Simulation Study of Micro strip antenna for Terahertz Frequency Application

Arpita Santra*, Maitreyi Ray Kanjilal*, Moumita Mukherjee, Angsuman Sarkar

Abstract The microwave frequency has a wide range of applications. Now-a-days researchers are looking at the Terahertz frequency to find a solution for this un-nurtured frequency. It is gaining popularity due to its increased spectral bandwidth and increased data rate. The modern communication requirements may get a solution through the proposed planar inverted patch antenna operating between 2.30THz to 6.59THz. Four different designs are being considered here for the Terahertz antenna. In this work, the study on the terahertz antenna has been designed for the communication-based applications.

Index Terms— **Terahertz, VSWR, S11, wireless technology, gain, Directivity.**

I. Introduction

THE wireless data communications has been increased exponentially in the recent years. The speed of data transfer also has expected to reach in the Terabit per second speed by the next decade. The alternative to ultra wideband, millimeter wave, infrared or visible light may be considered as the terahertz. The terahertz can have the bandwidth enhancement. The serious issue of the high speed data transfer can be addressed by terahertz.

To scale down the device size the use of terahertz can significantly provide a new arena. Increase in frequency and corresponding decrease in wavelength will reduce the device size. The low profile design of the terahertz antenna may be suitable for use but may also suffer from path loss in due to attenuation by the atmosphere and absorption due to the sensitivity. Considering the mentioned issues, the proposed antenna has been designed for the less complex communication system in this terahertz domain. The terahertz frequency band is 0.1 THz to 10 THz.

This paragraph of the first footnote will contain the date on which you submitted your paper for review. It will also contain support information, including sponsor and financial support acknowledgment. For example, "This work was supported in part by the U.S. Department of Commerce under Grant BS123456".

The next few paragraphs should contain the authors' current affiliations, including current address and e-mail. For example, F. A. Author is with the National Institute of Standards and Technology, Boulder, CO 80305 USA (e-mail: author@ boulder.nist.gov).

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Antenna miniaturization and use of antenna for wireless applications has been increased from the last decade. In recent times the graphene has obtained a rich position in the recent advances. The author found that many researchers have tried to design with gallium nitride as the substrate for the design of the patch antenna [1]. The objective of the work is to find a suitable terahertz antenna for application in imaging and detection system for medical diagnosis. During the nCovid-19 pandemic times the people all around the world have faced many issues like costly medical diagnostics tests, unaffordable costs of some medical tests lead them to avoid the test and the result is of course not good. Many people died due to no medical support as no tests they can undergo. In government funded hospitals/ hospitals running under any charitable trusts/ Free health checkup camps are not in that much numbers available as well as the people are not getting the facilities of all kinds of medical diagnosis at a time from all of the mentioned places. Now have to think on it so that the entire mankind can be survived. The author here tries to find a suitable terahertz antenna for medical applications in the early detection and diagnosis. The terahertz frequency communication is a new dimension for the wireless communication. The antenna will attract special attention in the wireless technology [2,3].

1.1 Circular shaped patch antenna with one cut – C1

The terahertz frequency is till now not that much explored by the researchers. Many researchers are working on the back stage for a solution in this frequency range. To the best of the author's knowledge the designed patch antennas are the novel antennas in this terahertz frequency. The medical diagnosis in this frequency is getting special attention as the terahertz ray can be incorporated in the medical diagnosis and detection. As a solution to this the author have designed four different patch antennas with FR4 Epoxy as the substrate material [4,5]. The first designed antenna named as C1 is shown in the figure 1. The author has used the HFSS simulation platform for the simulation study of the antenna.

