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CARBON NANOTUBE BASED FLEXIBLE ANTENNAS

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Abstract- Ever since the discovery of carbon nanotubes by S. Iijima, they have been a hot topic of research for scientists for their several potential applications because they have better properties and yield better results. The electrical, mechanical and thermal properties of CNT's show tremendous behavior when compared with other metals. They are being studied for their integration into several fields. Some of these fields include nano-electronics, nano-photonics, nano-biotechnology, nano-mechanics etc. Through this paper we tend to present the design of patch antennas made of CNTs using simulation tool FEKO. A circular patch array has been designed to operate at 5.8 GHz frequency which lies in the ISM band. Such antennas can be utilized for several novel applications such as human body communication, spying and military applications, etc. Simulation results show these antennas conforming to deliver better performance.
Keywords- Carbon nanotubes (CNT), multi Walled carbon nanotube, fullerene, polarization versatility, circular patch array, micro-strip antennas, effective radius, dielectric constant

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Introduction

The term nanotube is normally used to refer to the carbon nanotube, which has received enormous attention from researchers over the last few years and a host of interesting applications. Nanotubes have received much attention due to their interesting properties. The current research in carbon nanotubes is a direct outcome of the synthesis of buckminsterfullerene C_{60} in 1985 and its family afterwards [1]. Carbon nanotubes (CNTs) were discovered by Iijima as elongated fullerenes in 1991. Nanotubes are concentrically rolled graphene sheets with a large number of potential helicities and chiralities. Japanese microscopist S. Iijima observed graphitic carbon needles ranging from 4 to 30 nm in diameter and up to 1 mm in length as by-products of an arc-discharge evaporation of carbon in argon environment [2, 3].

Carbon nanotubes are one of the most commonly mentioned building blocks of nanotechnology. These nanotubes exhibit electrical conductivity as high as copper, thermal conductivity as high as diamond, strength100 times greater than steel at one sixth the weight. The important parameters of individual carbon nanotubes are the nanotube diameter and chirality [4]. Rolling the lattice at different angles creates a visible twist or spiral in the nanotubes molecular structure, though the overall shape remains cylindrical. There are three unique geometries of carbon nanotubes. The three different geometries are also referred to as flavors. The three flavors are armchair, zig-zag, and chiral [4, 5]. Also the (n, m) index defining the orientation of the cut is called the chirality of the tubes. The nanotubes behave as metallic or semi-conducting depending upon the chirality.

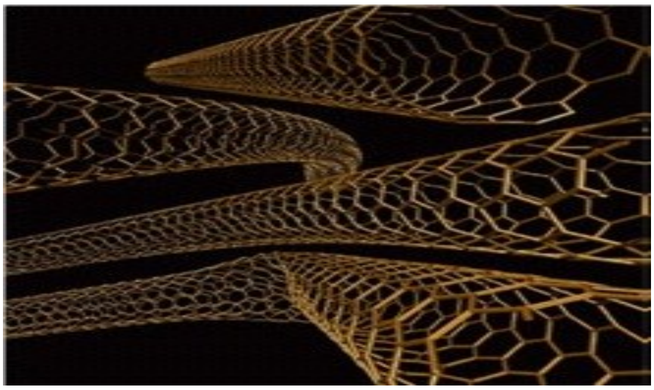

Fig. 1- Carbon nanotubes structure

The chiral vector (*n, m*) can be used to calculate the diameter of a carbon nanotube using the relationship [6, 7]

$$d = \sqrt{3}a_{c-c}\frac{(n^2 + nm + n^2)}{2\pi} \quad (1)$$

a_{c-c} being the nearest-neighbor atomic distance 1.421 Å for graphite (*n, m*) represent chiral vectors. *d* is the resultant diameter.

CNTs are classified as Single Walled CNTs, Multi Walled CNTs and Double Walled CNTs. A single walled CNT may be defined as a single rolled up sheet of graphene mainly consisting of hexagonal rings of carbon atoms in which the ends are capped by fullerene molecules [7, 8]. MWCNTs consist of multiple layers of graphite rolled in on them to form a tube shape with an interlayer spacing of 3.4 Å. It consists of concentric layers of grapheme [8].

Patch antennas have gained relative importance in communication industry for being low profile antennas, inexpensive, conformal and light weight. They are known to have polarization versatility making them useful for several integrated applications. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonance frequency [9]. A single patch antenna provides a directive gain of around 6-9dB while arrays can yield better performance provided that the antenna elements are well matched i.e. overall impedance matching is appropriate [9,10]. The paper describes the design of circular patch array.

Circular Patches

The circular patches are the next most preferable configuration after the rectangular patches in micro-strip antennas. They have attracted a lot of consideration as a single element as wel as in arrays [11, 12]. Circular patches are also termed as circular disks.

