PRELIMINARY DESIGN AND CHARACTERISATION OF A NOVEL T-SHAPED NANO-ANTENNA ON DIAMOND LIKE CARBON MATERIAL

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Abstract

The rapid growth of nanotechnology has led to the development of many devices with advanced characteristics such as high frequencies Gunn diodes, transistors, nano-antennas etc. Nano-antenna applications are numerous and encompass a variety of fields such as broadband communications, imaging, sensing, energy harvesting, and disease diagnosis. In this research paper, A novel T-shaped nano-antenna was designed and its resonant frequency was analysed. Moreover, parametric investigation had been performed to figure out the effects of T-shaped nano-antenna on Diamond Like Carbon (DLC) material. The momentum model in Advanced Design System (ADS) software was used to simulate the novel T-shaped nano-antenna and the results were directly compared to other nano-antennas. Initial results suggests that the T-shaped nano-antenna had a higher bandwidth and smaller geometrical size when compared to the other nano-antenna at Terahertz frequency.

Index Terms

T-shaped antenna, resonant frequency, diamond like carbon material and bandwidth.

1.INTRODUCTION

Antennas are widely used in low frequency part of the electromagnetic spectrum, but recently nano-antennas have been explored up to visible range [1][2][3]. There is a wide range of antenna forms that are able to accommodate the stated operating frequency or may be scaled correspondingly for recommended operation.[4][5][6][7].

On the other hand, a greater number of designs feature a wide surface space which may not proper for suitable applications, while a few designs may not be appropriate because of the bandwidth limitations. [8]. Accordingly, the main objective for the present design was to resolve a compact nano-antenna which can provide the recommended impedance and gain achievement over frequency [1 THz−5 THz].

The design of an antenna working at optical frequencies is not a straightforward task, due to the inherent nature of the optical radiation and to the dispersive properties of the materials in such a frequency range. Following the previous works by Alu´ and Engheta [9][10][11], from an electrical engineering perspective, a possible way to design nano-antennas consists in adapting the concepts commonly used at radio and microwave frequencies to the design of optical nano-antennas. Such an approach has been successfully employed in the case of simple nano-antennas,such as the nano-dipoles and nanodimers [9][10][11], this is also applicable for more complex radiators, such as the bowtie[12], the spiral [13], and the Yagi-Uda[14] antennas.

The concept of the design was to realise a radiating device which is able to generate several resonances in the operating spectrum to obtain ultra-wideband performance. The proposed nano-antenna has a novel T-shaped that is capable of preserving a low profile and fitting in a tiny area and gaining resonances for wideband performance at the same time. The following stage of the design was to focus on further improvements for the overall performance. Section III will focus on the major steps for enhancing the propsed T-shaped nano-antenna on DLC substance by utilising momentum model in Advanced Design System (ADS)[15]. The structure was designed to achieve the circular polarisation in terahertz frequencies. The novel T-shaped nano-antenna was found to have higher bandwidth and return loss when compared to the other nano-antennas[16][17][18].

2.NANO-ANTENNA BACKGROUND

Antennas are vital devices in modern day communications. The first era of antennas began from the first test of an antenna done by Marconi in 1897. He sent the world's first ever wireless communication over Bristol Channel and sent a Morse code from Flat Holm Island to Lavernock Point in Penarth (a distance of 3.7 miles).

Antennas at that time were wires which were used for transmitting and receiving radio waves. Later in 1992 [19],researchers improved the design of microwaves antennas which facilitated the production of a variety of new structures (e.g. microstrips, apertures, phased-array radars)[20]) which had reduced size as this depends on the wavelength of the frequency in question.

The normal size of antennas working in radio and microwave frequencies starts from a hundred metres to a few millimetres[21]. Shrinking antennas below this range (ie. into the nanoscale) is the area of focus for this work. Consequently, these devices operate in the optical regime are also known as optical antennas.

Until the tools and methods were developed to fabricate devices at the nanoscale scale (largely within the semiconductor industry), it is only now that the capabilities and potential applications of nanoantennas can be truly explored [22]. Nanotechnology can be defined as the utilisation of scientific knowledge to design, fabricate, control and use matter at the nanometer scale (about 1100 nm). At this scale size, different characteristics and phenomena can emerge[23] and it is also applicable to microwave antennas to some extent.

3.DESIGN AND ANALYSIS OF A T-SHAPED NANOANTENNAS

A schematic view of the T-shaped nano-antenna is illustrated in figure 1 and 2. The nano-antenna has three layers; ground plate, dielectric medium, and the metallisation layer. The metallisation layer has a T-shaped with an inner length of L, thickness of T with a sectorial angle θ, the apex corner of the nano-antenna is straight fed from a 50 Ohm micro-strip line.

