Folded Terahertz Antenna based on MoS_2 and Gold for Biomedical Imaging

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***Abstract*—This paper presents a hybrid antenna design for terahertz communication. The proposed antenna operates in the frequency range of 0.85 - 0.95 terahertz (THz). Full wave electromagnetic simulations show that combination of molybdenum disulfide MoS_2 material and gold improves the antenna efficiency from around 60% to almost 85% in the desired frequency band. The proposed hybrid design can be used in high-resolution imaging and suitable for biomedical applications.**

***Index Terms*—terahertz, MoS_2, gold, biomedical imaging**

I. Introduction

Due to the growing needs of higher datarate, reliable and low-latency wireless communication systems, research trends have shown a migration towards the THz spectrum [1]. Latest research has been concentrated to overcome the transmission and fabrication challenges of THz communication system including antennas, system reliability and applications [2]. Consequently, THz devices can be found in applications such as bio-sensing, imaging, and radar communication [3]. Due to limited penetration capability inside the human body, the possibility to create harmful ionization to the skin is very low. This feature is considered as a great advantage to medical imaging systems such as x-rays. An effective antenna is a crucial in developing a high-implementation THz system. Hence, several design aspects need to be studied to create an antenna which is ready to satisfy the requirements of THz applications [4]. Rapid growth has been observed in the use of 2D-dimensional materials as alternative to conventional material such as copper and aluminium which generates high loss and poor radiation efficiency due to skin depth effect [5]. Carbon-based materials,mi.e., Graphene have shown promising results in this regard [6]. Alongside, Perovskites, due to superconductivity, ferro-electricity, and low cost also studied at THz frequency band [7]. Transition metal dichalcogenides (TMDs) are reported to be interesting because of their varied physical and electrical properties [8], in particularly molybdenum disulfide (MoS_2). MoS_2 has become a popular material due to its unique electrical and chemical properties and its use as a potential substitute for graphene [9]. This paper presents a novel design of an efficient, meta-material-based THz antenna through which high-resolution imaging can be achieved for biomedical applications.

II. hybrid Antenna Design

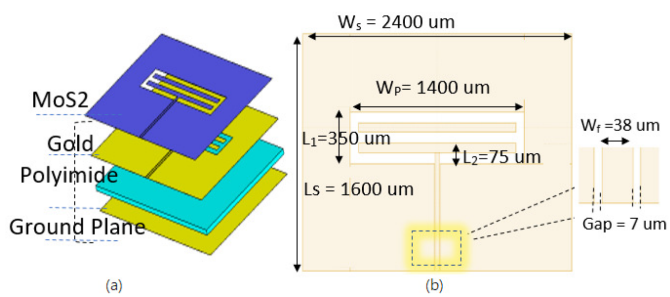


Fig. 1: Proposed antenna design: (a) Antenna structure; (b) Front view.

The hybrid ($MoS2/gold$) antenna design is simulated and analyzed using a full-wave commercial electromagnetics solver, CST Microwave Studio 2018. The MoS_2 material was set through the complex permittivity values. Figure 1 a and b shows the antenna design with the dimensions $2400 \times 1600 \times 50 \mu m$, consisting of a MoS_2 based gold and polyimide substrate. Thin flexible film of Polyimide is used as a substrate with the dielectric constant $\varepsilon_r = 3.5$ and loss tangent $\tan \alpha = 0.00025$).

III. Results and Discussion

Figure 2 shows reflection coefficient S_{11} in the frequency range of $0.85 - 0.95$ THz. The hybrid material design as well as gold-based antenna provides an excellent antenna performance in the desired frequency range. The hybrid antenna design provide better S_{11},i.e., -40 dB at the center frequency.

