The Propagation of the Longitudinal and Transverse Spatial Modes in a Metamaterial

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Metamaterials have been shown to exhibit frequency and spatial dispersion. (A. Al`u, arxiv.org/ftp/arxiv/papers/1012/1012.1351.pdf) In a frequency and spatially dependent medium the permittivity ($\varepsilon(\omega, k)$) and permeability ($\mu(\omega, k)$) are dependent on ω the frequency dependence and k a potential with the periodicity of the lattice in a crystal or unit cell in a metamaterial. Spatial dispersion is also dependent on the ratio period (a) of the lattice or unit cell and the free space wavelength (λ_0) of the incident wave where $a/\lambda_0 < 1$(V. Ginzburg, Physics Reports (Review Section of Physics Letters, 194, 12 (1990)). In this work we demonstrate the behavior of the longitudinal and transverse spatial modes in a metamaterial and show the affect of the spatial modes on the loss and negative refraction in the medium. To demonstrate the longitudinal and transverse behavior in the metamaterial we ran parametric simulations changing the geometric dimension of SRRs and wire post keeping the period of the unit cells constant. The Figure below shows a unit cell used in the simulation and the results from the simulations of $\varepsilon(\omega, k)$ and $\mu(\omega, k)$ for 3 unit cells. The Figure (a), (b), and (c) below also shows how the spatial dispersion varied in the unit cell as the geometrical dimensions of the SRRs and wire post were changed. The unit cells for Figure (a) and (b) were to used fabricate into slab and wedge prism structures to demonstrate the interaction of the longitudinal and transverse spatial waves with the incident wave in the medium. The frequency response and polarization behavior of the slabs and refractive behavior of the wedges were measured. Using the simulated and measured results, we are able to show the interaction between the longitudinal and transverse spatial wave and the incident wave propagating in the metamaterial and how the spatial waves affect the losses and negative refraction in the metamaterial.