

Network-Based Reconfigurable Metasurface Synthesis Methods

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In this work, synthesis methods for reconfigurable metasurfaces will be presented which are compatible with a hybrid spatial/spectral network-based model. The metasurface consists of unit cells loaded by active elements to provide local tunability, as shown in Fig. 1a. The model used to compute the field scattered by the metasurface for a given loading condition is depicted in Fig. 1b, and is compatible with commercial full-wave solvers. The model assumes macroscopic periodicity in the x and y dimensions, with terminated padding elements used to approximate a finite aperture. This assumption admits a formulation for a hybrid spatial/spectral scattering matrix which utilizes full-wave simulations collected for a number of progressive phase boundary conditions. The spectral sampling can be interpolated after the full-wave data is collected to investigate a variety of aperture sizes. The final synthesized model is a scattering matrix which captures the coupling between individual lumped element (e.g. diode) ports to the discrete spatial harmonics supported by the periodic array, and is shown in Fig. 1b. For an incident plane-wave spectrum defined by vector $\tilde{E}_k^+$, the scattered field produced by the metasurface when loaded by reactive terminations with reflection coefficient $\Gamma_r = e^{j\gamma_r}$ at spatial coordinate “ r ” is given by

$$\tilde{E}_k^- = \left(\bar{S}_{\tilde{E}\tilde{E}} + \bar{S}_{\tilde{E}V} \left(\bar{I} - \bar{\Gamma} \bar{S}_{VV} \right)^{-1} \bar{\Gamma} \bar{S}_{V\tilde{E}} \right) \tilde{E}_k^+. \quad (1)$$

This is similar to the method proposed in (M. Almunif and A. Grbic, USNC-URSI NRSM, IEEE, 2024), wherein the current distribution produced by given lumped element ports is used to synthesize a desired far-field pattern. In contrast, the technique proposed in this work bypasses the current, directly connecting the lumped element ports to the far-field. This enables straight-forward integration of the analysis method with global optimization strategies established for optical fields (R. W. Gerchberg and W. O. Saxton, Optik, 35, 1972) as well as gradient based methods which have recently received significant attention for the design of metasurfaces (J. Budhu, L. Szymanski, and A. Grbic, IEEE Journal of Microwaves, 2,2022).

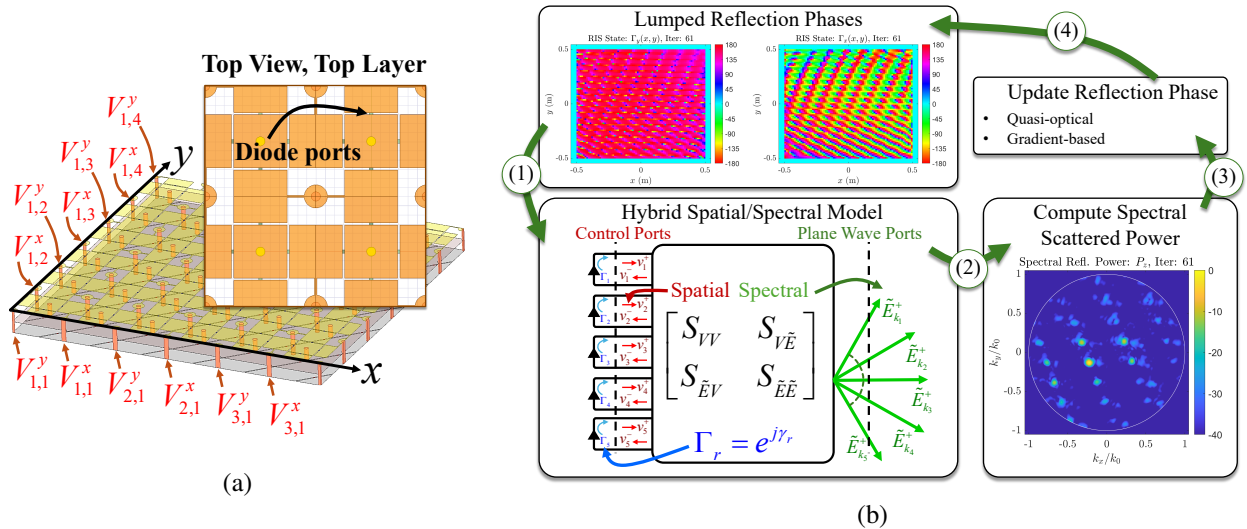


Figure 1: (a) Representative active metasurface loaded by diodes in two orthogonal orientations. Bias voltages can be applied for analog control. (b) Design flow for synthesizing optimal lumped-element reflection coefficients to achieve a targeted power spectrum.