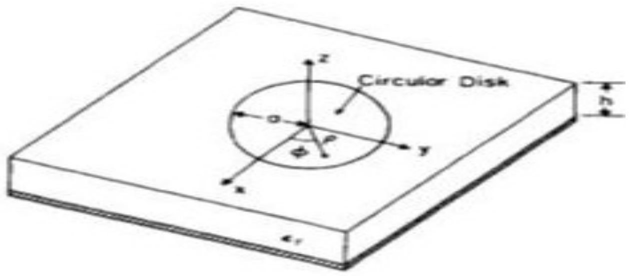

Fig. 2- Circular Disk

Electric field within the substrate has only z component and the magnetic fields have r and f components. Here *a* represents the radius of the circle. The resonant frequency can be given by the relation [12, 13]

$$f_{nm} = \frac{\chi_{nm}.c}{2\pi a_e\sqrt{\varepsilon_r}} \quad (2)$$

Where, c is velocity of light and a_e is effective radius which is taken into account for the fringing effects and c_{nm} is the m[th] zero of derivative of Bessel function. Further the effective radius (a_e) for a given mode TM_{11} is given as [13]

$$a_e = a\{1 + \frac{2h}{\pi a \varepsilon_r}\left(\ln\frac{\pi a}{2h} + 1.7726\right)\}^{1/2} \quad (3)$$

Fig. (2) Circular disk patch design offer performance similar to that of rectangular patches. There are certain applications in which these disk arrays yield superior results than other configurations [14]

Design

The antenna is usually designed on substrates such as RT Duroid [14]. The antenna proposed has design on a cotton substrate whose dielectric constant is taken to be equal to 2.7. The antenna operates in the Industrial, Scientific and Medical (ISM) band at a frequency of 5.8 GHz. Though there are several frequency ranges in the ISM band, the one which is being utilized is in the range (5.725-5.875) GHz with 5.8GHz being the centre frequency. The design has been created using simulation tool FEKO. It is a 4-element array. The height and the dielectric constant of the substrate are 1.57mm and 2.7 respectively.

Design Parameters

Fig. (3) single circular disk's diameter (D) is 18.0796mm and has been calculated using the standard formulae. The input impedance is 50Ω. The antennas elements should be properly matched so that the power fed at the feeding point is appropriately delivered to the antenna. A proper matched circuit yields minimum mismatch losses. So characteristic impedance (Z_c) of the transmission line can be calculated using [15],

$$Z_c = \begin{cases} \frac{60}{\sqrt{\varepsilon_{reff}}}\ln\left[\frac{8h}{W_0} + \frac{W_0}{4h}\right], & \frac{W_0}{h} \le 1 \\ \frac{120\pi}{\sqrt{\varepsilon_{reff}}\left[\frac{W_0}{h} + 1.393 + 0.667\ln\left(\frac{W_0}{h} + 1.444\right)\right]}, & \frac{W_0}{h} > 1 \end{cases} \quad (4)$$

Where, W_0 is the width of the micro-strip line. The value of the effective dielectric constant for "W/h>1" is given by [15]

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-\frac{1}{2}} \quad (5)$$

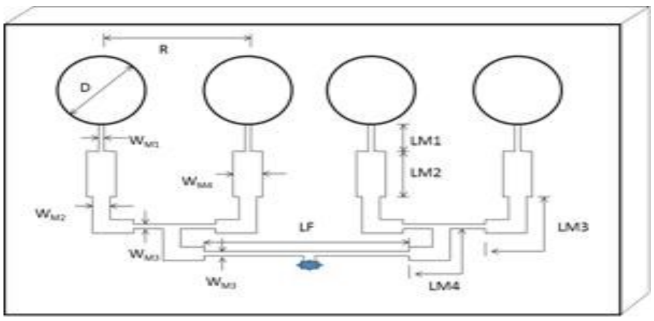

Fig 3- Dimensional view of the antenna

Table1- Parameters and their values used

Parameter	Value	Parameter	Value
LM 1(mm)	8.8392	WM 1 (mm)	0.2570
LM 2 (mm)	8.8392	WM 2 (mm)	1.7252
LM 3 (mm)	8.9252	WM 3 (mm)	1.1689
LM 4 (mm)	8.8439	WM 4 (mm)	2.4272

Simulation and Results

Simulation results show that the antenna is a dual band antenna radiating at two frequencies, 5.562GHz and the other one being 6.031GHz. The graph below of S11 indicates that the antenna radiates at two frequencies below the -10 dB level.

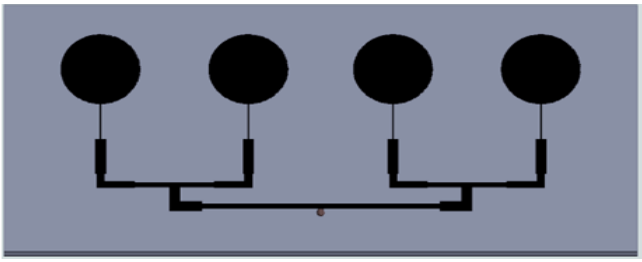

Fig. 4- Antenna designed in FEKO

Return Loss (S11)

S11 represents the input port voltage reflection coefficient. For efficient operation of antenna, this value should be lesser that -10 dB.

