investigated. Results are shown for both copper and CNT antennas, and their performance is compared. It is observed that CNT composite is an effectively alternative to metal for the antenna structure.

Keywords– Antenna, Carbon nanotube (CNT) composites, Rectangular patch antennas, WLAN, HFSS.

1. Introduction

Patch antennas play a very significant role in today's world of wireless communication systems. A Microstrip patch antenna (Fig 1) is very simple in the construction using a conventional Microstrip fabrication technique. The most commonly used Microstrip patch antennas are rectangular and circular patch antennas. These patch antennas are used as simple and for the widest and most demanding applications. Dual characteristics, dual frequency operation, frequency agility, broad band width, feed line flexibility, beam scanning can be easily obtained from these patch antennas.

A Microstrip patch antenna is a thin square patch on one side of a dielectric substrate and the other side having a plane to the ground. The simplest Microstrip patch antenna configuration would be the rectangular patch antenna.

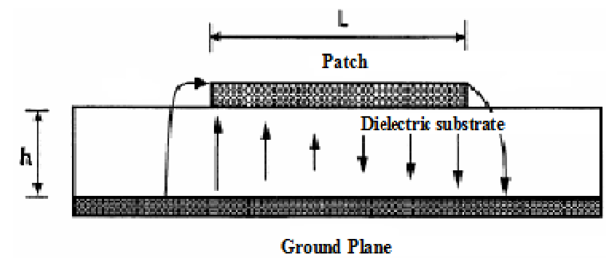

Figure 1. Patch antenna

The patch in the antenna is made of a conducting material Cu (Copper) or Au (Gold) and this can be in any shape Fig 2 [1].

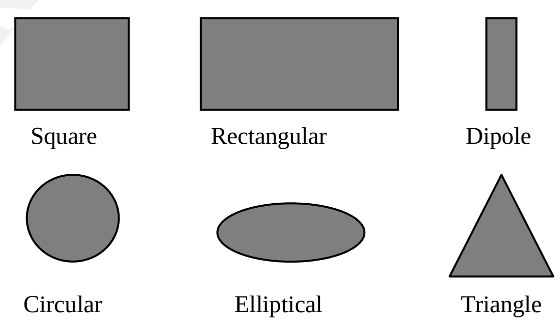

Figure 2. Different shapes of patches.

Metal are commonly used in antenna structures for the radiating elements, feed lines, and ground plane. However, for some applications, cost, fabrication procedure, weight or corrosion resistance can limit the usefulness of metal antennas. Some recent studies have used various composite materials as replacements for metals [2]–[6]. In [2], a conducting polymer patch antenna is proposed. Silver nanoparticle ink [3], [4] and metallo-organic conductive ink [5] have been used to prepare a highly-conductive antenna. In [6], metalized foam is used to make microstrip patch antenna.

Due to the favorable mechanical and electrical properties, CNTs have been of interest in nanoelectronics and nanoantenna applications [7]–[14]. The density of CNT composites is around 1.4 g/cm, half that of aluminum and more than five times lower than copper. Showing high thermal conductivity of about ten times that of copper, CNTs are attractive for high heat-transfer applications. CNT composites can be made using single-wall carbon nanotubes (SWCNT) or multi-wall carbon nanotubes (MWCNT). Details about CNT types and models of materials are given in [9], [10]. However, CNT dipoles show extremely low efficiency in the order of 10^{-8} for microwave applications [11], [12], due to their high resistance per unit length, of about 10 kΩ/μm [11]. Therefore, CNT arrays and composites are proposed to improve the efficiency [15]–[19]. The electrical conductivity of CNT composites depends on the properties and loading of the CNTs, the aspect ratio of the CNTs, and the characteristics of the conductive network throughout the matrix [20].

Recently WLANs and the worldwide-interoperability-for-microwave-access (WiMAX) technology have been extensively used in commercial, medical and industrial applications. The allocated spectrum for these WLAN systems is centered at 2.4, and 5.8 GHz. Wi-Fi (also known as WLAN) has become a standard in most computers. Almost every modern mobile phone and other gadgets are being implemented with Wi-Fi technology. Wi-Fi makes it possible for the user to connect to the internet or LAN (Local Area Network) though a wireless connection hence its other name is WLAN. WLAN uses the technical term "IEEE 802.11" and has standards in the names of 802.11 b/g/n. Microstrip Patch Antennas have been widely used in a various useful applications, due to their low weight and low profile, conformability, easy and cheap realization. In this paper, an attempt has been made to design Microstrip patch antenna structure for WLAN systems at 2.4 GHz and 5.8 GHz Frequency Using Ansoft-HFSS v13**.**

2. Performance of CNT over Copper

The CNT antenna is less affected by nearby conductive objects than is the copper antenna. The antenna performance such as gain can be adjusted by changing the conductivity of composite, while it is not possible for materials with fixed conductivity such as copper. The CNT antenna shows low dispersion characteristics. The housing effect on the performance of the CNT antenna is much lower than for the copper antenna. Because of the presence of large kinetic inductance (due to large momentum relaxation time) in each CNT, the skin effect in CNT bundles is significantly reduced compared to that in conventional conductors.

