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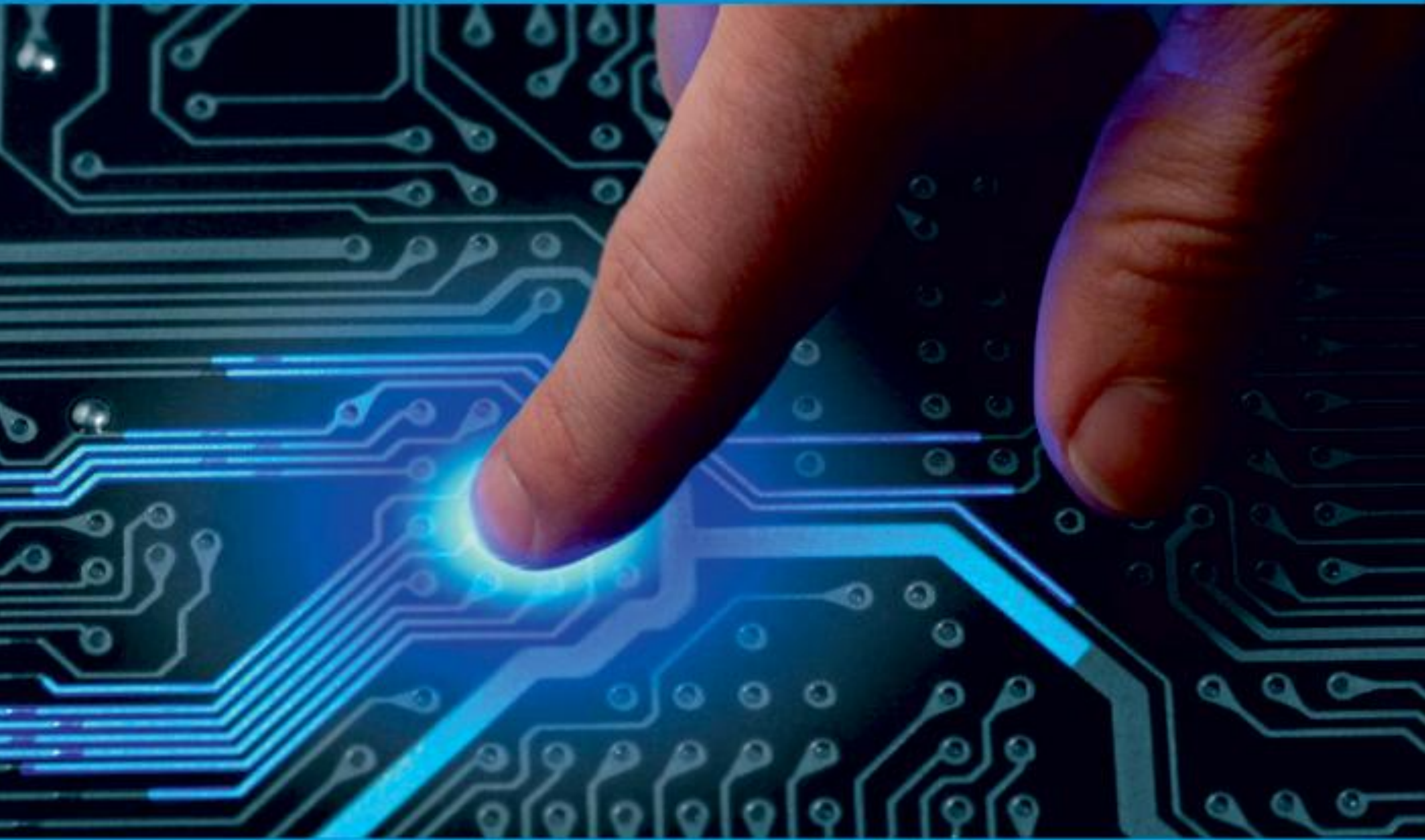

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Design and Simulation of Miniaturized Wide Band Microstrip Antenna for High Speed Thz Applications using Graphene Material

