Next Generation Terahertz mm-Wave Technology and its Applications

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***Abstract*—The objective of this research is to investigate and propose a pulse-based communication, localization, and imaging scheme. Sub-100 picosecond pulses will be coherently transmitted through multiple transmitters for secure communication and localization. The technique aims at achieving an information beam width of less than 0.1° and an RF imaging system with sub-millimeter resolution. In addition to this, high-speed samplers and transmitters fabricated with advanced CMOS technology will be used, with an overarching goal of building a complete pulse-based communication and localization system.**

I. Introduction

During my undergraduate education, I became fascinated with mm-wave circuits and terahertz research. Terahertz waves, which occupy the band from 0.1 mm to 1 mm, are unique in the spectrum because of their potential applications in secure communications, automotive radar, and medical imaging [1]–[5]. Despite the interest in using terahertz waves, we currently lack the underlying hardware platform to build upon. To solve this problem, I proposed the development of mm-wave and terahertz-integrated circuits and antennas, which would serve as the starting point for developers in this field of work [6], [7]. I'm happy to report that, as part of my research in developing a terahertz transceiver, I have made the following accomplishments over the course of my fellowship:

- I was invited to write a magazine article about my research on silicon-based generation and detection of terahertz waves. The article, titled "*Gone in a Picosecond: Techniques for the Generation and Detection of Picosecond Pulses and Their Applications*," was published in the November issue of IEEE Microwave magazine. The article focused on different techniques for the generation and detection of terahertz waves and their real-life applications [8].

- I developed a new pulse-based joint spacial coding approach for spatially secure communication, and a new mathematical linearization-based imaging approach to image partly occluded objects. This work was published in IEEE Microwave Transactions in a paper titled "*Ultra-Wideband Joint Spatial Coding for Secure Communication and High-Resolution Imaging*" [9]. In this project, not only were we able to show spatially secure communication with information beam-width as narrow as few degrees, we demonstrated pulse-based complex scene imaging. As shown in Fig. 1, multiple transmitters and receives are used to image a scene with different level of occlusions.

- I published a conference paper, which was the precursor to the above-mentioned journal, titled "*Ultra-Wideband Pulse-based Directional Modulation*" in IEEE MTT-S International Microwave and RF Conference. This paper was nominated for the best paper award [10].

- I currently have a conference paper and a journal paper, both of which highlight novel impulse-based sampling architecture for UWB ultra-high-speed ADCs, under review.

Finally, I plan to defend my Ph.D. at the end of this summer. My thesis investigates and reports on the building of next-generation terahertz transceivers and samplers with picosecond-sampling windows that are based on integrated circuit technology.

II. Future Work and Career Plans

My plan for the immediate future is to build a complete single-chip solution for the generation and detection of terahertz waves in order to utilize their latent potential to create real-world applications.

In the long term, I hope to become an entrepreneur by starting my own research company that is based largely on my Ph.D. work, as I believe that the next generation of sensing will be largely based on the terahertz wave. However, I haven't surrendered the possibility of working in the industry for a couple of years prior to starting my own company in order to gain exposure and valuable experience

III. Impact of the MIT-S Fellowship and IMS

It has been a privilege and honor to have my research recognized by the IEEE Microwave Theory and Techniques Society (MTT-S) and bestow with a fellowship. This recognition not only promulgated my work but also igniting endless discussions with like-minded professionals, thus serendipitously cultivating to new ideas. I have been attending IMS every year since 2012 and the quality of research showcased is second to none. It provides a great platform for novice apprentices to interact with the honorifics and foster collaboration in this closely knit society. I strongly recommend every young researcher to apply for this fellowship.

