Active metamaterials with embedded electronics for millimeter wave and THz applications

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Metamaterials are engineered composite materials with tailored electromagnetic properties. Recent years have seen a great deal of research in metamaterials, driven by a futuristic potential for realizing fascinating ideas like negative index of refraction, invisibility cloaking and perfect lensing. However, it will be the more practical applications of metamaterials, such as electrically small antennas and ultra-thin perfect absorbers that will see a commercial impact. Of special interest has been the achievements made in realizing metamaterials in the *terahertz gap* (0.1–10 THz), where usable naturally occurring material are rare, making it a challenging area to build traditional electronic or photonic devices.

Research in our group has focused on making practical devices such as modulators and detectors for the millimeter wave and terahertz applications. The key enabling technology for realization of such components is the embedding of active devices, such as transistors and diodes, into metamaterials. In one application, we demonstrate a state-of-the-art terahertz amplitude modulator based on embedding of an actively driven GaAs HEMT within each metamaterial unit cell. In another application, we demonstrate a focal plane array based on metamaterial perfect absorbers and active receiver circuitry.

Beyond these promising applications, embedding active elements within metamaterials could also address some key barriers, such as high losses and narrow bandwidth operation, that have plagued metamaterial-based designs.