Advances on Passive and Active Huygens' Metasurfaces

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We will discuss the concept of the Huygens' metasurface which comprises co-located electric and magnetic dipoles forming an electrically dense array of Huygens' sources or scatterers (M. Selvanayagam and G.V. Eleftheriades, "Discontinuous electromagnetic fields using orthogonal electric and magnetic currents for wavefront manipulation", *Optics Express*, vol. 21, issue 12, pp. 14409-14429, June 2013). These engineered surfaces can be designed to control electromagnetic waves at will. Both passive and active Huygens' metasurfaces can be envisioned (A. Wong and G.V. Eleftheriades, "Active Huygens' Box: Arbitrary electromagnetic wave generation with an electronically controlled metasurface," *IEEE Trans. on Antennas and Propagat*. in print, DOI: 10.1109/TAP.2020.3017438 , Aug. 2020). Unlike traditional antenna transmitarrays, Huygens' metasurfaces can be made sub-wavelength thin and deprived of spurious Floquet modes, while preserving excellent matching characteristics (A. Epstein and G.V. Eleftheriades, "Floquet-Bloch analysis of refracting metasurfaces ", *Phys. Rev. B*, 90, 235127, Dec. 2014). Huygens' metasurfaces can be used to manipulate the phase, magnitude and polarization of incident electromagnetic waves, including those from nearby elementary antennas, for a variety of applications (A. Epstein, J. Wong and G.V. Eleftheriades, "Cavity-excited Huygens' metasurface antennas for near-unity aperture illumination efficiency from arbitrarily-large apertures", *Nature Comm*., vol. 7, p. 10360, Jan. 2016). For example, Huygens' omega bi-anisotropic metasurfaces enable wave refraction at extreme angles without any reflections (M. Chen, E. Abdo-Sanchez, A. Epstein and G.V. Eleftheriades, "Theory, design, and experimental verification of reflectionless bianisotropic Huygens' metasurface for wideangle refraction," *Phys. Rev. B*, 97, 125433, 29 March 2018). They also allowed the demonstration of generalized flat reflectors having an arbitrary angle of reflection with respect to the angle of incidence and with 100% theoretical efficiency (A.M.H. Wong and G.V. Eleftheriades, "Perfect anomalous reflection with a bipartite Huygens' metasurface", *Physical Review X*, 8, 011036, Feb. 2018).

After some brief review of the fundamentals of Huygens' metasurfaces, we will highlight recent advances on the topic such as active cloaking, high aperture efficiency/low-profile antennas, antenna aperture beamforming with simultaneous magnitude and phase control, and electronic beam steering.