Impedance Matching, Energy Squeezing and Reconfigurable Lenses Based on ENZ Metamaterials

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In this work, we first show our experimental verification that ε-near-zero (ENZ) narrow channels can provide a unique matching tool for waveguides and antennas, unusually robust to perturbations, feeding position and discontinuities. We use for this purpose the unique property of an ENZ channel to support a quasi-static, largely enhanced electric field distribution, which provides a position-invariant matching mechanism ideal for waveguides of arbitrary geometry, high-Q distribution networks, antennas and material measurements. We then extend this concept to realize and experimentally demonstrate impedance-matched ENZ metamaterial slabs able to pattern in arbitrary ways the impinging radiation. In this case the metamaterial is composed of 2D arrays of ENZ narrow channels carved in a metallic screen. The fast phase velocity and impedance matching of our lens allows transforming an impinging cylindrical wavefront excited by a coaxial source to an arbitrarily shaped wavefront shaped by the outer surface of the lens. We demonstrate uniform, oblique, converging, and "brick" phase patterns (c.f. Figure 1). Our lens design is readily reconfigurable, is well impedance matched to free-space and can be tailored to various configurations of interest. Our experiments shed physical insights into the anomalous propagation in long ENZ channels, in which a constant output phase is found for up to two-wavelength long slabs. Flat, ultrathin, conformable lenses may be envisioned using this approach, which may be used as radomes for a multitude of novel antenna designs. Directivity enhancement of antennas is also envisioned to improve upon near-field measurement techniques as well as in compact ranges.

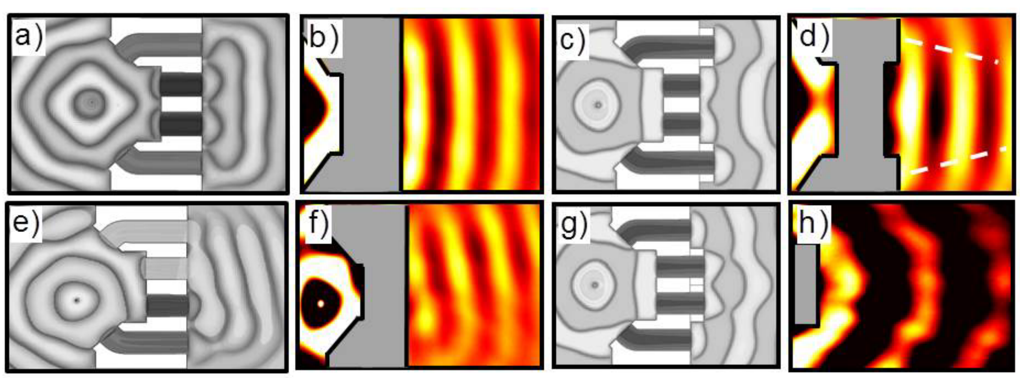

Figure 1. (a,c,e,f) Full-wave and (b,d,f,h) measured time snapshot of the transverse electric field distribution. (Please note: the same measurement scale here is used throughout, except for the "brick" phase-front (h), for which we plot only the amplitude.)