Building Simple and Effective Metasurfaces by Coarse Discretization

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***Abstract*— This work summarizes the authors recent research experiences and identifies advantages which one can gain by designing a metasurface with coarse discretization. Whereas most metasurfaces approximate a continuous impedance variation with a finely-discretized one, we show that in some cases coarse-grained discretization yields surprising benefits. In the presentation, we will summarize our recent works which show that the coarse discretization paradigm produces metasurface designs which are power efficient, simple to fabricate, and feature robust and broadband operation beyond traditional continuous metasurfaces. We will also preview our ongoing works in applying this paradigm to improve communication and imaging devices.**

***Index Terms*—metasurfaces, beamforming, imaging, diffraction, electromagnetic wave synthesis.**

I. Introduction

The past decade has seen rapid progress in understanding, designing and demonstrating electromagnetic (EM) surfaces which perform near-arbitrary operations on EM waves. Phase gradient metasurfaces were first proposed, which control the reflected or transmitted EM waveform by tuning the spatially-varying phase delay along the surface. More recently, Huygens' metasurfaces have emerged, which exhibit both electric and magnetic responses to satisfy Maxwell's boundary equations and thereby achieve a wide variety of EM wave manipulations with high efficiency and fidelity. To date, metasurfaces have been used to design anomalous reflectors and refractors, lenses, beam splitters, polarization rotators and filters of various kinds. The versatility, low form factor and relative cost-efficiency of the metasurface makes it a preferred tool for many wave manipulation applications.

Notwithstanding these developments, the metasurface design flow has remained largely unchanged: first the designer calculates a continuous metasurface profile desirable for a certain application, then the surface is realized by combining finely-discretized metasurface elements, usually around or smaller than $\lambda/10$ in size. While this method has been by and large successful, it requires deeply subwavelength components which can be hard to fabricate, sensitive to operate, and often prone to electromagnetic coupling between adjacent metasurface elements. In contrast, several recent works feature coarsely-discretized metasurfaces. In this talk, I review our recent works in this area and explain that, very often, surprising benefits can be gained by aggressively discretizing a metasurface (down to 2 metasurface elements per spatial period, or 3 to 4 elements per wavelength). Some benefits include greatly simplified metasurface design and realization, robust operation, broadband performance, increased power efficiency, and achieving novel properties which are at first glance impossible for continuous metasurfaces. We will illustrate these benefits through demonstrated passive and active metasurface designs, which include a large-angle metasurface retroreflector, a perfect anomalous reflection metasurface, an optical Huygens' metasurface and an active Huygens' box for highly versatile EM wave manipulation [1-4]. Fig. 1 shows the design, simulation and characterization of some of these devices. We will also present ongoing research works which employ the discretized metasurface paradigm for applications in antennas, imaging, EM wave manipulation and microwave signal processing.

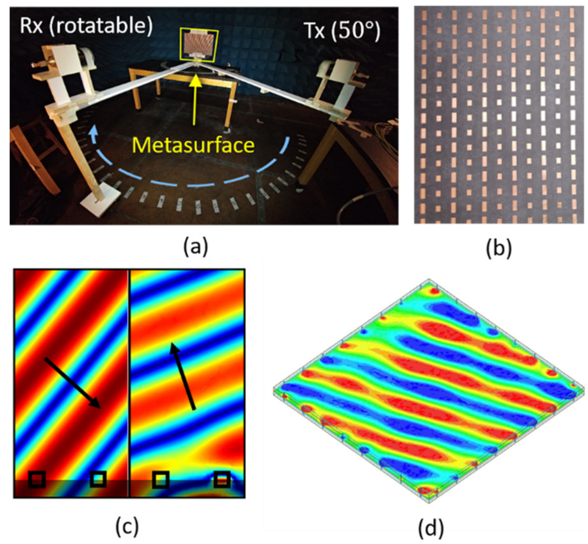

Fig. 1. (a) An experimental apparatus for passive discretized metasurfaces. (b) A coarsely-discretized Huygens' metasurface. (c) Simulated incident and reflected waves from a perfect anomalous reflection metasurface. (d) An active discretized metasurface achieving waveform synthesis inside a box.

References

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