The structure of the nano-antenna can be fabricated on a dielectric substrate with a thickness of H and a relative permittivity sr . Using the electromagnetic package in ADS, the structure design was analysed by setting it up as a momentum model. Special care was conducted in choosing the mesh size to obtain sensible results and it is one of the specification for the high frequency antenna. In practise, the mesh size was limited by the available desktop computer. The nano-antennas were analysed on DLC material with a thickness of 100 nm and a relative permittivity of 2.615. The 50 Ω microstrip line had a width W of 60 nm and these were calculated by using the

ADS (line calculator). It was founded that by reducing the inner length L of the T-shaped nano-antenna, the resonant frequency was increased. The T-shaped nano antennas had superior performance over the bowtie antenna and it had a higher Q. In practical terms, it is difficult to calculate the length of a T-shaped nano antenna for a particular resonant frequency. Separate work was carried out and polynomial equations relating to radius and internal angle for the nano antennas were obtained. The simulated result for a T-shaped nano antenna having an inner length of 400 nm and sectorial angle of 60 degree is shown in figure 3. The simulated results show that the T-shaped antenna was resonating at 1.3 THz and 3.3 THz with a operational bandwidth of more than 100% performs significantly better than the traditional nano-antenna. Simulated gain and directivity performance for T-shaped nano antenna is shown in figure 4, which shows that a gain of 1.8 dBi at 1.3 THz and 1.1 dBi at 3.3 THz and it has almost flat response thought out the majority of the frequency. A typical radiation pattern for the novel T-shaped nano-antenna is shown in figure 5 . The antennas were designed to radiate in broad side i.e. perpendicular to the axis of the patch. The main beam is sharp between 90° and 270° while minimum in between 0° and 180°. Figure 6 verifies the designed antennas directivity. Figure 7 shows even more precise graph of radiation pattern shown by Electro Magnetic Design Solver, which is an extension of ADS.

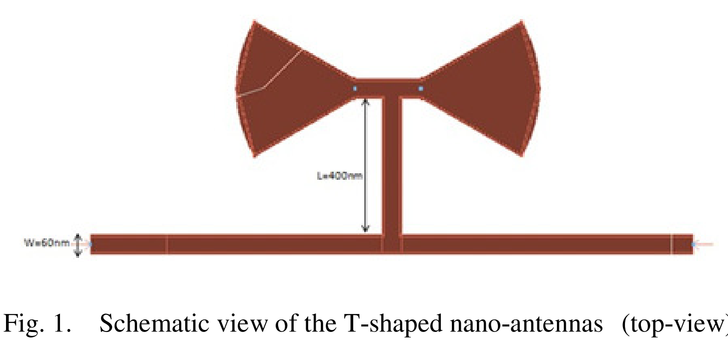

Fig. 1. Schematic view of the T-shaped nano-antennas (top-view)

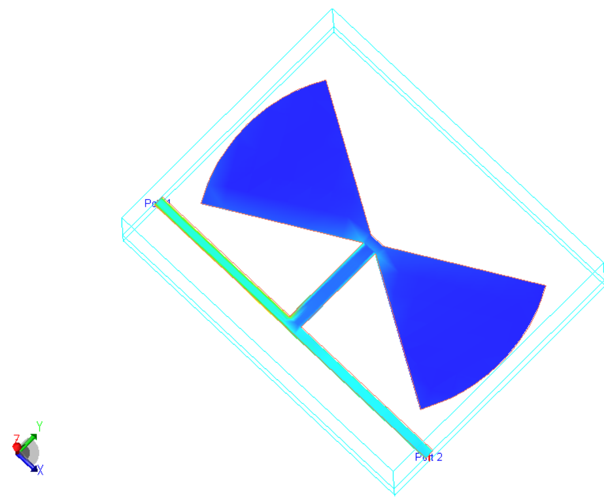

Fig. 2. Schematic view of the T-shaped nano-antennas (angular-view)

