ISSN : 2230-7109 (Online) | ISSN : 2230-9543 (Print)

Novel Terahertz Microstrip Patch Antenna Design Employing FR4 as Substrate for Detection of Riboflavin

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Abstract
This paper demonstrates the design and analysis of Terahertz Microstrip Patch Antenna employing FR4 (Flame Retardant 4) as substrate material, having thickness of 1.6 µm and dielectric constant ($\in_r$) of 4.4. The patch and ground are made up of Copper material and rectangular slot has been introduced in patch to improve the antenna parameters such as return loss, directivity, gain and bandwidth. The ground has been reduced to increase the bandwidth and gain of the antenna. The design and simulation of antenna has been carried out using Computer Simulation Technology (CST) Microwave studio (2014). The proposed antenna design has been analyzed interms of resonant frequency, return loss(S_{11}), VSWR, gain (dB), directivity (dBi), Half Power Beam width (HPBW) and percentage bandwidth. It has been observed that the designed antenna is resonantat 4.17 THz with an impedance of 50.32 Ω. The designed antenna has return loss (S_{11}) magnitude of -39.73dB at resonant frequency of 4.17 THz. The antenna has gain of 6.8dB and directivity of 6.4dBi at corresponding resonant frequency of 4.17THz. The proposed antenna can be used for detection of Riboflavin applications.

Keywords
Terahertz, Microstrip Patch Antenna, Riboflavin, Drug detection, Gain, Return loss

I. Introduction
Terahertz (THz) radiation is electromagnetic radiation whose frequency lies between the microwave and infrared regions of the spectrum. Over the last two decades, the THz technology has ripened enough that a thorough summary and review of the relevant topics is in order and this technological gap has been rapidly diminishing from the last two decades. Besides, the THz community is growing fast and the THz technology is in a transitional period. The THz research activities have been mainly focused on generation and detection, THz frequencies and the practical applications of THz frequencies such as high-speed communication, molecular spectroscopy, security imaging, and medical diagnosis. Terahertz imaging has been employed in quality control process in manufacturing of aircrafts, cars, drugs and computer chips. Furthermore, terahertz imaging is considered for security applications such as screening for concealed weapons. Much of the scientific interest in T-rays is due to the unique properties of this type of radiation [1]. With the development in Terahertz sources and detectors, the development of Terahertz systems with a variety of sources, such as Gunn diodes, photoconductive dipole antennae and quantum cascade lasers is quite easy [2]. In the field of wireless communication, the efforts mainly focuses on the antenna designs, which is usually one of the most cumbersome element of the system. Several technologies have been developed in this direction, and microstrip antennas are among the most interesting technological solutions and provides uncountable features [3]. However, the use of this class of antennas is hampered by limitations in the efficiency of radiation and the bandwidth remains generally very narrow. These limitations can be overcome by the implementation of various techniques such as the use of slots or superstrates [4-5]. 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. However, the main drawback of the microstrip antenna is its poor directivity and the low gain at the frequency [6-7]. Riboflavin (vitamin B-2) is an important B-vitamin that is found in the large variety of foods. A deficiency of riboflavin has manifested to increase susceptibility of humans to be associated with poor iron assimilation, an etiology link to anemia, and as a risk for cancer [8] [9]. As intake of riboflavin increases so does the urinary excretion clearance [8]. Riboflavin is an important participant in numerous diverse internal redox reactions as a part of metabolism and an inadequate intake of this vitamin would contribute to difficulties in intermediary metabolism [10]. The presence of these vitamins can be detected with the help of terahertz radiations as the peak absorption frequencies of these vitamins act as their fingerprints [11]. In the proposed paper, the FR4 material has been employed as substrate in order to design an antenna for the detection of vitamin riboflavin.

The paper is divided in various sections as follows:
Section II (Antenna Geometry) describes the geometry of the proposed antenna including side view, top view and bottom view of antenna illustrating the dimensions of patch, substrate and ground plane.
Section III (Simulated Results) describes the competency of designed antenna in terms of return loss (S_{11}), bandwidth, gain, directivity, VSWR and impedance. Section IV (conclusion) includes the conclusion of the proposed antenna design for detection of vitamin riboflavin.

