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Near-Field Focusing Plates: Theory and Experiments

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Summary

Superlenses that can focus electromagnetic energy to resolutions beyond the diffraction limit have attracted widespread interest in recent years. Since the discovery of the perfect lens by John Pendry, various superlenses consisting of slabs with negative material parameters have been developed and experimentally verified at microwave, infrared and optical frequencies. Here, we present a different approach to focusing electromagnetic waves to subwavelength resolutions. This new approach does not rely on slabs (volumetric structures), but rather patterned, grating-like surfaces. Unlike the metamaterial slabs possessing negative material parameters, the proposed structures are two dimensional and can be fabricated using single layer processing, thus obviating the need for 3D fabrication techniques. These surfaces have been referred to as evanescent field lenses or near-field focusing plates in [1,2]. A near-field focusing plate is a finely structured surface that acts as a modulated surface reactance. It is completely passive, consisting of only inductive and capacitive elements. The plate's textured surface (modulated reactance) sets up a highly oscillatory electromagnetic field at its surface which can focus energy in the near-field. Near-field plates can be designed to focus the field of a plane wave or that of a finite source incident from one side of the plate to the other with subwavelength resolution. Moreover, they can be designed to produce focal patterns of various symmetries at prescribed planes within their near-field.

In this presentation, the intrinsic properties of near-field plates will be described and a procedure for designing them will be outlined. In addition, simulation and experimental results will be reported which demonstrate the feasibility of implementing near-field plates; passive surfaces that can focus electromagnetic waves to extreme subwavelength dimensions. The experimental plate we have developed consists of an array of interdigitated capacitors printed on an electrically thin dielectric substrate. At 1.027 GHz, it focuses microwaves emanating from an S-polarized cylindrical source to a focus with full width at half maximum of approximately $\lambda_0/20$. The focal plane is located $\lambda_0/15$ from the plate.

Applications of this new technology in antennas and beam-shaping devices as well as probing and non-radiative power transfer systems will be discussed. Nanostructured implementations of near-field plates at optical frequencies using plasmonic and dielectric materials will also be touched upon. At light frequencies, near-field plates hold promise for near-field microscopy, data storage and lithography applications.

References

1. R. Merlin, Science, 317, 927 (2007).
2. A. Grbic, R. Merlin, arXiv: 0708.0049 (2007).