

Literature Review of Metamaterial Based Sensing Devices

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ABSTRACT: In this literature review paper, different Metamaterial based devices are presented. These devices are of portable, cost effective and which gives the accuracy. Metamaterial are artificially made electromagnetic materials consisting of periodically arranged metallic elements which are less than wavelength of incident electromagnetic (EM) wave in size. Their precise shape, geometry, size, orientation and arrangement gives them their smart properties capable of manipulating electromagnetic waves: by blocking, absorbing, enhancing, or bending waves, to achieve benefits that go beyond what is possible with conventional materials. The theoretical approach of Metamaterial with its different applications is discussed here.

KEYWORDS: Metamaterial, Sensors, Absorbers, Cloaks, Electromagnetic.

I. INTRODUCTION

We are aware of sensor device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing. Recently, significant advances have been done for material characterization using properties techniques. Some of these techniques are presented for the real part of the dielectric constant measurement; conversely, each technique is suitable and valuable for certain kinds of frequency ranges and certain kinds of materials. Material characterization has an application in various areas such as bio-sensing, quality control in the food industry, substrate properties and so on [1]. The work in this paper is divided in four stages. (i) Related Work (ii) Metamaterial Based Devices (iii) Electromagnetic Metamaterial and (iv) Frequency Bands Used.

II. RELATED WORK

In modern years, Metamaterial became one of the main topics of current research in the field of high-frequency technology. Metamaterial are a combination of conductive and non-conductive materials, whose arrangement and characteristics lead to new and exotic properties that do not occur in nature. These materials can show a negative permeability and permittivity in certain frequency ranges, whereby a negative refractive index is possible [2]. Negative-index materials were first described theoretically by Victor Veselago in 1967. He proved that such materials could transmit light. John Pendry was the first to identify a practical way to make a left-handed metamaterial, a material in which the right-hand rule is not followed. Such a material allows an electromagnetic wave to convey energy (have a group velocity) against its phase velocity. In 2000, Smith et al. reported the experimental demonstration of functioning electromagnetic metamaterials by horizontally stacking, periodically, split-ring resonators and thin wire structures. A

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method was provided in 2002 to realize negative-index metamaterials using artificial lumped-element loaded transmission lines in microstrip technology.

III. METAMATERIAL BASED DEVICES

Man-made meta-atoms: Natural materials consist of large quantities of fundamental particles, atoms or molecules. The macroscopic electromagnetic (EM) properties of a material are usually presented by the electric permittivity and the magnetic permeability. In contrast, metamaterial are composed of periodically or non-periodically arranged unit cells of man-made meta-atoms. These meta-atoms are essentially sub-wavelength electric or/and magnetic resonators which response to the external electromagnetic fields as harmonic oscillators [5]. The followings are some applications of metamaterial.

- **Antennas:** Metamaterial antennas are a class of antennas which use Metamaterial to increase performance of miniaturized (electrically small) antenna systems. Their purpose, as with any electromagnetic antenna, is to launch energy into free space. A Metamaterial antenna behaves as if it were much larger than its actual size, because its novel structure stores and re-radiates energy. For example, a wideband horn antenna (loaded with metamaterial-inspired particles) can be enabled to perform different manipulations on the transmitted and received signals, such as band-pass and band-stop filtering processes, and polarization transformation. Therefore, the modules can be considered as a new family of microwave components that perform signal manipulation directly inside the radiating element of a communication system. By using these compact modules, we reduce the number of components constituting a communication system, with clear advantages in terms of cost, weight, complexity, and space occupancy [5].
- **Absorbers:** A Metamaterial absorber is intended to efficiently absorb electromagnetic radiation such as light. As Metamaterial is an advance in materials science. Hence, those Metamaterial that are designed to be absorbers offer benefits over conventional absorbers such as further miniaturization, wider adaptability, and increased effectiveness. Intended applications for the Metamaterial absorber include emitters, sensors, spatial light modulators, infrared camouflage, wireless communication, and use in solar photovoltaic and thermophotovoltaics. A structure is designed to broaden the bandwidth of metamaterial absorber composed of a patterned square metallic patch and a metallic ground plane separated by a dielectric layer [6]. The conductivity of the metal and the thickness of the dielectric layer determine the bandwidth of the metamaterial absorber [7].
- **Super lens:** A Super lens is a lens which uses Metamaterial to go beyond the diffraction limit. The diffraction limit is a feature of conventional lenses and microscopes that limits the fineness of their resolution. A two-dimensional Luneburg lens based on bulk Metamaterial is composed by a number of concentric layers. By varying the geometric dimensions of unit cells in each layer, the gradient refractive index profile required for the modified Luneburg lens can be achieved. The cylindrical waves generated from a point source at the focus point of the lens could be transformed into plane waves as desired in the microwave frequency. This modified Luneburg lens can realize wide-angle beam scanning when the source moves along the circumferential direction inside the lens [8].
- **Cloaks:** Metamaterial cloaking is the usage of Metamaterial in an invisibility cloak. This is accomplished by manipulating the paths traversed by light through a novel optical material. Metamaterial direct and control the propagation and transmission of specified parts of the light spectrum and demonstrate the potential to render an object seemingly invisible. Metamaterial cloaking, based on transformation optics, describes the process of shielding something from view by controlling electromagnetic radiation. A new pi-shaped metamaterial unit cell that exhibits more than a 2 GHz wideband near zero refractive index (NZRI) property in the microwave region. The material was then utilized in the design of three types of cloak shapes (rectangular-shaped, eye-shaped, and triangular shaped) for hiding a metal cylinder. It was found that, for all the three types of shapes,

