Graphene Based Terahertz Antenna Design for Medical Applications

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***Abstract*-The current research interest is growing in the Terahertz domain. Due to this, the researchers are also nurturing the THz Antennas the most. Micro strip patch antenna with a minor modification in the structural formation have been found helpful in designing the THz antenna. In this paper, the step by modification of THz antenna presented. The author aims to find a suitable THz antenna for medical applications. The performance of the antenna has been studied by the HFSS software and the comparisons of the patch antennas are analyzed.**

I. INTRODUCTION

The recent application in spectroscopy, medical science study, sensing and imaging study have been shifted in the THz frequency. The range of the THz frequency is within the Microwave and Infrared Frequency. This frequency have the nature of non-ionization. The penetration is high with attenuation in the low level. This signal also have high resolution in image quality. By the literature survey, it has been found that the material used coper, graphene, carbon-nanotube etc. The THz antenna with copper as the metal have been found to suffer with losses in propagation in that frequency. Also, it shows inefficiency in skin depth and conductivity at this frequency. The carbon is gaining its interest here as it can cure the losses showed by copper. Even graphene and carbon nanotubes are also in the queue to overcome the issues with the copper material. The graphene has been considered to be as infinite thin layer having a complexity in surface conductivity. The intraband and interband conductivity properties constitute the graphene sheet conductivity property. The material, graphene shows intraband and interband conductivity contribution as per the Kubo formalism[1]

$\sigma_{intra}(\omega, \mu_c, \tau, T) = -j[(e^2 k_B T)/\{\pi\hbar^2(\omega - j\tau^{-1})\}][(\mu_c/k_B T) + 2\ln(e^{-\mu_c/k_B T} + 1)]$

$\sigma_{inter}(\omega, \mu_c, \tau, T) = -(je^2/4\pi\hbar)\ln[\{2|\mu_c| - \hbar(\omega - j\tau^{-1})\}/\{2|\mu_c| + \hbar(\omega - j\tau^{-1})\}]$

where, $f_d(\varepsilon) = [e^{(\varepsilon-\mu_c)/k_B T} + 1]^{-1}$ is the Fermi Dirac distribution. Here, angular frequency is ω, energy is ε, j is the imaginary unit, chemical potential is μ_c, Temperature is T, k_B is the Boltzmann's constant, reduced Planck's constant is $\hbar$ and the relaxation time is τ.

Table 1 : The material properties of Carbon Nanotube

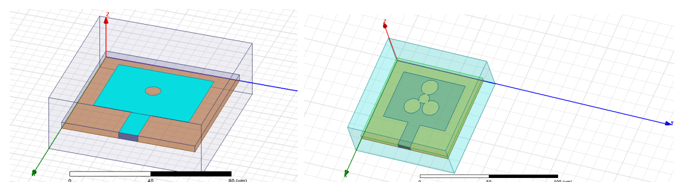
Parameters	Value
Thermal conductivity	3000 W m^{-1} K^{-1}
Current density	~ 10^9 A cm^{-1}
Electronic mobility	8 x 10^4 cm^2 V^{-1} s^{-1}
Tensile strength	50-500 GPa
Surface area	387 m^2 g^{-1}

The definition of THz wave is given by 0.1 to 10THz where 1THz = 10^{12} Hz with the corresponding wavelength range as 0.03 to 3mm. As per the IEEE the range is 0.3 to 10 THz. There has been some special characteristics of this THz i.e. Low value of single-photon energy compared to X-ray[2-7], THz possess high resolution spectral capability, it can be utilized for non-metallic and non- polar material scanning, wide bandwidth would be achievable using THz for communication[8,9].

II. DESCRIPTION

The proposed micro strip patch antenna has been designed considering a regular repetition of a shape. In our work, we have a circular cut on the patch and step by step the cuts are increased from one to four. The circle radius is having the ratio of 4:6.32 for the final design with four circles cut on the patch antenna. Before the proposed design the features of the graphene has been explored [10]. The proposed nano antenna can be manufactured by method of focusing ion beam (FIB) technique. Here the work has been carried out on micron scale. Now-a-days reconfigurable system is gaining its popularity. Our proposed design met with such features. The antenna will be a reconfigurable[11-13] one.

In our design we have taken one circular cut at the centre of the patch antenna and the proposed design shows a suitable frequency response at 8.341 THz. The antenna is shown in the figure 1(a), where a single circular cut will be clearly visible. The HFSS software[14] has been chosen for the simulation study. The patch antenna design is having graphene as the chosen material for the substrate.



