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Abohmra, A., Kazim, J., Abbas, H., Imran, M. , Alomainy, A., Rehman, M. and Abbasi, Q. H. (2021) Ultra-wideband Hybrid PICA Terahertz Antenna for High-Resolution Biomedical Imaging. In: 2020 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting, Montréal, QC, Canada, 05-10 Jul 2020, pp. 1759-1760. ISBN 9781728166704 (doi:10.1109/IEEECONF35879.2020.9329897).

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Deposited on: 19 March 2020

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Ultra-wideband Hybrid PICA Terahertz Antenna for High-Resolution Biomedical Imaging

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***Abstract*—This paper presents the utility of a hybrid perovskite material, methyl-ammonium lead iodide (chemical formula, $CH_3NH_3PbI_3$) in the design of a terahertz (THz) antenna. The proposed planar inverted cone antenna (PICA) operates in the frequency range of 0.6 - 2.4 THz. Full wave electromagnetic simulations show that antennas fabricated using a combination of the perovskite material and gold improve the antenna performance, and can be used for imaging in biomedical applications.**

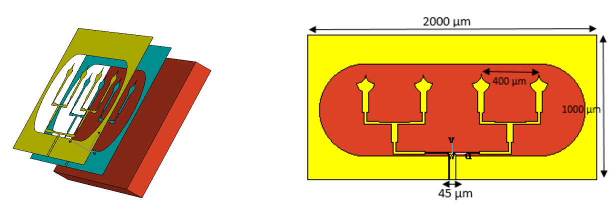
***Index Terms*—terahertz, perovskite, gold, biomedical imaging**

I. Introduction

For biomedical applications in particular imaging, terahertz (THz) waves provide a powerful tool as they are non-ionizing in nature, thus causing minimal radiation harm [1]. Furthermore, THz waves are strongly absorbed by water molecules that enable a high-resolution observation of problems that emanate on the human skin such as burns, and malignant growth, all without any detrimental effects [2]. Owing to the enormous potential in developing non-invasive biomedical devices, there has been an enormous amount of research conducted lately in proposing THz based imaging and sensing devices. However, the naturally available materials fail to display high radiation efficiency at the terahertz band. The advancement in nanotechnology fabrication techniques can enable the realization of highly specific designs based on metamaterials that can then be manufactured at a mass scale [3]. Perovskite compounds, due to features such as superconductivity, ferroelectricity and low cost, have gained focus in various novel applications. In this work, the possible solutions to the above-mentioned challenges in THz technology will be explored [4]. In this paper, we focus on the design of an efficient and meta-material-based THz antenna through which high-resolution imaging can be achieved for biomedical applications.

II. Hybrid Antenna Design

The hybrid antenna design proposed in this paper is simulated and analyzed using a full-wave commercial electromagnetics solver, CST Microwave Studio 2018. The perovskite material was set through the complex permittivity values by following [4], [5]. Figure 1 shows the antenna design with the dimensions $2000 \times 1000 \times 125\mu m$, consisting of a Perovskite based picat patch, gold pica patch and a substrate. Figure 1 shows a multilayer planar inverted cone antenna (PICA) that consists of MLI perovskite, gold and a polyethylene napthalate (PEN) substrate. The proposed antenna has a width of $2000\mu m$ whereas the length is configured as $125\mu m$. Thin flexible film of Polyethylene naphthalate (PEN) is used as a substrate with dielectric constant of the PEN substrate is $\varepsilon_r = 2.5$ and loss tangent $\tan\alpha = 0.00025$). The proposed antenna with small size and different materials properties and structure of planar inverted cone antenna (PICA), which can provide an ultrawideband (UWB) with omnidirectional coverage. [6].



