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# Multiwalled carbon nanotube-based patch antenna for bandwidth enhancement

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ABSTRACT

A novel carbon nanotube (CNT)-based rectangular microstrip antenna for wide impedance bandwidth applications has been designed and developed. The copper patch commonly placed on the substrate in a conventional rectangular microstrip antenna is replaced with a CNT patch prepared using spin coating. The MWCNT patch antenna was fabricated by spin coating method and it exhibits an increased impedance bandwidth of 20%. The enhancement of the impedance bandwidth does not affect the broadside radiation characteristics. The carbon nanotubes are highly conductive nanomaterial. Due to this unique property, each nanotube present on the surface resonates electromagnetic waves individually and influences the enhancement in the bandwidth. The simple design and fabrication of the proposed antenna can be employed for synthetic aperture radar applications.



## 1. Introduction

Carbon nanotubes (CNTs), experimentally discovered in the early 1990s by Iijima, are among the most commonly investigated building blocks in nanotechnology [1]. They have been used in several research fields to utilize their unique physical properties. The AC conductivity and electromagnetic wave interactions of conductive CNTs are superior to those of traditional conductors, such as copper, of the same size. Recently, several studies investigating the possibility of using multiwalled CNTs (MWCNTs) as patch antennas [2–4] have been reported based on different numerical analysis and modelling approaches [5–10]. CNTs are particularly attractive in nanoscale electronic applications because they show excellent mechanical, electrical, and thermal properties [1,2]. The use of MWCNT-based antennas in low-power communication devices, such as synthetic aperture radar (SAR), in harsh chemical and gas environments is of particular interest because antennas using conventional copper patches can become oxidized in such environments [5,11–15].

MWCNT thin-film patch antennas have been fabricated by using dispersed MWCNT solution. However, obtaining stable MWCNT dispersions is difficult because of the different forces present within the MWCNT bundles. At the nanoscale, van der waals interactions may significantly hinder the stability of CNT dispersions. Recently, many methods have been developed for dispersing CNT in ethanol by employing various chemical and mechanical modifications. Some unique nature of CNT thin film, such as ultra-thin thickness and soft nanoporous structure, have made the measurement process challenging. Therefore, obtaining accurate measurements of thickness of CNT thin films to evaluate the properties of the nanocomposites is critical [16]. These MWCNT-solution based thin film can be applied in several applications such as interconnections, microelectronic chips, transmission lines, and radio-frequency identification (RFID) microstrip patch antennas [4].

Bandwidth enhancement is a major requirement for the practical application of microstrip patch antennas. The challenges encountered in the development of nanomaterial-based radio frequency (RF) antennas are associated with the determination of the material resonance at lower frequencies and the formation of reliable electrical contacts with the nanomaterials to determine their performance; examining the RF response is also very challenging. These challenges impede the determination of the radiating properties of nanomaterials, and the RF applications of materials such as metallic nanofilms have not yet been investigated. Nanostructured MWCNTs exhibit several desirable electromagnetic and mechanical properties suitable for the design and development of microstrip patch antennas [5]. A highly uniform current distribution can be achieved using CNT-based antennas compared to those of traditional antennas comprising conventional metallic and dielectric materials, thereby enabling

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the production of an antenna with a greater bandwidth [19]. The MWCNT microstrip patch antenna exhibited the highest possible impedance bandwidth in the X-band frequency range.

In this study, we experimentally characterize the CNT-based patch antenna in which the radiating patch is composed entirely of MWCNT nanofilm. We discuss the design and fabrication of these structures and the properties of the obtained antenna. Three key issues are addressed: determining the best MWCNT formulation, investigating fabrication methods for MWCNT antennas, and testing the performances of the fabricated MWCNT antennas. We characterize the MWCNT antenna performance using a network analyser and an anechoic chamber.

## 2. Experimental

### 2.1. Materials

MWCNTs (CAS No 698849), sodium dodecyl sulphate (SDS), and ethanol were supplied by Sigma Aldrich. The ultrasonicator was supplied by Chemilabs, while the centrifuge device and FR4 sheet were supplied by Entuple Technologies.

