Meta-Material Properties and Application Design

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Abstract: This paper reviews on meta-material sensor circuit and antennas based on wireless communication. This paper concerned about the characteristics of meta-material system design. The meta-material properties are useful for the implementation of high performance and accurate instruments as well as different functional devices. The characteristics impedance and phase constant are main component for application design. Meta materials are used for newly designed structures not only for properties of base material. Meta-Material properties are capable for consideration of electromagnetic wave radiation by enhancing, absorbing, bending, blocking to design the application that go beyond the possibility with conventional materials. Meta material research is inter disciplinary for example nanoscience, material science, optoelectronics, microwave and solid state, electromagnetic and semiconductor engineering.

Keywords: Meta-materials; left-handed materials; negative-index of refraction materials; absorber.

Introduction

The unit cell is not constructed by physical atom but it contains the small metallic resonator, which depend upon electromagnetic wave wavelength λ [1]. The Meta material determine with medium properties such as the permittivity and permeability become simultaneously negative. An Incident electromagnetic wave in term of effective permittivity ($\varepsilon_{eff} = \varepsilon_o\varepsilon_r$) and permeability ($\mu_{eff} = \mu_{o\mu r}$) represents the response of material. The resonant circuit artificially contructed for the requirement of small wavelength with resonant factor S. For that, the averaged value of ε_{eff} and μ_{eff} considered for medium, due to this effect spatial dispersion ignored legitimately. Based upon these fundamental characteristics, the meta-material are constructed. The Negative refractive index is the main parameter [2]. The meta-material characterized with Maxwell equation:

$$\nabla \times E = -\mu_0\mu_r \frac{\partial H}{\partial t} \quad (1)$$

$$\nabla \times H = \varepsilon_0\varepsilon_r \frac{\partial E}{\partial t} \quad (2)$$

from the equation $\nabla = \frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}$ the value given as:

$$\nabla^2 E = \varepsilon_0\varepsilon_r\, \mu_0\mu_r \frac{\partial^2 E}{\partial t^2} \quad (3)$$

As per harmonic conditions consideration and S is wave vector.

$$E_{(x,y,z)} = Ee^{jwt - ts.r} \quad (4)$$

$$S \times E = -\omega\mu_0\mu_r H \quad (5)$$

$$S \times E = +\omega\varepsilon_0\varepsilon_r E \quad (6)$$

In given equation the cross product term E, H and S are the triple vector for right handed and left handed system. if the value of $\varepsilon_r > 0$ and $\mu_r > 0$, it is for right handed system. If the value $\varepsilon_r < 0$ and $\mu_r < 0$, it is for left handed system. As per shown in figure.1

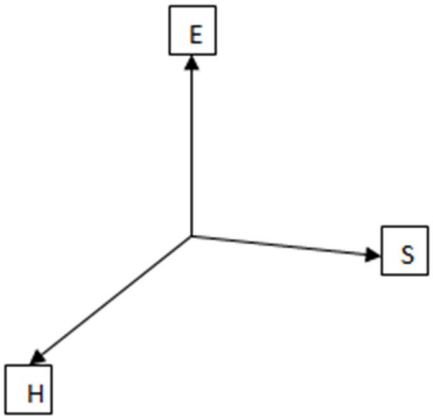

Fig-(a) and , it is for right handed system for vector E,H and S

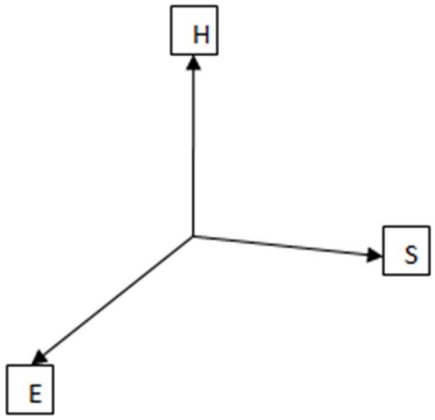

Fig-(b) and , it is for left handed system for Vector E,H and S

Figure.1

Meta-material Classification

The system response depends upon the presence of electromagnetic field . The material properties are determined by this electromagnetic field. These properties describes the material parameter Permittivity and permeability. The material classification based upon these properties are shown in the Figure.2.

