A Corrugated SIW Based Slot Antenna for Terahertz Application

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***Abstract*—This paper proposes a Corrugated Substrate Integrated Waveguide (CSIW) based slot antenna for THz application. A CPW to CSIW transition is realized and the antenna operates around 0.9 THz. The antenna uses Cyclo Olefin Copolymer (COC) as a dielectric material which exhibit a loss tangent of 0.0007 at THz frequencies. The proposed slot antenna has realized gain of 5.9 dB when using Gold. The radiation, as well as total efficiency of the antenna, is around 50% using Gold which increases to 85% with a gain of 7.6 dB by replacing it with Graphene.**

Keywords— SIW; Tera-hertz; slot antenna

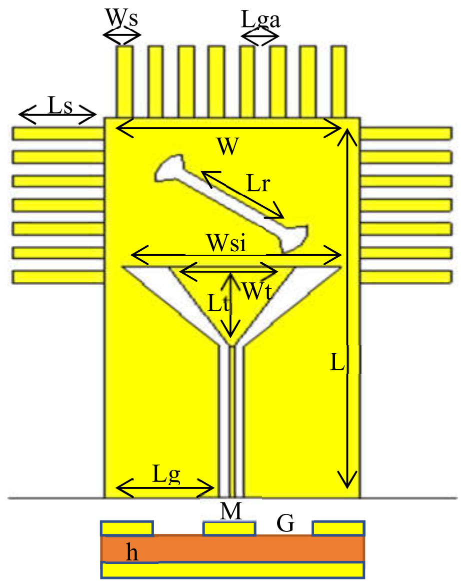
I. Introduction

In 2017 IEEE Std 802.15.3d standard [1] was approved as 100 Gbps wireless switched point-to-point system. Continuous data transfer, theoretically unlimited bandwidth and ultra-fast download are all features of the THz technology which is expected to alter the telecommunications landscape. The THz band which spans around (0.1–10 THz) has been finding its applications in numerous fields including post 5G communication network [2], Imaging and detection, [3] and non-contact sensing of materials [4].

The implementation of THz components and circuits poses two significant challenges i.e., choice of material and fabrication. In terms of material, metals such as copper, gold and silver which is employed in mmWave circuits experience high conduction losses due to reducing skin depth at THz frequencies. It is in this regard a THz antenna with low loss and high gain is essential for efficient working in THz circuits. The choice of graphene as a radiating element has recently triggered researchers to develop components and especially antennas for THz application. Graphene is a two-dimensional material with excellent electromagnetic properties. At higher frequencies typically beyond 30 GHz, transmission losses and radiation prevent the use of microstrip or coplanar waveguide technology. An alternative to microstrip based technology is SIW technology [5] which is a typical rectangular waveguide in planar form. It exhibits high-quality factor and high power-handling capability. The most significant advantage of SIW is the integration of all the components-passive and active devices including antennas on the same substrate. This at THz frequency would make a System In Package (SIP). One of the complexities in integrating an active device within the waveguide structure is the need for DC isolation of the bias circuit. In this case, an SIW is converted to CSIW [6] eliminating vias in the SIW design. In this paper, a CSIW slot antenna at THz with CPW to SIW transition is presented. A comparison between Gold and Graphene in terms of efficiency and gain is presented.

II. Antenna Design

The proposed antenna is designed and optimized using CST Microwave Studio. Figure 1 shows the layout of the proposed antenna. The antenna height 'h' is kept 6 um on a COC



(a)

Fig. 1. The geometry of the proposed THz antenna. (M=4 um, G=10 um, Lm=190 um, Lg=113 um, Lt=100 um, Wt=125 um, Wsi=215 um, Lr=125 um, Ls=100 um, Ws=14 um, Lga=16 um,)

substrate. The COC is a low loss substrate with a dielectric constant, $\varepsilon_r = 2.2$ and $\tan\delta = 0.0007$ at 1 THz [7]. The thickness of the gold conductor is kept around 200 nm. The total dimension of the top layer CSIW antenna 'W×L' is around 250×477 um. The width of the ground plane which is a gold layer at the bottom is kept 450 um. The proposed antenna could be easily fabricated by spin coating COC after deposition of gold layer on a silicon wafer which will form a ground plane. A PMMA layer as photoresist followed by lithographic process and development. The deposition of final gold layer on the top will complete the antenna fabrication process. Conventional vias that are normally used to realize SIW structure have been replaced with quarter-wavelength open stubs. This will eliminate the complex fabrication steps involved in creating via holes during the micro-fabrication process. Due to CPW feed the proposed antenna could be easily measured using GSG probe station.

