Directive emissions of antennas on metamaterial ground planes: Role of anomalous reflection phases

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Efficiency and radiation pattern are two important characteristics of antenna radiations[1]. Recently, there has been much interest to employ metamaterials to control the radiation behaviors of antennas[2–5]. For example, directive emission can be achieved by simply putting a point source inside a metamaterial with zero refractive index[2], or inside a subwavelength cavity formed by specifically designed metamaterials[3]. In this work, we study the radiation properties of antennas put on ground planes formed by metamaterials, aiming to find the conditions under which the antenna emissions could be highly directive. We first applied a dyadic Green's function approach to analytically study the radiation properties of antennas put perpendicular or parallel to the ground plane, and found that the metamaterial ground plane should possess certain reflection phase properties in order to support directive emissions. We then employed finite-difference-time-domain (FDTD) simulations to successfully design realistic metamaterials structures as appropriate ground planes to support directive emissions for both orientations of antennas. Microwave experiments, in good agreements with FDTD simulations, were performed to verify the theoretical predictions[6].

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