Novel Terahertz Microstrip Patch Antenna for detection of L-ascorbic acid and Thiamine hydrochloride

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Abstract *— Owing to the revolutionary development in the field of terahertz technology numerous advancement has taken place. In order to make a contribution to this field the proposed work focuses on the design and analysis of terahertz microstrip patch antenna that can be suitably deployed for determination of vitamins L-ascorbic acid and Thiamine hydrochloride. Flame Retardant (Fr4) material with thickness of 1.6 µm has been deployed as dielectric substrate with electrical permittivity of 4.4. The patch and ground plane are made up of copper of thickness 17 microns. A rectangular slot has been introduced in middle of the ground plane in order to improve the return loss of the antenna. The design and simulation of proposed antenna has been done using Computer Simulation Technology (CST) Microwave Studio 2016. Analysis of the proposed antenna has been done on various antenna parameters like return loss (S_{11}), directivity(dBi), gain (dB), Half Power Beamwidth (HPBW) and impedance. It has been observed that the designed antenna is resonant at 3.12 THz with an impedance of 50.77 Ω. The designed antenna has return loss (S_{11}) of -36.40 dB at resonant frequency of 3.12 THz with a gain of 4.56 dB and directivity of 5.69 dBi which makes it suitable for detection of vitamins L-ascorbic acid and Thiamine hydrochloride.*

Keywords — *L-ascorbic acid, Thiamine hydrochloride, Flame Retardant, Electrical permittivity, Vitamin.*

I. INTRODUCTION

Over the past few years, wireless technology has immense widely and has faced a drastic increase in wireless communication due to change in the way today's society creates, shares and consumes information [1]. In order to keep pace with an increasing demand in wireless technology terahertz band is a new solution to it. In recent years, the terahertz technology in the field of wireless systems has been found as interest to many researchers because of its potential applications in space communications, astronomy and image screening systems [2]. Terahertz band has a frequency range of 0.1 THz-10 THz [3]. It serves as a key to wireless technology by enabling a plethora of applications [4]. Along with wireless technology it is also an emerging field in fundamental science as it provides numerous efficient ways for medical diagnostics and environmental monitoring [5]. Due to its good transparency of non-polar materials including common clothing, packaging materials [6] like envelopes and plastic packages, high reflection on metals, and very low risk for health concern, make it suitable for sensing and imaging applications including safety inspection for concealed objects, medical diagnosis [7] like detection of diseases or deficiency of any vitamin in human body and non-destructive testing of materials [8].

Nowadays, the new advancement in the terahertz technology is implementation of terahertz antennas that can be deployed for detection of explosives, drugs, medical diseases etc. The terahertz antennas are a kind of hybrid technology raised from wireless communication and fundamental sciences applications. As day by day the requirement of antennas with low transmitting power in a high mobility environment is increasing immensely. In terahertz frequency regime, the microstrip patch antenna is essential device because of its compact size [9] and can be easily deployed for detection purposes. A microstrip patch antenna comprises of a dielectric substrate sandwiched between radiating patch and ground plane. These are easy to fabricate, low in cost and are capable of being integrated on planar and non -planar surfaces [10].

Terahertz antenna detect vitamins, explosives and concealed materials through their spectral features generally named as "fingerprints" in the THz regime [11]. The proposed narrowband terahertz microstrip patch antenna can be suitably deployed for detection of vitamins L-ascorbic acid and Thiamine hydrochloride. L-ascorbic acid is also known as ascorbic acid or vitamin C. It is one of the most common antioxidant found in number of fruits and vegetables. It plays a great role in the metabolic process of human bodies. It is highly

electrochemically active compound [12]. Its deficiency can cause scurvy and dandruff problems. Whereas Thiamine Hydrochloride is a white crystalline compound generally also referred as antiberiberi vitamin or vitamin B_1. It is essential for the liberation of energy and transfer of pyruvic acid into Kerbs cycle. Its deficiency can cause beriberi disease [13].

In the proffered paper Fr4 material has been employed as substrate so as to design terahertz microstrip patch antenna for determination of vitamins L-ascorbic acid and Thiamine hydrochloride. These vitamins are determined through their peak absorption frequency which act as their fingerprints. The paper comprises of four sections and they are as follows:

Section II relates with the geometry of the proposed antenna and provides an illustration of dimensions of patch, substrate and ground plane. Further section III relates with the various antenna parameters on the basis of which proposed antenna has been observed and section IV provides a conclusion of the proposed technique for the determination of vitamins L-ascorbic acid and Thiamine hydrochloride.