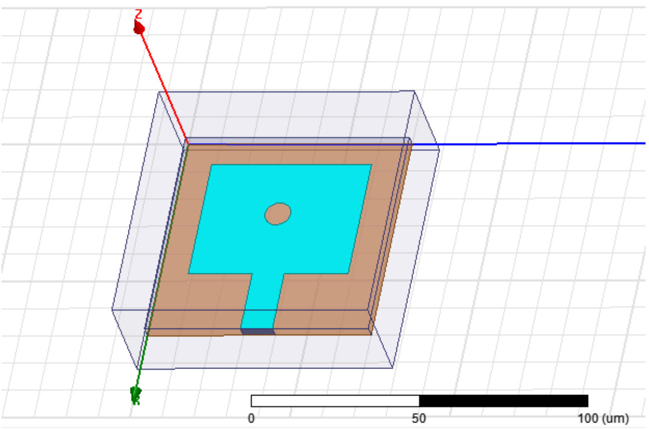

Figure 1 Simulated Patch Antenna in HFSS software as per design proposal C1

The simulated antenna is having one cut and it has been shown in the figure 1. The designed patch antenna shows considerable response at 6.841THz, 7.561THz, 8.341THz, 8.581THz, 10.761THz, 11.741THz and 14.741THz respectively.

1.2 Circular shaped patch antenna with two cuts – C2

The second design of the designed patch antenna is with two cuts has been shown in the figure 2. The simulated antenna with two cuts showed the frequency response at 2.770THz, 3.410THz, 3.650tHz, 3.970THz, 4.580THz, 5.130THz, 5.970THz, 7.060THz, 7.500THz and 8.630THz respectively.

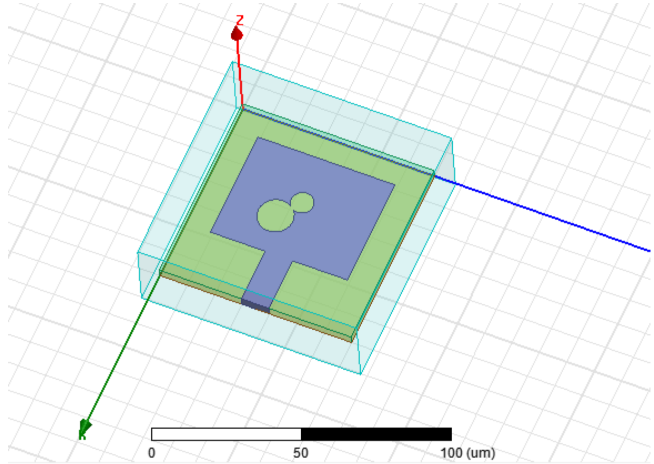

Figure 2 Simulated Patch Antenna in HFSS software as per design proposal C2

1.3 Circular shaped patch antenna with three cuts – C3

Another circular patch antenna with three cuts has been designed with the FR4 Epoxy as the substrate material. The simulated antenna in the HFSS platform has been shown in the figure 3. The frequency response of the antenna has been found at 2.770THz, 4.430thz, 4.620THz, 5.260THz, 7.150THz, 7.610THz and 7.990THx, 6.45THz, 6.67THz and 7.64THz.

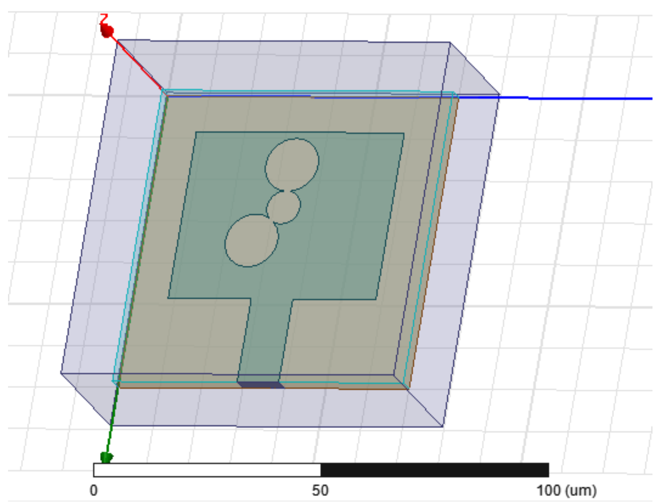

Figure 3 Simulated Patch Antenna in HFSS software as per design proposal C3

1.4 Circular shaped patch antenna with four cuts – C4

The fourth design of the simulated patch antenna is with four cuts has been shown in the figure 4. The frequency response has been found at 2.4THz, 6.02THz, 6.81THz, 7.39THz and 8.66THz respectively.