(a) (b)

Fig. 1. The proposed patch antenna with single circular cut at the centre (a) and four circular cut, three cuts making centre with one circle at the centre (b)

The final version of the patch antenna with four circular patch is having the radius ratio of 4:6.32 with the centre circle. This patch antenna proposed geometry can be seen in figure 1(b) where the simulation model of the patch in HFSS software has been shown.

III. RESULTS

The VSWR vs frequency plot shows satisfactory results as per the frequency response of the proposed antenna at 8.341 THz. The VSWR vs Frequency and the S11 vs Frequency has been shown in the figure 2 and figure 3 respectively.

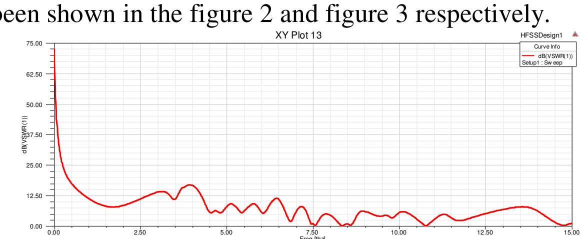


Fig. 2. VSWR vs Frequency plot for single circular cut

The S11 vs Frequency plot is showing satisfactory results at the proposed frequency. In the terahertz frequency band, it is very essential that the VSWR value must comply with the resonating frequency.

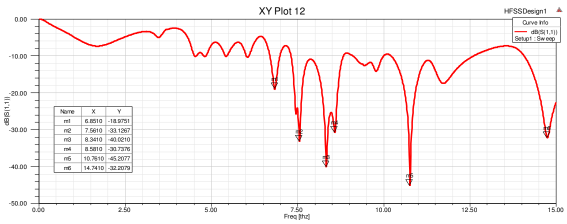


Fig. 3. S11 vs Frequency plot for single circular cut

The results with the four circular cuts has been outstanding with the resonating frequencies at 2.69 THz, 4.35 THz, 5.88 THz, 7.10 THz and 7.53 THz respectively. The comparative study[15] has been made in the following figure 4 and figure 5 for S11 and VSWR relations at the terahertz frequency.

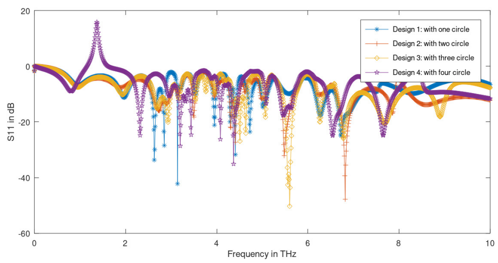


Fig. 4. Comparisons on S11 vs Frequency plot for the proposed designs

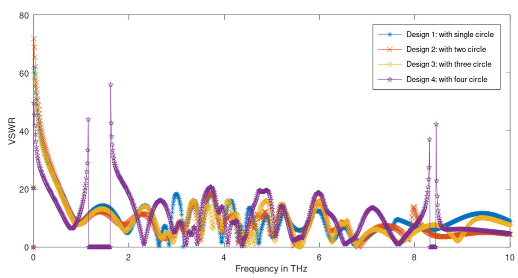


Fig. 5. Comparisons on VSWR vs Frequency plot for the proposed designs

The VSWR vs frequency and the S11 vs Frequency plot shows acceptable results of the proposed antennas. The proposed antennas may be utilized for the medical diagnosis as the

terahertz frequency have the capability to detect the non-polar, non- metallic detection. The directivity property of each of the antennas also has been studied. In figure 6 the results of the final antenna is shown where the directivity is suitable for the detection by the antenna.

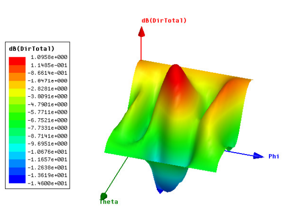


Fig. 6. Directivity plot for the proposed design with four circular cuts

IV. CONCLUSION

The analysis has been made on the simulation study of the proposed antennas. The recent trend of medical study is looking for a suitable detection tool in THz. The performance of the THz antenna is satisfactory for use in the medical applications. The THz antenna may replace the existing medical tools with its non-invasive and non-ionizing characteristics. The future work on this antenna will be to analyze the antenna radiation with the existing techniques with their radiation characteristics.

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