II. ANTENNA CONFIGURATION AND DESIGN

The proposed Terahertz microstrip patch antenna has been designed and simulated using CST Microwave Studio 2016. In the proffered antenna design Flame Retardant (Fr4) has been used as substrate with electrical permittivity of 4.4 and thickness 1.6 µm. It has good strength and flexibility. The substrate has been sandwiched between radiating patch and ground plane made up of copper of thickness 17 microns. Copper has been used because of low resistivity and high bounding ability with epoxy materials like Fr4.

A small rectangular slot has been introduced at the centre of the ground plane in order to improve the return loss of the proposed antenna design. The ground plane also has an extension along its length in order to improve antenna parameters in terms gain, directivity etc. The basic design strategy that has been adopted is to keep return loss as minimum as possible. The proposed antenna has input impedance of 50.77 Ω so as to have minimal reflection and to fed maximum power from port to the antenna feedline. The dimensional aspects of top view and bottom view are illustrated in fig 2.1 and fig. 2.2.

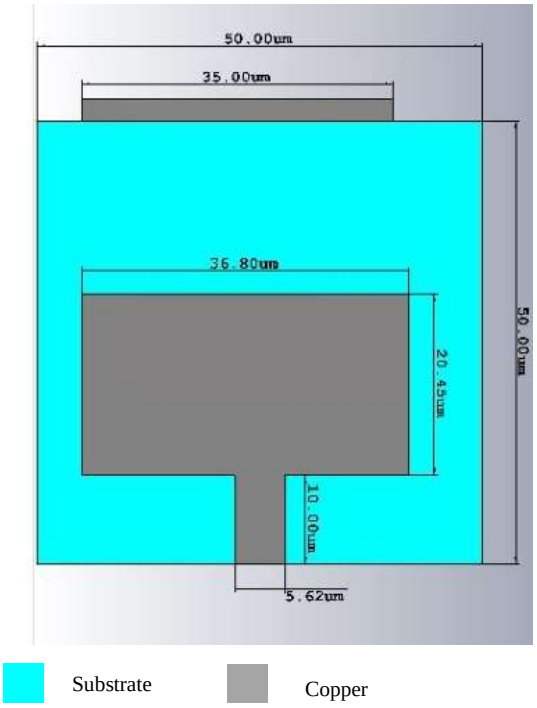

Fig. 2.1 Top view of the proposed antenna

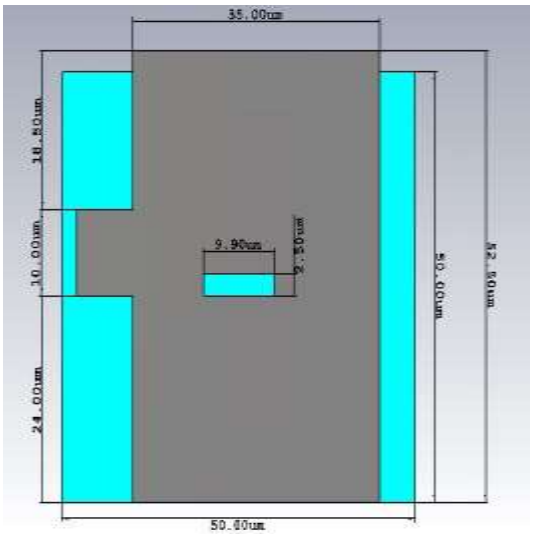

Fig. 2.2 Bottom view of the proposed antenna

III. SIMULATED RESULTS

The CST Microwave Studio 2016 has been employed to analyse the performance of antenna on various parameters that are return loss (S_{11}), impedance bandwidth (THz), gain (dB), directivity (dBi), impedance (ohms) and HPBW (degrees). The proffered antenna resonates at 3.12 THz with impedance bandwidth of 0.15 THz and S-parameter of -36.40 dB. It has a gain of 4.56 dB and directivity of 5.69 dBi. The proposed antenna has input impedance of 50.77 Ω in order to have minimum reflection losses and to transfer maximum power from port to antenna.

A rectangular slot has been introduced on the ground plane of the proposed antenna in order to improve the return loss and to achieve the desired resonant frequency. The effect of introducing the slot can be clearly depicted from fig. 3.1 and fig. 3.2. The fig. 3.1 shows the return loss of antenna with slot whereas fig. 3.2 shows the return loss of the antenna without slot. It can be seen that a distorted return loss plot is attained without slot. Further fig. 3.3 depicts the gain and directivity plot of the proposed antenna. Its impedance is shown in fig. 3.4. It has HPBW of 83.5 degrees as shown in fig. 3.5. The simulated results of antenna are shown in table I.

