Inverse Designed High-efficiency Multifunctional Millimeter-wave Electromagnetic Devices

Hong Tang*[(1)], Bowen Zheng*[(1)], Sensong An[(1)], Hang Li[(1)], and Hualiang Zhang[(1)]
(1) The University of Massachusetts Lowell, Lowell, MA 01854, USA

In this paper, we report a multifunctional beam-forming device designed using the inverse design algorithm. Different from the conventional beam-forming systems, which are based on the unit cell design and array synthesis, the proposed beam-forming device is directly generated by the algorithm with random optimized patterns. Moreover, enabled by the fully automated design process, multifunctional beam-forming device operating at two separate frequencies are investigated and designed. The resulting beam-forming devices (e.g. operating at the millimeter-wave spectrum) can be easily fabricated by 3D printing techniques and applied in telecommunication and radar systems. They can also be combined with existing systems to improve the performance.

Inverse design is a method which uses the predefined goal to generate feasible physical structures. It features the capability of introducing random patterns that are non-intuitive and therefore significantly different from the conventional electromagnetic structures. The resulting random patterns introduce more degrees of design freedom and bring up the possibilities for achieving attractive features such as high efficiency and multi-functional operation. In general, the inverse design method can be applied to design electromagnetic devices operating within a wide range of frequencies (e.g. from radio-frequency (RF) to visible). So far, it has been applied to achieve high-performance optical waveguides [A. Y. Piggott et al., Nature Photonics, vol. 9, 374-377, 2015]. However, there are no inverse-designed millimeter-wave electromagnetic devices with multi-functions reported. In this paper, a new high-efficiency dual-functional device is designed using the inverse design algorithm (i.e. it is designed by the objective-first algorithm). The general structure of the device is shown on the left of Fig. 1. It is formed by polymer (the relative dielectric constant of the polymer is 3.1.) and can be easily fabricated by 3D printing technology. The performance of the designed device is shown on the right of Fig. 1. It functions as a dual-functional beam deflector, operating at 20GHz and 24.8GHz. Numerical simulation results show that the designed device can efficiently (efficiency > 80%) deflect the normal incident wave to +30-degree and -45-degree at 20GHz and 24.8GHz, respectively. The size of the prototype device is 30mm by 240mm,

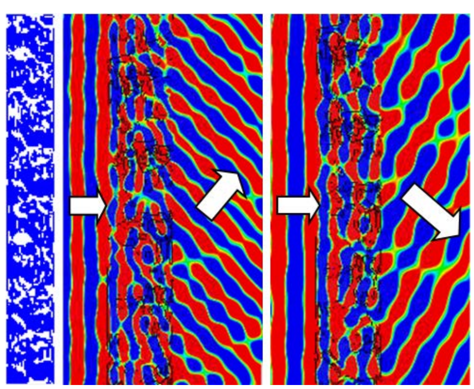

Figure 1. The general schematic and numerical results of the proposed device.