3. Designing calculation for rectangular patch antenna

There are several theories that can be used to analysis and design of rectangular microstrip patch antenna like transmission line model, cavity model etc. In the purposed antenna follow transmission line model design technique. According to this model a rectangular patch of length L and width W can be viewed as a very wide transmission line that is transversely resonating, with the electric field is varying sinusoidal under the patch along its resonant length L. The electric field is assumed to be invariant along the width W of the patch. Furthermore, it is assumed that the antenna's radiation comes from the fields leaking out along out the width, or radiating edges of the antenna. Consider a Rectangular patch of Width W and Length L over grounded substrates with the thickness h and relative permittivity εr. For efficient radiator, a practical width that leads to good radiation efficiencies for fundamental TM10 mode is [1]

$$w = \frac{c}{2 f_0 \sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Since some of the wave travel in the substrate and some in the air, an effective dielectric constant εreff is introduced to account for fringing and the wave propagation in the line and is given by [1]

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

Also it can be seen that the fields slightly overlap the edges of the patch making the electrical length of the patch slightly larger than its physical length. Thus a Correction term ΔL also called Edge extension is introduced in account for the fringe capacitance. This edge extension ΔL is given by [1]

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

Because of the fringing effect, the dimension of the patch along its length have been extended on each end by a distance L, so the effective length of the patch is given by [1]

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}}$$

Then actual length is given by

$$L = L_{eff} - 2\Delta L$$

After finding the actual length of the patch, the desired Rectangular Microstrip patch antenna is designed using Ansoft HFSSv113. HFSS (High Frequency Structure Simulator) software is the industry-standard simulation tool for 3-D full-wave electromagnetic field simulation and is essential for the design of high-frequency and high-speed component design.

After calculation and optimization for the desired output the specification for the rectangular patch antenna is given in table 1.

4. Data analysis for 2.4 GHz and 5.8GHz Rectangular patch antenna

Here we design antenna for 2.4GHz and 5.8GHz Frequency. Design parameter are calculated using above equation and given in table 1.

Table 1. Specification for the Rectangular Patch Antenna

Parameters	**Units**	**Units**
Operating Frequency	2.4Ghz	5.8GHz
Patch Length	33.41	13.74
Patch Width	41.76	17.28
Dielectric Constant	3.48	3.48
Dielectric Material	Rogers 4350	Rogers 4350
Dielectric Substrate height	0.508mm	0.508mm

5. Simulation of rectangular Patch antenna

To simulate rectangular patch antenna, all above calculated parameters of the rectangular patch antenna is to be used for the designing in the HFSS simulation Software. The design specifications are given in table 1. In this antenna we used copper as material for patch design. Figure 3 shows the designed rectangular patch antenna structure within the HFSS simulation software.

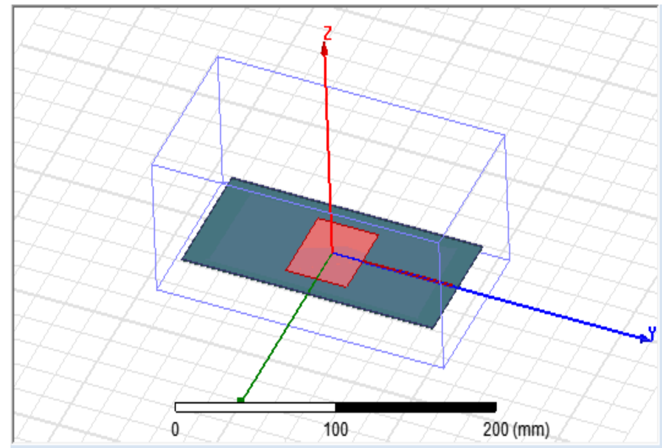

Figure 3. Ansoft-hfss Designed patch antenna

Then we design the antenna with same parameters value. But now we use the CNT (carbon nanotubes) as patch material. The designed CNT antenna is shown in figure 4.