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ABSTRACT: Over the past decades, in wireless communication widely used material is graphene, particularly in terahertz applications due to its amazing characteristics. This paper presents microstrip patch antenna based on graphene material operates at 0.625 THz operating frequency for faster data rates in wireless communication. The proposed graphene based antenna shows 14.4% impedance bandwidth ranging from 0.58 to 0.67 THz at the resonance frequency 0.625 THz. The simulation results are demonstrated in terms of reflection coefficient (S11 < -10 dB), voltage standing wave ratio (VSWR), impedance, E-field and H-field radiation pattern, surface current distribution, gain, directivity and radiation efficiency are analyzed. Using a full-wave electromagnetic CST microwave studio simulator which is based on the time domain finite difference method, the designing and simulation of antenna are performed. The designed antenna offers good impedance matching characteristics shows a minimal return loss -13.32 dB, VSWR 1.55, and good radiation pattern at 0.625 THz. The proposed THz antenna would be exemplary choice for future high-speed wireless communication as well as imaging system, homeland defense system, sensing, detection of explosives, and material characterization in THz applications.

I.INTRODUCTION

In recent years, wireless technologies created a revolutionary growth for the necessity of inexhaustible bandwidth to meet high data rate, channel capacity. In electromagnetic radiation whose frequency lies between the microwave and infrared regions of the spectrum is terahertz radiation. Wireless communication for next-generations requires massive data traffic rate facility for different electrical devices. Day by day demand for high-speed data transmission is increasing and will reach limit of wired capacity very soon [1]. A special frequency band ranges from 0.1 to 10 THz called as terahertz frequency band is one of the possible solutions to achieve high-speed data communication [2]. The technologies operated in THz frequency band are having an expeditious development to support many high prospective applications like remote sensing, chemical detection, medical diagnoses, agriculture field, astronomy, ultra-fast wireless communication system etc.

In free space an antenna that transmits and receives plays a major role in wireless communication. The terahertz system performance directly depends on antenna performance [3]. The numerous advantagesof the THz waves like the wider usable frequency band, higher spectral resolution, lower diffraction, and better anti-interference performance as compared to millimeter waves are supported by THz spectrum. Radiation of most of the radio frequency antenna or microwave antenna are using copper conductor. The copper conductor implemented in terahertz frequency range is difficult for this low mobility and lower conductivity [4].The microstrip antennas have various advantages like low-cost, compatibility, and reliability which can be harnessed for the terahertz wireless communication by designing the terahertz microstrip antenna of order of few microns.Riboflavin or Vitamin B-2 is an important B-vitamin that is found in different variety of foods. A deficiency of vitamin B-2 is having manifested to increase susceptibility of humans to be who are having poor iron assimilation, an etiology link to anemia, and as a risk for cancer.The presence of these vitaminscan be detected using terahertz radiations as the peak absorption frequencies of these vitamins act as their fingerprints. So the designs of highly efficient compact antennas are of earnest concern to compensate for high path loss energy at THz regime.

In the THz devices and wireless communications, the invention of graphene is a breakthrough. Recently, in several educational and industrial researches in the THz regime has attracted extreme attention towards graphene [5]. The most popular applications in wireless communication are graphene-enabled filters, modulators, absorbers, waveguides,

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resonators and phase shifters. However, the graphene-based antenna gives interesting applications in THz frequency regime [6-11]. Using Kubos formula graphene surface electrical conductivity can be determined [12].
Total electrical conductivity of graphene is summation of inter-band and intra-band conductivity. The conventional antenna and graphene-based antenna both are different for their unique electromagnetic formation procedure [13]. Recently, graphene is preferred as a conductive material for low energy consumption, high charges motilities, current-voltage linear characteristics, low channel electrical resistance, dispersion of linear energy, and fermi velocity by researchers. For high frequency operations it is also a compatible material. In frequency-dependent behavior the conductivity of graphene changes from microwave frequencies to THz frequency range [14].The graphene material comprehensive characterization have chosen for implementing the proposed antenna for their considerable electrical, physical, mechanical, and optical properties. The default material property of CST microwave studio software is used in the designed antenna.In recent antenna designs several studies have performed in THz frequency band for different applications in wireless communication. Nickpay et al has been presented a wideband graphene-based antenna, [15] using silicon dioxide (SiO_2) substrate at 1.06 THz resonance frequency. Impedance bandwidth of proposed antenna is of 26% with the return loss of -24 dB at 1.06 THz operating frequency. Likewise Younssi et al has been investigated on rectangular microstrip patch antenna using RT/Duriod 6006 substrate [16]. This antenna is larger in size 1000 x 1000 x 200 μm^3 which is exhibited as 22.7% of impedance bandwidth. Nejati et al has been implemented a photonic band-gap structure-based patch antenna [17] on the Pyrex substrate. Dimensions of this antenna has larger in size 500 x 500 x10 μm^3 having 33% of impedance bandwidth. The fishnet –based metamaterial loaded patch antenna has been reported by Sirmaci et al [18] for terahertz applications using a Quartz substrate. In this proposed antenna the bandwidth of -10 dB has been found 8.2%. Dhillon et al [19] has been implemented a rectangular microstrip patch antenna with a small impedance bandwidth of 5.85% using a polyimide substrate for video rate imaging and defense application. Kushwaha et al has been implemented and analyzed a novel microstrip patch antenna using a polyimide substrate at 0.63 THz as resonance frequency.

