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METAMATERIAL UNIT CELL STRCTURE

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***Abstract*— For the past few years, there is wide scope for research on metamaterials and its applications. These materials are designed artificially which possess composite structures with exotic material properties. Metamaterials unveil negative permittivity and/or negative permeability. This paper covers design of metamaterial unit cell and their scope of applications.**

Keywords—metamatrials, split ring resonator,cst microwave studio,applications

I. Introduction

A Metamaterial is a material designed to have a property which are not readily available in nature. They are fabricated from assemblies of multiple elements carved from composite materials. These materials are usually arranged in repeating patterns, at scales that are smaller than wavelengths of the phenomena they influence. Metamaterials derive the properties not from their base material, but from their newly designed structure. 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. Unit cell structure of metamaterial is designed using High Frequency Structure Simulator software or Computer Simulation Technology. In particular composite media electromagnetic waves interact with the inclusions which are artificially embedded in the cell, which in turn produce electric and magnetic moments which affects the permittivity and permeability of the composite medium.

II. METAMATERIAL CLASSIFICATION

The existence of an Electromagnetic field in a system is determined by the properties of the materials. The parameters like permittivity and permeability illustrates the properties of these materials. The metamaterial classification is graphically shown in Fig. 1.1

A. Double positive material

A medium with both permittivity and permeability values greater than zero is called as double positive medium. Dielectric materials are best example for this type of media.

B. Epsilon negative material

A medium with negative permittivity and permeability greater than zero is called as Epsilon negative medium. In certain frequencies many plasmas exhibit this characteristic.

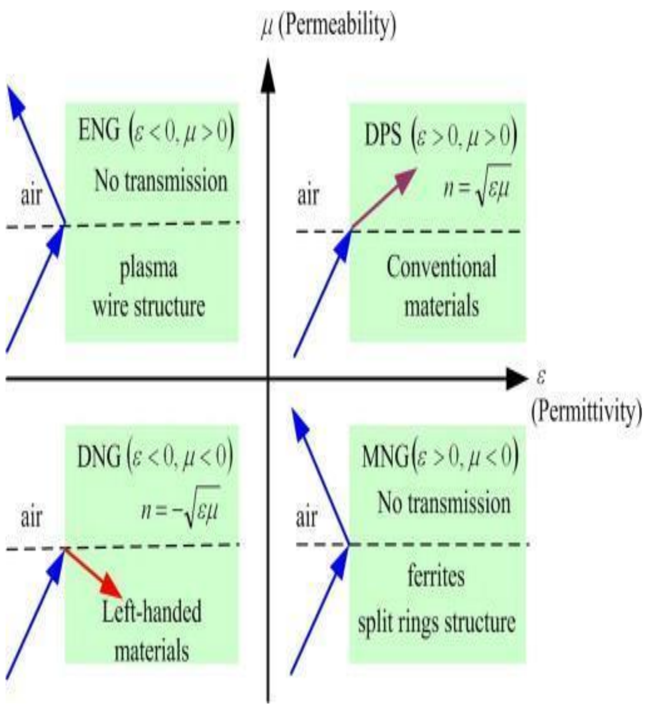

Fig. 1.1: Classification of Metamaterials

C. Mu negative material

A medium with negative permeability and permittivity greater than zero is called as Mu negative medium. The gyroscopic materials exhibits this characteristic.

D. Double negative material

A medium with negative values of both permittivity and permeability is called as Double negative medium. These are not found in nature but realizable physically.

III. DESIGN

Design of metamaterial cell consists of split ring resonators and metal strip. Split ring resonators are responsible for negative permeability and also for forward and backward wave propagation. There are different types of SSR, circular split ring resonators and square split ring resonators. A single cell SRR has a pair of enclosed lops with gaps in loops which are opposite to each other. This loops may be circular or square or gapped as needed.

The loops are etched on a dielectric substrate which are made of nonmagnetic metals like copper and loops are separated by small gap. Due to splits in the ring structures can support wavelengths much larger than the diameter of the rings. The small gaps between loops raises to large capacitance which are reason for reducing resonating frequency. The dimensions of the structure are small compared to resonant wavelength which are responsible for low radiative losses and high quality factors. Different split ring resonators are shown below.

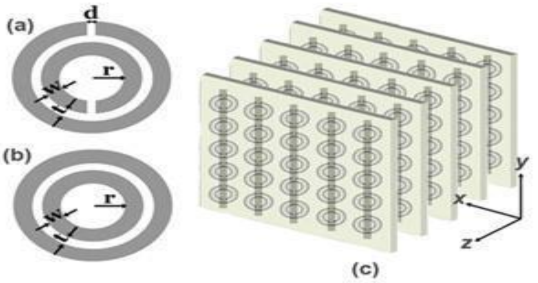

Fig 3.1 Schematics of **(a)** a single split ring resonator (SRR) **(b)** a ring resonator with splits closed (CSRR) **(c)** Periodic CMM composed of SRRs on one side, wires on the other side of dielectric board.

The metallic wire which is on other side of substrate is responsible for negative permittivity. The SSRs and metallic strips are optimised to fabricate a cell with optimum dimensions which results in negative parameters.

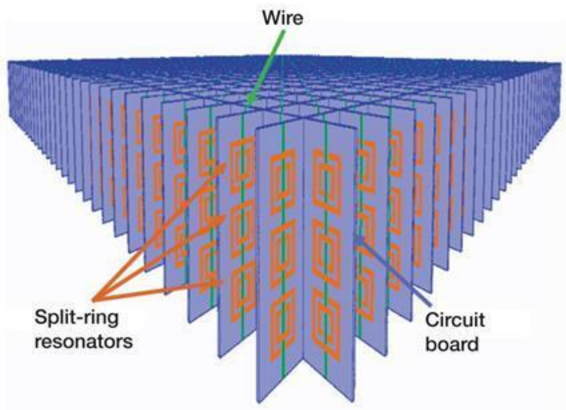

Fig 3.2 Split-ring resonator consisting of an inner square with a split on one side embedded in an outer square with a split on the other side. Split-ring resonators are on the front and right surfaces of the square grid, and single vertical wires are on the back and left surfaces.

