Dynamically Tunable and Reconfigurable Antennas for Advanced THz Sensing and Imaging

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Abstract: Sensing, detection and imaging in the terahertz frequency range have become a vital concern for many important research and technology communities including astronomy, chemistry, biology, medicine, and security. Unfortunately, current THz sensing and imaging systems have limited performance and available functionalities despite their vast development and deployment in the last decade. For example, most sensing and imaging systems demonstrated to date work in the "grayscale" mode without the ability to discriminate the spectral information of the incident THz waves. In addition, the capability for THz beam-steering and forming is challenging to realize while it is essential in remote sensing and imaging, surveillance, and radar and tracking applications. As key elements in above systems, THz antennas that can be dynamically tuned and reconfigured in real-time will enable additional functionalities for advanced THz sensing and imaging.

In this paper, we explore two different technologies to realize such tunable and reconfigurable THz antennas. The first approach is to load planar antennas with tunable reverse-biased varactor diodes. For a prototype demonstration, the operation frequency of a G-band (140-220 GHz) annular slot antenna (ASA) has been successfully tuned for 50 GHz with a tunability of ~2.5 GHz/fF using a VDI (Virginia Diodes, Inc.) Schottky diode. This frequency-tunable ASA will soon be employed in spectral-resolved detectors and focal-plane arrays for spectroscopic THz sensing and imaging. The second approach is based on optical THz spatial modulation (OTSM) using photo-induced free carriers in semiconductors. Using this approach, dynamically reconfigurable beam-steering and forming antennas at 740 GHz have been successfully developed and demonstrated using virtual Fresnel zone plate (FZP) patterns directly projected on a high-resistivity silicon wafer (using commercially available Digital Mirror Device chip from a DLP projector). The antenna beam angle can be scanned from -8° to +8° in both the E- and H-planes, while the beam width can be dynamically tuned with a high speed up to 20 kHz. This antenna has been applied in remote scanning imaging, and will find promising applications in adaptive THz communication and short-range point-to-point interconnections.