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Rectangular Microstirp Patch Antenna Design at THz Frequency for Short Distance Wireless Communication Systems

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Abstract In this paper, we have presented the simulation results of a rectangular microstrip patch antenna at terahertz (THz) frequency ranging from 0.7 to 0.85 THz. THz electromagnetic wave can permit more densely packed communication links with increased security of communication transmission. The simulated results such as gain, radiation efficiency and 10 dB impedance bandwidth of rectangular microstrip patch antenna at THz frequencies without shorting post configuration are 3.497 dB, 55.71% and 17.76%, respectively, whereas with shorting post configuration, corresponding parameters are 3.502 dB, 55.88% and 17.27%. The simulation has been performed by using CST Microwave Studio, which is a commercially available electromagnetic simulator based on the method of finite difference time domain technique.

Keywords THz electromagnetic spectrum · Microstrip patch antenna · Bandwidth · Photo- conductive antenna and microstrip-line.

1 Introduction

Development of the next generation wireless communication network requires systems with extremely broadband capabilities in high mobility environment. For such applications, range from personal communications to home, car and office networking, high data rates, high spectral efficiencies and stronger fading mitigation have to be achieved. Due to its particular role, the microstrip antennas simultaneously satisfy stringent requirements concerning geometrical characteristics (small-size, light-weight, adaptability to actual platform and non-obstructive to user), electrical performance (wide-bandwidth, radiation properties, high-efficiency, reconfigurability and suitability for diversity) and manufacturing constraints (low-cost, reliability, packaging capabilities) as well as the performance must not be degraded by environment and design must satisfy radiation safety standards.

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The frequencies higher than microwaves offer many advantages for wireless communication technology, including broad-bandwidth for high data rate information transmission, improved spatial directivity and resolution, low transmission power, and low probability of interference/interception with system compactness. THz electromagnetic spectrum is very useful for the communication, which will satisfy most of the aforementioned requirements. This electromagnetic wave spectrum is of increasing interest to service provider and system designers also because of extremely broad bandwidth available for carrying communication information and relatively free of spectrum users. Among the practical advantages of using THz regime for satellite communication systems are the ability to employ smaller transmitting and receiving antennas [1–7]. THz regime of the electromagnetic spectrum occupies a large portion of the spectrum located between the microwave and optical frequencies and normally defined as the band from 0.1 to 10 THz [1–3]. This radiation is rich with emerging possibilities in sensing, imaging and communication, with unique applications to screening for weapons, explosives and biohazards, imaging of concealed object water contents and skin [2–5]. Despite the increasing use of THz systems in many research areas, the virtual absence of practical, compact sources have limited widespread use of this technology. Many efforts have been made to make practical sources at the THz frequencies, but no THz sources currently satisfy size, output power level and operating temperature requirements.

For the wireless communication systems at THz frequency, the microstrip antenna is very important component. Using carrier frequencies above 300 GHz, oscillator and amplifier sources with approximately 10% fractional bandwidth would enable very high data rate (>10 GB/sec) wireless communications with high security protection [6]. If adequately powerful, compact and wideband sources will be available, this capability could be realized with extremely simple, low-cost amplitude modulation schemes. A photoconductive antenna is an alternative THz source because of its compactness and wide tunability at room temperature [7, 8]. However, the photoconductive antenna has the significant disadvantage of low output power. This is mainly due to high impedance inherent to photomixer. When an antenna with moderate input impedance is connected to a photomixer, the power transferred from photomixer to the antenna is poor due to the severe impedance mismatching. Impedance mismatching between the photomixer and the antenna can be improved by increasing the antenna resistance, which results increase in radiated power from the antenna [9–11].