### 2.2. MWCNT dispersion

We prepared a stable and homogeneous CNT dispersion by mixing the purified MWCNTs (98%) with an aqueous solution of ethanol in a 1:1 ratio by weight. In the second step, SDS, which exhibits a great capacity in dispersing CNTs in aqueous media, was used as a surfactant [10] to establish good interactions between the CNT walls and ethanol.

In order to obtain a stable good solution, the concentration of the CNTs was fixed as 0.1 mg $ml^{-1}$. An ultrasonicator was used for dispersing the CNTs. The key parameter employed for obtaining the stable solution was the amplitude of sonication for 8 h in a room-temperature environment i.e., 25 °C. After sonication, a CNT solution with the required viscosity was obtained Fig. 1.

Large CNT aggregates were separated from small aggregates through centrifugation. The ultrasonication and centrifugation cycle was repeated five times until no aggregates remained at the bottom of the vial. The homogeneous stable solution thus obtained was filtered. This solution was used for fabricating a thin film on the FR4 substrate by a spin-coating method Fig. 2.

## 3. Antenna fabrication and geometry

The microstrip antenna was fabricated using rectangular MWCNT patch. The MWCNT patch size was calculated based on the centre frequency of 10 GHz in the X-band frequency range of 8–12 GHz. The substrate and the ground plane used measured 30 mm × 30 mm. Fig. 3 depicts the antenna geometry. The detailed design parameters used are listed in Table 1.

The antenna was fabricated on an FR4 substrate with the relative permittivity of 4.4. Rectangular-shaped MWCNT patch geometry was first calculated theoretically for 10 GHz centre frequency over 8 GHz–12 GHz range. These antenna design parameters were transferred to the mask on the top of the FR4 substrate by laser lithography. Then, the MWCNT solution was coated on FR4 substrate with optimized spinning speed of 3000 rpm - 60 s in spin coating device. A Subminiature version A (SMA) connector was soldered to the copper microstrip feed line. The fabricated MWCNT patch antenna is shown in Fig. 3.

## 4. Results and discussion

### 4.1. CNT electrical conductivity

Conductivity measurement is an essential test when characterizing of MWCNT material. The conductivity of a material is highly sensitive to variations by factors such as temperature, humidity, and thickness; therefore, the stability of these parameters is important for providing repeatable evaluations of the material properties.

To measure the electrical conductivity of MWCNT material, two probes provide the current path and another two determine the voltage. This configuration is the so-called four-point probe measurement. The four-point probe approach provides more reliable test results compared to the conventional two-point probe

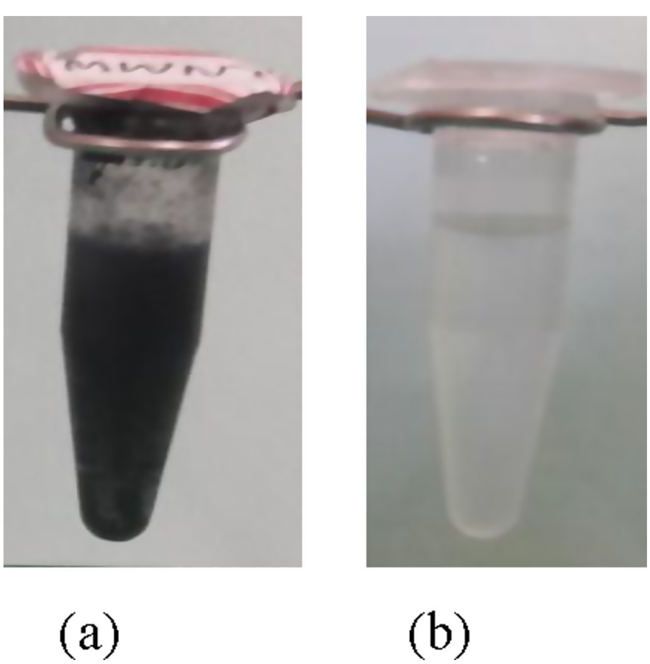


**Fig. 1.** (a) Solution of MWCNT, (b) Aqueous solution of ethanol with SDS.


**Fig. 2.** Spin coating device.