Analysis and Design of a Metamaterial based Microstrip Antennas

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***Abstract*—In the course of the past ten years, a great attention in the research of metamaterials has been perceived. Metamaterials are artificially invented materials that show the properties which are not detected in naturally occurring materials. Metamaterials produce electromagnetic phenomena that are not seen in natural materials, and come in a wide variety of types. When developing a new metamaterial, simulation can be used both to analyze both the bulk property of the material and individual element. On modeling of metamaterials the researcher should be aware about several special considerations. So, for the efficient development of a device, several modeling techniques are used.**

***Index Terms*—Metamaterial, Patch antenna, Performance enhancement**

I. INTRODUCTION

In wireless communication the antenna performs an vital function. For factor to point wireless communication and wireless the antenna must be compact and efficient for comfort. Metamaterial antennas are a category of antennas which use Metamaterials to growth performance like advantage and performance of miniaturized (electrically small) antenna systems. Metamaterial is the only fabric (synthetic) in the global which well-knowns hows simultaneously negative permittivity and permeability which ends up in poor refractive index. Due to having the negative refractive index it helps backward waves (antiparallel segment and institution velocities) and does not obey some optical region of nature. These unique space assist Metamaterial to exchange the electric and magnetic properties of electromagnetic waves passing via it and this facilitates in getting stronger regions whilst implemented to antenna layout. Again because the structural common mobile size of Metamaterial is less than one-fourth of the guided wavelength so it supports high degree of miniaturization. These Metamaterial antennas may be very suitable to use in WLAN (Both 2.4 and 5 GHz) due to its high overall performance and small size.

The radiation sample of an antenna is a plot of relative field electricity of the radio waves emitted via the antenna at exclusive angles. Return loss is the loss of sign power resulting from the mirrored image prompted on the discontinuity in a transmission line. VSWR is the Voltage Standing Wave Ratio defined as reflected energy of the Transmission line. Depending upon the packages, the homes of an antenna which includes bodily structure varies. There are different forms of antenna now and all of them have their region. Every machine demands for compact and efficient components to be embedded with it. Microstrip patch antenna is such a thing which is so popular by using its compact size. A microstrip or patch antenna is a low profile antenna that has some of advantages over different antennas. Microstrip antenna located software in special fields due to its compact size. Akin to the 2 sides of a coin, a patch antenna additionally has some drawbacks. Bandwidth and gain being the two most crucial factors of an antenna is low for patch antennas. There are many approaches to clear up this trouble but each of them results in any other trouble which requires similarly interest.

Electromagnetic Metamaterials are effectively homogenous artificial structures engineered to provide electromagnetic properties not readily observable in nature. Effectively homogeneous means that scattering/diffraction is a minor/non-existent effect in a propagating wave in a Metamaterial. Lattice constants of the Metamaterial are much smaller than the electromagnetic wave. So what kind of unique electromagnetic properties can Metamaterials provide? First let's define what we mean by electromagnetic properties. Electromagnetic properties are the effect a material has on the electric and magnetic field of a wave, which is determined by the material's permittivity and permeability respectively. The four possible combinations of permittivity and permeability are shown in fig.1. As shown in the figure, when the wave incident from air to plasmas and ferrites it gets reflected so the wave attenuates. But in case of conventional materials and Metamaterials positive and negative refraction takes place respectively and wave propagates [16]. Materials that reside in quadrant I, II and III are known to exist in nature, however naturally occurring materials with negative permittivity and negative permeability have not yet discovered. In 1967 Victor Veselago speculated about the existence of such double negative materials in his paper entitled "The electrodynamics of substances with simultaneously negative permittivity and negative permeability".