In addition, different antennas in THz frequency bands for various application have been designed by different researchers. Their developed antennas either large in size or suffer from narrow bandwidth. Accordingly, to support high data rate at the THz spectrum further studies are required. In this paper, an effectual rectangular microstrip patch antenna is proposed and presented for remote sensing, spectroscopic detection and diagnostics, imaging system, material characterization, viruses, chemical detection, explosive detection, medical diagnoses, and ultra-fast wireless communication system. The proposed antenna has a wide impedance bandwidth of 14.4% ranging from 0.58 THz to 0.67 THz at center frequency 0.625 THz. However, the antenna performance has been demonstrated in terms of return loss, VSWR, input impedance, directivity, E-plane and H-plane radiation pattern, surface current distribution.

II. ANTENNA DESIGN AND CONFIGURATION

The rectangular microstrip patch antenna is a low cost, low profile, simple fabrication and capability of integration with electronic devices. To design a high-performance antenna a good understanding of various antenna parameters is required. Radiating patch, feeding technique, dielectric material with appropriate thickness, loss tangent and dielectric constant these parameters are included. The substrate material is place between the ground plane and radiating patch with the same length and width as that of ground plane.

The proposed antenna is designed by using Arlon 1000 substrate material with relative permittivity 10.2 and loss tangent of 0.0023 the substrate. The thickness of designed substrate material is 45 μm, length of 120μm and width of 120μm. The dielectric constant (ε_r) of the substrate material is direct effect upon the antenna size and performance. A rectangular radiating patch shape have 60 μm and 70 μm with the microstrip feed line, has been implanted over a substrate material. Using high conductivity copper and graphene materials, the ground plane and radiating patch of the antenna are designed. So, overall dimensions of proposed antenna is 120 x 120 x 45 μm^3, which is shown in Fig. 1. To feed the antenna different techniques, i.e., microstrip line, coaxial coupling, and proximity coupling are available. In the proposed antenna microstrip edge line feeding technique is used for ease of fabrication procedure and good impedance matching and radiation pattern. In this microstrip antenna a waveguide port excitation source is chosen. The geometric parameters of antenna are tabulated in Table 1.

$$\sigma_{intraband}(\omega,\mu_c,\Gamma,T) = -j\frac{e^2 K_B T}{\pi h^2(\omega - j2\Gamma)} \times \left(\frac{\mu_c}{K_B T} + 2\ln\left(e^{\frac{-\mu_c}{K_B T}} + 1\right)\right) \quad (1)$$

Where, h is Planck's constant, k_B represents the Boltzmann's constant and e is charge of electron.

