U-Shaped Terahertz Microstrip Patch Antenna for 6G Future Communications

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***Abstract*— In this article a terahertz antenna has been proposed which is designed on Rogers RO3010 substrate, with a standard thickness 10 µm having relative dielectric constant (Ɛr) = 11.2 and thermal conductivity of 0.66 W/K/m. A dielectric material with a high epsilon value is used, the effective wavelength of the electromagnetic wave is reduced within the material, resulting in a reduction of the physical size of the antenna. The designed antenna is compact light weight and is fed using a microstrip line feeding technique which provides ease of integration inside the device. The resonating frequency of the designed antenna is 0.854 THz with a return loss -19.5 dB offering a high bandwidth of 44 GHz. High bandwidth application of the future communication requirements is achieved by the modelled antenna**.

Keywords—6G, Terahertz, microstrip, Roger 3010, CST, wide bandwidth.

I. Introduction

After the expansion in 5G the gateway for the autonomous world has been commenced for the smart devices which are capable of communicating and operating to the real time responses. These devices need high data rate and larger bandwidth to operate at the best potential. Researchers have proposed 6G could be the best solution to provide higher data rate and larger bandwidth to fulfil the current demands. The advanced features of the 6G includes low latency, increased energy efficiency and improved coverage. 6G has significantly lower latency than previous generations of wireless technology. This would reduce the delay between sending and receiving data, enabling real-time applications such as remote surgery, autonomous vehicles, and smart cities [1]. 6G has the potential to offer even lower latency than 5G, which could enable new applications like haptic feedback and real-time remote control of devices [2]. 6G technology is expected to be more energy-efficient than previous generations of wireless technology. This would reduce the energy consumption of devices and networks, making them more environmentally friendly and reducing operating costs [3]. On the other hand, the wavelength of the electromagnetic radiation for 6G is very short, which makes it challenging to use conventional antennas for wireless communication. However, research is ongoing to develop new types of antennas and technologies that can operate at these frequencies [4]. In terms of potential applications for 6G at 0.845 THz, some possible areas of interest include high-speed wireless data transfer, high-resolution imaging, and sensing [5]. The high bandwidth available at these frequencies potentially enables data rates in excess of 100 Gbps, which could revolutionize wireless communication [6]. High-resolution imaging and sensing applications could include medical imaging, security screening, and industrial process monitoring [7]. Article comprises of four different sections which are structured as follow, Section II explains the designing of the Antenna. Section III illustrates the simulated results and analyzes the performance. Section IV divers towards conclusion.

II. Antenna Design and Modelling

The dimension of the antenna is shown in the table. The Rogers RO3010 substrate was employed, containing thickness h = 50µm and εr = 11.2. A dielectric material with a high epsilon value is used, the effective wavelength of the electromagnetic wave is reduced within the material, resulting in a reduction of the physical size of the antenna. This is because the speed of propagation of the electromagnetic wave is slower in the high epsilon material, effectively increasing the wavelength and reducing the physical size required to achieve a resonant condition.The microstrip patch antenna comprises of resonating patch, substrate made of dielectric material and ground layer, the ground layer is compose from copper having height 10 µm. The designed antenna is squared in shaped whereas the radiating patches are placed above the substrate which are rectangular structured. Both the radiating patches are feed in same time without any phase difference. The constructive interference of the radiated signals is observed. Roger RO3010 was selected as the substrate material because of its several advantages, RO3010 has low dielectric losses, which proposes it can support high-frequency signals with minimum signal attenuation [8], it has a excellent thermal stability, which makes it endure high temperatures without suffering any significant changes in its physical or electrical properties [9]. Moreover, RO3010 is compatible with high-frequency applications, as it has a relatively high cut-off frequency and can operate up to several tens of GHz. This makes it an ideal choice for millimetre-wave and other high-frequency application for upcoming generation [10]. The 6G microstrip patch antenna resonates at 0.845 THz range. Radiating patches are feed using microstrip line feeding techniques as it can be easily integrated in the design of the antenna, it is suitable for the antenna application where height is limited [11]. Moreover, it can be manufactured using low-cost materials which makes it economical choice for many applications [12] [13]. Antenna is perfectly matched, the electrical dimensions of the microstrip line were calculated using the equations described below. The structural

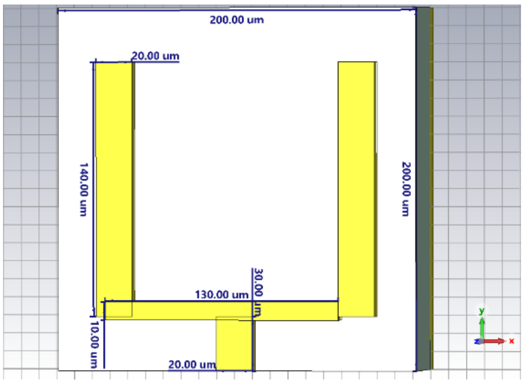

Figure 1 Antenna front view

dimensions of the for proposed 6G antenna are stated in Table I. The well-known equations for Microstrip patch antennas are given below used for calculations.