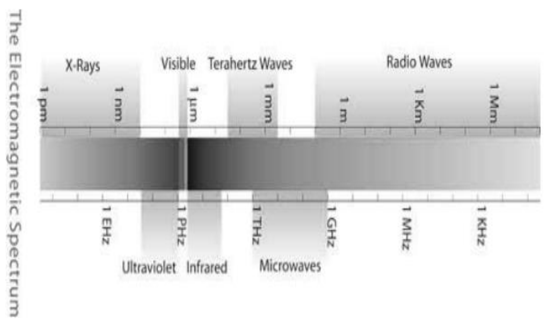

Fig .1: The EM Spectrum

Veselago discussed the unique phenomena occurring for an electromagnetic wave in a double negative material. These are

1. Electric field, Magnetic field and Wave vector form a left-handed. (LH) triad
2. Negative refractive-index leads to reversal of Snell‟s law, Doppler Effect and Vavilov Cerenkov Radiation
3. Frequency dispersion

Classification of metamaterials

Electromagnetic field is determined by the properties of the materials involved. These properties define the macroscopic parameters permittivity ε and permeability μ of materials. On the basis of permittivity ε and permeability μ, the metamaterials are classified in following four groups as shown in Fig. 2:

A. Double Positive (DPS) Material: The materials which have both permittivity & permeability greater than zero ($\varepsilon > 0$, $\mu > 0$) are called as double positive (DPS) materials. Most occurring media (e.g. dielectrics) fall under this designation.

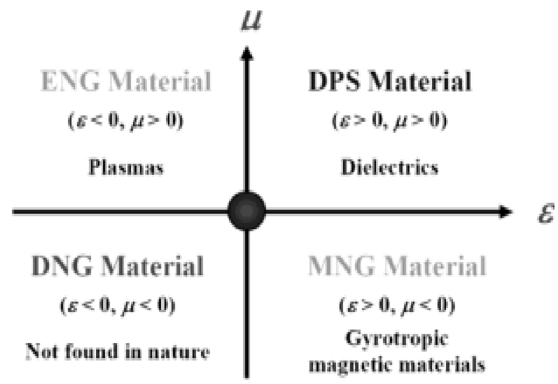

Fig.2 Classification of metamaterials

B. Epsilon Negative (ENG) Material: If a material has permittivity less than zero and permeability greater than zero ($\varepsilon < 0$, $\mu > 0$) it is called as epsilon negative (ENG) material. In certain frequency regimes, many plasmas exhibit these characteristics.

C. Mu Negative (MNG) Material: If a material has permittivity greater than zero & permeability less than zero ($\varepsilon > 0$, $\mu < 0$) it is called as mu negative (MNG) material. In certain frequency regimes, some gyro tropic material exhibits these characteristics.

D. Double Negative (DNG) Material: If a material has permittivity & permeability less than zero ($\varepsilon < 0$, $\mu < 0$) it is termed as double negative (DNG) material. This class of materials can only been produced artificially.

Various techniques used to increase the bandwidth of a microstrip patch are described previously as follows:
a) Decreasing the Q factor of the patch by increasing the substrate height and lowering the dielectric constant
b) Use of multiple resonators located in one plane
c) Use of multilayer configurations with multiple resonators stacked vertically and
d) Use of impedance matching networks.

The problems associated with the use of multiresonator configurations are larger area requirement and the variation in radiation pattern. The difficulty with application of wide band impedance matching network approach is the need for larger substrate area required for incorporating matching network. The most direct method of increasing the bandwidth of the microstrip element is to use a thick, low dielectric constant substrate.

II. LITERATURE SURVEY

In 1946, Kock was first to suggest an artificial dielectric antenna lens [1]. In 1962 rotman and in 1968 smith has presented the work on artificial electric plasma produced using parallel plate and wire media respectively.

In 1968, Victor Veselago [2] published the work about the electrodynamics of material with negative permittivity and permeability without practical realization and application of these material. J.B.pendry et.al, had shown firstly the realization of negative permittivity medium at microwave frequency using 2D matrix of thin wire medium [3] and in the subsequent paper [4], Pendry and his co-workers extended this idea to 3D wire net, by which the isotropic behaviour was achieved.

