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Metamaterial Incorporated Planar Antenna for C-band Application- A Review

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Abstract-Planar antenna has been widely used having an advantage of low weight, ease of fabrication & small size but it also has a disadvantage of having low gain, efficiency &narrow range of bandwidth. To overcome this limitation of narrow bandwidth, a review on microstrip planar antenna using metamaterials has been elaborated in this paper. Further paper describes introduction, basics of metamaterial structures, design of various antenna using metamaterial structures.

Keywords-*Frequency basis,C-Band, Microstrip planar antenna, Metamaterial, RIS, CSRR.*

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I. INTRODUCTION

Antennas are basic components of any electric system and are connecting links between the transmitter and free space or free space and the receiver. Thus antennas play very important role in finding the characteristics of the system in which antennas are employed. Antennas are employed in different systems in different forms. The IEEE Standard Definitions of Terms (IEEE Std 1451983)"A means for radiating or receiving radio waves"

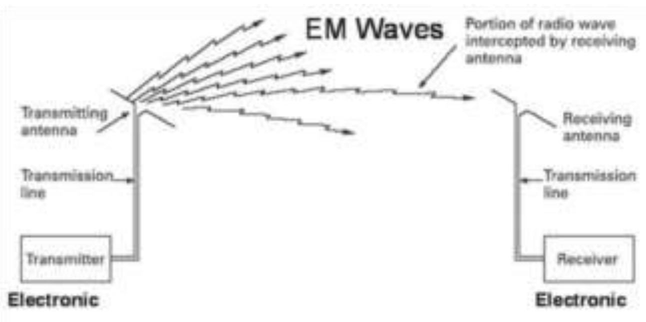

Figure 1. Electromagnetic wave transmission by antenna

Planar antennas find its application in several area based on frequency as tabulated below.

Table 1. Frequency basis for antenna applications

Frequency Band	Designation	Typical service
3-30 KHz	Very Low frequency (VLF)	Navigation, SONAR.
30-300 KHz	Low Frequency (LF)	Radio beacons, Navigational Aids.
300-3000 KHz	Medium Frequency (MF)	AM broadcasting, maritime radio, direction finding.
3-30 MHz	High Frequency (HF)	Telephone, Telegraph and Facsimile, amateur radio
30-300 MHz	Very High Frequency (VHF)	Television, FM broadcast, air traffic control
300-3000 MHz	Ultra High Frequency (UHF)	Television, satellite communication, radiosonde, surveillance RADAR
3-30 GHz	Super High Frequency (SHF)	Airborne RADAR, Microwave Links, Satellite Communication.
30-300 GHz	Extremely High Frequency (EHF)	RADAR, Experimental

In today's wireless era, the designing of an antenna should be smaller in size and easy to fabricate. So microstrip patch antenna also known as planar antenna has been chosen for its several applications. In order to overcome limitations of patch antenna i.e. lower Gain & narrow range of bandwidth, various techniques has been carried out to improve its overall performance. [1]

In order to enhance the bandwidth range, various techniques such as use of multiple resonators in ground, increasing the height of dielectric substrate,stacking layer configuration etc. can be used. All these techniques require largersurface area, spurious feed radiations, production of surface wave, and complicated designs which are not desirable. Therefore these complications led to the designing of special material structures known as metamaterials.[2-4]

Metamaterial are the material designed from artificial materials that are not generally found in nature but can be

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engineered. Victor Veselago studied the behaviour of such materials that show negative permittivity and permeability. These materials exhibit negative refractive index, since the structure consists of a Split Ring Resonators (SRR). SRR consists of two rings placed with a split on opposite sides of rings at 180 deg. phase. Metamaterials find their uses in variety of applications.[3-5]

II. BASICS OF METAMATERIALS

Metamaterials are artificially engineered material that derived its properties from its array structure. Permittivity (ε) and magnetic permeability (μ) are the two basic parameters which describe the electromagnetic property of a material or medium. Permittivity indicates how a material is affected when it is placed in electric field. Permeability shows how a material is affected in presence of magnetic field. Metamaterials may have either negative permittivity or permeability or both may be negative simultaneously. Metamaterial is an arrangement of periodic array structures of unit cells in which the average size of a unit cell should be much smaller[5] than wavelength of the light.

Metamaterial was first introduced by Victor Veselago [7] in 1967 after the Second World War. He showed that wave propagation in metamaterial is in opposite direction than the naturally occurring materials. Metamaterial are expected to have an impact across the entire range of technologies where electromagnetic radiation are used and will provide a flexible platform for technological advancement. Among metamaterials, negative refractive index materials or left-handed materials have drawn special attention in microwaves. Metamaterial properties, which allows reduction in size as compared to other materials for the multiband operation and reconfigurability of microwave devices and antennas.
In fig 2, Pendry showed that the negative permittivity could be achieved by aligning metallic wires along the direction of a wave whereas negative permeability by placing split ring with its axis along the direction of propagation of wave.