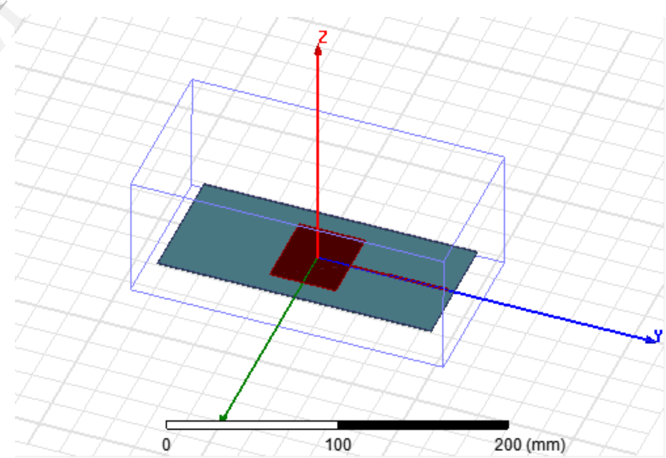

Figure 4. Ansoft-hfss Designed patch antenna

6. Simulation Result for 2.4GHz and 5.8GHz of rectangular Patch antenna

The Return loss and gain of copper and CNT antenna for 2.4GHz and 5.8GHz frequencyare shown in below figure.