II. Antenna Configuration and Design
Theproposed Terahertzmicrostrippatchantennahasbeen designedandsimulatedusingCSTMicrowaveStudio2014. In the proposed antenna design, the flexible Flame Retardant (FR4) has been used as substrate with dielectric constant of 4.4 and thickness of 1.57µm. The substrate is lodged between the radiating patch and ground plane made up of copper. The thickness of patch is 0.02µm and thickness of ground surface is 0.05µm. The extension in the dimensions has been done in both patch and ground plane along width and length
Respectively, in order to enhance the antenna parameters. The rectangular shaped patch is designed with a small rectangular slot, sheered on its surface so as to acquire the desired results and improve the antenna performance in terms of gain, directivity etc. The rectangular slot is sheered along the depth of the patch. The power is fed to the antenna through coaxial cable having impedance of 50 ohms. The proposed antenna has the input impedance of 49.93 ohms that approximately matches up with impedance of coaxial cable resulting in the minimal back reflections and transfer

maximum power from port to antenna. The dimensions of the illustrated antenna are represented in the below given Table 1. The top view of illustrated antenna is represented in Fig. 2.1, the side view of illustrated antenna is shown in Fig. 2.2 and the bottom view of the illustrated antenna is shown in Fig. 2.3. The Fig. 2.4 represents 3D view of proposed terahertz antenna design.

Antenna Parameter	Dimension(μm)
Wp	42.4
Lp	21
Wf	5.6
Lf	25
Ws	35.79
Ls	22.89
Wg	28
Lg	31
Wh	2
Lh	8
Tp	0.02
Ts	1.57
Tg	0.05

where,
Wp = Width of patch
Lp = Length of patch
Wf = Width of feed
Lf = Length of feed
Ws = Width of substrate
Ls = Length of substrate
Wg = Width of ground
Lg = Length of ground
Wh = Width of slot
Lh = Length of slot
Tp = Thickness of patch
Ts = Thickness of substrate
Tg = Thickness of ground

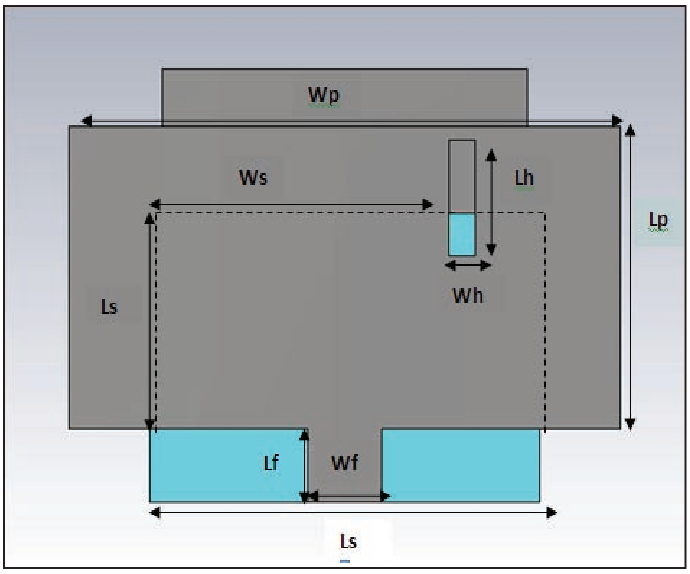

Fig. 2.1: Top View of Proposed Antenna

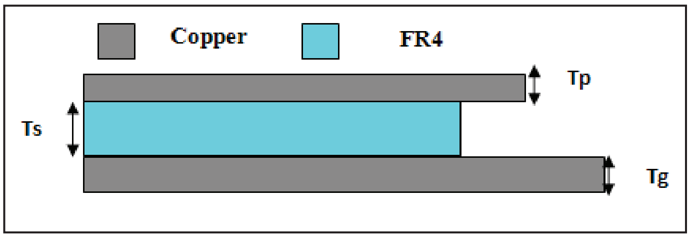

Fig. 2.2: Side View of Proposed Antenna

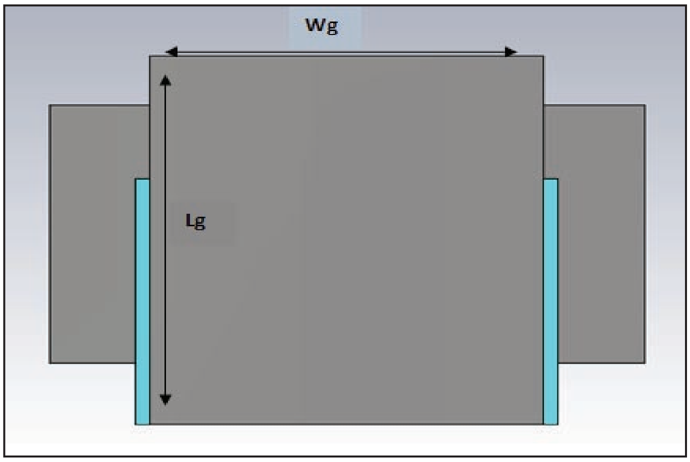

Fig. 2.3: Bottom View of Proposed Antenna

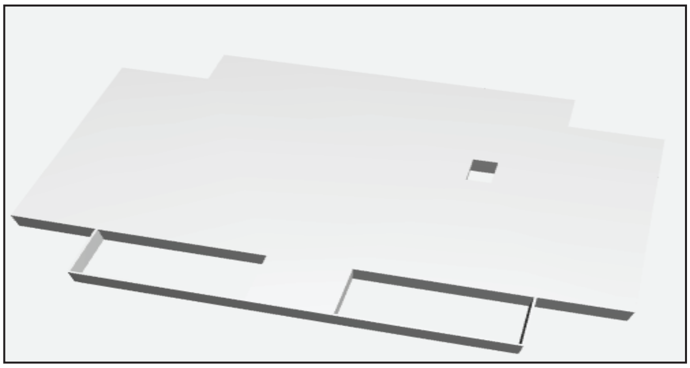
Fig. 2.4: 3D View of Proposed Terahertz Antenna Design