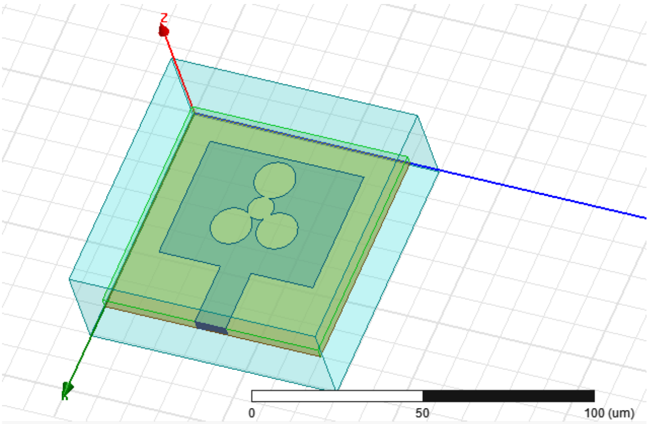

Figure 4 Simulated Patch Antenna in HFSS software as per design proposal C4

1. FR4 Epoxy as the substrate

The conductivity of the FR4 Epoxy is considered with a complex surface conductivity $\sigma_{ga}(\omega, \mu, \Gamma, T)$ where σ_{ga} is a function of which changes the surface conductivity of FR4 Epoxy for a tunable frequency. Here ω is the frequency of radiation, μ is the potential of the chemical doping, relaxation time = $(1/\Gamma)$ and T = temperature respectively.

The conductivity of the FR4 Epoxy is computed as intra-band and inter-band conductivity of the FR4 Epoxy and has been shown in the equation no. 1.

$$\sigma_{ga}(\omega, \mu, \Gamma, T) = \sigma_{intra}(\omega, \mu, \Gamma, T) + \sigma_{inter}(\omega, \mu, \Gamma, T) \qquad \ldots\ldots\ldots\ldots[1]$$

where, $\sigma_{intra}(\omega, \mu, \Gamma, T)$ is the intra-band conductivity of the FR4 Epoxy and $\sigma_{inter}(\omega, \mu, \Gamma, T)$ is the conductivity of the inter-band respectively.

II. IV. RESULTS AND ANALYSIS

The simulation results of each designed antenna has been shown in the following figures. The S11 vs Frequecy, VSWR vs Frequency, Gain and Directivity plots are satisfactory for the proposed designs.

A. *Circular single cut*

C1

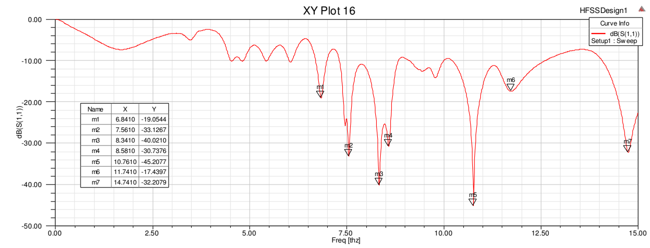

Figure 5: S11 vs Frequency plot of Simulated Patch Antenna in HFSS software as per design proposal C1

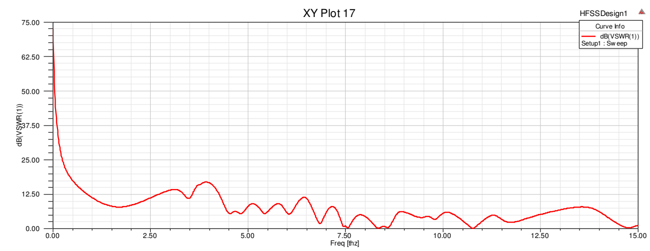

Figure 6: VSWR vs Frequency plot of Simulated Patch Antenna in HFSS software as per design proposal C1

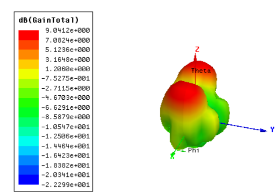

Figure 7: Gain of Simulated Patch Antenna in HFSS software as per design proposal C1

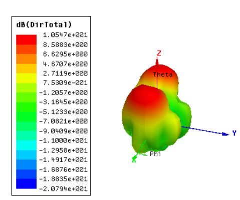

Figure 8: Directivity of Simulated Patch Antenna in HFSS software as per design proposal C1