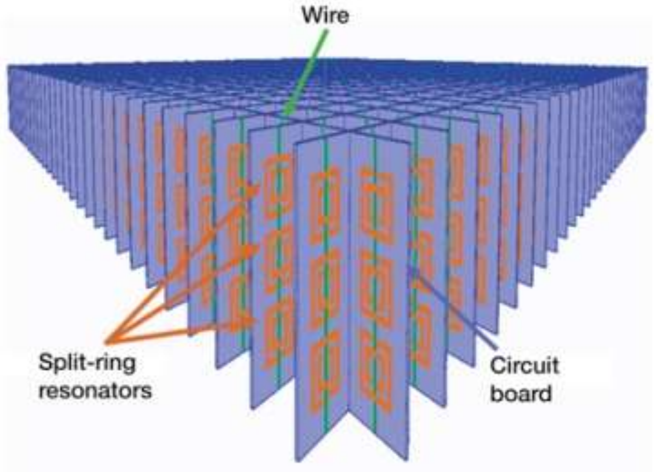

Figure 2. Combination of Alternating Layers of Thin Metallic Wires and Square Split Rings

1. Properties of Metamaterial

Consider the Maxwell's first order equations,

$$\nabla \times E = -j\omega\mu H \quad (1)$$
$$\nabla \times H = j\omega\epsilon E \quad (2)$$

Where ω is natural angular frequency

$$E = E_0 e^{(-jk.r+j\omega t)} \quad (3)$$
$$H = H_0 e^{(-jk.r+j\omega t)} \quad (4)$$

Where k is a wave vector.

$$k \times E = \omega\mu H \quad (5)$$
$$k \times H = -\omega\epsilon E \quad (6)$$

For simultaneous positive values of ε and μ, the vectors E, H and **k** make a right handed orthogonal system [10].

For simultaneous negative values of ε and μ, equations (5) and (6) can be rewritten as:

$$k \times E = \omega|\mu|H \quad (7)$$
$$k \times H = \omega|\epsilon|E \quad (8)$$

Figure 3, shows a plane ofε and μ, divided into four quadrants, based on the signs of ε and μ. The first quadrant contains the majority of dielectrics, where ε and μ are positive. Substances with one negative constitutive parameter are easy to find in nature. For example, the plasma medium, such as ionized gas or free electrons gas in metal, has negativeε all the way up to the plasma frequency, and belongs to the second quadrant. Materials such as ferromagnets and antiferromagnets can have negative magnetic permeability near the ferromagnetic resonance and belong to the fourth quadrant. However, left-handed materials, which belong to the third quadrant, do not exist in nature.

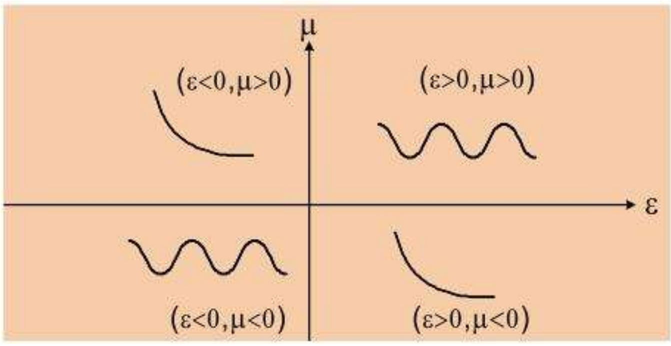

Figure 3ε and μ coordinate system.

For right handed system, n is positive, thus the phase velocity will be positive. Therefore, energy and wave will travel in same direction resulting in forward wave propagation.

These materials are exciting because of their unusual optical properties; in a left-handed material, light seems to propagate opposite the direction of energy flow. This leads to a negative index of refraction and reversed Doppler shift for radiation [10-11]. Figure 4 shows the right-handed system and left-handed system in left and right respectively.

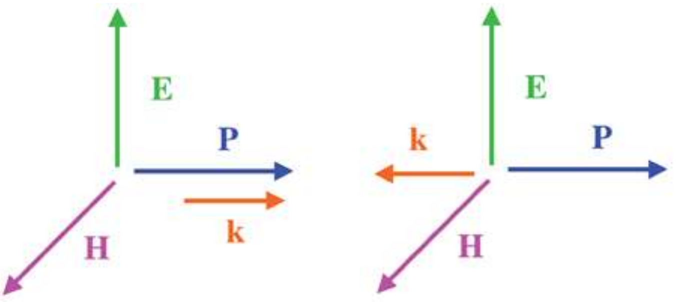

Figure 4. Left: Right Handed System and Right: Left Handed System

This is what metamaterials theoretically can do. They guide light around an object, rather than reflect or refract the light. So to the light waves and the human eye that perceives them the object might as well not even be there. If the light waves can be guided by the metamaterials around the object and back to its original course, the object wouldn't cast a shadow, either. This is another goal of using metamaterials to create cloaking devices.

III. METAMATERIAL INCORPORATED MICROSTRIP ANTENNA

N.Nizamuddin used Patch antenna with a circular ring slot.[11].A 7*7 rectangular ring unit cell metasurface & a single Feed, CP, ring slotted rectangular patch antenna is proposed to enhance bandwidth at 4.0 GHz. A ring slot provide patch radiator down to lower edge of the 3-dB AR frequency range. It provide 36.0% 10-dB return loss BW & a 7.0-7.5 dBic gain than the conventional antenna.