III. Results

The proposed antenna has been designed and simulated using Computer Simulation Technology (CST) Microwave studio 2014. The proposed antenna design employs substrate of FR4 material having ground on the lower surface of the substrate and slotted patch on the upper surface of substrate. In the proposed structure, a rectangular slot has been introduced to improve the return loss, directivity and bandwidth. The ground and patch are extended along length and width, respectively to increase gain and return loss of the designed antenna.

The analysis of the antennahave been done in terms of return loss (dB), impedance (Ω), Voltage Standing Wave Ratio (VSWR), gain (dB), directivity (dBi) and HPBW (degree) as illustrated in Fig. 3.1, Fig. 3.2, Fig. 3.3, Fig. 3.4, Fig. 3.5 and Fig. 3.6 respectively. The return loss is the ratio of power reflected to power incidence. It has been observed in Fig. 3.1 that the antenna has return loss of 4.17 dB at the resonant frequency of -34.74 THz. The simulated impedance bandwidth of the proposed microstrip antenna is 0.188 THz. The Smith Chart plot indicates the variation of impedance of the antenna with respect to frequency. It can be clearly observed from the Smith Chart plot of the proposed antenna shown in Fig. 3.2. The input impedance for the proposed antenna is 49.94 Ω. The Voltage Standing wave ratio is shown in Fig. 3.3. It must

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be less than 2 and for the proposed antenna it is 1.037. The gain of an antenna is the ratio of power radiated by the antenna to the power radiated by an omnidirectional antenna when both are fed with the same input power. The designed antenna has gain of 6.873 dB and directivity of 6.422 dBi corresponding to the resonant frequency of 4.17 THz. The simulated results of antenna are shown in Table 2.

