Time-modulated metamaterials based on reconfigurable field-focused cavity for non-reciprocal near-field wave transmission control

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Metamaterials have been explored as a promising approach to govern magneto-inductive waves, especially at the deep subwavelength scale. Beyond the previous static metamaterials, time-modulated metamaterials have been exhibiting new and extraordinary abilities of wave propagation control. Mainly, the time-modulated metamaterials have significantly contributed to many applications demanding nonreciprocity. Non-reciprocal devices have been used in various applications, including the isolator applied in high-power microwave transmitters, circulators found in multi-function communication receivers and radars, and wave propagation manipulation.

In this work, we investigate time-modulated metasurface for non-reciprocal magneto-inductive waves (MIWs) propagation control. The metamaterials dealing with MIWs have demonstrated a significant role in regulating the field distribution for wireless power transfer (WPT), magnetic cloaks, and biomedical imaging; nevertheless, this potential for near-field wave propagation control has not been fully explored using a time-modulated metamaterial. To achieve field manipulation, we propose a tunable unit cell suitable for time modulation. By breaking the translational symmetry of the unit cells, spatial field modulation allows the creation of reconfigurable waveguides on the metasurface [1]. Temporal field modulation, achieved by breaking the capacitive symmetry of the varactor, allows direction-dependent transmission in the waveguide.

To examine the electromagnetic problems in the periodic structure where time modulation is applied, the dispersion relation and specified boundary conditions are considered to constitute the necessary formulation [2]. In this problem, the electromagnetic field is expanded in terms of spatial harmonics, and a relation between the amplitudes of these space harmonics is found. In the experimental, temporal modulation successfully achieves non-reciprocal wave propagation and frequency conversion, which are investigated and confirmed under various conditions.

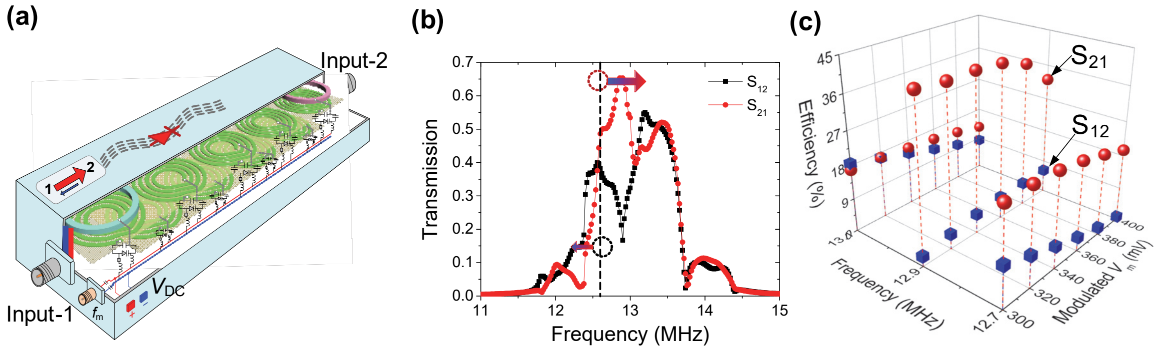

Figure 1. (a) Schematic of the MIWs waveguide using time-modulated metamaterial. (b) Transmission of the waveguide with time modulation at 554 kHz and amplitude 400 mV. (c) Transmissions as a function of the modulated amplitude.

References

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[2] A. Ranaweera, T. S. Pham, H. N. Bui, H.N, V. Ngo, J.-W. Lee, “An active metasurface for field-localizing wireless power transfer using dynamically reconfigurable cavities. *Sci. Rep.* **2019**, *9*, Aug. 2019, p. 11735.