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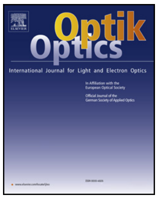

Original research article

Analysis of reflection and transmission from a planar NID-dispersive slab

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ABSTRACT

Behavior of transmitted and reflected power from a planar non-integer dimensional lossless dispersive slab, placed in free space, is explored for uniform electromagnetic plane wave excitation. Dispersion has been incorporated through the Lorentz-Drude model. As the frequency of excitation increases, the dispersive slab respectively behaves as epsilon positive, double negative, mu negative, double positive meta-material. Effects of variation of angle of incidence, width of the slab and frequency of excitation on behavior of the powers have been noted taking different values of the parameter modeling non-integer dimensional space.

1. Introduction

In scientific literature, meta-materials are defined as materials which are synthetically fabricated and illustrate unique electrical properties not found in nature [1,2]. Meta-materials attain their properties from their structure irrespective of constituent material composition. In reference to the sign of permittivity and permittivity, double negative (DNG) and single negative (SNG) materials are examples of meta-materials. DNG meta-material has simultaneously negative permittivity and permeability whereas SNG meta-materials have either permittivity or permeability negative [3,4]. SNG meta-materials may be divided into two categories: epsilon-negative (ENG) and mu-negative (MNG) meta-material [5]. DNG meta-materials have a wide range of applications in electromagnetics, i.e., wavelength focusing, cloaking, antenna, backward couplers and filters, etc. [6–10]. Use of SNG meta-materials for transparency, resonance and tunneling has introduced a new direction for research in electromagnetics [11]. Application of SNG meta-material for tunable antenna and dipole antenna had also been reported [12,13]. Mu-negative materials were also used for modeling patch antennas and resonators [14,15].

It is well known that frequency dependent expressions for permittivity and permeability may be obtained using the Lorentz-Drude model [16–21]. Changing the value of operating frequency may yield positive and/or negative sign of permittivity and/or permeability. Thus enable us to get ENG, DNG, MNG and DPS materials. Using Lorentz-Drude model, general mathematical expressions for relative permittivity and permeability are written below [22].

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Table 1
Definition and value of parameters of Lorentz-Drude model.

Parameters	Definition	Value
ω_p	Plasma frequency	$2\pi(14.63 \times 10^9)$
ϵ_∞	Permittivity at high frequency limit	2.2
ω_o	Resonant frequency	$2\pi(9.5 \times 10^9)$
δ	Damping factor	1.24×10^9
ν_c	Collision frequency	30.69×10^6
μ_s	Permeability at low frequency limit	1.26
μ_∞	Permeability at high frequency limit	1.05

Table 2
Categorization of Lorentz-Drude model for lossy case.

Material	Region ($\times 10^9$)	Frequency ($\times 10^9$)	$\mu_r(\omega)$	$\epsilon_r(\omega)$
ENG	7–9.496	9	$3.0261 + i0.3794$	$-0.4424 + i0.0014$
DNG	9.5–9.85	9.6	$-3.9516 + i4.9612$	$-0.1224 + i0.0012$
MNG	9.86–10.38	10.2	$-0.2957 + i0.1964$	$0.1427 + i0.001$
DPS	10.39–11.99	11	$0.4367 + i0.0433$	$0.4311 + i0.0008$

Table 3
Categorization of Lorentz-Drude model for lossless case.

Material	Region ($\times 10^9$)	Frequency ($\times 10^9$)	$\mu_r(\omega)$	$\epsilon_r(\omega)$
ENG	7–9.496	9	3.0261	−0.4424
DNG	9.5–9.85	9.6	−3.9516	−0.1224
MNG	9.86–10.38	10.2	−0.2957	0.1427
DPS	10.39–11.99	11	0.4367	0.4311

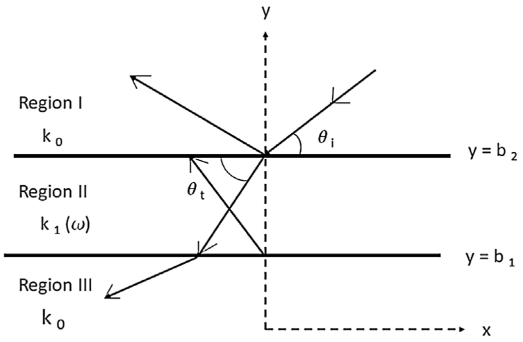

Fig. 1. Dispersive dielectric magnetic slab.

$$\mu_r(\omega) = \mu_\infty + \frac{(\mu_s - \mu_\infty)\omega_o^2}{\omega_o^2 - i\omega\delta - \omega^2} \tag{1a}$$

$$\epsilon_r(\omega) = \epsilon_\infty - \frac{\omega_p^2}{\omega(\omega + i\nu_c)} \tag{1b}$$

Setting $\delta = 0$ and $\nu_c = 0$ yields lossless case. Definition and values of different parameters are given in Tables 1–3, respectively.

It is important to acknowledge that many natural objects, for example: rough surfaces, cracks on a surface, turbulence in fluids,