A 4k-pixel Single-bit, Single-pixel Compressive Sensing Camera for THz Imaging Applications

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Compressive THz imaging systems utilizing single-pixel sensors hold great promise for realizing low-cost, high-resolution signal acquisition for many applications in sensing and spectroscopy. Recently, single-bit compressive sensing (CS) has been proposed which can recover the signal by recording only the sign of the measurements (i.e., single-bit measurements) (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). This algorithm enables a simple-comparator to be used as the analog-to-digital converter, lowering the cost and increasing the speed of the hardware. Also, it has been shown that, the single-bit CS is more effective than the conventional CS in low signal-to-noise-ration (SNR) systems (Laska, Jason N., and Richard G. Baraniuk. "Regime change: Bit-depth versus measurement-rate in compressive sensing." IEEE Transactions on Signal Processing 60.7 (2012): 3496-3505), which can potentially reduce the cost of the transceiver. However, there is still room for improvement in the speed of data acquisition as it is directly related to the system SNR.

In this work, we present -for the first time- a single-pixel compressive imaging system for the THz band capable of producing 4k-pixel images utilizing the single-bit CS. To demonstrate this unique approach, the object wave is spatially encoded by random binary mask patterns and a pair of frequency extender modules coupled with a vector network analyzer were used as the transceiver system. By projecting patterns of visible light on a high-resistivity Silicon wafer using a commercially available digital projector, spatial encoding of THz wave is realized via the photoelectric effect. To acquire the “single-bit” data, intensity measurement for one mask pattern is compared with the measurement for its complementary mask. As such, recording only a single bit of information, that is the “sign” of the difference between the two complementary masks measurements, we are able to recover 64×64-pixel THz images using only 25% of the conventional Nyquist-Rate number of measurements and applying the single-bit CS reconstruction algorithm. We demonstrate that this single-bit approach also has better noise performance than the classical CS approach, enabling faster data acquisition. We also show that the single-bit CS is more effective under lower SNR illumination than the classical CS, hence significantly lowering the cost of the source. Finally, a simple comparator can be used as the analog-to-digital conversion device for the single-bit measurement which suggests the possibility of realizing a very low-cost, high performance THz imaging system for ubiquitous applications.