

MEASURED AND SIMULATED FIELDS INSIDE NEGATIVE  
REFRACTIVE INDEX METAMATERIALS

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To date most measurements (both simulated and experimental) of the properties of negative refractive index metamaterials (NIMs) have relied on wave transmission and reflection measurements. These measurements at best exactly determine the material properties (as opposed to more robust overdetermination) and can in some cases be ambiguous and difficult to interpret. Moreover, they do not easily demonstrate the fundamental behavior of electromagnetic waves in these materials (for example, the antiparallel phase velocity and energy flow direction). We show, using HFSS simulations of a wire-SRR (split ring resonator) metamaterial that, although the field structure inside the metamaterial is complicated due to the metallic inclusions, there can be slices through the material where the total fields inside the metamaterial are surprisingly close to the wave fields expected if the medium were homogeneous. This supports the general finding that metamaterials behave like homogeneous materials even for surprisingly large inclusions (only a few per wavelength). This also suggests the possibility of robustly measuring the effective medium properties of the metamaterial (i.e., permittivity and permeability) by probing the spatial field dependence in a three slab (air/NIM/air) configuration.

To test this idea experimentally, we designed and constructed a wire-SRR medium with negative permittivity and permeability near 2.6 GHz and measured the spatial field distribution in a three slab configuration inside a rectangular waveguide. The phase gradient shows directly and unambiguously that inside the NIM, the phase velocity points towards the source while the energy flows away from the source. We also show how the measured three slab spatial field pattern determines the effective medium properties robustly and with minimum uncertainty.

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2. B - Fields and Waves
3. (a)
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5. I'd like this paper contributed  
to the metamaterials special  
session that, last I heard,  
would be chaired by Nader  
Engheta and John Volakis