Active Metasurfaces with Embedded Gain Medium

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In this paper, an active metasurface cell design is reported. Different from the existing metasurfaces which are either non-tunable or tunable but featuring no gain, the proposed active metasurface cell is constructed by incorporating active transistors into the metasurface design. In this way, a highly integrated metasuface cell with amplitude gain is achieved. The resulting active metasurfaces can be employed as the fundamental building block to realize beam-steering systems and other RF/microwave systems for dynamic beam/wave-front control, impacting the broad areas of radar, navigation, telecommunication, and security.

Metasurface is an artificial two-dimensional metamaterial structure composed of planar electromagnetic units in subwavelength scales. It features the capability of introducing abrupt phase change to the incident electromagnetic wave with an ultra-thin aperture, which has enabled it to manipulate wave propagation across the entire electromagnetic spectrum (e.g. from radio-frequency (RF) to visible). So far, there are a lot of metasurface-based applications demonstrated including ultra-thin lens for imaging, holography, beam-forming, and vector beam generation [H. Zheng et al., arXiv:1707.00760, July 2017]. To enable dynamic beam-steering and wave-front control, tunable/reconfigurable metasurfaces are explored recently [H. Ren et al., URSI 2016, July 2016; B. Zheng et al., URSI 2017, July 2017]. However, the amplitude (i.e. transmission efficiency) of existing tunable metasurface cells is low, which is due to the passive components employed during the tuning. In this paper, a new active metasurface cell is proposed. The general schematic of it is shown in Fig. 1. It is formed by integrated amplitude and phase control building blocks, operating in the transmission mode. Specifically, active transistors have been embedded into the amplitude control part, which will enable significant boosting of the transmission amplitude. The amplitude control building block is then seamlessly integrated with the phase control building block, enabling the simultaneous control and tuning of both the amplitude and phase responses of transmitted signals. An experimental prototype operating at around 5-6 GHz has been designed, fabricated, and characterized. The measurement results of the fabricated sample show that it can achieve the active amplitude tuning ranging from +5 dB to -20 dB or even beyond. Moreover at each amplitude stage, a large range of phase tuning (e.g. 2π phase coverage) can be simultaneously realized. To the best of our knowledge, this is the first time that a truly active metasurface cell featuring amplitude gain is reported.

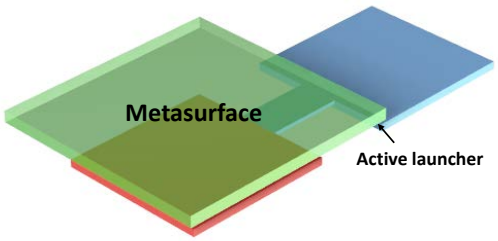

Figure 1. The general schematic of the proposed active metasurface cell.