ISSN: 2278-0181
Vol. 2 Issue 4, April - 2013

7. Simulation result for 2.4GHz copper

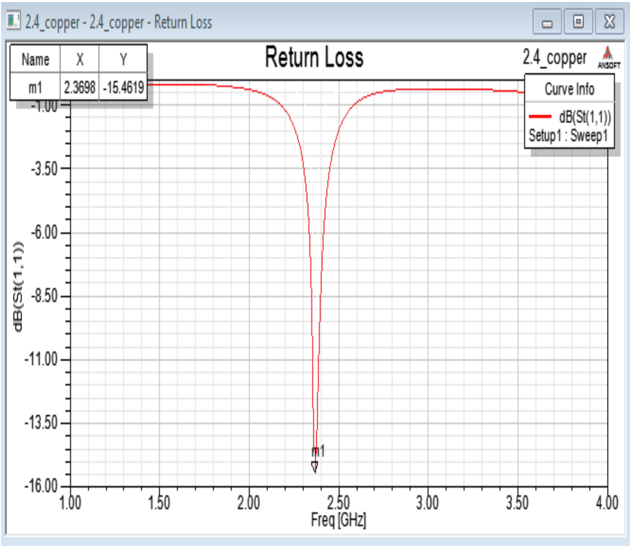

Figure 5. Return loss for patch antenna

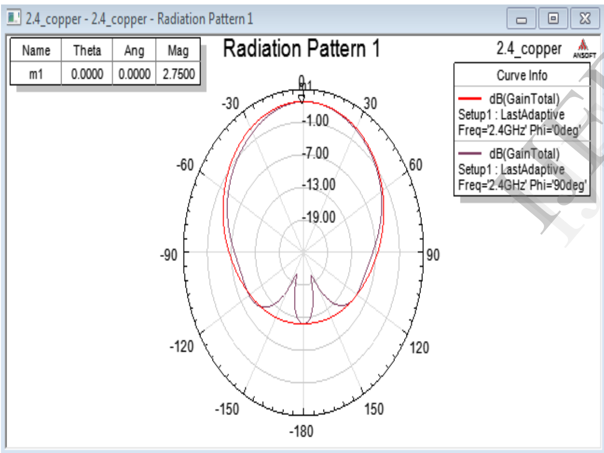

Figure 6. Gain of Designed patch antenna

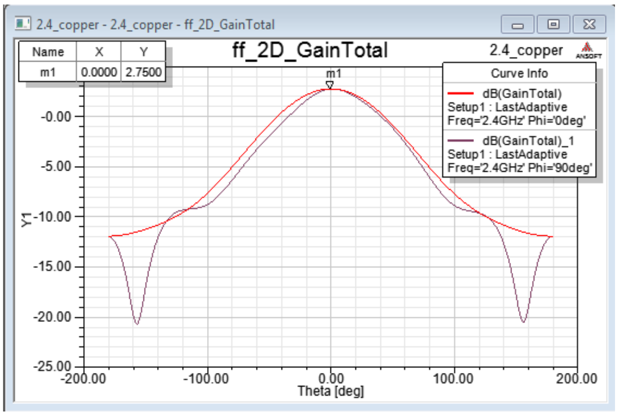

Figure 7. Gain of Designed patch antenna

8. Simulation result for2.4GHz CNT

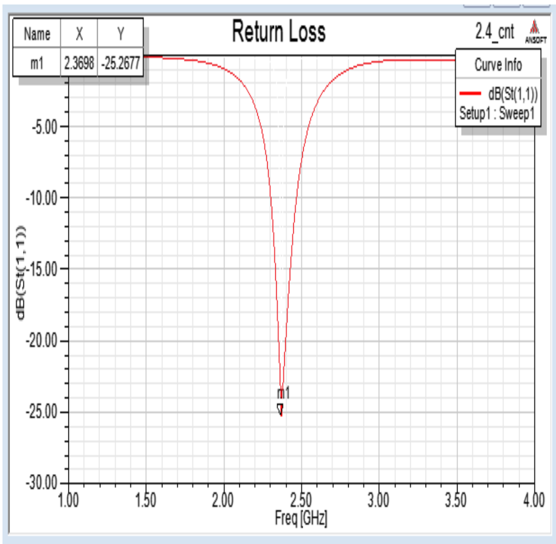

Figure 8. Return loss for patch antenna

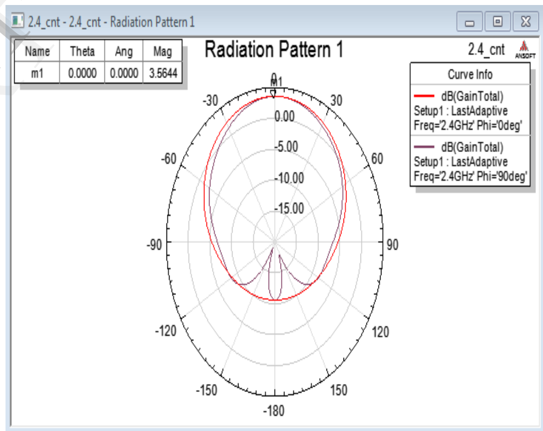

Figure 9. Gain of Designed patch antenna

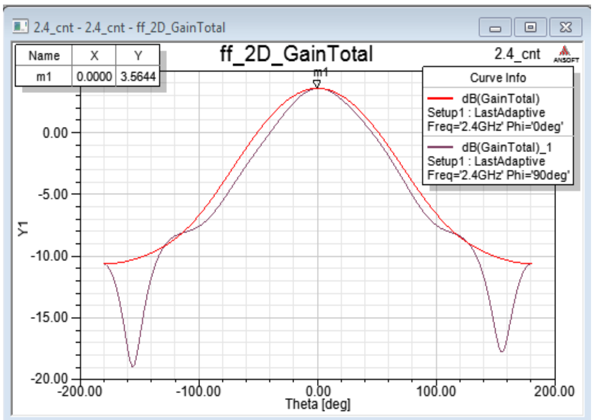

Figure 10. Gain of Designed patch antenna

ISSN: 2278-0181
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9. Simulation Result for 5.8GHz copper

