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Double Port MIMO Antenna for THz Applications using Graphene Patch

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ABSTRACT

In this paper, a concept for Microstrip Patch antennas are presented. The antenna has a working frequency of 1.8-2.9 THz and a dielectric constant of 4. SiO_2 is the substrate material. THz band communication will make it possible to use new applications, easing the wireless systems. Antennas are designed using CST simulation software. The designed antenna could be used for data transmission, spectroscopy, and a variety of sensors. The performance analyses of the S-parameter, Reference impedance, and total efficiency are calculated.

Key words : Tera Hertz (THz), Microstrip Antenna, CST

1. INTRODUCTION

The THz band is being extensively investigated to meet the need for faster data transmission rates in wireless communications. Edholm's rule states that the past few decades, wireless data speeds have typically doubled every 18 months and are now quickly catching up to the capability of wired infrastructure for communication [1]. The channel capacity needed for the next generation of communication systems will be at least 100 Gbit/s due to the ever-increasing demand for bandwidth, necessitating the use of larger frequency range for data transport [2]. The introduction of the least-studied communication spectrum, the terahertz range can meet this requirement. This band's electromagnetic spectrum spans the microwave to mid-infrared range. In comparison to optical transmissions, this band supports a faster data throughput, a wider bandwidth, and less attenuation [3]. Broadband, high spatial resolution, large data rates, and secured data transmission are all made possible by communication systems that operate at Terahertz frequencies (THz)[4]. Microstrip patch antennas would be suitable for this situation because miniaturization is a necessary prerequisite for THz range devices. It is also planar and simple to integrate with other MMICs. But it has some significant flaws, including a limited bandwidth, low gain, and weak power handling [5].

In the foreseeable future, the Terahertz Band (0.1–10 THz) is expected to meet the demand for Tbps wireless communications [6]. A variety of applications, including videoconferencing in high resolution between portable electronic devices in small cells or extremely quick huge data transfers between adjacent devices, will be made possible by In order to alleviate the spectrum shortage and capacity constraints of present wireless systems, THz Band communication will be used. Additionally, new networking paradigms at the nano scale, such Wireless Nano Sensor Networks and the Internet of Nano Things, will be made possible by the THz Band. Above 10 THz, compact wireless technologies are unable to support Tbps links. Operating at infrared (IR) frequencies and higher are Free Space Optical (FSO) communication technologies have a very large possible bandwidth, however there are a number of difficulties that restrict the viability of these methods for personal wireless communications [3].

A promising material, graphene may find use in devices for the terahertz spectrum, wireless nano-sensors, high-frequency transistors, modulators, and organic electronics. Due to certain extremely intriguing characteristics, such as mechanical flexibility, dynamic tuning, integration with graphene RF active electronics, and downsizing, graphene is being used in antenna design [7,8]. Microstrip patch antennas are appropriate in these circumstances since miniaturization is a fundamental prerequisite for terahertz range equipment. The traditional patch antenna, which uses copper as the patch conductor, has a number of drawbacks, including a limited bandwidth, low gain, and poor power handling [9].Metallic antennas are excellent for microwave frequencies, however they have limits due to their limited conductivity at higher frequencies. Therefore, finding metal replacements for various THz-frequency devices is necessary [10].

The research is being pushed toward 2-dimensional (2D) materials as a result of the limitations of metallic devices [11]. One of the most well-known 2D materials is graphene, which is made from graphite [12,13]. The primary benefit of employing graphene is that it can have its conductivity customised through doping during production or by using an external electrostatic DC voltage [14,15]. The carbon allotrope known as graphene is tightly packed into a hexagon-based, two-dimensional (2D) honeycomb structure. It has incredible optical and electrical characteristics [16]. Graphene-based devices with cutoff frequencies in the Terahertz band are made possible by the higher carrier mobility of graphene. Because graphene is built with dimensions of only a few micro-metres and enables Surface Plasmon Resonances (SPR), it has the potential to emit electromagnetic waves in the THz band [3]. Modern technology is currently using systems with multiple inputs and outputs (MIMO) at microwave frequencies to accomplish the increased data transfer rate[17]. Either raising the channel bandwidth or the input signal strength will enhance the data transmission rate. [18].

