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Flexible and Wearable Terahertz Antenna for Future Wireless Communication

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***Abstract*—With the help of $\mathrm{CsPbBr_3}$ perovskite quantum material, we propose a wearable antenna that operates in the terahertz frequency range. $\mathrm{CsPbBr_3}$ was specifically employed to improve the performance of the antenna, and the findings reveal that the reflection coefficient and radiation efficiency of the antenna are improved. The performance of the antenna is assessed both on the skin and in free space. Based on the simulation findings, the suggested antenna has a bandwidth of 29 GHz and provides radiation efficiency of 90% in free-space and 45% on the human body. Moreover, gains of $4.5\mathrm{dBi}$ and $6.2\mathrm{dBi}$, respectively, in the free space and human body scenarios are achieved. As a result of the antenna's tiny and flexible construction, as well as its outstanding impedance matching and high efficiency, it is a great option for short-distance wireless communication in close proximity to the human body.**

***Index Terms*—terahertz, perovskite material, antenna**

I. Introduction

High data rate and large bandwidth are required in short-range wireless communication, and the terahertz (THz) band, which spans from 0.1 to 10 THz, is ready to satisfy these needs [1]. Furthermore, since THz waves are non-ionizing in nature, they produce the smallest amount of radiation damage to the human body. Furthermore, because of its tiny size (just a few micrometres in dimensions), the THz antenna is an excellent choice for wireless body area network (WBAN) devices [2]. However, because of the human body's radiation absorption, it is difficult to maintain excellent antenna performance on a WBAN system. Human skin is a complex, diverse tissue that behaves as an anisotropic medium electromagnetically. Because tiny structures such as blood arteries, and pigments are spatially scattered in depth, it is difficult to precisely define their form and function [3]. Consequently, wearable antennas must be carefully engineered to provide superior performance, regardless of whether the antenna operates on the human skin or within the human body. The electromagnetic characteristics of the THz spectrum are significantly different from those of the visible frequency range [4]. These characteristics make THz frequency an excellent choice for evaluating a wide variety of novel materials.

Metamaterials have been extensively employed to alter electromagnetic waves during the last decade owing to their functionally diverse and spectrally scalable features. Metasurfaces, also known as 2D planar

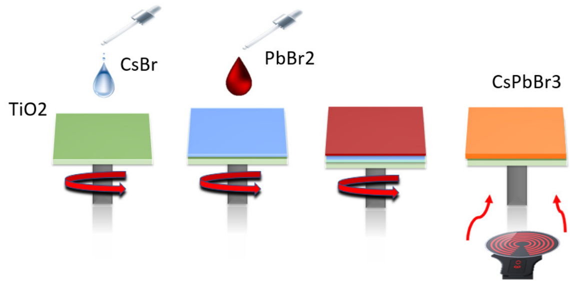


Fig. 1: Schematic fabrication procedure for the $\mathrm{CsPbBr_3}$ perovskite double layer via static coating

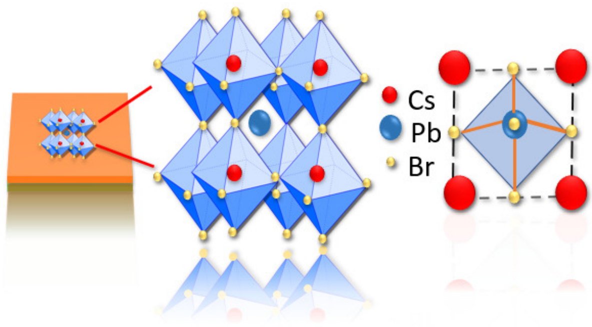
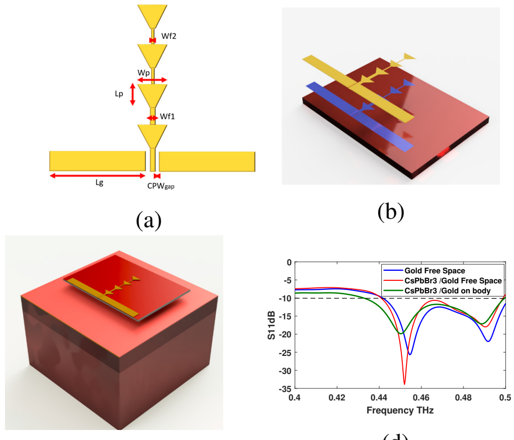


Fig. 2: Orthorhombic crystal structure of $\mathrm{CsPbBr_3}$

metamaterials, are intentionally constructed periodic resonators that may mimic quantum mechanical processes [5] [6] [7]. Since 2009, perovskite has been used as a high performance optical material in the photovoltaics area. Due to its superior optical characteristics and quantum confinement effect, inorganic halide perovskite quantum dots QDs (e.g. $\mathrm{CsPbBr_3}$ QDs) have garnered considerable interest. Kovalenko et al. described the optical features of $\mathrm{CsPbBr_3}$ perovskite for the first time, demonstrating exceptional colour purity, variable absorbance, and a remarkable quantum yield. Pervskite have been widely used in the fields of light capture [8], light-emitting diode (LED) [9], and solar cell [10]. To create a perivskite layer, a three-step sequential spincoating technique is shown in Fig 1. On the TiO2 substrate, the CsBr solvent was spincoated first, followed by a PbBr2 solution, to create $\mathrm{CsPbBr_3}$ by means of an intercalation process. $\mathrm{CsPbBr_3}$ has exceptional features like superconductivity and high



(a) (b) (c) (d)

Fig. 3: The proposed antenna design: (a) antenna array dimensions (b) Two-layer antenna structure, and (c) antenna placed on a three-layer human skin (d) Reflection coefficient.

carrier mobility, which have been investigated in a variety of unique applications [11]. Our study examines the absorption and attenuation of the human body at 0.45 THz by simulating a simple human skin model. We also propose viable solutions to WBAN issues at THz frequency.

