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Design of THz Antenna sensor and instruments in astronomy

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Abstract

In this paper, a monopole patch antenna sensor is proposed for instruments in astronomy. Indium Phosphide (InP) substrate is chosen due to its unique dielectric behavior at THz frequencies. It has high resistivity and high absorption coefficient which is essential for THz radiations. It is proved in the simulated results of the proposed antenna model that with the addition of the Benzocyclobutene (BCB) layer, the improvement in the value of the bandwidth. The designed antenna exhibits a sharp resonance dip of Reflection coefficient (S11) –39.8dB, at 408 GHz, and achieves a wide impedance bandwidth of 25.6 % from 361 GHz to 467 GHz, and maximum gain 2.6 dB. The antenna radiation pattern is almost stable over the entire bandwidth, which is very suitable for a reliable wireless connection. Furthermore, this compact antenna only occupies an active area of 240 µm × 295 µm × 60 µm. All of the results obtained make the proposed design a viable candidate for high speed and short-range wireless communication systems. The proposed antenna has a simple and compact structure which can be integrated into microelectronic components. The analysis of the proposed antenna is done in HFSS software and is validated using the CST software.

Keywords: Submillimeter wave technology, detector, Indium Phosphide (InP), Benzocyclobutene (BCB), ultra large band UWB.

Introduction

As the number of subscribers and services in the wireless communication channel is increasing day by day, there is a requirement to use THz spectrum in the near future to avoid congestion and traffic in RF and Microwave frequency spectrum. THz frequencies require miniaturized antennas that would possibly transmit and receive at a high data rate, high spatial resolution, low transmission power, and wide bandwidth.

The saturation of wireless spectrum access is leading to technology innovations in areas such as spectrum resource usage. The millimetric frequency bands currently in use (below 100 GHz) do not seem sufficient to accommodate the predicted future data-rate requirements . On the horizon beyond 4G and 5G networks, Terahertz wireless communications transceiver components will play a crucial role in ultra-fast data capacity wireless link oriented to data centre networks. Also behaving in real world short-range scenarios as offices or universities areas. This entails to satisfy extremely highly controlled environmental conditions, and significantly alleviating the workloads interconnections in this area.

In the past 20 years, NASA has been leading Terahertz (THz) technology development for the sensors and instruments in astronomy. THz technologies are expanding into much broader applications in recent years. Moreover, the emerging THz antennas extend their imaging technique towards the screening of metals, weapons, explosives in the military application

Antenna Design and Configuration

The bottom view and side view of the proposed antenna is shown in Figure 1. Gold is used as a conducting material for the patch and ground having a thickness h3 of 2µm with a conductivity of 4.561×10^7 S/m. The substrate used for the proposed antenna design is composed of two layers, in which the top layer material . Indium Phosphide (InP) which has a dielectric constant of 12,5 with a loss tangent of 0,003 and thickness h2=6µm, the inferior layer is made of Benzocyclobutene (BCB)) with a dielectric constant of 2,5 with a loss tangent of 0.005 and thickness h1=50µm. Silicon is chosen due to its unique dielectric behavior at THz frequencies. It has high resistivity and high absorption coefficient which is essential for THz radiations.

A commercial computer simulation tool High Frequency Structure Simulator (HFSS), is used to design the antenna. The optimized dimensions are presented in Table 1.

parameter	(µm)	parameter	(µm)
W_s	240	W_p	240
L_s	295	L_p	109
h_1	50	W_f	40
h_2	6	L_f	115
h_3	2		

Table 1 : Parameter values of the geometry antenna

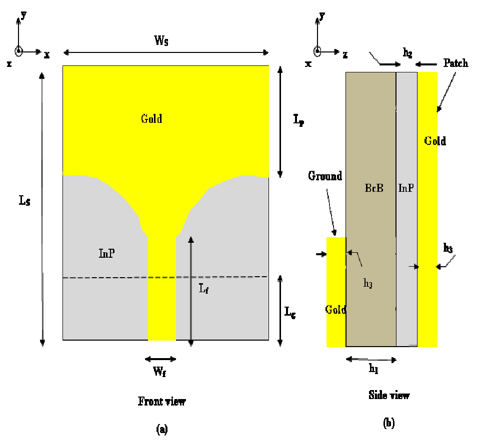

Figure 1 : Geometry and configuration of the proposed Antenna

Results

Figure 2 shows the curves of the simulated S11, the prototype antenna is designed to activate in a bandwidth of 361-467 GHz and 380-500 GHz by HFSS and CST software, respectively. The antenna exhibits a sharp resonance dip of S11 is –39,8dB at 408 GHz with HFSS. The curve with CST exhibits a sharp resonance dip of S11 is –21dB at 435 GHz. The difference between the simulated results of CST and HFSS is due to the different numerical techniques employed by the two software. HFSS uses the finite element method, and CST the finite integration technique.

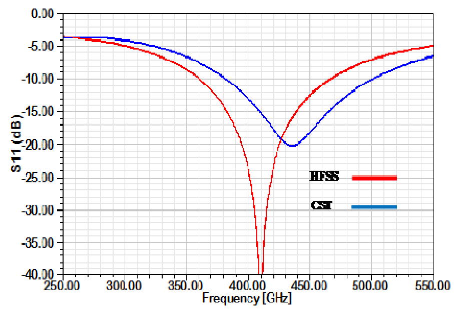

Figure 2: Simulated S11 of the proposed antenna using CST and HFSS software.

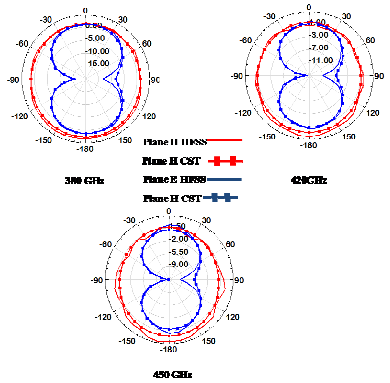

Figure3: Simulated 2D polar radiation patterns of the proposed terahertz antenna at several frequencies on both the E- and H-planes by CST and HFSS simulators..

The simulation results 2D of radiation pattern at the following frequencies: 380 GHz, 420 GHz, and 450 GHz with two simulators HFSS and CST MWS are shown in Figure 3. A good Omni-directional pattern in H-plane and dipole like pattern in E-plane is observed in Figure.. As can be seen that a good agreement is achieved between the two simulators.

Conclusion: **In this paper, a conventional Microstrip patch antenna, has been analyzed and simulated at terahertz frequency on two substrates having different dielectric permittivity values. The designed antenna bandwidth is about 361-467 GHz. Furthermore, the simulation results reveal that the gain of the antenna is around 2.6 dBi at this frequency band. The obtained gain is high which makes the antenna promising for communication systems. All the results achieved make the proposed designs viable candidates for high-speed and short-distance wireless communication systems. This compact antenna only occupies an active area of 240 μm × 295 μm × 60 μm.**

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