In this paper, we have simulated the rectangular microstrip patch antenna at THz frequencies for short-distance wireless communication systems. An advantage of microstrip THz patch antennas is that their bandwidth limitation can be overcome by the use of electrically thick substrates [12–15]. Thus, fabricating patch antennas on a high dielectric constant substrate are becoming attractive for miniaturized modes. However, direct use of high dielectric constant substrates results strong surface wave modes. The diffraction from the surface waves at the edge of the finite size substrate degrades the radiation pattern and reduces the radiation efficiency of the patch. The bandwidth increases rapidly with increasing substrate thickness [15]. At higher frequencies, substrates are much thicker and have high dielectric constant than at lower frequencies. As we move from frequency above 100 GHz that is towards THz regime, ohmic losses become more severe, but due to the benefits of larger bandwidth and efficiency, we are interested to work at this frequency regime. We have also discussed the role of shorting pin to reduce the dimension of the radiating patch. The organization of the paper is as follows. The section 2 discusses about the patch antenna configuration. The section 3 concerned with the simulation results. Finally, section 4 concludes the work.

2 THz antenna configuration

The microstrip patch antenna size mostly depends on the frequency band of operation. There are several other factors that also contribute to determine the dimension of the microstrip antenna and its behavior such as the substrate material used and its thickness. The patch material affects the efficiency of the antenna, while the type of substrate plays a major role in the determination of the antenna dimensions [14, 15]. A rectangular microstrip patch antenna consists of a conductive rectangular patch on a dielectric substrate above a conductive ground plane as shown in Fig. 1. The excitation of the patch is accomplished by a microstrip feed-line [16, 17]. This feed technique supply the electrical signal to radiating patch which will be converted into an electromagnetic wave. When the patch is excited by the feed, the bottom of patch at a certain time will have a positive charge distribution, and the ground plane will have a negative charge distribution. The attractive forces between these charges will hold most of them on the bottom and top surfaces of the patch and ground material, respectively. On the patch surface, repulsive charges within the same polarity tend to push some of the charges towards the edges. These charges will develop a fringing effect at the edges, causing radiation. The geometrical structure of this THz rectangular microstrip patch antenna is as shown in Fig. 1. In this antenna, the substrate has length, width and thickness as 1000 μm×1000 μm×200 μm, respectively. The substrate material is RT/Duriod6006 (ε_3=6.15) with tan $\delta = 0.0019$. The patch has length and width as 600 μm×400 μm, respectively. The microstrip feed line has the dimension 40 μm× 300 μm and thickness 40 μm. In this antenna, we use microstrip line edge feeding technique and simulation has been performed by using CST Microwave Studio.

3 Results and discussion

The interest in short-range wireless communications is accompanied by an increasing need for the higher data rates, low transmit power and secured wireless communication capability for numerous new multimedia broad-bandwidth demanding applications proliferate at a great pace. The communications in THz frequency band should satisfy the demand of aforementioned requirements. We have proposed a high-gain ultra-broadband rectangular microstrip patch antenna for such a short-distance wireless communication

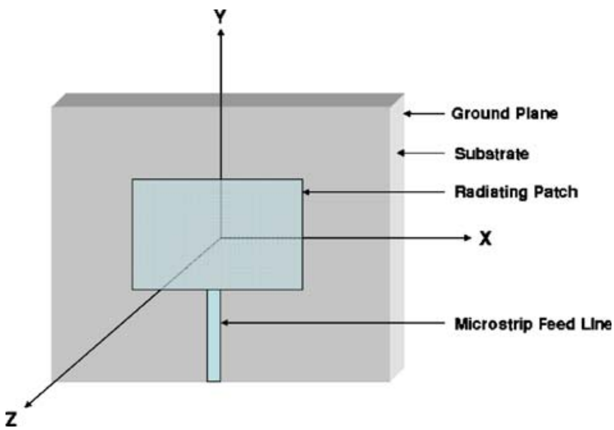

Fig. 1 Geometrical configuration of the rectangular microstrip patch antenna at THz frequency.