It can be analysed from above results that the proposed antenna can be suitably deployed for determination of vitamins L-ascorbic acid and Thiamine hydrochloride at resonant frequency of 3.12 THz as it is spectral signature of both the vitamins. These spectral signatures are generally used to detect the various compounds or vitamins.

IV. TABLE I – ANTENNA PARAMETERS

S.no.	Parameter	Value
1.	Return loss	-36.40 dB
2.	Impedance	50.77 Ω
3.	Gain	5.69 dB
4.	Directivity	4.56 dBi
5.	Bandwidth	0.15 THz
6.	Half Power Beamwidth	83.5 deg

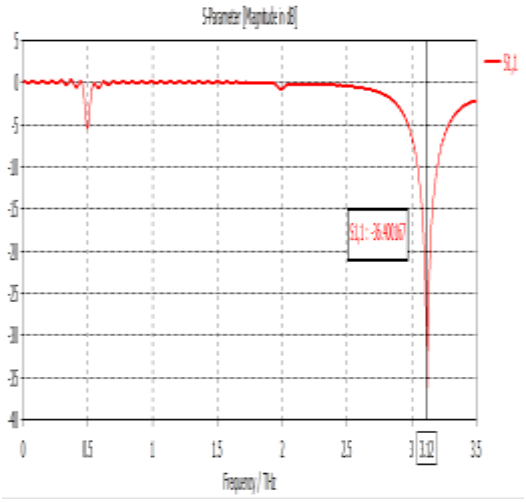

Fig. 3.1 Return loss of the proposed antenna with slot

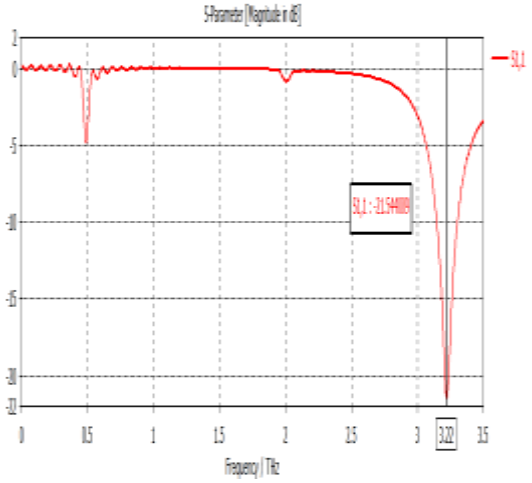

Fig. 3.2 Return loss of the proposed antenna without slot

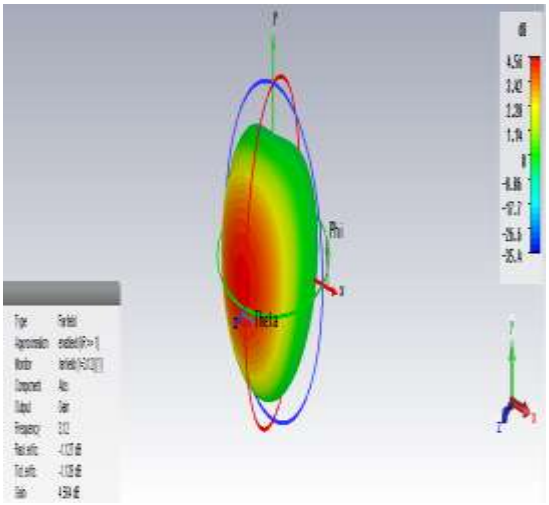

Fig. 3.3 Gain of the proposed antenna

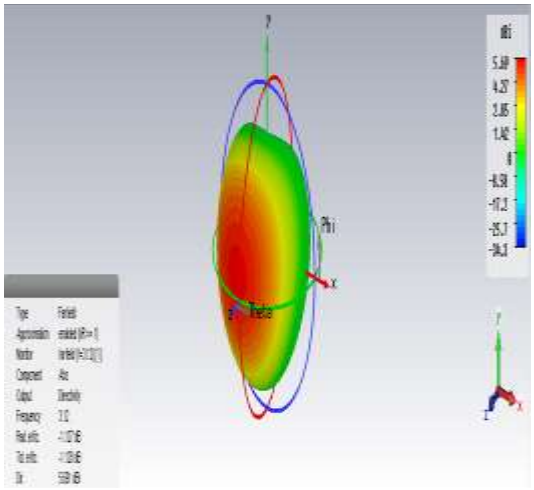

Fig. 3.4 Directivity of the proposed antenna

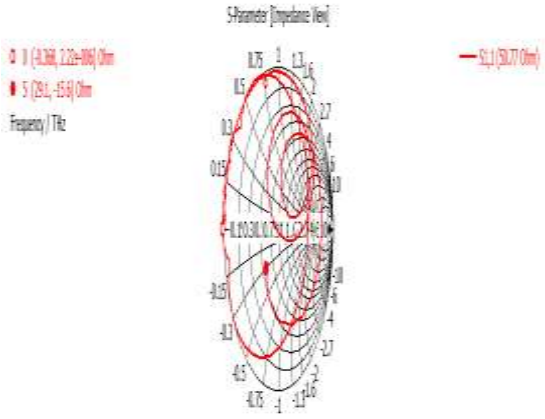

Fig. 3.5 Smith chart of the proposed antenna

V. CONCLUSION

In this paper, a compact Terahertz microstrip patch antenna has been designed using CST Microwave Studio 2016. The proposed antenna operates in the frequency range of 3.04 THz to 3.19 THz resonating at 3.12 THz. The proposed antenna has been designed by employing FR4 as substrate with dielectric constant of 4.4 of thickness 1.6 µm. It is a narrow band terahertz microstrip patch antenna that can be suitably deployed for determining vitamins L-ascorbic acid and Thiamine hydrochloride at peak resonant frequency of 3.12 THz. A small rectangular slot has been introduced on the ground plane so as to improve the return loss and to resonate the antenna at required frequency. The main purpose to propose this work is to provide a new technique for detection of vitamins L-ascorbic acid and Thiamine hydrochloride as it is quite simpler and convenient than earlier proposed techniques because the microstrip patch antennas can be easily integrated with the system.

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REFERENCES

[1] I. F. Akyildiz, J. M. Jornet, and C. Han, "Terahertz band: Next frontier for wireless communications," *Phys. Commun.*, vol. 12, pp. 16–32, 2014.

