Position-Independent Gain for Arbitrarily Polarized Antennas Using Phase Conjugating Metasurfaces

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A ground plane in close proximity to an antenna is well-known to modify the radiation pattern and radiation efficiency. As a function of the distance, polarization and wavelength, the effect can be detrimental or advantageous in terms of the overall antenna performance. These features play a crucial role in the design and implementation of wireless radio systems.

Using conventional electric conductors, we typically face a trade-off between radiation gain and form factor, since only vertically polarized dipoles very close to a ground can radiate efficiently. In modern antenna design, artificial media inspired by photonic crystals and metamaterials provide opportunities to use tailored surface impedances to enhance the antenna metrics, as in the case of artificial magnetic conductors. In particular, these high-impedance surfaces enable gain enhancement for sources polarized parallel to the surface, enabling both high gain and low profile. However, also this solution is polarization selective and typically suffers from narrow bandwidths and bulky implementations.

Here, we study the possibility to achieve position-independent antenna gain for any polarization using a phase conjugating ultrathin metasurface. We first derive the decay rate of a dipole in the vicinity of a general planar surface impedance and show intuitively how the source position affects its radiation efficiency. We then show based on the Green's function method how a phase conjugating metasurface can realize position-independent decay rates for arbitrary polarization. Next, we design a phase conjugating metasurface in the terahertz-band based on degenerate four-wave mixing, which enables gain for arbitrarily polarized sources placed at any distance from the surface. We also demonstrate that it is possible to manipulate the radiation efficiency in real time by modifying the phase and amplitude of the external pumps, while maintaining its independence on the source position and polarization.

Our work extends approaches to manipulate the antenna radiation with a ground plane based on the use of a single nonlinear metasurface. Possible applications consist in realizing optimal gain for antennas with a flexible support structure, and can be extended to manipulate the spontaneous emission decay rates of quantum emitters. In the presentation, we will also discuss additional possibilities to achieve position-independent decay rates using temporal switching.