Multiple antennas are present on the transmitter and receiver sides of MIMO technology, which enables simultaneous transmission and reception of large amounts of data. Numerous advantages will be possible with MIMO technology [19]:

1. Increase the data rate since several antennas allow for simultaneous data transfer from many users, increasing processing capacity.
2. Enhanced Reliability The radio signal could travel along numerous independent paths thanks to the numerous antennas.
3. Increase energy efficiency by directing the base station's energy emissions in the general direction of the terminals.
4. Less interference sincea the base station can decide not to transmit in areas where doing so would cause interference to spread.

Currently, the communication industries want antennas to function at a distinct band while being lightweight, inexpensive, and capable of excellent performance. A Microstrip antenna [20] is used to boost the MIMO channel's capacity. It offers a number of benefits low weight, conformal to the surface of objects, low profile, and ease of manufacture. Numerous Microstrip patches of different forms, including square, rectangle, ring, disc, triangle, elliptic, and pentagonal, have been designed for use in wireless applications [21]. Communication standards require MIMO antennas because they enable the sent signal characteristics. Adaptable to take into account the millimeter of the wave's effects [22]. 10-100 times the bandwidth may be achieved using a MIMO antenna system compared to 4G and LTE communication systems [23].

2. ANTENNA DESIGN AND MODELLING

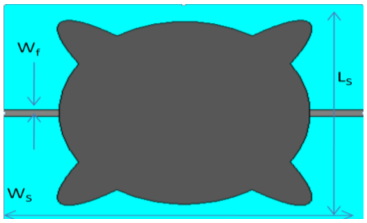

Figure 1: The design-1 of a graphene patch antenna with two port MIMO

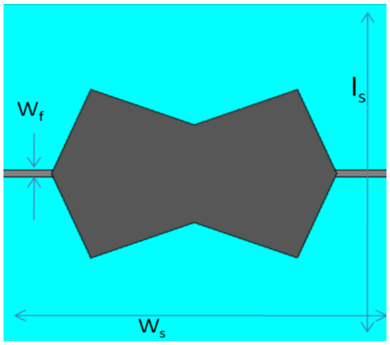

Figure 2: The design-2 of a graphene patch antenna with two port MIMO

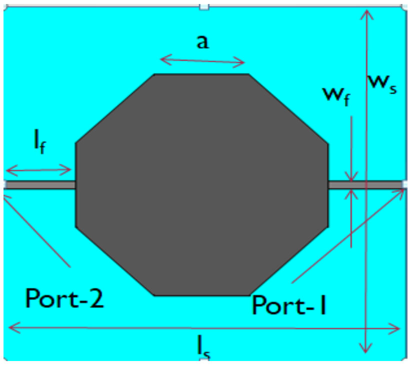

Figure 3: The design-3 of a graphene patch antenna with two port MIMO

Table 1: Dimensions of antenna structure

Parameter	ls	ws	hl	h2	lf	wf	a	b	t
Dimension	60	60	1.6	1.6	23	1.4	36	16	0.0002

Table 2: List of symbols

L_S	SUBSTRATE LENGTH
W_S	SUBSTRATE WIDTH
H_1	SUBSTRATE-1 HEIGHT
H_2	SUBSTRATE-2 HEIGHT
W_F	FEEDLINE WIDTH
A	PATCH LENGTH
B	PATCH WIDTH
T	PATCH THICKNESS

Figure 1,2,3 depicts the design of a graphene patch antennas with two port MIMO Two substrates make up the structure of the proximity coupled antenna. Table 1 shows the dimensions of the antenna. The antenna structure's substrates are made of silicon dioxide, which has a relative permittivity of 3.8 at optical frequency. Above height h1 substrate-1 is the ideal electrical conductor that acts as the ground plane. The two nanostrip feedlines are positioned at the top of substrate-1. Another substrate-2 of height h2 is positioned in between these feedlines and the antenna's radiating element in the proximity coupled structure.

The electromagnetic waves that fall within the terahertz range are those with wavelengths ranging from 3 mm to 30 millimeters, or 100 GHz to 10 THz. There are some special properties of light between radio waves and infrared. Terahertz can "look inside" things like paper and cardboard, textiles, and plastics. At frequencies between 0.1 and 5 THz, numerous bio-molecules, proteins, explosives, and drugs also possess distinctive absorption lines, or spectral "fingerprints." Thus, the penetration of conventionally opaque materials and the high chemical selectivity are the two main benefits of terahertz radiation.