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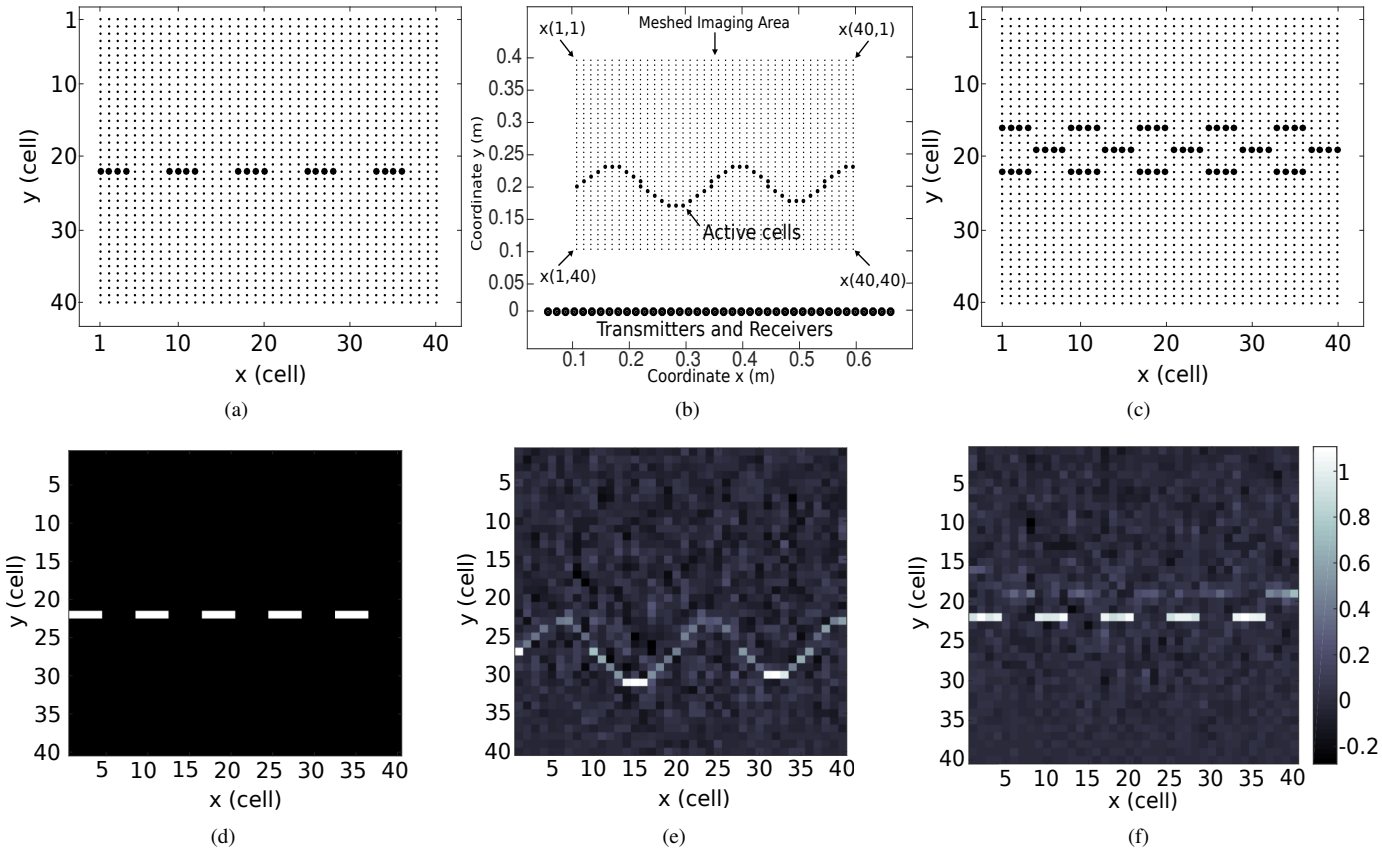

Fig. 1. Simulated and recovered scenes for a system of dimension $300 \times 500\,\mathrm{mm}^2$ with a 40×40 grid. (a) scene without occlusion; (d) linearized recovery delivers excellent quality; (b) scene with partial occlusion; (e) linearized recovery is able to faithfully extract an accurate estimate; (c) scene that contains fully occluded objects; (d) linearized recovery is able to partially identify the second partially-occluded layer, whereas the fully occluded layer cannot be recovered. (adapted from [9])

It has been a privilege and an honor to have my research recognized by the IEEE Microwave Theory and Techniques Society (MTT-S), as well as to be bestowed a fellowship. This recognition has not only promulgated my work, but it has also ignited many discussions with like-minded professionals; thus, it has serendipitously led to the cultivation of new ideas.

I have been attending IMS every year since 2012, and the quality of the research showcased is second to none. The conference provides a great platform for novice apprentices to interact with the honorifics and to foster collaboration in this closely knit society. I strongly recommend that every young researcher apply to this fellowship.

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