The results in Figure 2 also show the value of the Voltage Standing Wave Ratio (VWSR) vs frequency. VWSR is less than 2.5 in both antenna structures. Both the the gold-based design and the hybrid ($MoS2/gold$) design leads to better reflection coefficient performance which is due to the skin depth effect of the gold at THz band. The efficiency and the realized gain of the proposed antenna is shown in Figure 3. The radiation efficiency of the gold and the hybrid material structure (($MoS2/gold$)) is considerable higher in the whole frequency band. It is clear that adding MoS_2 material on top of gold the radiation efficiency of the antenna increases from 65% to 85%. The antenna gain is fluctuating with frequency for both gold and hybrid antenna structure. A maximum gain of 13 dBi is achieved with Mos2 hybrid structure and about 11 dBi at the high end of desire band. Figure 4 shows the simulated E- and H-plane radiation patterns at selected frequencies, i.e., 0.9 and 0.95 THz. It is seen that this antenna has nearly omni-directional radiation characteristics while the cross-polarisation level rises with frequency increase owing to the horizontal components of the surface.

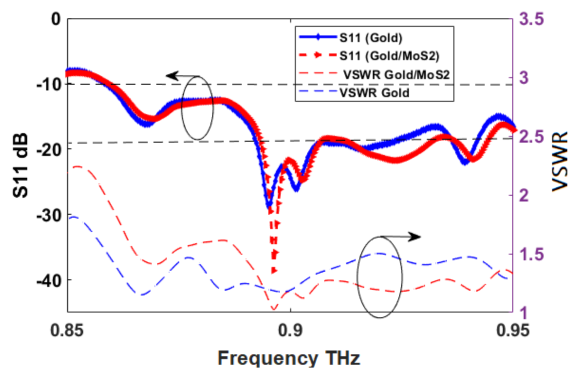


Fig. 2: Simulated VSWR and S_{11} profile of antenna

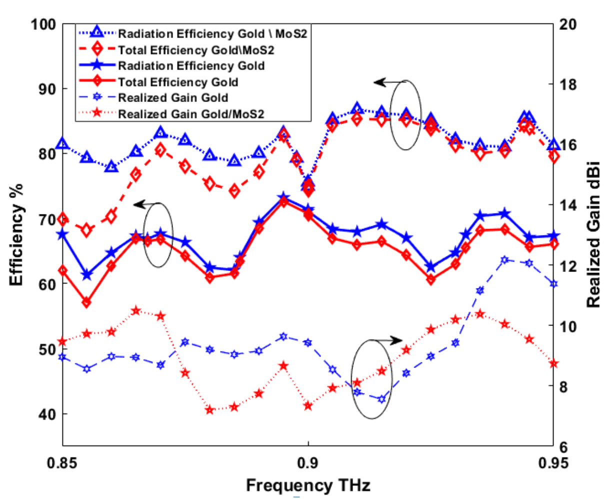
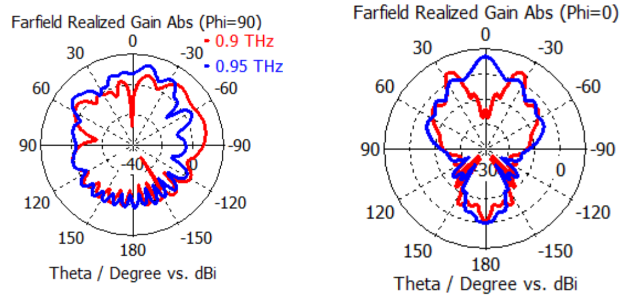


Fig. 3: Efficiency and gain of the two proposed Folded antenna structure (Gold/ MoS_2 and gold only).



(a) H plane

(b) E plane

Fig. 4: The H-and E-plane radiation patterns of the hybrid Folded $goldMos_2$ antenna.

IV. Conclusion

A folded antenna simulated using a multilayered structure of MoS_2, gold and polyimide substrate was presented. Results show that in the terahertz frequency range of 0.85 to 0.95 THz, the antenna performance of the hybrid design (gold/MoS_2) is significantly better than the antenna based on conventional metals such as gold. Due to the extremely thin nature of the proposed multilayered structure along with the flexible nature of the substrate, the proposed design can be used for biomedical imaging applications.

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