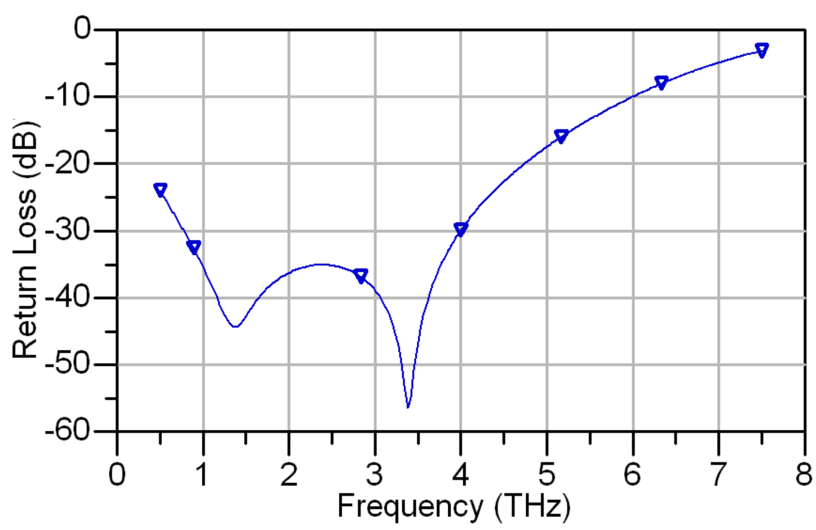

Fig. 3. Simulated return loss response of the designed T-Shaped nano-antennas

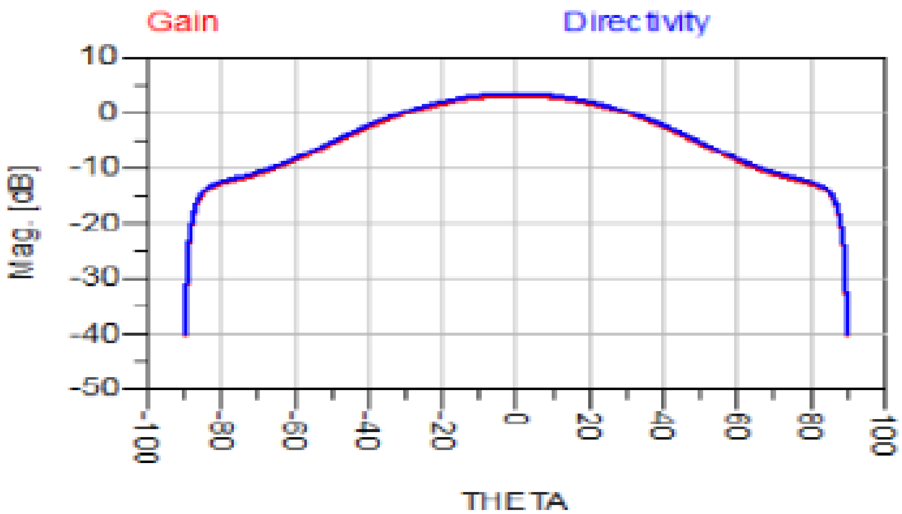

Fig. 4. Gain and directivity of the T-shaped nano-antenna

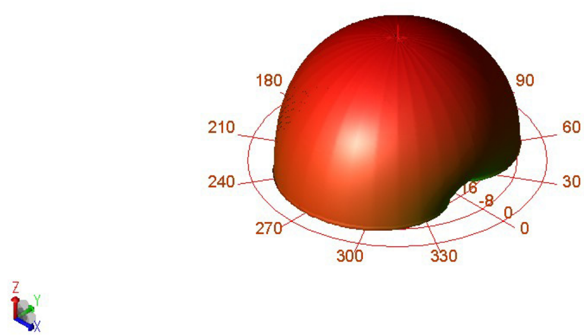

Fig. 5. Front view of 3D directivity pattern

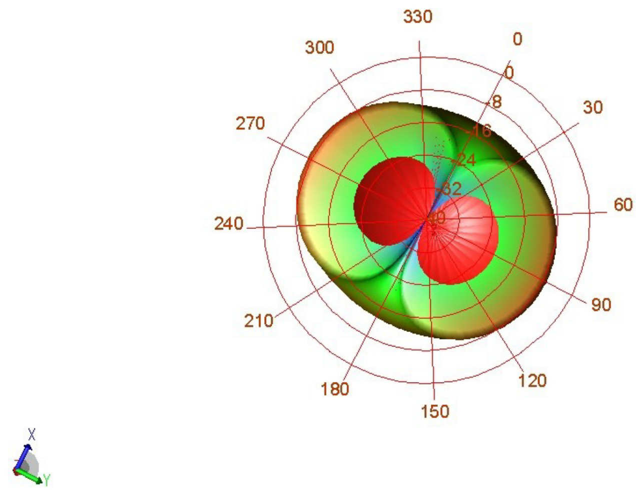

Fig. 6. Opposite view of 3D directivity pattern

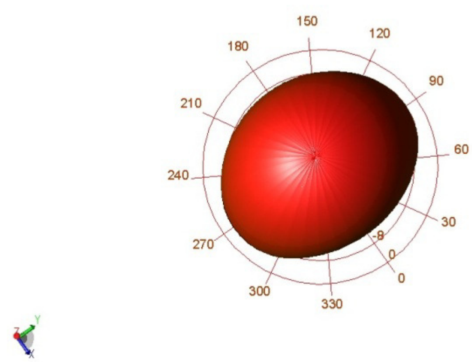

Fig. 7. 3D Radiation Pattern in EMDS

4.CONCLUSION

This paper describes a novel T-shaped nano-antenna on DLC material. The novel T-shaped nano-antenna was designed and analysed by using momentum model in ADS software and the simulations results were directly compared with other nano-antennas. The results indicate that the novel T-shaped nano-antenna had a smaller physical size and higher bandwidth when compared to the other nano-antennas at terahertz frequency.

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