B. *Circular Double cut*

C2

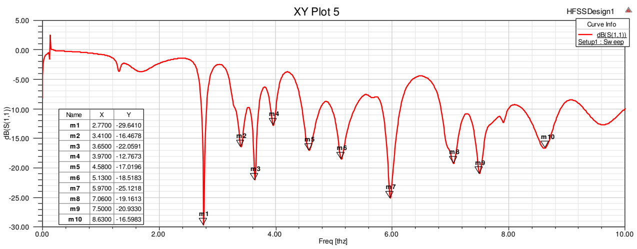

Figure 9: S11 vs Frequency plot of Simulated Patch Antenna in HFSS software as per design proposal C2

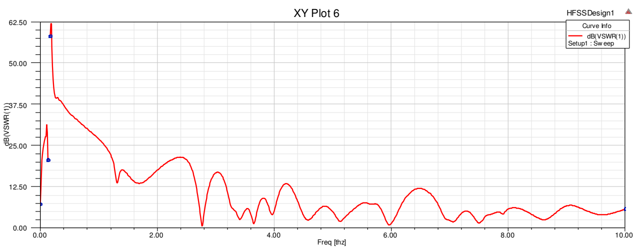

Figure 10: VSWR vs Frequency plot of Simulated Patch Antenna in HFSS software as per design proposal C2

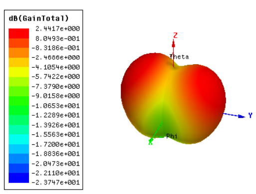

Figure 11: Gain of Simulated Patch Antenna in HFSS software as per design proposal C2

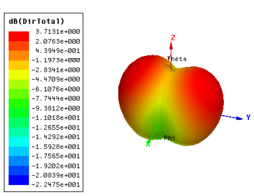

Figure 12: Directivity of Simulated Patch Antenna in HFSS software as per design proposal C2

C. Circular Tripple cut

C3

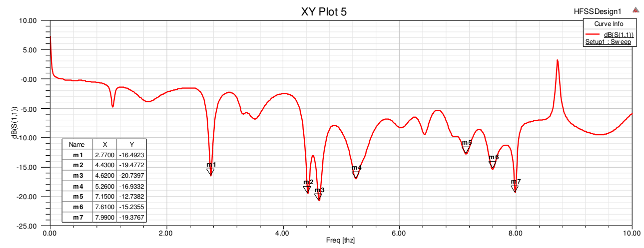

Figure 13: S11 vs Frequency plot of Simulated Patch Antenna in HFSS software as per design proposal C3

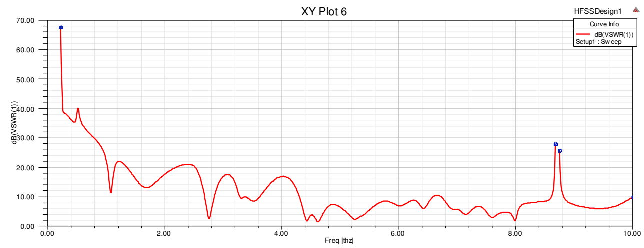

Figure 14: VSWR vs Frequency plot of Simulated Patch Antenna in HFSS software as per design proposal C3

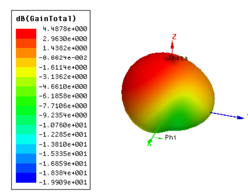

Figure 15: Gain of Simulated Patch Antenna in HFSS software as per design proposal C3

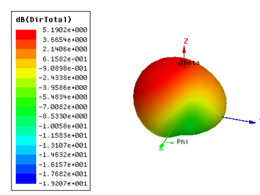

Figure 16: Directivity of Simulated Patch Antenna in HFSS software as per design proposal C3

D. Circular Quadruple cut

C4

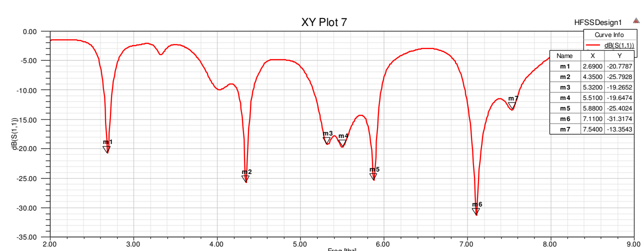

Figure 17: S11 vs Frequency plot of Simulated Patch Antenna in HFSS software as per design proposal C4

