Ray-oriented design of Huygens metasurfaces for multiple source excitation

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Huygens metasurfaces (HMS), combining subwavelength electric and magnetic polarizable particles, have demonstrated impressive wave manipulation capabilities, such as engineered refraction, focusing, and polarization control. Recently, a general methodology to design HMSs for converting given (arbitrary) source fields to directive radiation has been presented, facilitating antenna design (A. Epstein and G.V. Eleftheriades, IEEE Trans. Antennas Propag., 62, 5680-5695, 2014). However, this methodology guarantees proper performance only for the designated source excitation, whereas for many modern applications multifunctional devices, e.g. multidirectional antenna, are desirable.

In this work we present a path to synthesize Huygens metasurface devices with multiple source excitations, implementing multiple functionalities. Harnessing the results of our recent Floquet-Bloch (FB) analysis, the dominant direction of transmitted fields can be reliably predicted for each incident ray at each point on the metasurface (A. Epstein and G.V. Eleftheriades, Phys. Rev. B, 90, 235127, 2014); this enables utilization of ray tracing for design purposes. Consequently, the transmitted waveform can be tailored by modifying the local periodicity of the surface reactance modulation typical to refracting HMSs. For a complete analysis of the design the FB coefficients are evaluated locally, resolving the fields on the HMS facets and subsequently everywhere in space.

We demonstrate the proposed method by designing a (2D) switched-beam antenna using an HMS and 5 electric line sources [Fig. 1(a)]. The HMS is designed to convert the fields generated by the middle line source (blue) to broadside radiation; thus, it acts as a lens for the designated excitation. Based on a known paraxial effect it is expected that the main beam would be tilted in a predictable manner when the source is translated along the focal plane, as confirmed by the proposed ray-oriented analysis [Fig. 1(b)]; switching between the sources provides a scanning range of 29° with high aperture efficiencies (>88%). The semianalytical predictions are verified by finite element simulations, with excellent agreement in terms of main beam direction and width [Fig. 1(c)].

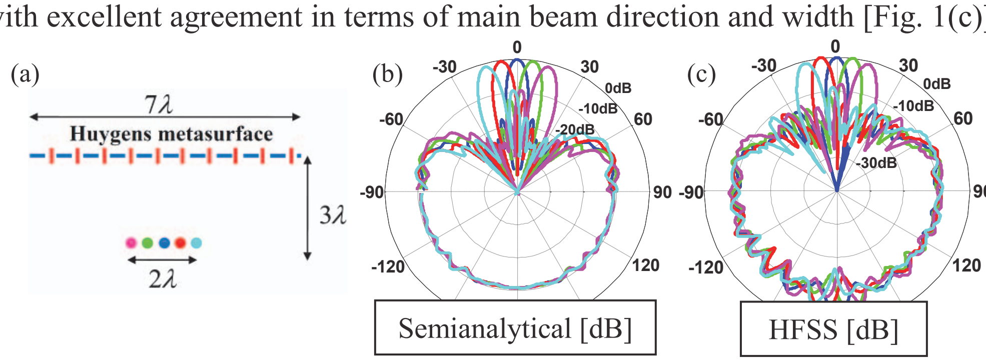

Fig. 1 Switched-beam antenna synthesized and analyzed via the proposed ray-oriented method.