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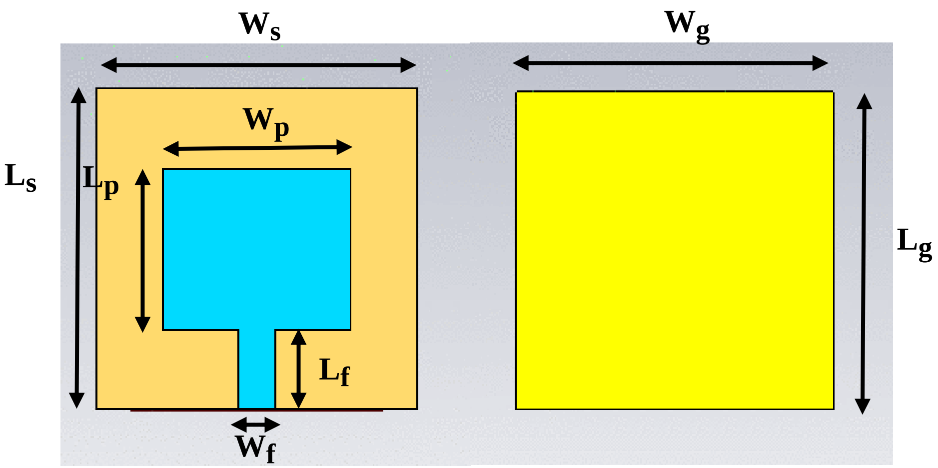
$$\sigma_{interband}(\omega,\mu_c,\Gamma,T) \approx \frac{-je^2}{4\pi h}\ln\left(\frac{2|\mu_c|-(\omega-j\Gamma)h}{2|\mu_c|+(\omega-j\Gamma)h}\right) \quad (2)$$

III.RESULTS AND DISCUSSION

The proposed antenna is simulates using electromagnetic simulation software CST (Computer simulation Technology) microwave studio. In terms of return loss, VSWR, input impedance, gain, directivity, E-field and H-field radiation pattern, surface current distribution and radiation efficiency the radiation characteristics of proposed antenna is designed and investigated.



(a) front view (b) back view

Figure 1: The perspective view of proposed antenna at 0.625 THz

Table: 1 Antenna Geometry Parameters

parameters	Dimensions (µm)
Length of the substrate (L_s)	120
Width of the substrate (W_s)	120
Length of the ground (L_g)	120
Width of the ground (W_g)	120
Length of the patch (L_p)	60
Width of the patch (W_p)	70
Microstrip feed length (L_f)	30
Microstrip feed width (W_f)	14

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Return loss which is measured in decibels (dB) is the ratio of incident power to the reflected power of the antenna. This return loss should be less than -10 dB and represented in S11 (dB) for an effective antenna. The simulated return loss graph of the proposed antenna is shown in Figure 2. The designed antenna has a reflection coefficient or return loss of -13.32 dB and bandwidth of 0.144 THz at the resonant frequency 0.625 THz. The wide impedance bandwidth of designed antenna is 14.4% ranging from 0.58 THz to 0.67 THz. Between the transmission line and antenna, impedance matching is the key factor to evaluate antenna performance.

VSWR (voltage standing wave ratio) defines how much signal is reflected back to the source due to mismatch between source impedance and antenna impedance. VSWR for the proposed antenna is plotted as shown in Figure 3. VSWR values always should be less than 2 for good impedance matching [20,21]. The signal reflected