Epsilon Negative (ENG)

If permittivity less than zero & permeability greater than zero ($e < 0, \mu > 0$) is known as Epsilon negative medium .Example are plasmas characteristics medium.[3] **.**

Double Positive Medium (DPS)

If both permittivity & permeability greater than zero ($e > 0, \mu > 0$) are known as double positive medium. Example is Dielectric medium.[4]

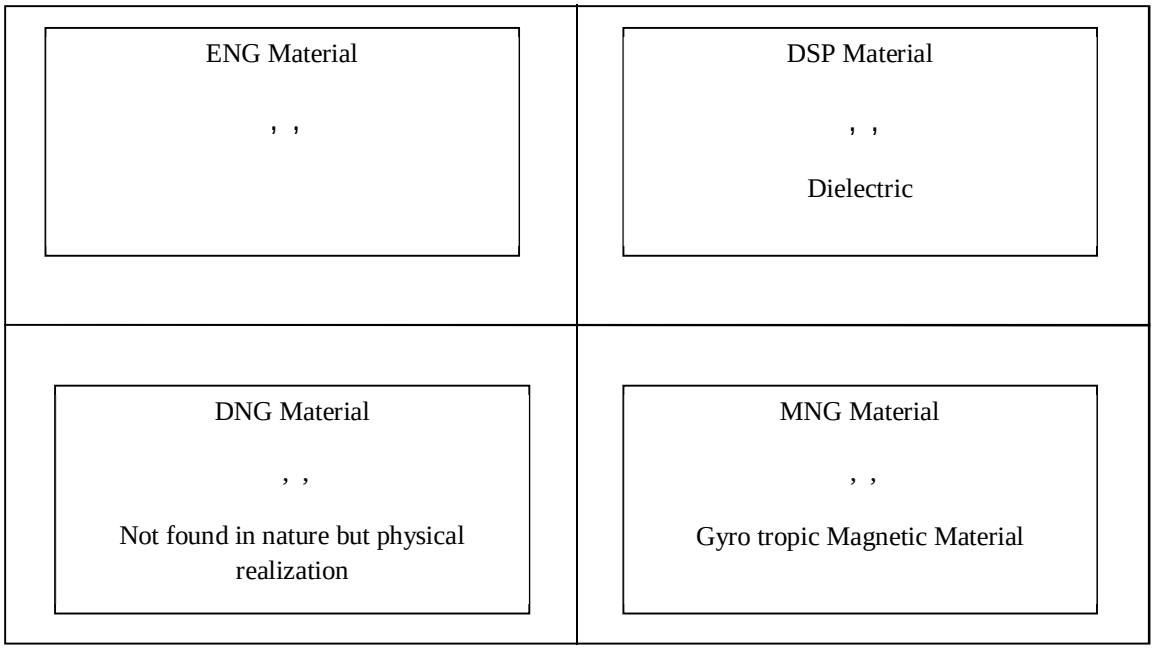

Figure.2

Double Negative Medium (DNG)
If both permittivity & permeability less than zero ($e < 0$, $\mu < 0$) are known as Double negative medium. Artificial construction is demonstrated with this medium. [5]

Mu Negative Medium (MNG)
If both permittivity greater than zero & permeability less than zero ($e > 0$, $\mu < 0$) are known as Mu negative medium. Example is gyrotropic material medium requirement. [6]

Meta-material Applications

Antenna Meta-material
Meta-material antenna radiates 95% of input radio signal at 350 MHz .Experimentally , meta-material antenna are as small as one fifth of a wavelength. Patch antenna with meta-material increase the directivity of antenna. . Zero-index meta-materials are used for high directivity flat horn antenna design.[7]

Super-lens Meta-material
Conventional optical materials have a problem of diffraction limit because only the propagating components are transmitted from a light source and non propagating evanescent waves, are not transmitted. Super-lens concept can improve such requirement to significantly enhance and to recover the evanescent waves that carry information at very small scales. For perfect image it constitutes the evanescent waves by the super-lens. [8]

Sensor Meta-material
Meta-material are applicable for design of different types of sensor with specified sensitivity. Meta-material sensors are used in the field of biomedical, agriculture etc. In agriculture the sensors are designed with resonant material and construct with SRR for improvement of sensitivity. In bio medical, wireless sensor, strain sensors are mostly used with SRR to enhance the sensitivity. [9]

Phase compensator Meta-material
Phase compensator is design with the DPS slab, having positive phase shift while DNG slab has opposite phase shift. For the same the DNG slab have total phase difference is zero.[10]

Cloaks Meta-material
The concept of Cloaking are guiding electromagnetic wave by cancellation of the electric filed.[11]

Biosensor Meta-material
The investigation of biological phenomena concerned with biosensor, like environmental monitoring, food safety and disease diagnostics. Meta-material use as biosensor for label-free bio molecules and efficient cost.[12]

Absorber Meta-material
With meta-material as absorber can be used for properties like supplementary miniaturization, wider adaptability, and increased effectiveness. The effective medium design, permittivity and magnetic permeability are design with high ratio of electromagnetic radiation absorption.[13]

Sound filtering and Light Meta-material
Meta-material are used in medical diagnostics, sound suppression and nondestructive material testing. [14]

Conclusion
Meta-material has advance technical design properties by which we can construct wide range of application in the field of electromagnetic radiation. With their application based properties like negative refractive index materials are applicable in microwave field. Microwave devices and antennas require multiband operation, which can be fulfilled by the meta-material. The absorber properties are applicable for design of sensors for humidity, soil moisture measurement. From their advance properties of meta-material it can be also applicable in the field of optics and medical. In future the nanotechnology devices will be design with involvement of meta-materials.

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