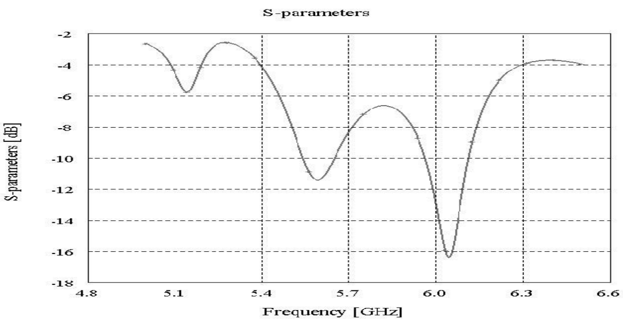

Fig. 5- Graph of S11 Vs. Frequency

VSWR (Voltage Standing Wave Ratio)

VSWR is defined as the ratio of standing wave maximum voltage to standing wave minimum voltage. Fig. (**7**) shows the variation of VSWR with frequency. It is a similar measure of port mismatch to return loss. It is always a real number and greater than or equal to 1. A VSWR of value 1 indicates no mismatch losses.

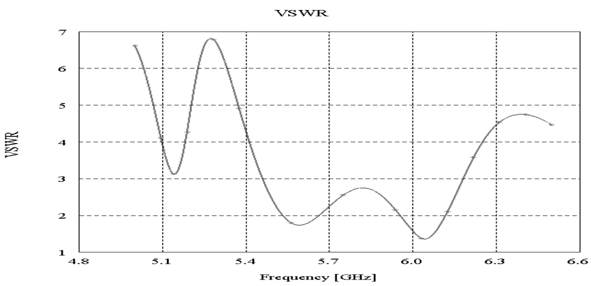

Fig. 6- VSWR vs Frequency

Gain

It is observed that gain at frequency 5.562 comes out to be 6dB while the gain at frequency 6.031GHz is more than 10dB.

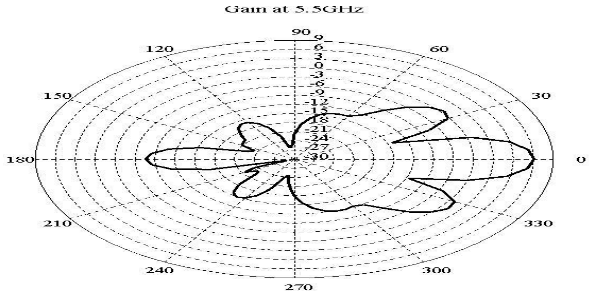

Fig. 7- Gain at 5.5GHz

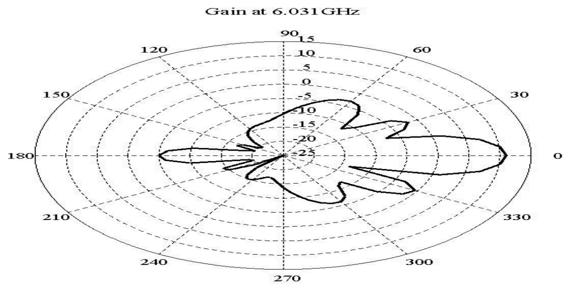

Fig. 8- Gain at 6.031GHz

Efficiency: Following graphs in fig. (**9**) and fig. (**10**) indicate that at both the radiating frequencies the antenna delivers an efficiency of 70%.

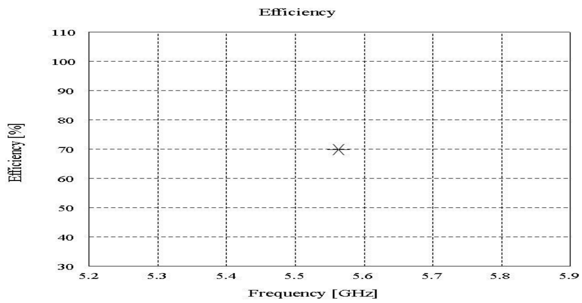

Fig. 9- Efficiency at 5.562GHz

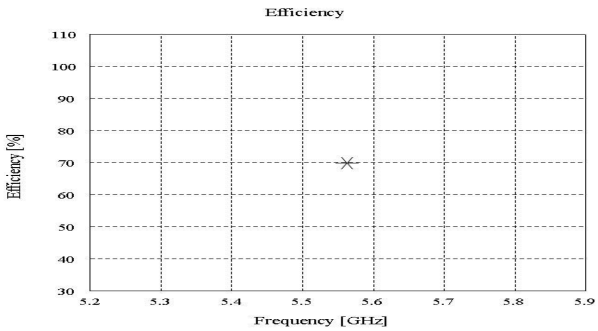

Fig. 10- Efficiency at 6.031GHz

SAR (Specific Absorption Rate)

Since the proposed antennas are to be worn in the vicinity of human body, the radiations should have lesser effect on human body. For that SAR is calculated. SAR is the rate at which the RF energy is absorbed by the human body. SAR values for this specific design comes out to be -.2415W/kg

Conclusion

The last decade of research has shown that indeed the physical properties of nanotubes are remarkable. A carbon nanotube is an extremely versatile material. It is hard to think of another material that can compete with nanotubes in versatility. The antenna thus designed can be used for human body communication as well as tracking. Further work can be done to improve the size of the antenna making it smaller.

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