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the metal object could be cloaked in the C-band region by reducing the normalized scattering width to below zero, where the material was showing near zero refractive index property [9].

- **Sensors:** As Metamaterial are artificial media structured on a size scale smaller than wavelength of external stimuli, and they can exhibit a strong localization and enhancement of fields, which may provide novel tools to significantly enhance the sensitivity and resolution of sensors, and open new degrees of freedom in sensing design aspect. There are varieties of metamaterial sensors which can be used for specific application. These sensors are Biosensor (microwave, terahertz, plasmonic), Thin-film sensor, Wireless strain sensor, etc [10]. A microwave sensor based on an artificial transmission line is used for non-invasive blood glucose monitoring. Corresponding numerical model shows dimensions of the sensor leading to sensitivity suitable for accurate monitoring of glucose in blood [11].

IV. ELECTROMAGNETIC METAMATERIAL

Electromagnetic metamaterial affects electromagnetic waves that cooperate with its structural features, which are smaller than the wavelength. To behave as a consistent material precisely described by an effective refractive index, its features must be much smaller than the wavelength. For microwave radiation, the features are on the order of millimetres. Microwave frequency metamaterial are usually constructed as arrays of electrically conductive elements (such as loops of wire) that have suitable inductive and capacitive characteristics. One microwave metamaterial uses the split-ring resonator. Photonic metamaterial, nanometre scale, manipulate light at optical frequencies. To date, sub wavelength structures have shown only a few, questionable, results at visible wavelengths [10][11]. Electromagnetic metamaterial are divided into different classes, as follows:

- Negative Index
- Single Negative
- Bandgap
- Double Positive Medium
- Bi-isotropic and bianisotropic
- Chiral
- Frequency selective surface-based

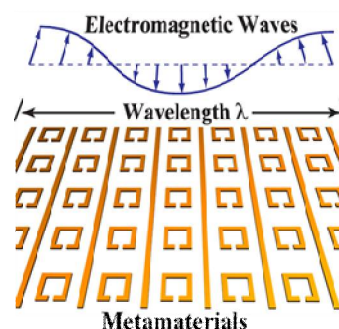


Fig.1. Electromagnetic metamaterial Structure Review

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V. FREQUENCY BANDS USED

As per the frequency range required for specific use or application of metamaterial, the following frequency bands are used.

- Terahertz metamaterial interact at terahertz frequencies, usually defined as 0.1 to 10 THz. Terahertz radiation lies at the far end of the infrared band, just after the end of the microwave band. This corresponds to millimeter and sub millimeter wavelengths between the 3 mm and 0.03 mm.
- Photonic metamaterial interact with optical frequencies. The sub-wavelength period distinguishes them from photonic band gap structures [12][13].
- Tunable metamaterial allow arbitrary adjustments to frequency changes in the refractive index. A tunable metamaterial expands beyond the bandwidth limitations in left-handed materials by constructing various types of metamaterial.
- Plasmonic metamaterial exploit surface plasmons, which are produced from the interaction of light with metal-dielectrics. Under specific conditions, the incident light couples with the surface plasmons to create self-sustaining, propagating electromagnetic waves known as surface plasmon polaritons.

VI. CONCLUSION

The Metamaterial inspired sensing devices will overcome the limitations of the current generation of high cost, low availability and bulky measuring and sensing devices by developing a device that will not only provides high levels of accuracy at a wide range of temperatures but is low in cost and is highly portable. Also it will introduce to a new concept of metamaterial inspired micro sensor application for fuel detection.

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