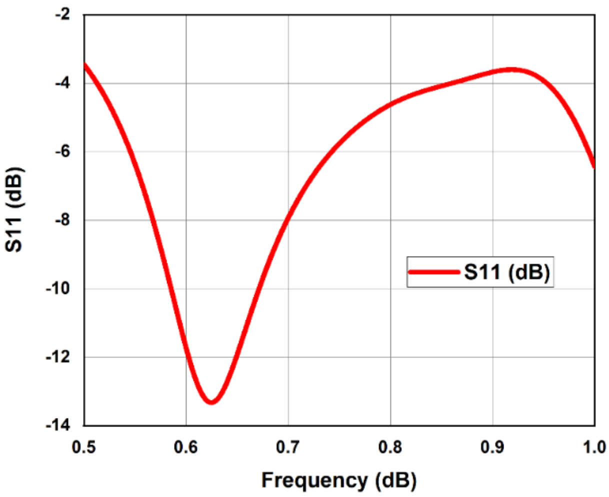

Figure 2: The return loss characteristics of proposed antenna at 0.625THz

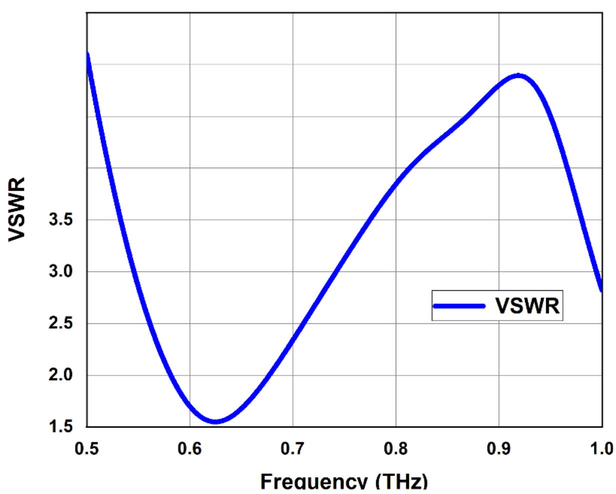

Figure 3: The VSWR characteristics of proposed antenna at 0.625THz

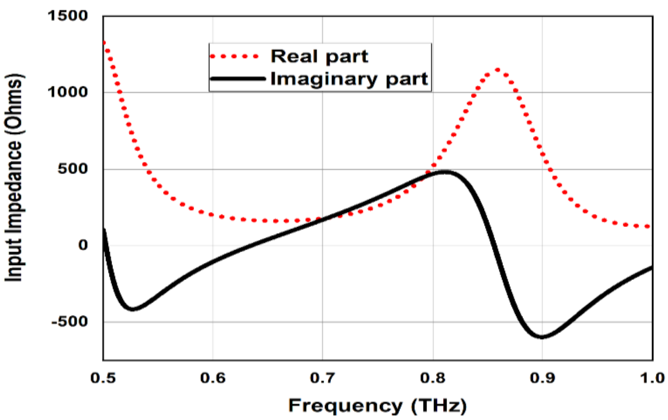

Figure 4: Input Impedance characteristics of proposed antenna at 0.625THz

cause standing wave voltage to be present in the feed where it degrades the performance of antenna. The proposed antenna VSWR has a value of 1.55 at resonance frequency 0.625 THz. Preferably, the value of VSWR should be equal to 1 which means 100% power accepted, and having zero reflection.

Input impedance versus frequency plot is important characteristic for the proposed antenna performance to evaluate it. Figure 4 shows the input impedance characteristic of the proposed antenna. It is defined as impedance matching between the input signal and feed line. The proposed antenna has input impedance of 172.09Ω in real part and -27.46 Ω in the imaginary part at operating frequency 0.625 THz. The impedance should be 50 Ω in real and 0 Ω in imaginary for perfect match between the input signal and feed line [22].

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Antenna gain is the ability of the antenna to radiate more or less in any direction compared to a theoretical antenna. The Gain describes how well the antenna converts input power into radio waves headed in a specified

direction. At resonant frequency 0.625 THz, the antenna has a gain value of –0.3 dB, the plot is achieved in Figure 5. Directivity is to evaluate the performance of antenna that defines the directionality of the antenna which is crucial parameter. At respective operating frequency 0.625 THz, the proposed antenna is having directivity of 4.88 dB. The plot of directivity is observed in Figure 6.

