CHIRAL -NEGATIVE – REFRACTIVE – INDEX (CNRI) MEDIA

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Inclusions embedded in conventional right hand media are used to fabricate artificial materials, with negative permittivity, permeability and negative refractive index, (NRI), that have the properties of left-hand media (LHM). Helical inclusions can also be embedded in conventional host media to fabricate artificial materials that possess chiral properties. In this paper we propose to consider electromagnetic wave propagation in negative refractive index material with chiral properties that are not negligible. Thus the total effect of the inclusions is to produce chiral-negative-refractive-index media labeled here as CNRI media. Several unique applications are proposed.
The Drude-Born-Fedradov constitutive relations for chiral media are give by (Paul E. Crittenden and Ezekiel Bahar, Canadian Journal of Physics, **83** 1-24, 2005).

$$D = \varepsilon(E + \beta\, \nabla x E), \quad B = \mu(H + \beta \nabla x H) \tag{1}$$

For negative refraction index chiral media the permittivity ε and the permeability μ are negative and β is the chiral parameter. The canonical solutions to Maxwell's equations in chiral media are the Right Circular Polarized (RCP) and the Left Circular Polarized (LCP) waves.
At a planer interface between free space and chiral media, Generalized Snell's law is satisfied (E. Bahar, editors Tuan Vo-Dank, Robert. A. Likerman, and Gunter Gaungletz, Proceedings of SPIE **5993**, OG 1-9, 2005).

$$k_0 \sin\theta_0 = \gamma_1 \sin\theta_1 = \gamma_2 \sin\theta_2 \tag{2}$$

Moreover at a planer interface between free space and chiral media the relationship between the incident and reflected linearly polarized electric fields E_j^P in free space, is given by the 2 x 2 reflection coefficient matrix .

$$\begin{pmatrix} E_r^v \\ E_r^H \end{pmatrix} = \begin{pmatrix} R^{VV} & R^{VH} \\ R^{HV} & R^{HH} \end{pmatrix} \begin{pmatrix} E_i^v \\ E_i^H \end{pmatrix} \tag{3}$$

in which the superscripts V and H denote Vertical (Parallel) and Horizontal (Perpendicular) polarizations and the subscripts i and r denote incident and reflected waves. It is shown that to within first order of the chiral parameter $(k\beta << 1)$, the diagonal terms are the familiar Fresnel reflection coefficients for the vertically and horizontally polarized waves, R^{vv} and R^{HH} respectively. However the off diagonal cross polarized reflection coefficients R^{PQ} $(P \neq Q)$ (which are zero for the host non chiral media) are given by

$$R^{VH} = -R^{HV} = \frac{1}{2} jk_1\beta_1 T_{10}^V T_{01}^H \tan^2\theta_1 \tag{4}$$

in which β_1 and k_1 are the chiral parameter and the wave number of the host medium below the free space-chiral media interface. Using a complete modal expansion of the Green's function associated with the problem, it is shown that the wave species include evanescent and propagating radiation fields, several types of lateral waves (propagating just below the interface) associated with the phenomena of total internal "backward" reflection as well as several different surface waves (plasmons) associated with the residues at the poles of the reflection coefficients. Thus for instance using the CNRI materials it is possible to fabricate lenses with parallel planer interfaces associated with two focal planes at the opposite side of the source. Furthermore the lateral waves, associated with total internal "backward" reflected waves by a Chiral Negative Refraction Index Medium, could be used to make the CNRI materials perform like reflectors (with images at the same side as the source)