II. Hybrid Antenna Design

Most of research investigations simulate human skin by modelling it in three layers: epidermis, dermis, and hypodermis, which correspond to the three most vital layers of human skin. [12].

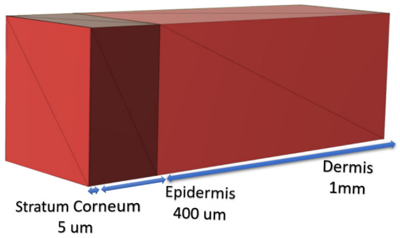


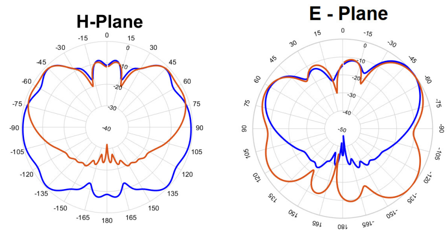
Fig. 4: Human skin model, three layers (Stratum Corneum, Epidermis, and Dermis)

The width of the antenna Wp 250μm, the length Lp is configured as 119μm. the width of feed line Wf_1 is 38 μm, and Wf_2 38 μm. The length of ground Lg is 500 μm (3a). A thin flexible film of polyethylene naphthalate (PEN) is used as substrate with a dielectric constant of $\varepsilon_r = 2.5$ and loss tangent $\tan\alpha = 0.0001$). The substrate dimensions are taken as $2000 \times 2000 \times 125\mu m$. The antenna arrays consisting of $CsPbBr_3$ material, gold and a substrate as shown in Fig 3b. The suggested hybrid antenna design is simulated and analysed in this article using a commercial full-wave electromagnetic solver, CST Microwave Studio 2020. The complex permittivity data in the THz band were used to characterize the $CsPbBr_3$ material. [13].

Figure 3c demonstrates how the thickness of human skin varies. The epidermis typically has a thickness of 0.05–1.5 mm, whereas the dermis has a thickness of 1.5–4 mm. The hypodermis has no typical value. [14], [15].

III. Results and Discussion

On a free space and on the body, the scattering parameter (S11) is shown in Figure. 3d. When compared to a gold antenna array on its own, the reflection coefficient was lowered when utilising $CsPbBr_3$ material with gold, indicating that the antenna's resonant nature has been improved. When $CsPbBr_3$ material was added, the resonant frequency to be shifted slightly.



(a) (b)

Fig. 5: The H-and E-plane radiation patterns of the proposed antenna arrays

The antenna has a wide bandwidth of 29.2 GHz. Some radiated waves penetrate through the body and dissipate as heat due to the high dielectric constant feature of the three layers of the human body, resulting in a larger bandwidth as seen in Fig. 3d. The antenna gain reduces from 5 dBi to 4 dBi because of body absorption. The directivity rises from 5 dBi in the open space scenario to 7.7 dBi in the body situation. As the gain falls, radiation efficiency decreased from 90% to around 45% at 0.45 THz, resulting in a lesser gain on the human body Fig (6). The overall radiated efficiency of an antenna on a flat body phantom is reduced by 40% due to the high conductivity of the outer layer and the lossy human body tissues. As the frequency increases, the cross-polarization level increases due to the horizontal components of the antenna's surface. This antenna exhibits almost omnidirectional radiation properties. The H- and E-plane radiation patterns of the Human body and free space senrio are shown in Fig 5. The radiation pattern of both states is consistent at the 0.45 THz. Body tissue has a variable permittivity and thickness at each layer, causing electromagnetic waves to internally reflect back to the source. During the on-body condition, the main lobe's magnitude increases. Therefore, the superposition of antenna back radiation and reflections from the multilayered human tissue introduces an improvement in directivity.

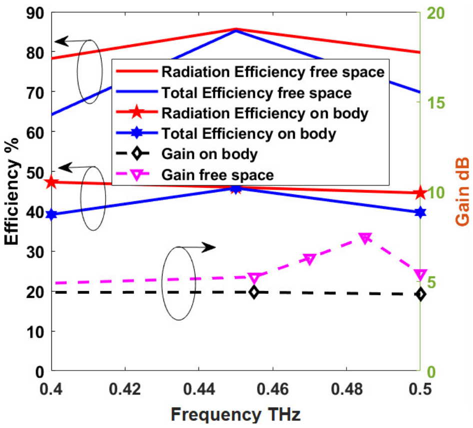


Fig. 6: Total and Radiation efficiency of proposed antenna arrays on free space and on body scenario.

IV. Conclusion

This paper describes the simulation of a THz antenna array employing a multilayered structure, $\mathrm{CsPbBr_3}$, gold, and a PEN substrate. The results demonstrate that the performance of antenna arrays based on $\mathrm{CsPbBr_3}$ is superior to that of an antenna based only on gold metal. Because of the exceedingly thin nature of the suggested multilayered structure, as well as the flexibility of the substrate, the proposed design is suitable for use in wireless body area network applications.

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