systems at THz frequency which would support multi-gigabit data rates transmission [18, 19]. The simulation results of rectangular microstrip patch antenna at THz frequency (0.7–0.85 THz) are presented. The shorting pin located close to the feed point results a significant reduction in overall patch dimension [20]. Figure 2 shows the return loss of the proposed rectangular microstrip patch antenna with and without shorting pin. The resonant frequency downshifts for shorting pin structure compared to that of without shorting pin. The radiation efficiency and gain of the antenna has been increased in the shorting pin configuration compared to that of without shorting pin. From the Fig. 2, the resonant frequency of the proposed antenna for without shorting pin structure is around 742.15 GHz and the 10 dB impedance bandwidth of the antenna is 17.76% with respect to the centre frequency of operation. Without shorting pin the gain, directivity and radiation efficiency of the antenna are 3.497 dB, 6.038 dBi and 55.71%, respectively, whereas for the shorting pin structure, these parameters are 3.502 dB, 6.03 dBi and 55.88%, which is quite high for proposed small antenna. The 10 dB impedance bandwidth in the case of shorting post microstrip patch antenna is 17.27%, which decreases as compare to without shorting pin structure. As we know that the patch antennas on a high dielectric constant substrate are becoming attractive for miniaturized modes but it results strong surface wave modes. The diffraction from the surface waves at the edge of the finite size substrate degrades the radiation pattern and reduces the radiation efficiency of the patches. This is the basic reason behind the less efficiency and gain of the antenna without shorting post. For the shorting post structure the surface wave in the substrate will be discontinues. So the electrical parameter of the antenna increases. In the proposed antenna structure, we have taken the shorting pin close to the feed point (15 μm distance away from the feed point).

The E and H plane far-zone radiation pattern for the gain of rectangular microstrip patch antenna at 775 GHz frequency is shown in Fig. 3. Without using a shorting pin, the main lobe magnitude of the E-plane is 3.5 dB with direction 225°, where as main lobe magnitude

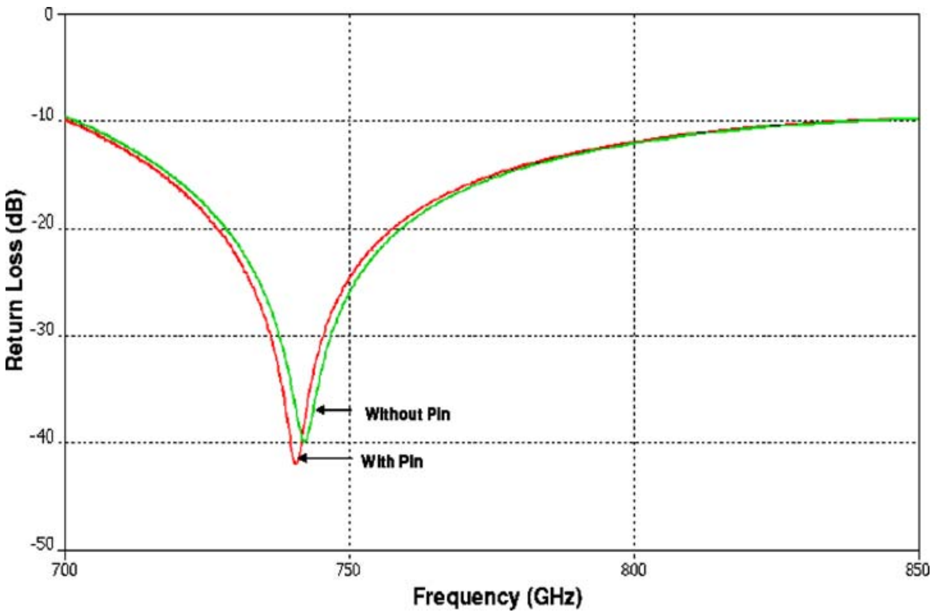

Fig. 2 Return losses (dB) of the rectangular microstrip patch antenna at THz frequencies for with shorting pin and without shorting pin.

