Perfect Transmission of Evanescent Waves Through Single-Negative Media

Spencer Bostock, Kenneth J. Chau, and Loïc Markley*
School of Engineering, University of British Columbia, Kelowna, BC, Canada

In 2000, J. B. Pendry showed that a finite slab with a refractive index of $n = -1$ and a wave impedance equal to that of free space could focus an image with sub-diffraction-limited resolution at a focal plane located a distance of twice the slab thickness from the object plane. He showed that the optical transfer function for this system was unity for both propagating and evanescent components of a source field's plane-wave expansion. Unlike traditional lenses where evanescent waves decay from source to image, a negative index slab supports growing evanescent waves that can restore the evanescent spectrum at the image plane to theoretically enable perfect spatial resolution.

Although the material necessary to construct Pendry's lens is not a naturally occuring substance, it turns out that a single-negative medium with permittivity or permeability below zero can be used in practice if the source-to-image distance is much smaller than the wavelength. For example, silver has a negative permittivity at visible and ultraviolet frequencies. This so-called "poor man's" super lens operates in the quasi-static limit for TM waves when permittivity is negative and for TE waves when permeability is negative.

In this study we examine the precise conditions necessary for perfect (unity) transmission of evanescent waves through a single-negative medium lens. We show that by changing the slab thickness, we can achieve perfect transmission for any lossless single-negative slab, regardless of distance between source and image! We provide a closed-form expression for the optimal slab thickness in the limit where the source-to-image distance becomes very large and show that in the TM case it is a function only of transverse spatial frequency $k_\perp = \beta k_0$ and relative slab permittivity ϵ_r. The figure below shows the transmission function for evanescent waves with $\beta = 2$ through a non magnetic slab with with $\epsilon_r = -1$ for a variety of slab configurations.

In our talk, we will discuss the implications towards perfect lensing and show how the "poor man's" super lens can be improved to achieve working distances outside the extreme near field.