(a) Three-layered antenna structure

(b) Front view

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

III. Results and Discussion

Figure 2 shows the simulated reflection coefficient in the frequency range of 0.6 - 2.4 THz. The perovskite material separately as well in a hybrid combination with gold provides an excellent antenna performance in the desired frequency range. On the other hand, the antenna performance of the gold based PICA deteriorates at higher frequency. For PICA antenna based gold material failed to achieve the -10 dB at frequencies above 1.9 THz, and this is due to the skin depth effect of the conventional conductive materials at THz band. As compared to gold, perovskite materials have significantly higher conductivity which leads to better antenna performance. The radiation efciency of the antenna is shown in Fig. 3. although the radiation efciency at the lower end of the desired band range decreases at frequency of 0.6 THz, it is still achieving a high radiation efficiency above 70 % for both perovskite and hybrid materials design. As the conductivity of perovskite increases, consequently, the radiation efficiency is improved, on the other hand, the conductivity of gold decline with the frequency higher than 1.9 THz due to high surface impedance which leads to degreed of radiation efficiency, the gold antenna efficiency continue to decrease until it reaches a value of 49 % at 2.4 THz. The radiation efficiency of the perovskite material and the hybrid material structure (gold and perovskite) maintain an excellent radiation efficiency of 96 % and 90 % respectively. Both structures maintain a high efficiency within the whole frequency band. Similarly, in Fig. 4. The antenna gain gradually increases with frequency for both perovskite and hybrid material structure. A gain of 8 dBi at the lowest operating frequency of 0.6 THz is achieved and about 16.5 dBi at the high end of the interesting desire band and it is continuing to increase. Whereas for the gold pica antenna the highest gain achieve was less than 12 dBi at 1.9 THz and decrease gradually until reaches 9 dBi at 2.4 THz. Figure. 5 shows the simulated E- and H-plane radiation patterns at representative selected frequencies namely 0.9, 1.5 and 2 THz. It is seen that this antenna has nearly omnidirectional radiation characteristics, while the cross-polarisation level rises with frequency increase owing to the horizontal components of the surface.

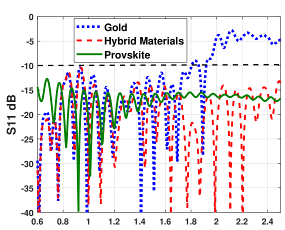


Fig. 2: Simulated S_{11} profile of antenna

IV. Conclusion

A PICA simulated using a multilayered structure of perovskite, gold and PEN substrate was presented. Results show that in the terahertz frequency range of 0.6 - 2.4 THz, the antenna performance of the proposed antenna is significantly better than antenna fabricated from 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.

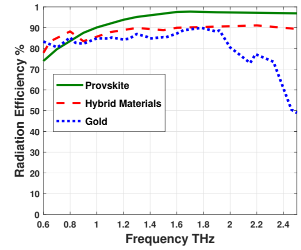


Fig. 3: Radiation efficiency of the three materials separately.

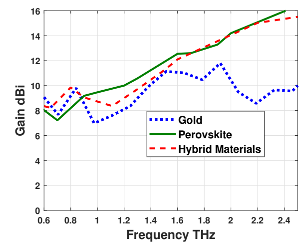
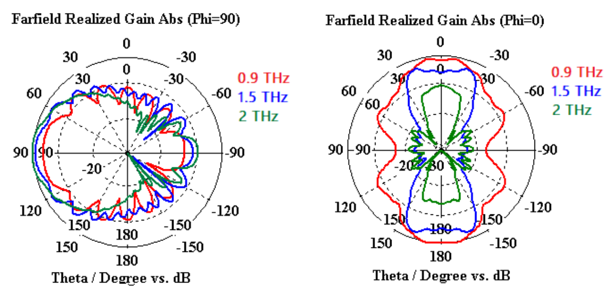


Fig. 4: Gain of the proposed PICA antenna.



(a) H plane (b) E plane

Fig. 5: The H-and E-plane radiation patterns of the hybrid PICA antenna.

Acknowledgment

Authors would like to thank the Government of Libya for providing funding for the doctoral studies of the primary author.

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