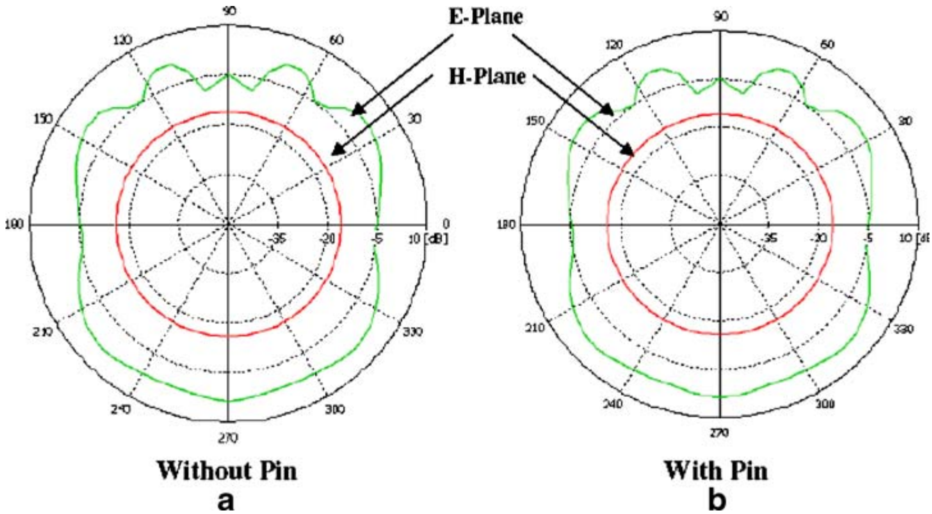

Fig. 3 E and H plane far-zone radiation pattern for the gain of proposed rectangular microstrip patch antenna at frequency 775 GHz (**a**) without shorting pin, and (**b**) with shorting pin.

of the H-plane is -16 dB with direction 15°. When we use the shorting pin at close to the feed point, the main lobe magnitude of the E-plane is 3.5 dB with direction 270°, where as main lobe magnitude of the H-plane is -15.8 dB with direction 0°.

We have also studied the radiation efficiency and gain of the proposed microstrip patch antenna in the frequency range 700 GHz to 850 GHz. With the increase of the frequency, the radiation efficiency of the proposed rectangular microstrip patch antenna increases as frequency of operation increases as shown in Fig. 4. The gain of the antenna increases with increase of the frequency as shown in Fig. 4. But we have performed simulation at the center frequency 775 GHz of operation, which has radiation efficiency and gain as 55.74% and 3.09 dB, respectively. Because the electrical parameters at the frequency 742.15 GHz, which is dip of the return loss of the antenna without shorting pin have radiation efficiency (50.74%) and gain (3.099 dB). Similarly with shorting pin at frequency 740.8 GHz the radiation efficiency and gain are 50.98% and 3.068 dB, respectively, which is smaller than the center frequency parameters.

The width of the microstrip line that is the feeding technique used in the simulation of the proposed rectangular microstrip patch antenna strongly affects the radiation efficiency. As the width of the strip-line increases, the radiation efficiency and gain decreases as shown in Fig. 5, whereas the return loss decreases with the increase of the strip-line width. We have discussed the variation of the width of the strip-line from 10 μm to 60 μm, but here we are interested at the width of 40 μm, on which we get satisfactory radiation efficiency and gain as well as return loss. Due to this reason, we have not considered the point at which radiation efficiency and gain are high, instead the point of interest is at 40 μm width of strip-line. At this point we get balanced radiation efficiency and gain as well as return loss.

4 Conclusion

In this paper, we have attempted to provide simulation results of the rectangular microstrip patch antenna at THz frequencies for potential application in short-distance wireless

