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Review

Terahertz planar antennas for future wireless communication: A technical review

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HIGHLIGHTS

- The application scenario of the terahertz (THz) spectrum in communication has been discussed.
- A brief review of the semiconductor terahertz sources for compact communication system has been presented.
- The need of the high gain antennas for the communication has been presented.
- The importance of the planar antennas in the THz communication has been discussed.
- Various methods to enhance the gain of the planar antenna to meet THz communication requirement has been discussed.

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ABSTRACT

With the monotonic increasing demand of the higher bandwidth for the next generation wireless communication system, the extension of the operating frequency of the communication system to the millimeter/Terahertz wave regime of the electromagnetic spectrum where several low-attenuation windows exist is inevitable. However, before the commercial implementation of the wireless communication in these low-attenuation windows, there are various obstacles which need to be addressed by the scientists and researchers. The atmospheric path loss is the main obstacle to the full-fledged implementation of the terahertz wireless communication. The remedy to this problem is the use of high-power sources, efficient detectors and high gain antenna systems. This paper reviews these technical issues with the special attention to the planar antennas which might contribute to the compact, inexpensive, and low profile future terahertz wireless communication system design.

Contents

1. Introduction

Terahertz frequency (THz) band is coarsely defined as a portion of the electromagnetic spectrum, which extends from 0.1 THz to 10 THz and occupies an extremely large regime of the electromagnetic spectrum between the infrared and microwave bands. This

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far-infrared region is important because of the rich physical and chemical processes with spectrographic foot-prints. Due to the unavailability of powerful sources, detectors and other hardware, this band has remained untouched by the scientists and researchers for a long time and being named as a 'terahertz band gap'. In the last two decades, the semi-conductor technology has grown exponentially and its effect on the research in this band-gap of the electromagnetic spectrum has also been noticed [1]. With the sustaining progress in the terahertz research, various potential applications of this spectrum in the field of science and technology have been reported. Categorically speaking, terahertz spectrum finds its various applications in the medical science [2,3], imaging of concealed items [4–10], time domain spectroscopy [11], defense applications [12], earth and space science [13], basic science, and space instrumentation [14] agriculture, semiconductor wafer inspection, and air pollution checking [15]. The broad application area of terahertz spectrum is due to its unique radiation characteristics [16], which have been summarized as follows:

(a) Penetration: The terahertz wave can pass through the different materials with different level of the attenuation.
(b) Resolution: The resolution of an image increases with the decrease in the wavelength and the resolution in the terahertz band is better than that of the microwave regime of the spectrum.
(c) Spectroscopy: Various solid and gaseous materials exhibit terahertz signature in 0.5–3 THz band and can be used for the detection.
(d) Non-ionization: Due to the low power levels, terahertz exhibits low ionization effect on the biological tissues.
(e) Scattering: The scattering is inversely proportional to the wavelength and it is low in the terahertz band in comparison to the light wave.
(f) Intensity: The collimation of the wave is easier in the terahertz regime of the spectrum in comparison to that of the microwave.

As the aforementioned properties of the terahertz wave like collimation, resolution, terahertz signature, non-ionization effect are few, which indicate that the terahertz frequency of the electromagnetic spectrum is the potential candidate for the various scientific and industrial applications.

2. Terahertz in communication

Apart from the conventional applications, a new area of debate is the application of the terahertz band in the future wireless communication systems [17,18]. Due to the monotonic increase in the demand of the fast transmission and reception and an exponential growth of the population, the demand of the high data rate communication systems is increasing. As per the latest survey, by 2015, the communication system has to enhance its bandwidth to cater the data rate of 40–100 Gbps for the indoor and 100 Gbps for the outdoor communication [15], which is the potential challenge to the scientific community. There are two possible ways in which the data rate can be enhanced. First, by increasing the bandwidth of the communication system but the system is inherited with the narrow bandwidth and in most of the cases the device bandwidth is only about 10% of its operating frequency. The next solution to this problem is to increase the operating frequency to such an extent that even with the narrow bandwidth, communication systems may fetch a high data rate to the target customers. Recently, to meet the high bandwidth requirement, 60 GHz and 90 GHz [19–21] wireless systems have been developed but they are still insufficient to meet the future requirement. The next best solution to this problem is to move the operating frequency to the terahertz band which is sandwiched between microwave and far-infrared frequency regime of the spectrum as shown in Fig. 1. However, with the increase in the operating frequency, the device characteristic also changes and there is the need of the analysis of the various THz wireless communication system components. Interestingly, due to its unique position, as this band is situated between these two already well explored regimes of the spectrum, it is possible to use electronic as well as photonic route to pave the way in the terahertz spectrum. On this way, the electronic and photonic routes are capable of exploring these components in the in the near microwave and the far-infrared THz band, respectively [22].

However, before exploring the device characteristics in this band, it is interesting to compare the advantages and disadvantages of the terahertz wave with respect to the microwave and far-infrared communication. The various advantages of the application of this band of electromagnetic spectrum in the communication system are summarized as follows [23]:

(a) Microwave band is almost all pre-occupied by different services and its bandwidth is limited. In place of this, the terahertz can offer a wider bandwidth.
(b) The diffraction of the THz wave is low in comparison to that of the microwave and millimeter wave, which is the advantageous in the line-of-sight (LOS) point-to-point link.
(c) In the recent proposal the maximum allocated frequency is 250 GHz and thereafter it is license free.
(d) This band is comparatively secure, especially in the spread spectrum technology.
(e) In comparison to infrared, THz has low attenuation of the signal in certain atmospheric conditions like fog.
(f) Time varying refractive index of the atmospheric path increases the scintillation effect in the infrared link and it can be reduced in the THz communication link.
(g) It is a viable solution to the last and first mile problem.
(h) The significant development to enhance the data rate in the infrared wireless communication is slow due to the requirement of the advanced modulation formats like orthogonal

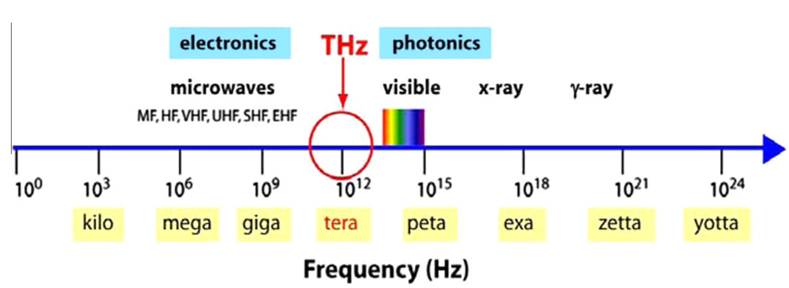

Fig. 1. The position of THz band between the microwave and far-infrared electromagnetic spectrum.