[2] K. Fan, Z. Hao, and W. Hong, "A 325-500 GHz High Gain Antenna for Terahertz Applications," vol. 1, no. 1, pp. 780–781, 2016.

[3] H. A. Abdulnabi, R. T. Hussein, and R. S. Fyath, "UWB Single Port Log Periodic Toothed Terahertz Antenna Design Based on Graphene Artificial Magnetic Conductor," *Mod. Appl. Sci.*, vol. 11, no. 3, p. 86, 2017.

[4] S. E. Hosseininejad *et al.*, "Surveying of Pure and Hybrid Plasmonic Structures Based on Graphene for Terahertz Antenna," *Proc. NANOCOM '16*, pp. 1–6, 2016.

[5] H. J. Joyce *et al.*, "conductivity spectroscopy Single n + -i-n + InP nanowires for highly sensitive terahertz detection."

[6] H. Li, K. Zhang, Q. Zhou, W. Mao, P. Dong, and F. Tian, "Case Report Terahertz spectroscopy for cancer diagnosis," vol. 10, no. 2, pp. 3766–3773, 2017.

[7] J. Gou, T. Zhang, J. Wang, and Y. Jiang, "Spiral Antenna-Coupled Microbridge Structures for THz Application," *Nanoscale Res. Lett.*, vol. 12, no. 1, p. 91, 2017.

[8] D. T. Nguyen, F. Simoens, J. L. Ouvrier-Buffet, J. Meilhan, and J. L. Coutaz, "Simulations and measurements of the electromagnetic response of broadband THz uncooled antenna-coupled microbolometer array," *2012 19th Int. Conf. Microwaves, Radar Wirel. Commun. MIKON 2012*, vol. 1, no. 3, pp. 116–121, 2012.

[9] S. Anand, D. S. Kumar, R. J. Wu, and M. Chavali, "Graphene nanoribbon based terahertz antenna on polyimide substrate," *Optik (Stuttg).*, vol. 125, no. 19, pp. 5546–5549, 2014.

[10] B. Garg and P. Singhal, "A Novel Approach for Size Reduction Of Rectangular Microstrip Patch Antenna," *Int. J. Electron. Comput. Commun. Technol.*, vol. 3, no. 1, pp. 35–39, 2012.

[11] N. Palka, "Identification of concealed materials, including explosives, by terahertz reflection spectroscopy," *Opt. Eng.*, vol. 53, no. 3, p. 31202, 2013.

[12] L. Yang, D. Liu, J. Huang, and T. You, "Simultaneous determination of dopamine, ascorbic acid and uric acid at electrochemically reduced graphene oxide modified electrode," *Sensors Actuators, B Chem.*, vol. 193, pp. 166–172, 2014.

[13] "Thiamine hydrochloride | definition of thiamine hydrochloride by Medical dictionary." [Online]. Available: http://medical-dictionary.thefreedictionary.com/thiamine+hydrochloride.