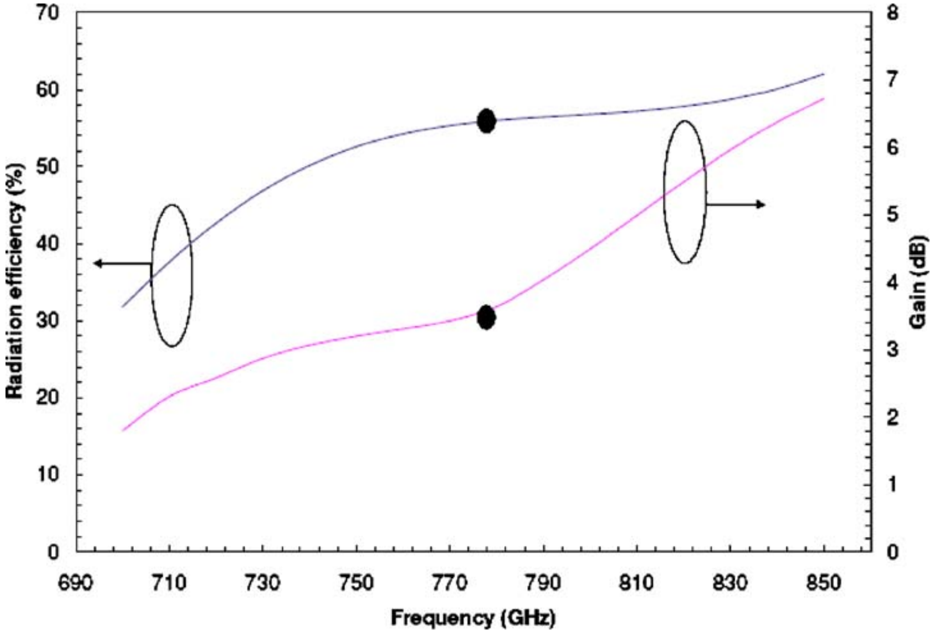

Fig. 4 Variation of the radiation efficiency and gain of the rectangular microstrip patch antenna at THz frequencies.

communication systems which is very interesting. The size of proposed microstrip antenna is very small and is appreciable for satellite communication systems. One of the principle challenges in realizing modern wireless communication links for long distance at THz frequency regime are phenomena occurring during electromagnetic wave propagating through

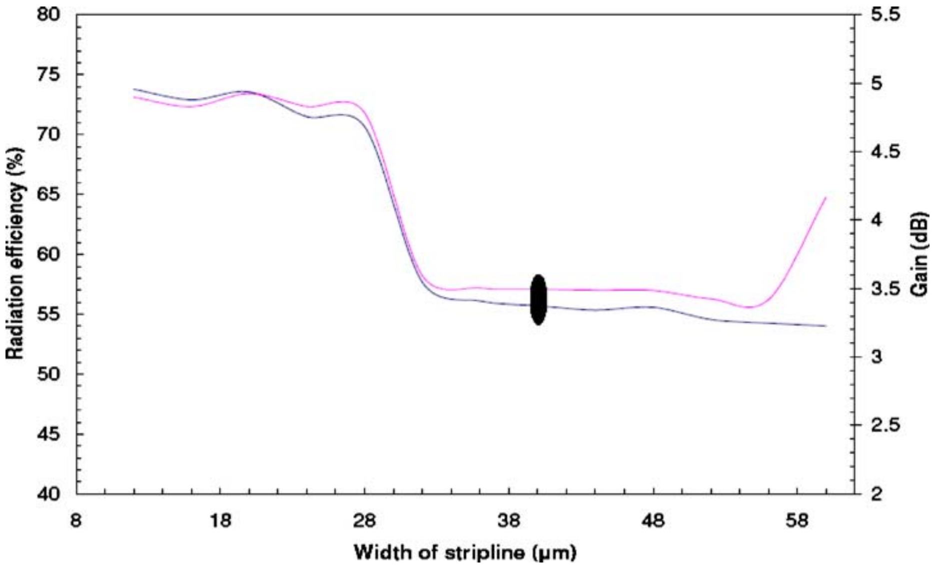

Fig. 5 The effects of variation of width of microstrip-line (feed-line) on the radiation efficiency and gain of the rectangular microstrip patch antenna.

atmosphere. For satellite-to-satellite communication, atmospheric absorption is not a problem. The theoretical analysis as well as experimental measurement of this proposed antenna is very interesting which is underway and will be reported in future communication.