In RF and microwave frameworks, the average framework impedances are 50 Ω and 75 Ω, which are additionally the trademark impedances of the standard coaxial transmission lines. The recieving wire impedance is much of the time the basic component restricting the data transmission of the radio wire. Impedance matching guarantees greatest productivity. Without legitimate coordinating, the radio wire turns into a chokepoint of execution because of decreased range, expanded power utilization and hindered information move. In an anechoic chamber. By supplying electricity to the antenna feed pads and gauging the effectiveness of the antenna, the strength of the electromagnetic field that is radiated into the surrounding space is determined. A high efficiency antenna, which typically radiates between 50% and 60% of the energy it receives, disperses the bulk of the power at the antenna's input (-3 to -2.2 dB).

Numerous MIMO antennas have utilized radiators made of metal and dielectrics at the microwave frequency. It is still necessary to conduct research and development on MIMO antennas for THz applications. Only two MIMO antenna designs have been used in the THz frequency range. The graphene and metamaterial radiating patch were utilized in the construction of an extremely massive MIMO antenna. The structural complexity is increased by the fact that this design requires a distinct feeding for each antenna structure component. This necessitates applying the gate voltage to each radiator separately. To achieve different radiation directions, certain radiating components are kept in a high conductive state while others are kept in a high resistive state. As a result, some antenna components remain redundant at a time, leading to an increase in antenna size. This necessitates the development of a MIMO antenna with a feeding strategy that is simpler to implement. For use in the THz band, a single radiating graphene patch and a proximity-coupled two-port MIMO antenna are suggested. The coplanar feedline and radiator are the most straightforward antenna geometry described in the literature as of the manufacturing location. The break at the feedline and radiating patch intersection, on the other hand, is a drawback of the coplanar antenna. This restriction of planar structures can be circumvented by the design of a proximity linked antenna. The proximity coupled antenna structure also has a wide impedance range thanks to the internal capacitance generated between the patch and feedline.

3. RESULTS AND DISCUSSION

3.1 Variation in length of the patch , a:

The impact of a modification on the S-parameter response is seen in Figure 2. The radiating graphene patch's aspect ratio (a/b) is determined by the variation in a which shows how the feedlines' fixed length affects the antenna's impedance matching. An acceptable impedance match is made for an impedance of 32m while the antenna is operating in single mode at a frequency of 2.5 THz. At 2.2 THz, a = 36 m exhibits a second higher order mode resonance, but the impedance matching is not particularly good.

3.2 Variation in width of the patch, b:

The antenna can be operated at the appropriate frequency between 2.0 and 2.5 THz by adjusting the value of b after choosing the patch length for effective impedance matching. B's variation is changed by changing the aspect ratio (a/b) maintaining a consistent to ensure that the antenna operates in a single mode, the graphene patch's aspect ratio is altered.

3.3 The height variation of substrate-1, h1:

The increase in h1 causes the frequency response to shift forward, while h1's moving of the frequency response is smaller than b's displacement, as shown and obvious that the isolation in the passband is larger than 25dB for all values of h1.

3.4 The height fluctuation of substrate-2, h2:

The substrate-2 height, or h2, is a crucial element that influences the field coupling between the feedline and radiating graphene patch. In order to keep S11 below 10dB, the value of h2 for the suggested antenna structure must be set to be between 1 and 2.5 m. There is good field coupling from the feedline to the graphene patch when h2 is set at 1.6 m. Compared to all other values in the plot, this value of h2 has the best impedance matching. Additionally, the isolation is greater than 25dB for this h2 value.

