Analysis and Design of Near-Field Plates in the Presence of Dielectric Media

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Achievable resolution of far-field imaging systems is set by the diffraction limit, a constraint attributed to the fact that the imaging aperture only captures a portion of the propagating-wave spectrum of the imaged source. The resulting image resolution is determined by the size of the imaging aperture and the wavelength of the imaged scene. This resolution is not sufficient to resolve subwavelength features, an increasingly desired capability in a variety of circumstances. Near-field imaging, which utilizes both the propagating and evanescent portions of the sources' spatial spectrum, was proposed as a means for overcoming the diffraction limit and achieving subwavelength image resolution or focusing. A near-field imaging system is typically composed of an aperture with a sub-wavelength arrangement of scattering/resonating reactive elements. These elements are used to couple with evanescent waves for the purpose of probing the subwavelength structure of a scene or to generate a tightly focused beam in the image plane. Near-field plates were proposed by R. Merlin as a means for focusing energy in the near-field region. Subsequent work demonstrated beam focusing in 2D space using linear plates and circularly-corrugated plates have achieved 3D beam focusing.

The corrugated near-field plates proposed by F. Imani are composed of a set of coupled parallel-plate waveguides in the 2D case and concentric circular grooves in the 3D case. The depth of the waveguides determines the input impedance of the waveguide via well-known transmission line equations. The structure is excited by a central waveguide and the corrugation depths are adjusted to synthesize the equivalent magnetic current distribution needed to generate the desired focused beam. The analysis and design of the near-field plates was performed only in free space using the method of moments. A number of practical applications involve subwavelength imaging in the presence of dielectric objects or subwavelength beam focusing into dielectric objects (e.g. highly-localized microwave heating of brain tumors). In such applications, the near-field plates must be optimized to produce the desired focused beam in the presence of dielectric media. We present an indirect constrained optimization approach for the design of near-field plates in the presence of dielectric media using the finite element method. Results pertaining to the design of linearly-corrugated near-field plates in the presence of a dielectric slab will be presented and discussed. In addition, preliminary results pertaining to the design of circularly-corrugated plates in the presence of dielectric slabs and spheres will also be presented and discussed.