Terahertz Imaging via Single-bit Compressive Sensing

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For millimeter-wave (mmW) and terahertz (THz) imaging, compressive sensing techniques that are based on coded- or random-modulation of object waves in conjunction with a single, low-noise detector have been demonstrated to circumvent the acquisition speed and noise issues that typically overwhelm raster scanning and focal plane arrays (G.C. Trichopoulos, H.L. Mosbacker, D. Burdette and K. Sertel, ``A broadband focal plane array camera for real-time THz imaging applications," IEEE Trans. on Antennas and Propagation, vol.61, no.4, pp.1733, 1740, April 2013), respectively. Recently, 32×32-pixel THz image reconstruction was demonstrated using photo-induced coded masks and CS with 40% of Nyquist measurements (M.I.B. Shams et al. “Approaching Real-time Terahertz Imaging with Photo-induced Coded Apertures and Compressed Sensing,” Electronics Letters, vol.50, no.11, pp.801-803, May 22 2014) using a low-cost spatial light modulator based on a high-resistivity Si wafer and a commercial DLP projector. This system has demonstrated the potential of realizing low-cost, real time THz imaging system; however, the minimum number of measurements and the speed of photo-induced mask modulation were directly related to the sensitivity of detectors and sampling rate of the analog-to-digital converters. As such, realizing a low-cost and video frame-rate THz imaging system still remains a focus of current research.

Recently, compressive sensing algorithm that relies on single-bit measurements was proposed, enabling, for the first time, use of a low-cost detector and a simple comparator as the analog-to-digital converter (L. Jacques et al. "Robust 1-Bit Compressive Sensing via Binary Stable Embeddings of Sparse Vectors," in IEEE Trans. on Information Theory, vol. 59, no. 4, pp. 2082-2102, April 2013). One-bit compressive sensing deals with severe non-linearity in measurements and in many cases, it outperforms traditional multi-bit approaches. In this work, we demonstrate 1-bit CS to reconstruct 64×64 image of a sparse scene using 25% of measurements at 690 GHz. Computer generated mask patterns are used in conjunction with a passivated silicon wafer to spatially modulate the object beam and a single comparator sensor is used for the measurements. Each measurement is taken by simply comparing measurements from two inverted binary mask patterns. We demonstrate that 1-bit compressive THz imaging shows superior noise-robustness than multi-bit approaches and enables faster modulation of the mask patterns to speed up the data collections process.