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Towards full control of multichannel metasurfaces

Xuchen Wang, Ana Díaz-Rubio, and Sergei A. Tretyakov
Department of Electronics and Nanoengineering, Aalto University, P.O. Box 15500, FI-00076 Aalto, Finland
meta.aalto.fi

In analogy with classical multi-port networks, metasurfaces can be considered as multiple input-output devices where different functionalities can be implemented for different illuminating directions. Using Floquet theory, the periodicity of the metasurfaces can be engineered to allow a specific number of "open channels". To fully exploit the possibilities of such platforms it is important to have independent control of the metasurface response when it is illuminated at each channel, allowing full control over reflections and transmissions into many directions. Although multichannel metasurfaces have been proposed and experimental verified [1], the design tools available in the literature do no offer freedom for choosing the functionality at each port and, in some cases, require heavy numerical optimization. In this talk We will demonstrate that by properly engineering the evanescent fields excited at the metasurface, i.e., engineering strong spatial dispersion, it is possible to independently control the reflection and transmission in each channel. Using simple equivalent circuits, we develop a fully analytical method to analyze and synthesize multichannel metasurfaces. We will present validations of our approach with the design of multichannel retroreflectors with arbitrary reflection phases, multifunctional reflectors, and multichannel perfect absorbers.

As an example, one can consider the functionally illustrated in Figure 1, a three-channel lossless retroreflector. The metasurface consists of a space-modulated surface impedance sheet placed on a grounded dielectric substrate. The main difference between these devices and the solutions presented in [1] is that we can fully engineer the reflection phases for incidence from each channel. In this example we present a three-channel retroreflector with reflection phases $\Psi_1 = 0$, $\Psi_2 = -\pi/3$, and $\Psi_3 = \pi$. Using the developed design method, we demonstrate that there may exist multiple solutions for the surface impedance that satisfy the boundary conditions when the metasurface is illuminated at from all of the three directions. For example, Fig. 1(b) shows two typical solutions. In Solution 1, the surface admittance in one unit cell exhibits both capacitive and inductive properties at different positions along the z-axis. Alternatively, we can impose additional constraints in the design tool to ensure that the surface reactance is always capacitive or inductive along the metasurface, as it is shown in Solution 2. Figure 1(c) presents simulated total fields for the design of Solution 2. This result confirms that waves incident from each direction indeed are reflected in the corresponding retrodirections with the prescribed phases. The reflection phases and field distributions are very close to the ideal solution. For incidence from Port 1, the total field is maximum at the reference plane, meaning that $\Psi_1 = 0$. The total field at the reference plane of Port 3 is zero which means that the reflection phase $\Psi_3 = \pi$.

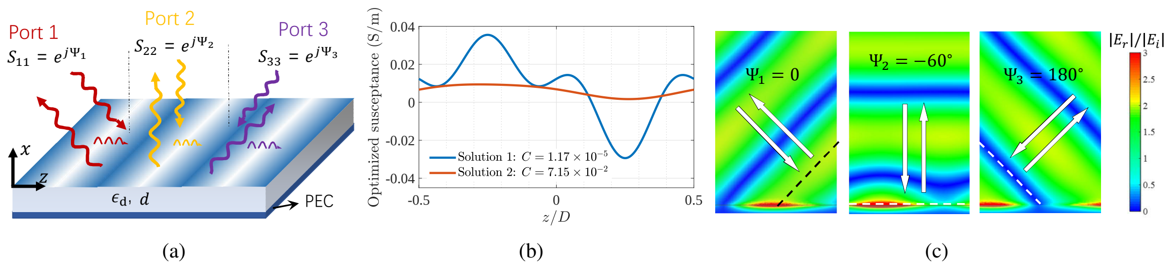

Figure 1. Example of a multichannel metasurface device: a phase-controlled multichannel retroreflector. (a) Schematic representation of the desired response. (b) Optimized grid susceptance profiles for desired phase responses at three ports: $\Psi_1 = 0$, $\Psi_2 = -\pi/3$, and $\Psi_3 = \pi$. (c) Simulated total fields for incidences from three ports of the metasurface modelled as a surface impedance.

References

[1] V. Asadchy, A. Díaz-Rubio, S. Tcvetkova, D.-H. Kwon, A. Elsakka, M. Albooyeh, and S. Tretyakov, "Flat engineered multichannel reflectors", *Physical Review X*, **7**, 031046 (2017).