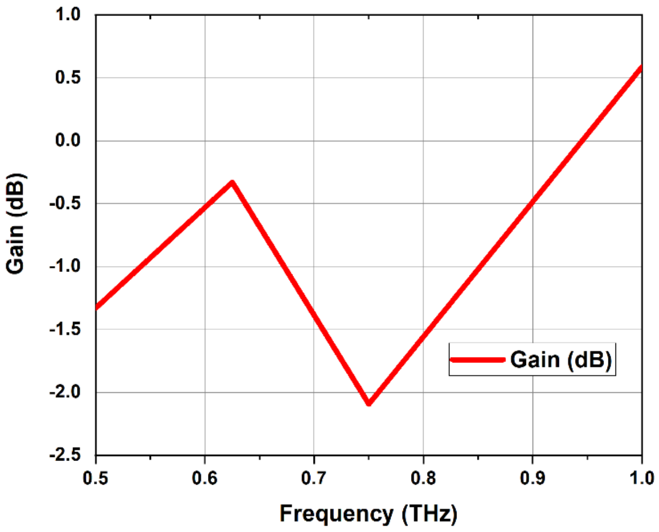

Figure 5: The Gain characteristics of proposed antenna at 0.625THz

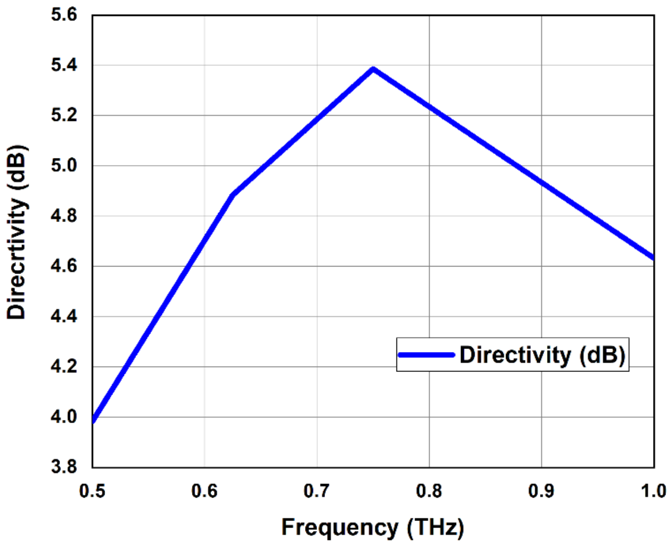

Figure 6: The Directivity characteristics of proposed antenna at 0.625THz

The radiation efficiency of an proposed antenna is defined as the ratio of power radiated in all direction to the total input power supplied to its terminals the radiation efficiency is achieved in Figure 7 shows that the better performance of the proposed antenna.

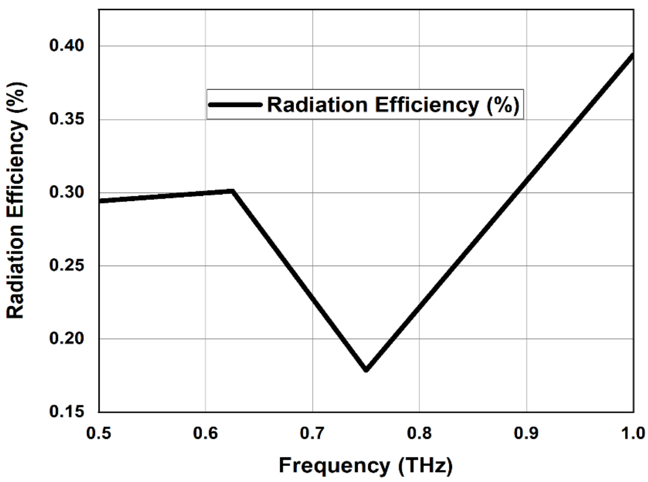

Figure 7: The radiation efficiency characteristics of proposed antenna at 0.625

The surface current distributions of the proposed antenna at the resonating frequencies (0.58 THz and 0.67 THz) are examined and presented in Fig. 8 at resonance frequency 0.625 THz. As observed, the distributed surface currents are