In 1999, pendry et.al published [5] the most significant publication in metamaterial, in which they had proposed the split ring resonator (SRR), a resonant practical, which is constituent of artificial negative permeability media. SRR practical is equivalent to an LC oscillator consisting of a magnetic coil with inductance L and a capacitor with capacitance C. if the frequency of incident wave is slightly higher than the LC- resonance frequency, the effective permeability of SRR array will be definitely negative.

After this pivotal work, Smith et al. [6] had presented the first implementation of left handed (LH) media by superimposing the SRRs with negative permeability and metallic wires with negative permittivity and subsequently the experimental demonstration of negative refraction was demonstrated in [7] by Shelby et al. After these work, medium with negative permittivity and negative permeability has attracted a great attention of researchers with the emphasis on subject of electromagnetics. They have been considered for use in wide variety of radiating and guiding structures [8-10].

III. RECOMMENDED OUTLINE

There are many complex problems, which can be easily solved by numerical methods only. Various Computational electromagnetic simulators based on Maxwell equations are used to test antennas and wave propagation in complex media. On modeling of metamaterials the researcher should be aware about several special considerations. So, for the efficient development of a device, several modeling techniques are used.

A. Finite Difference Time Domain (FDTD) method

FDTD is an efficient and robust method that used to model a variety of frequency dispersive and non-dispersive materials with electromagnetic wave interaction. It gives straight forward method to model complex periodic structures and commerce with the characteristics of metamaterials over a wide frequency band because it is a time domain solver. The FDTD algorithm gives accuracy in both time and space.

B. Finite-Element Method (FEM)

To solve the problems of inhomogeneous anisotropic materials and complex structures the finite-element method (FEM) is used. It eliminates the problem of spurious solutions by expanding the angular and transverse field components with the node-based scalar and edge-based vector basis functions respectively.

C. Transmission Line Method (TLM)

There are many numerical methods and theories that describe the properties of different structures of wire metamaterials. The modeling of metamaterials is much important with this method and is also very difficult task. TLM model permits the design of different structures based on conducting thin-wires.

ANSYS HFSS software

ANSYS HFSS software is the industry standard for simulating 3-D full-wave electromagnetic fields. Its gold-standard accuracy, advanced solver and compute technology have made it an essential tool for engineers designing high-frequency and high-speed electronic components. HFSS offers multiple state-of the-art solver technologies based on finite element, integral equation or advanced hybrid methods to solve a wide range of applications. Each HFSS solver incorporates a powerful, automated solution process, so you need only to specify geometry, material properties and the desired output. From there, HFSS automatically generates an appropriate, efficient and accurate mesh for solving the problem using the selected solution technology. With HFSS, the physics defines the mesh; the mesh does not define the physics.

Two Modes of Operation: To enhance user productivity, ANSYS HFSS includes two modes of operation:

1) 3-D
2) HFSS 3-D layout

The 3-D interface enables users to model complex 3-D geometry or import CAD geometry. Typically, the 3-D mode is used to model and simulate high-frequency components, such as antennas, RF/microwave components and biomedical devices. Engineers can extract scattering matrix parameters (S,Y, Z parameters), visualize 3-D electromagnetic fields (near- and far-field), and generate ANSYS Full-Wave SPICE models that link to circuit simulations.

The microstrip patch antenna is a popular printed resonant antenna for narrow-band microwave wireless links that require semi-hemispherical coverage. Due to its planar configuration and ease of integration with microstrip technology, the microstrip patch antenna has been heavily studied and is often used as elements for an array. In this tutorial, a 2.4 GHz microstrip patch antenna fed by a microstrip line on a 2.2 permittivity substrate is studied. The following topics are covered:

- Model Setup
- Waveport Feed
- Airbox and Boundary Conditions
- Meshing
- Analysis/Sweep Setup
- Plotting Results

IV. CONCLUSION

Metamaterials is the new field of research, short of any hesitation it becomes an tremendously exciting research area. The researchers from multiple disciplines are being fascinated towards metamaterials because of its unique electromagnetic properties. In this paper, a short assessment of the history of metamaterials, some of salient features, various types, applications and different modeling methods of metamaterials have been discussed.

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