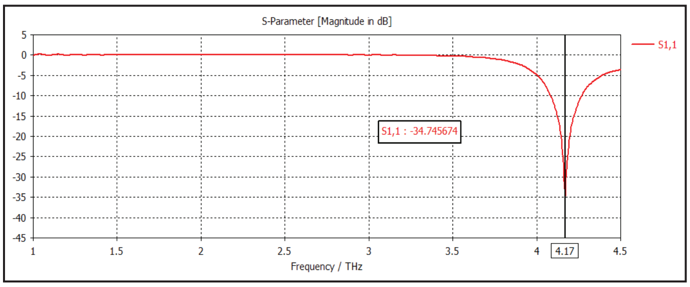

Fig. 3.1: Return Loss of the Proposed Antenna

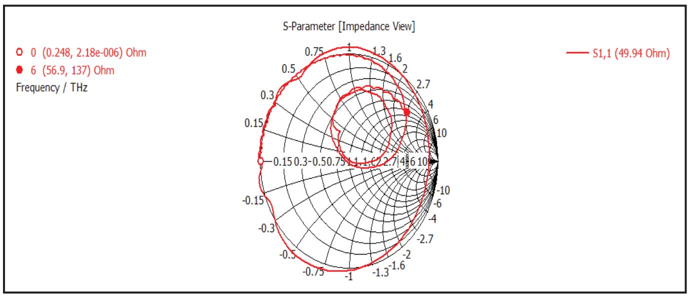

Fig. 3.2: Smith Chart of the Proposed Antenna

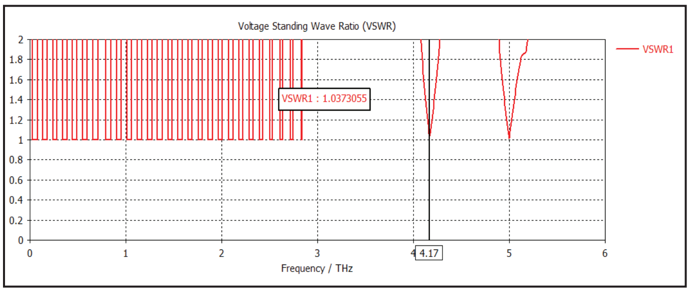

Fig. 3.3: VSWR of the Proposed Antenna

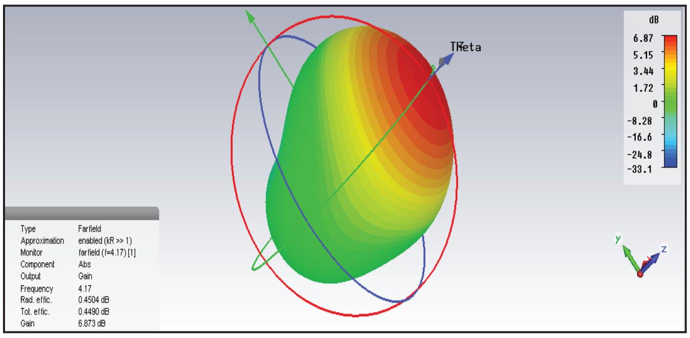

Fig. 3.4: Gain of the Proposed Antenna

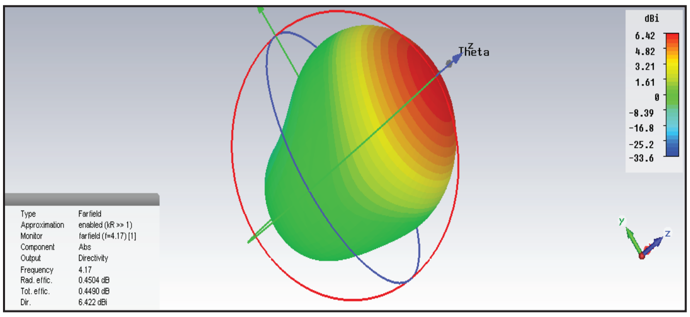

Fig. 3.5: Directivity of the Proposed Antenna

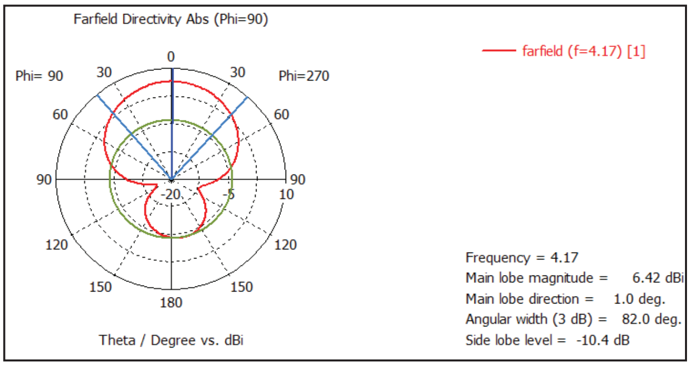

Fig. 3.5: HPBW of the Proposed Antenna

Table 2: Simulated Results of Proposed Antenna

S.no.	Parameter	Value
1.	Return loss	-34.74 dB
2.	Impedance	49.94 Ω
3.	Gain	6.87 dB
4.	Directivity	6.42 dBi
5.	Bandwidth	186 MHz
6.	VSWR	1.04
7.	Half Power Beamwidth	82.0 deg

IV. Conclusion

The simulated results attained through CST Microwave Studio 2014 shows a narrowband Terahertz Microstrip patch antenna with rectangular slot in patch structure and good matching with S11lower than -10 dB at the intended resonant frequency of 4.17 THz which is the peak absorption frequency of vitamin Riboflavin [12]. The proposed antenna design employs FR4 as substrate having rectangular slot on patch. The slot has been sheered on patch so as to increase the gain and return loss of the designed antenna. It has been observed that the proposed antenna has impedance bandwidth of 0.188 THz with operating frequency range of 4.08 THz to 4.26 THz and return loss of -34.74 dB at resonant frequency of 4.17 THz. It has been observed that the proposed antenna has gain of 6.873 dB, directivity of 6.422 dBi and percentage bandwidth of 4.31 percent.

Percentage Bandwidth

$$= \left(\frac{4.26 - 4.08}{4.17}\right) \times 100$$
$$= 4.31\%$$

The proposed antenna can be suitably used for detection of Riboflavin. Table 2 represents the various techniques proposed for the detection of Riboflavin proposing this technique.

Objective: Detection of Vitamin Riboflavin	
Techniques used earlier	**Description**
1.Alkaline borate Buffer with UV/Visible Spectroscopy	Under this technique, absorbance spectrum of Riboflavin was determined at different pH values utilizing several buffers for detecting Riboflavin [8]

2.Terahertz Spectroscopy and density functional theory	In this, the spectroscopy technique and Density Functional Theory (DFT) was employed for detecting the Riboflavin[13].
Proposed Technique	**Description**
Microstrip Patch Antenna	A simple terahertz MPA design using CST Microwave Studio 2014 that tends to detect the Riboflavin at resonant frequency 4.17 THz can be employed.

V. Acknowledgment

We would like to express our gratitude towards our Prof. EkambirSidhu, Assistant Professor, Department of Electronics and Communication Engineering, Punjabi University, Patiala for his guidance and supervision for the successful completion of this research work.

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