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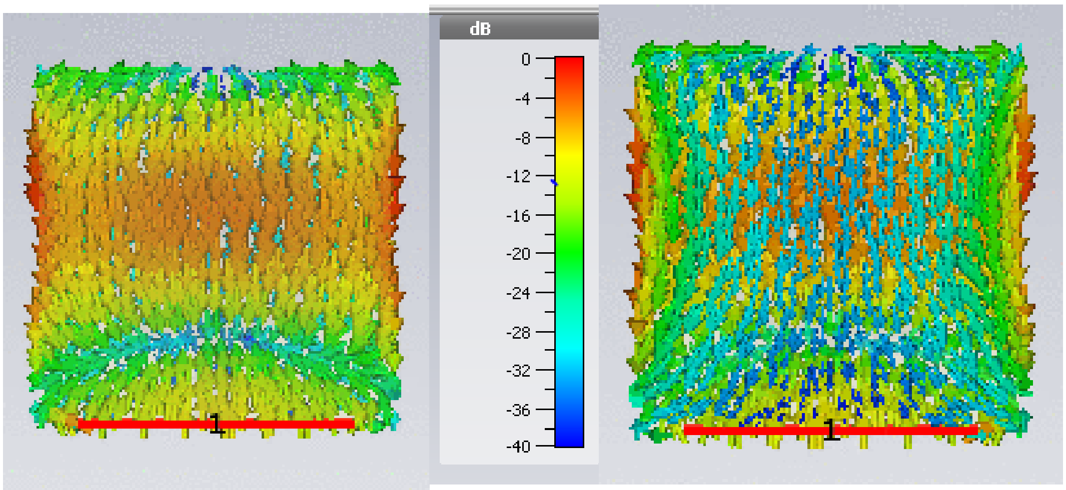
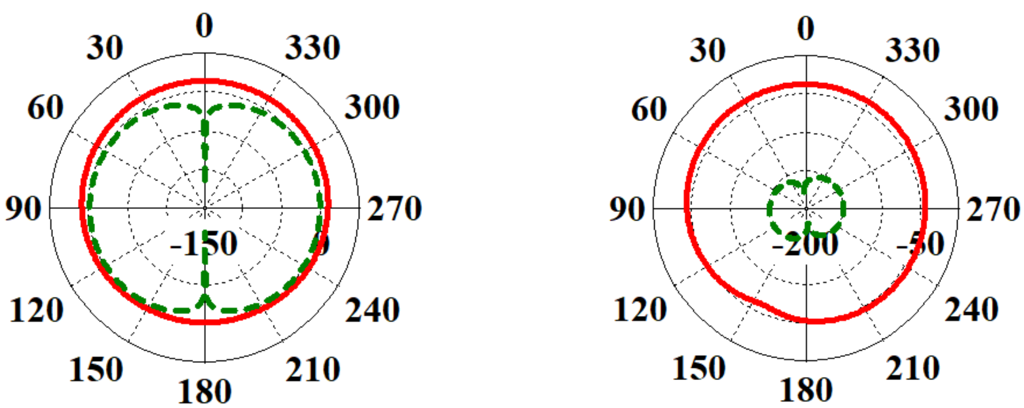
highly concentrated along the edge of the feed line. Also, a high surface current concentration is noticed on the edges of the proposed patch structure. However, the surface current distribution on the rectangular shaped structure is stronger and prominent at the higher resonant frequency which verifies its effect on the proposed antenna structure for the improvement of characteristics at the high resonance.



(a) Port Excited front plane (b) Port Excited back plane

Figure 8: Surface current distribution of proposed antenna at 0.625 THz

The radiation pattern in both E-plane ($\Phi=0^0$) and H-plane ($\Phi=90^0$) of the proposed antenna is depicted in Figure 9. The orientation of antenna in order to that bore-sight direction toward the vertical direction by varying theta (θ) from 0^0 to 360^0 for fixed value of phi (Φ). The magnitude of the main lobe magnitude, main lobe direction, side lobe level, and angular width respectively, are obtained at resonant frequency 0.625 THz. The antenna exhibits an almostbidirectional pattern in the E-plane and an omnidirectional circle-shaped pattern in the H-plane. However, changes are observed at the radiation patterns at a higher resonant frequency, 0.625 THz. The radiation pattern slightly deteriorates with the increase in operating frequency. At 0.625 THz, the E plane patterns look like a sectorial pattern with a shift in the direction of the main beam while the H-plane pattern is almost similar to omnidirectional oval-shaped.



(a) E- Field (b) H- Field

co polarization simulate — cross polarization simulated

Figure 9: Radiation pattern of proposed antenna at 0.625 THz

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The proposed antenna is compared with other reported terahertz antenna structure, which gives complementary results. The parameters considered for comparison of antenna is dimensions of antenna, return loss, percentage bandwidth, and substrate material. Hence, it is concluded that the proposed antenna has a wider bandwidth than the existing methods of antenna. The impedance bandwidth of proposed antenna is 14.4 % at 0.625 THz operating frequency. Which is compared and it is higher than the previous works. This large bandwidth in THz frequency band is good for future high-speed wireless communication. After comparing with other existing models of antenna in THz frequencies, the proposed antenna has good performance characteristics, small size and good impedance matching.

IV. CONCLUSION

A low-cost, compact and low-profile graphene based microstrip patch antenna is designed in this research. The simulation results demonstrates that the proposed antenna can operate from 0.58 THz to 0.67 THz at resonant frequency 0.625 THz, having 14.4 % impedance bandwidth. The maximum return loss is -13.32 dB has been achieved with a good radiation pattern. The maximum directivity is 4.88 dB, VSWR is 1.55 is obtained at 0.635 THz resonance frequency. The proposed antenna can also be used in various applications like imaging system, homeland defense system, sensing, detection of explosives, and material characterization in THz applications.

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