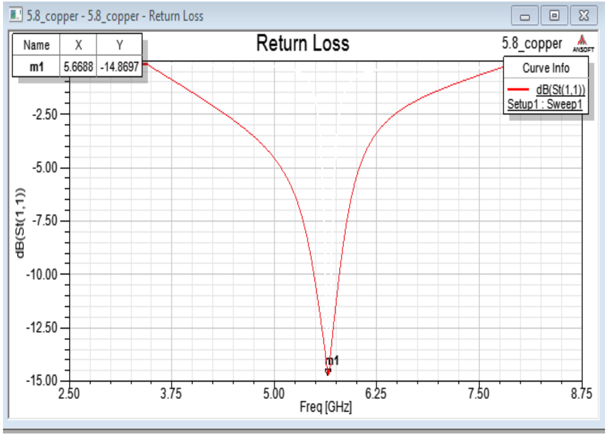

Figure 11. Return loss for patch antenna

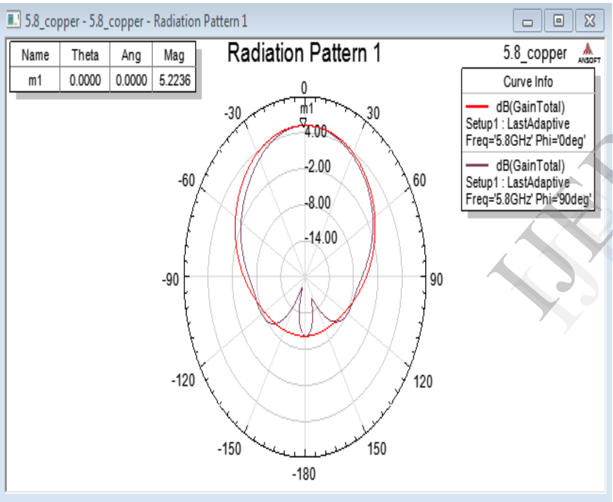

Figure 12. Gain of Designed patch antenna

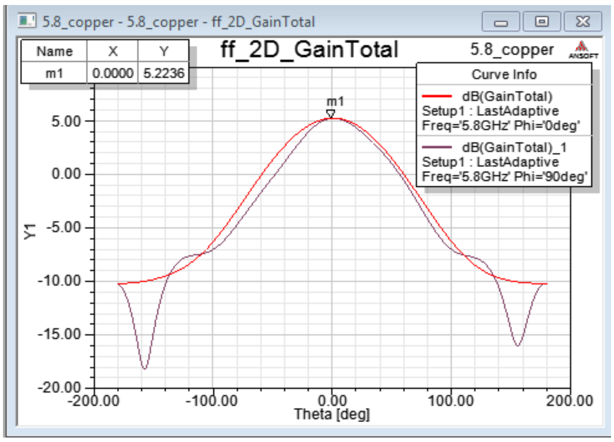

Figure 13. Gain of Designed patch antenna

10. Simulation Result for 5.8GHz CNT

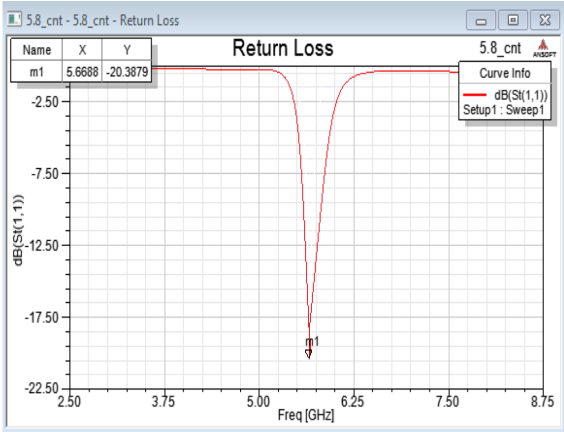

Figure 14. Return loss for patch antenna

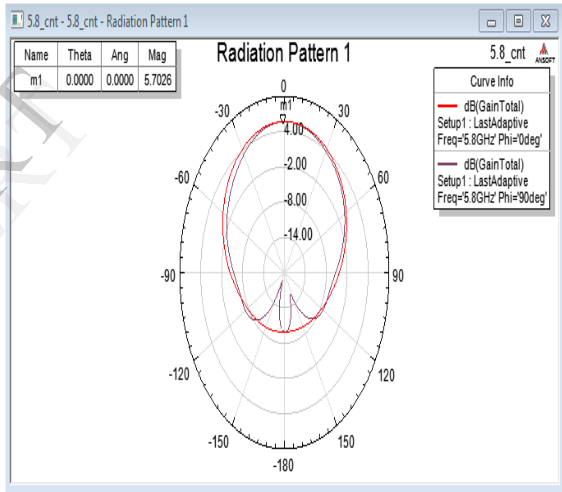

Figure 15. Gain of Designed patch antenna

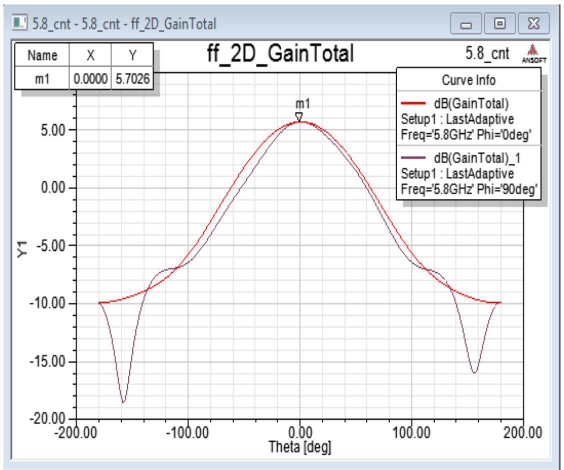

Figure 16. Gain of Designed patch antenna

11. Conclusion

In this paper the use of CNT was investigated for building antennas for WLAN antenna applications. Metal in the antenna structure was replaced with CNT. Good agreement was found between the copper antenna and CNT antenna. Carbon nanotubes materials can be used in many other antenna applications beyond those presented here.

12. Future work

Using the rectangular microstrip antenna as a basis, the circular dual frequency Microstrip antenna can be developed which cover Wi-Fi band as well as Bluetooth and Zigbee band. we can use different feeding methods such as Microstrip line feed, Probe feed techniques or Elliptical shaped patch can be used instead of Rectangular patch.

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