Abstract: Recent advancements in nanophotonics reveal new types of materials with negative refractive indexes. By altering the permittivity and permeability of a material, we can engineer new materials called metamaterials, into obtaining a negative refractive index. This project describes the operation and construction of a particular Negative Index Material (NIM) involving the use of Split Ring Resonators (SRR) and a wire frame. These designs will open the gateway to discovering new NIMs with disorderly systems, classifying them as isotropic materials.

Negative Index Materials

- Naturally occurring materials have refractive index: 
  \[ n > 1 \], where \( n = \frac{c}{v} \)
- Negative Index Materials have: 
  \[ n < 0 \], where \( n = \pm \sqrt{\varepsilon_r \mu_r} \)
- Thus, \( -n \) can only be achieved if \( \varepsilon_r < 0 \) AND \( \mu_r < 0 \)

Negative Relative Permittivity, \( \varepsilon_r \)

- Relative Permittivity, \( \varepsilon_r \):
  - Changed by altering electron density, \( n_e \):
    \[ \omega_p = \sqrt{\frac{n_e e^2}{\varepsilon_0 m_e}} \], this changes plasma frequency, \( \omega_p \)
  - Thus affecting permittivity: 
    \[ \varepsilon = 1 - \frac{\omega_p^2}{\omega^2} \]
  - Can be achieved by building wire-like frame:
    - \( n_e \downarrow \Rightarrow \varepsilon \downarrow < 0 \), obtaining negative permittivity value

Negative Relative Permeability, \( \mu_r \)

- Relative Permeability, \( \mu_r \):
  - Using split ring resonator (SRR) structured materials
  - Basis of operation:
    - Energy ray via z-axis
    - B-field via x-axis
    - Induced current on ring
    - Split in ring acts as capacitor and inductor
  - L and C in same circuit yields resonance capabilities
  - Concentric “rings” for added effect

Simulation & Results

Figure 1. The replication of the 10-unit cell periodic configuration using CST MWS software.

Figure 2. Consolidated results of 1-10 unit cells arranged in PERIODIC manner with verification of transmission in 8.5 GHz range with NIR.

Analysis, Conclusion and Future

- Metamaterials can be built using anisotropic materials through the use of split-ring resonators and wire frames; this enables us to achieve a negative index of refraction.
- This leads us to push the boundaries into the unknown world of isotropic materials where the energy rays can be sent via any direction
- This requires metamaterials to have unit cells to have multi-directional orientation capabilities

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