The design of metamaterial unit cell structure can be simulated by High frequency structure simulator (HFSS) or CST Microwave studio. First we have to select the substrate material, different substrates shows different properties so depend on the application we have to select the substrate. Then we have to create a split ring resonator on the substrate with appropriate dimensions of resonator. Then on other side which is opposite face to resonator we have create metallic wire so that it aligns along the split gaps. Below figure shows the structure of metamaterial unit cell which is designed using CST Microwave Studio.

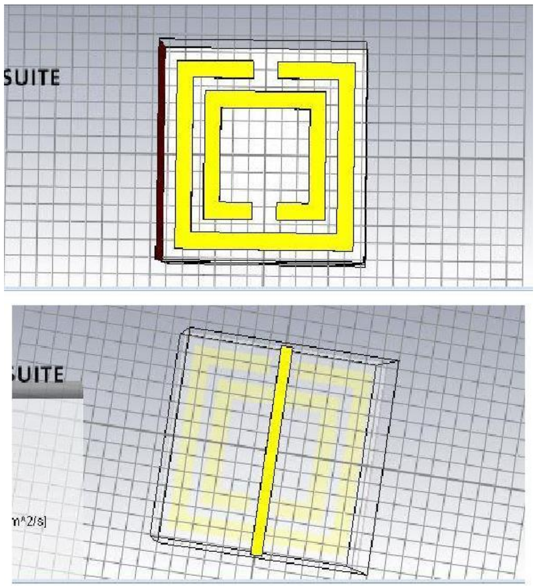

Fig 3.3 unit cell with square ring resonator and a wire on both sides of FR-4 substrate.

After designing the unit cell we have to assign boundaries and excitations to the cell and then is simulated using CST Studio software which results in different properties. The unit cell with electric and magnetic boundaries are assigned along Y and Z axis and waveguide ports along X axis which is the path of EM wave are assigned and is shown in below figure

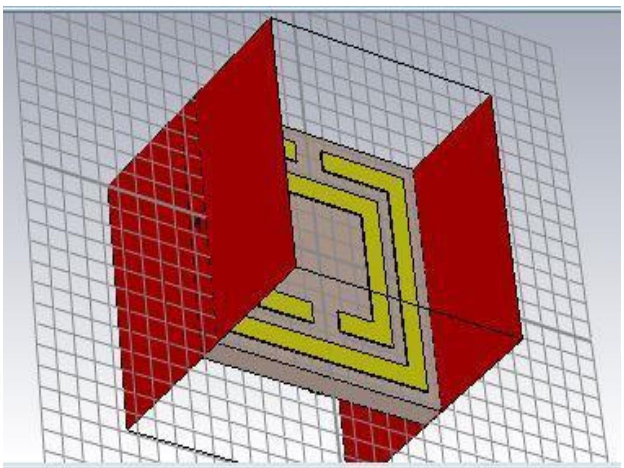

Fig 3.4 Unit cell with waveguide ports and boundaries

IV. APPLICATIONS OF METAMATERIALS

A. Metamaterial Absorber

These metamaterial absorbers are well known for absorbing the electromagnetic radiation. These absorbers deliver many beneficial aspects than the conventional absorbers such as supplementary miniaturization, increased effectiveness and wider adaptability.

B. Superlens

A Superlens is a multi-dimensional device that utilizes metamaterials with negative refraction properties, to achieve resolution behind the diffraction limit. Therefore, this behavior enables the capability of double-negative materials to yield negative phase velocity.

C. Cloacking Devices

Metamaterials are the basic component for attempting to build a practical cloaking device. The microwave beams are deflected by the cloaks so that they flow around the hidden objects with a negligible distortion.

D. Invisible Subs

Metamaterials can manipulate the wavelength of sound that are more than the wavelength of light. Submarines are made invisible to the enemy sonar. Metamaterials are also used to produce sound proofing rooms with perfect acoustics.

E. Electronic Devices

Metamaterials are used as a switching devices for building small phototonic equipment. In this device the semiconductor combines with the metamaterials in the device. These photonic chips are ten times faster than the current chips in usage.

F. Metamaterial Antenna

These metamaterials are used in the antennas to increase the parameters like gain of antenna, performance of miniaturized because it has unique structures. In conventional antennas the wavelength reflects back to the source. The antenna structure that stores and re-radiates energy which makes it size small and behaves as larger antenna. Metamaterials employed in the ground planes surrounding antennas offers improved isolation between radio frequency or microwave channels of multiple-input multiple-output antenna arrays. Metamaterial, high-impedance ground planes can also be used to improve the radiation efficiency, and axial radio performance of low profile antennas located close to the ground plane surface. Metamaterials have also been used to increase the beam scanning range by using both the forward and backward waves in leaky wave antennas.

V. CONCLUSION

Metamaterials is the new field for wide scope for research. Many research scholars are focusing on this area because of its composite structures with its exotic material properties. Metamaterials has wide field of applications where it can replace the existing materials. In this paper a brief of metamaterials and different types of metamaterials are discussed. Different modelling methods of metamaterials are there depending on their application field and in this paper one of modelling method is discussed. The metamaterials have surprising electromagnetic properties which results in wide are of applications and some of its applications where this materials can be used are reviewed.

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