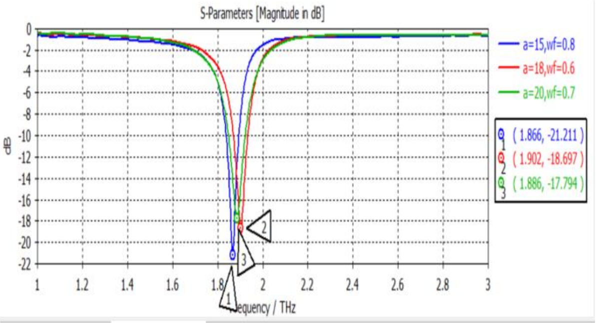

Figure 4: S_{11} parameter with variation in a, b and W_f for design-1

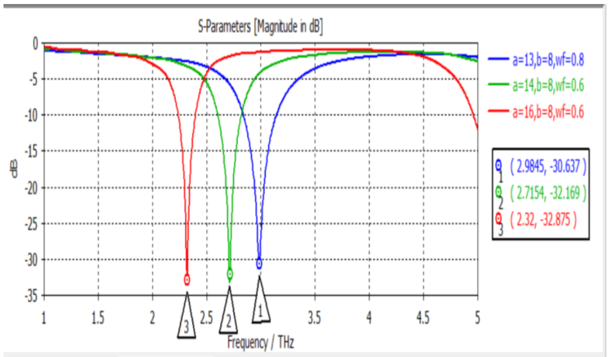

Figure 5: S_{11} parameter with variation in a, b and W_f for design-2

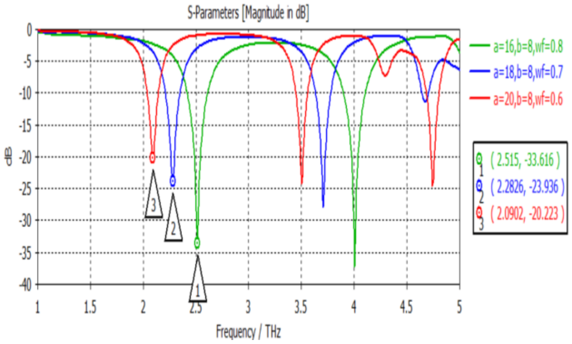

Figure 6: S_{11} parameter with variation in a, b and W_f for design-3

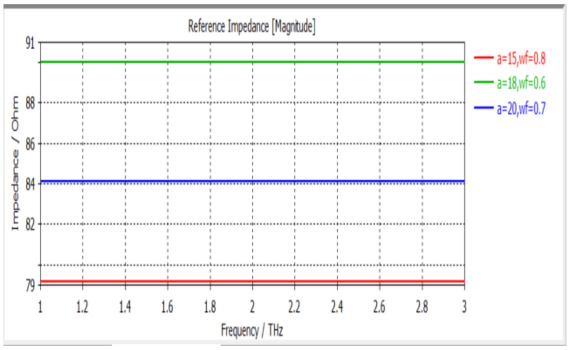

Figure 7: Impedance graph with variation in a, b and W_f for design-1

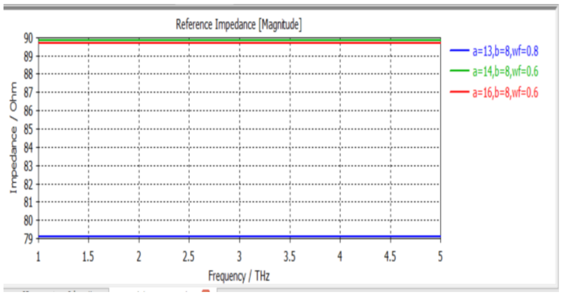

Figure 8: Impedance graph with variation in a, b and W_f for design-2

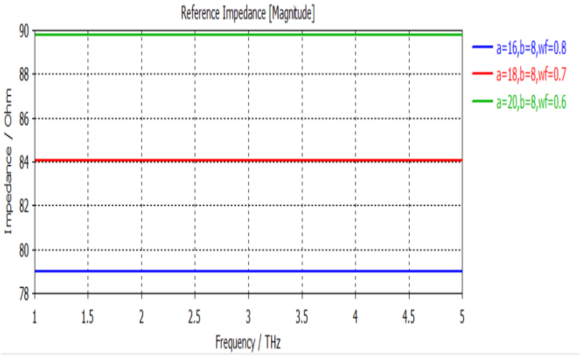

Figure 9: Impedance graph with variation in a, b and W_f for design-3

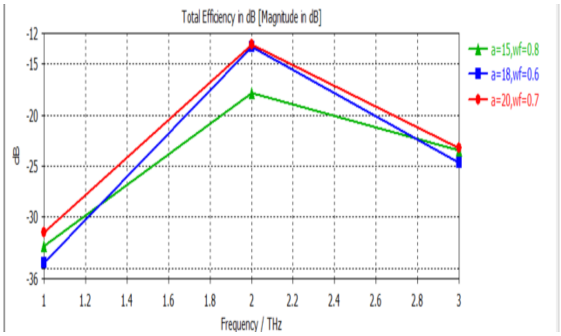

Figure 10: Efficiency graph with variation in a, b and W_f for design-1

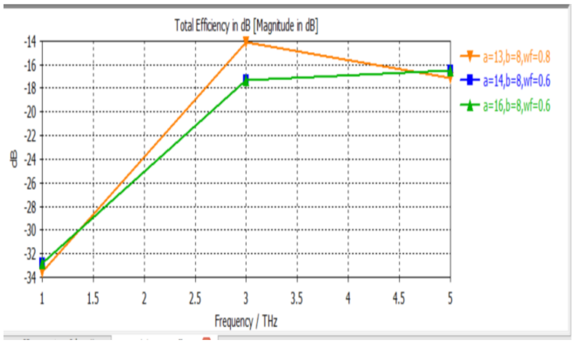

Figure 11: Efficiency graph with variation in a, b and W_f for design-2

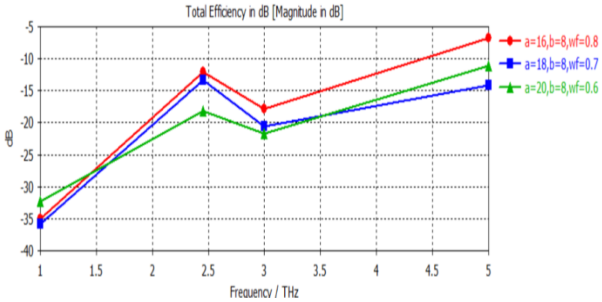

Figure 12: Efficiency graph with variation in a, b and W_f for design-3

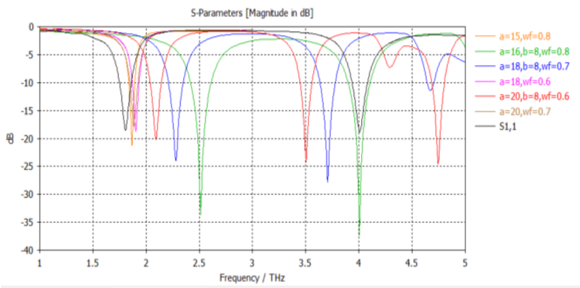

Figure 13: S_{11} comparison of all designs

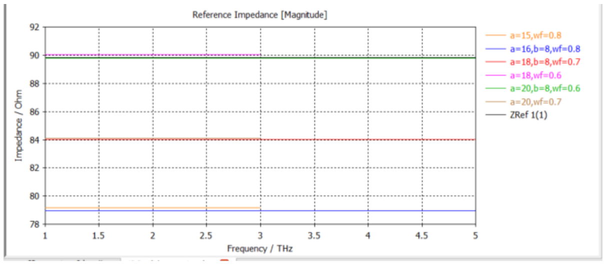

Figure 14: Reference Impedance comparison of all designs

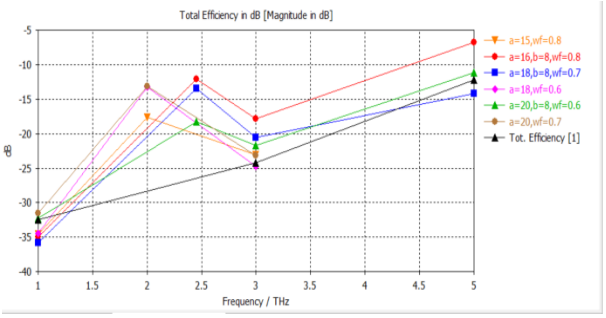

Figure 15: Efficiency comparison of all designs

From Figure 4,5,6 we can conclude that increase in ‘a’ value and decrease in ‘wf’ decreases the frequency and magnitude, decrease in ‘a’ value and increase in ‘wf’ increases in frequency and magnitude.

From Figure 7,8,9 we can conclude that decrease in ‘a’ value and decrease in ‘wf’ increases the impedance and increase in ‘a’ value and decrease in ‘wf’ decreases the impedance.

From Figure 10,11,12 we can conclude that increase in ‘a’ value and decrease in ‘wf’ value decreases the total efficiency. Decrease in ‘a’ value and increase in ‘wf’ value increases the total frequency.

Figure 13,14,15 shows the comparison of all the designs

4. CONCLUSION

Different Antenna designs were implemented and parametric analysis is done and is compared with the existing system. Existing system has a Frequency of about 1.82THz, Reference Impedance is about -74db and Efficiency is about -34db. The implemented designs have Frequency in the range of (2-2.5THz) and (1.86-1.92THz) and reference impedance is around 90db and efficiency is around -35 to -36db. All the above approximations are observed. The proposed design can be used in wireless communication systems where there is a requirement of higher data transfer rate.

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