References

1. S. Galoda, and G. Singh, *Terahertz technology — an emerging electromagnetic spectrum, Proc. International Conference on Information and Communication Technology (IICT-2007)*. (DIT Dehradoon, India, 2007,)pp. 482–486 July 26-28.
2. S. Galoda, and G. Singh, “Fighting terrorism with terahertz”. IEEE Potential Magazine **26**(6), 24–29 (2007)Dec.
3. J. Grade, P. Haydon, and D. V. Weide, “Electronic terahertz antennas and probes for spectroscopic detection and diagnostics”. Proc. IEEE **95**(8), 1583–1591 (2007)Aug.
4. P. Kumar, A. K. Singh, G. Singh, T. Chakravarty and S. Bhooshan. “Terahertz technology – a new direction.” Proc. IEEE Int. Symp. Microwave, pp. 195-201 (2006).
5. S. P. Mickan, and X.-C. Zhang, Terahertz Sensing Technology, edited by D. L. Woolard, W. R. Loerop, and M. S. Shur (World Scientific, Singapore, 2003).
6. D. R. Vizard, “Millimeter-wave applications: from satellite communications to security systems.” Microw J, pp. 22-36, July 2006.
7. E. R. Brown, K. A. McIntosh, K. B. Nichols, and C. L. Dennis, “Photo mixing upto 3.8 THz in low temperature grown GaAs”. Appl. Phys. Lett **66**, 285–287 (1995)Jan.
8. S. Verghese, K. A. McIntosh, and E. R. Brown, “Optical and terahertz power limits in the low temperature GaAs photomixer”. Appl. Phys. Lett **71**, 2743–2745 (1997)Nov.
9. R. Mendis, C. Sydlo, J. Sigmund, M. Feiginov, P. Meissnev, and H. L. Hastnagel, “Spectral characterization of broadband THz antennas by photoconductive mixing; Towards optimal antenna design”. IEEE Antenna Wireless Propagation Lett **4**, 85–88 (2005).
10. I. G. Gregory, W. R. Tribe, B. E. Cole, M. J. Evans, E. H. Linfield, A. G. Davies, and M. Missons, “Resonant dipole antennas for continuous wave terahertz photomixers”. Appl. Phys. Lett **85**, 1622–1624 (2004)Jan.
11. M. Matsuura, M. Tani, and K. Sakai, “Generation of coherent terahertz radiation by photomixing in dipole photoconductive antennas”. Appl. Phys. Lett **70**, 559–561 (1997).
12. F. K. Schwering, “Millimeter wave antenna”. Proc. IEEE **80**(1), 92–102 (1992)Jan.
13. T. Seki, N. Honma, K. Nishikawa, and K. Tsunekawa, “Millimeter-wave high-efficiency multilayer parasitic microstrip antenna array on Teflon substrate”. IEEE Trans. Microwave Theor. Techniques **53** (6), 2101–2106 (2005)June.
14. D. M. Pozar, “Microstrip antennas”. Proc. IEEE **80**(1), 79–91 (1992).
15. A. A. Abdelaziz, “Bandwidth enhancement of microstrip antenna”. Prog. Electromagn. Res **63**, 311–317 (2006).
16. R. Garg, and V. S. Reddy, “Edge feeding of microstrip ring antennas”. IEEE Trans. Antenna Propag **51** (8), 1941–1946 (2003)Aug.
17. M. Saed, and R. Yadla, “Microstrip-fed low profile and compact dielectric resonator antenna”. Prog. Electromag. Res **56**, 151–162 (2006).
18. A. Sharma, V. K. Dwivedi and G. Singh, “THz rectangular patch microstrip antenna design using photonic crystal as substrate,” Proc. Progress In Electromagnetic Research Symposium (PIERS 2008), pp. 161-165, July 2-6, 2008, Cambridge, USA.
19. R. Piesiewicz, T. Kleine-Ostmann, N. Krumbholz, D. Mittleman, M. Koch, J. Schoebel, and T. Kurner, “Short-range ultra-broadband terahertz communications: concept and perspectives”. IEEE Antennas Propag. Mag **49**(6), 24–38 (2007)Dec.
20. A. Sharma, and G. Singh, “Design of single pin shorted three dielectric layered substrates rectangular patch microstrip antenna for communication systems.” Prog. Electromag. Res. Lett **2**, 157–165 (2008).