Width of the radiating patch was determined using equation.

$$Wp = \frac{C}{2fo}\sqrt{\frac{2}{\mathcal{E}r+1}} \tag{1}$$

The radiating patch length was calculated using equation.

$$Lp = Leff + \Delta L \tag{2}$$

Effective dielectric Constant of the antenna.

$$\mathcal{E}eff = \frac{\mathcal{E}r+1}{2} + \frac{\mathcal{E}r-1}{2}\frac{1}{\sqrt{1+12\frac{h}{Wp}}} \tag{3}$$

Extension in the length ΔL:

$$\Delta L = 0.415h\left[\frac{(\mathcal{E}eff+0.3)\left(\frac{Wp}{h}+0.264\right)}{(\mathcal{E}eff-0.258)\left(\frac{Wp}{h}+0.8\right)}\right] \tag{4}$$

Effective length of the antenna is calculated:

$$Leff = \frac{c}{2fo\sqrt{\mathcal{E}reff}} \tag{5}$$

Length of substrate:

$$Ls = 6h + Lp \tag{6}$$

Width of substrate:

$$Ws = 6h + Wp \tag{7}$$

III. ANTENNA SIMULATED RESULTS AND DISCUSSION

The designed antenna is assessed considering free space important parameters like impedance matching of the antenna, reflection coefficient, current distribution over the entire antenna, Polar plot radiation pattern, three-dimensional radiation pattern results and gain achieved by the antenna at the resonant frequency.

A. Current Distribution

The simulated result of the current distribution is illustrated in fig. It illustrates the current spreading over the entire radiating patches which is directly coming from the transmission line. It is evident from the simulated result that travelling wave pattern has been achieved.

B. Impedance matching

The designed antenna transmission line is matched at 50 Ω, When the impedance of the antenna matches the impedance of the transmission line (usually 50 ohm), it allows for maximum power transfer from the source to the antenna, resulting in efficient use of power. The designed transmission line offers a perfect matching responsible for the transition between the power supply and the radiating patches with minimal losses. The dimensions of the transmission line are explained in table 1.

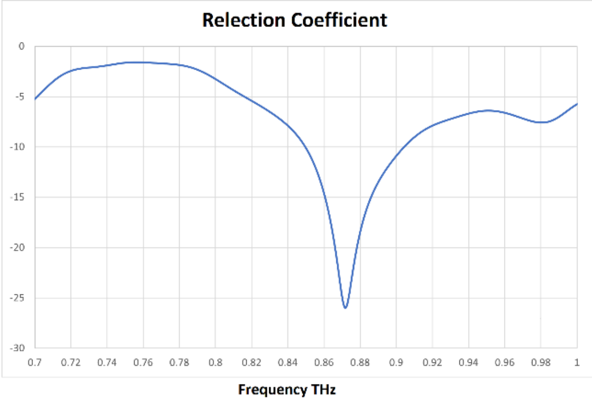

Figure 2 Reflection Coefficient simulated results.

C. Reflection Coefficient

The reflection coefficient of an antenna evaluates the matching of the antenna to the transmission line. Reflection coefficient provides the magnitude which ranges from 0 to 1, where 0 indicates no reflected power. Closer to 0 less power is being wasted. The designed antenna is resonating at of 0.854THz. The simulated results show in figure verifies the performance of antenna at the resonating frequency, it also verifies bandwidth of the antenna above 1.5GHz. in addition, antenna fulfils the requirement of the 6G communication devices.

D. Radiation Pattern

The polar plot graph of far-field radiation patterns of antenna in ϕ=0° and ϕ=90° planes are showed in Fig. 5 while the three-Dimensional far-field radiation pattern of the antenna is indicated in the Fig. 6. The simulated results explicit the antenna has a good radiation coverage over the azimuth and elevation angle. Main lobe is directed towards 61° and the sides lobes of the antenna are minimal with the value of –1.8dB on the other hand antenna is offering -3dB angular width of 43 °Generally, the antenna is providing an excellent radiation characteristic covering all the adjacent angles and provides a high Gain of 3.88dBi.