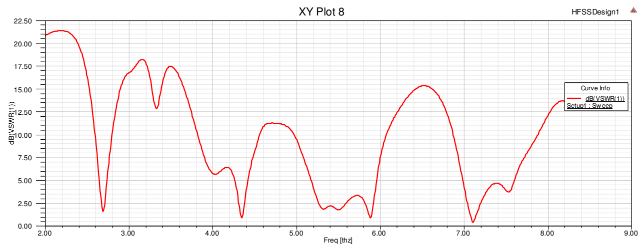

Figure 18: VSWR vs Frequency plot of Simulated Patch Antenna in HFSS software as per design proposal C4

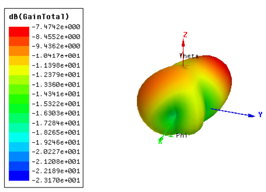

Figure 19: Gain of Simulated Patch Antenna in HFSS software as per design proposal C4

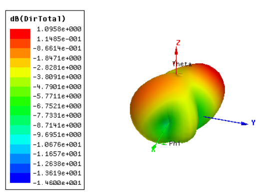

Figure 20: Directivity of Simulated Patch Antenna in HFSS software as per design proposal C4

Comparison of C1, C2, C3 and C4 for S11 vs Frequency:

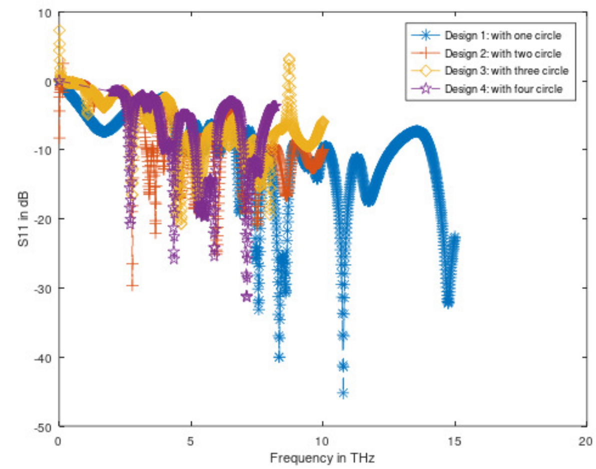

Figure 21: Comparison of S11 vs Frequency plot of Simulated Patch Antenna in HFSS software as per design proposals C1, C2, C3 and C4

Comparison of C1, C2, C3 and C4 for VSWR vs Frequency:

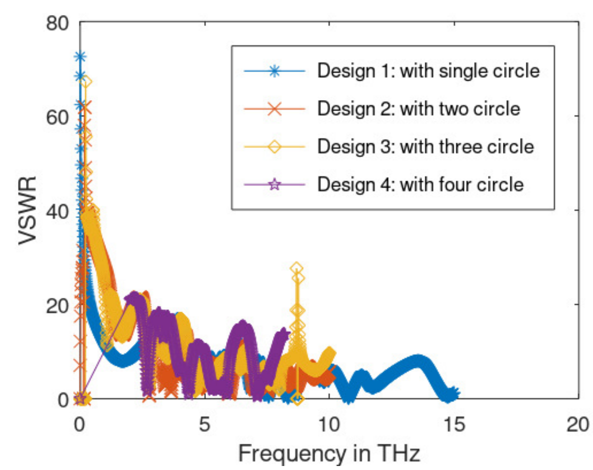

Figure 22: Comparison of VSWR vs Frequency plot of Simulated Patch Antenna in HFSS software as per design proposals C1, C2, C3 and C4

V. Conclusion

Among the simulated antennas, the design with four circular cuts give the better result to be useful in the terahertz frequency. The VSWR value is also showing satisfactory results for the frequency of use in all the four designs. The S11 vs Frequency plots are also acceptable for the proposed antennas. The simulation study of the antennas show that the proposed antennas will be reasonable to use in the terahertz frequency range and specifically the design C4 with four circular cuts show the best results among them all.

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