III. RESULT AND DISCUSSION

The reflection coefficient (S_{11}) is plotted in Fig. 2. The figure demonstrates a narrow-band resonance around 0.9 THz with -10 dB as a reference. The antenna has a bandwidth of 30 GHz, i.e., 900-930 GHz. The taper length 'Lt' can be varied to tune the resonance frequency at the desired operating frequency. The variation in the frequency with respect to change in 'Lt' is shown in figure 3. The gain and efficiency of the proposed slot antenna is given in Table I. The antenna metal layer was replaced with a graphene layer in simulation for comparison with Gold. It can be clearly seen that Gold has high conduction loss at THz frequency with the radiation efficiency of 50 %. With graphene as a conducting material, the efficiency increases to 85% without optimizing the impedance matching.

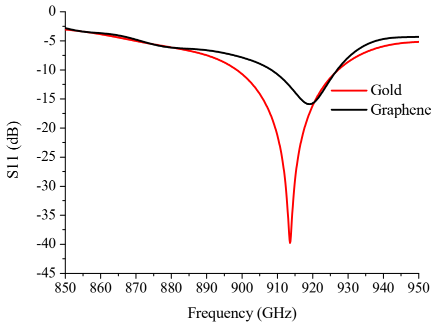


Fig. 2. Simulated S_{11} of the proposed THz slot antenna.

TABLE I. Performance metrics of the proposed THz antenna

Metal	Frequency (GHz)	Radiation Efficiency (%)	Realized Gain (dB)
Gold	915	50	5.9
Graphene	915	85	7.62

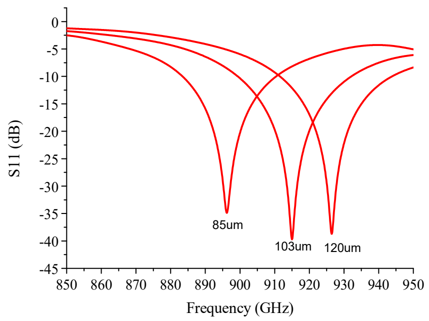
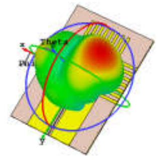


Fig. 3. Variation of taper length "Lt" of the proposed THz slot antenna

The E and H-plane radiation patterns of the antenna is shown in figure 4. The main lobe is shifted from the broadside to around 45°.



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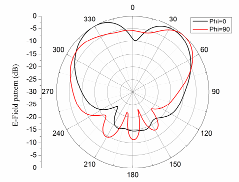

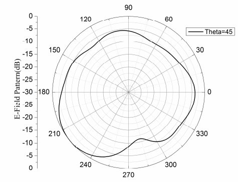

(b) (c)

Fig. 4. Simulated radiation pattern of the proposed THz slot antenna using Gold: (a) 3D radiation pattern, (b) E-plane cut and c) H-plane of the proposed antenna.

IV. CONCLUSION

A CSIW based THz slot antenna is designed to operate around 0.9 THz. The proposed antenna has gain of 5.9 dB with gold as a metal layer. This could be increased to 7.6 dB if simply replaced with Graphene. The proposed antenna is suitable for various kind of THz application including medical imaging, explosive detection and Tbit/sec links. The advantage of via less CSIW is that it could easily integrate an active device such as THz Gun diode on the top layer enabling a direct shunt connection to the ground due to isolation of the top and bottom layer in the waveguide. The proposed antenna could be extended to hundreds of slots to obtain a very high gain THz antenna.

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