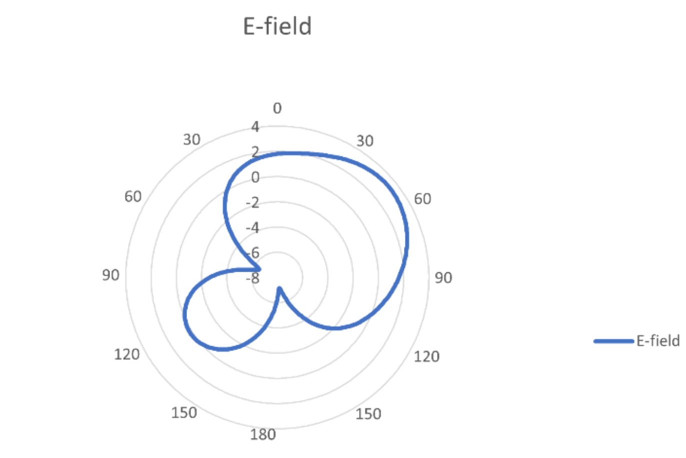

Figure 3 E-field polar plot

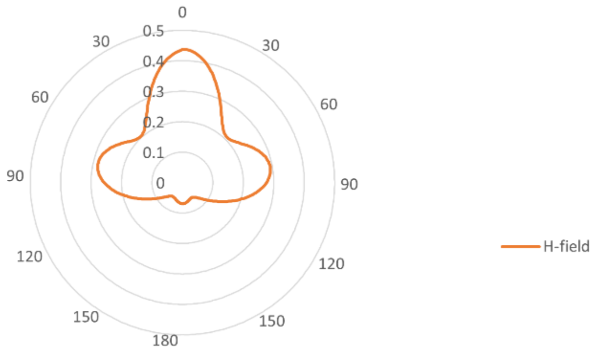

Figure 4 H-field polar plot

The comparison of the designed antenna with previous work is described in table II. Terahertz radiation has several advantages over other frequency ranges, including the ability to penetrate many materials. This makes it a promising technology for a variety of applications, including security screening, medical imaging, and wireless communications. In microstrip patch antenna design, the use of terahertz frequencies lead to smaller antenna dimensions and higher directivity, which is desirable for many applications. Additionally, the high bandwidth available at terahertz frequencies allows for high-speed data transfer, making it useful for future wireless communication systems. However, designing antennas for terahertz frequencies is still a challenging task due to the short wavelengths involved, and there are many technical hurdles to overcome before terahertz technologies can be widely adopted.

IV. Conclusion

In this paper a terahertz microstrip patch antenna has been designed for future communication. The designed antenna is compact and lightweight which makes it suitable for compact electronic devices. Antenna has been designed utilizing Roger RO3010 as a substrate whereas copper is used to design the radiating patches. The antenna is resonating at 0.85 THz frequency offering a high bandwidth of 44 GHz. Antenna performance is evaluated from the simulated results which are illustrated and analyzed in this paper. All the parameters were analyzed and compared with the previous work from which it is evident that the designed antenna is radiating perfectly and is suitable for future 6G communication.

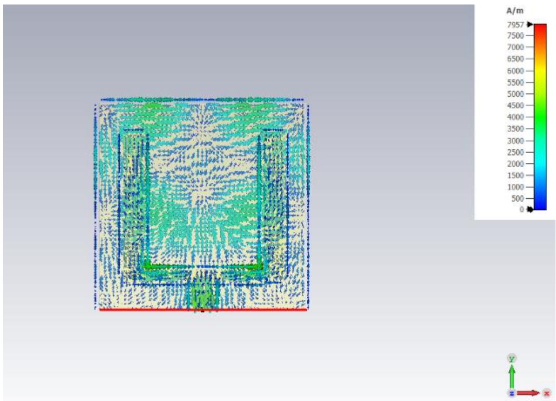

Figure 5 current distribution over the antenna

TABLE I. Dimension of the designed antenna

Antenna elements	Description	Parameters	Dimension (μm)
Patch	Length of Radiator	L_P	140
	Width of Radiator	W_P	20
Ground	Height of Ground	h	50
Substrate	Substrate Length	Ls	200
	Substrate Width	Ws	200
Feedline	Feedline length	F_L	30
	Feedline Width	Fw	20

TABLE II. Comparsion

Reference	Size	Frequency	Gain	Bandwidth	Design
[15]	28333x2833	0.125-0.3	40	82.35	Array
[16]	1032x396	0.258–0.355	5.6	31.6	Single
[17]	310x310	0.209	2.44	77	Single
This work	200x200	0.854	3.88	44	Single

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