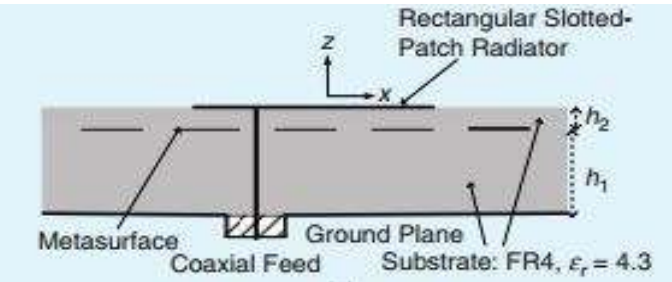

Figure 5. Cross-sectional view of proposed antenna [11].

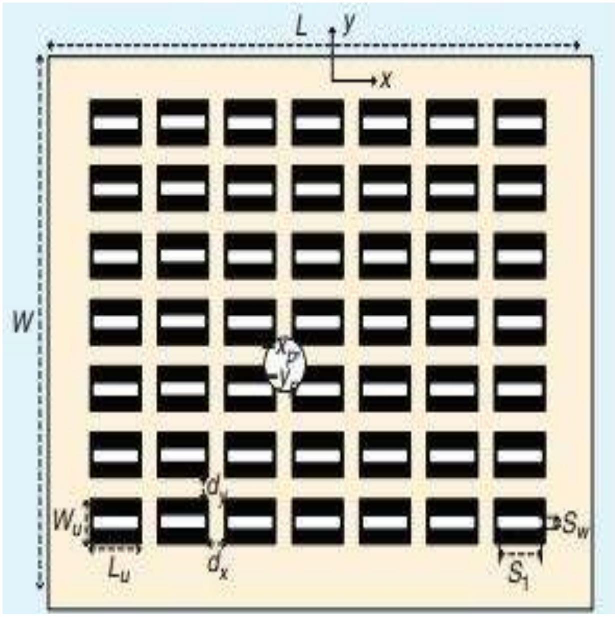

Figure 6. Array structure of metamaterial based antenna[11].

Swagata. B. discussed effect of split ring resonator on rectangular patch array antenna of 5.2 GHz [12]. It is seen that the multiple frequencies with different gain, return loss, VSWR are obtained after introducing array geometry with split ring resonator in the Rectangular Patch Antenna. The gain for rectangular patch antenna at 5.2 GHz is 4.39 dB. The gain is 5 dB for rectangular patch array. Gain improved to 8 dB for Rectangular patch array with Split Ring Resonator. Gain improves by 45.12% and bandwidth improves by 56.25%.The FR4 Epoxy substrate is used to design the antenna with HFSS software.

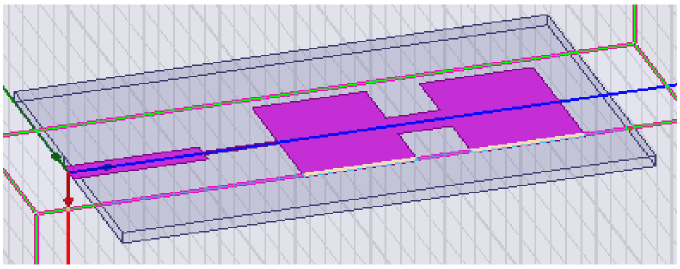

Figure 7. Rectangular Patch Array Antenna [12].

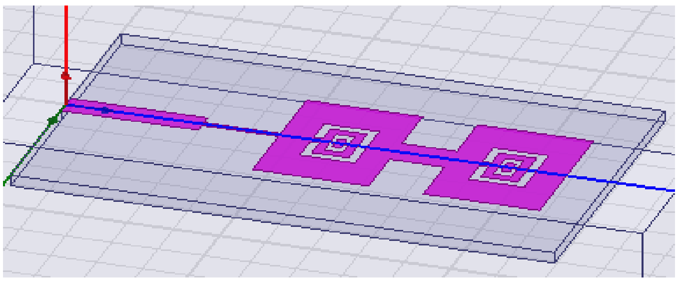

Figure 8. Split Ring ResonatorRectangular Patch Array Antenna[12].

Y.Dong *et al*, used a RIS reactive impedance surface on a substrate as a Metamaterial[15]. The antenna has a single feed configuration and loaded with composite mushroom like structure & RIS structure. RIS unit cell is placed atheight of 2.6mm on "Megtron 6" dielectric substrate. The proposed antenna resonates at 2.58GHz frequency.

The 10 dB return loss and 3-dB axial ratio bandwidth of an antenna was found to be 4.62% and 1.46% respectively. The gain of an antenna is measured as 2.98dBic.

Y.Dong *et.al*, used same structure as in [15] but instead mushroom structure, pair of CSRR complementary split ring resonators are used. The measured 10 dB return loss and 3 dB AR bandwidths of an antenna was found to be 4.9% and 1.68% and proposed antenna resonated at 2.8GHz frequency. [16]

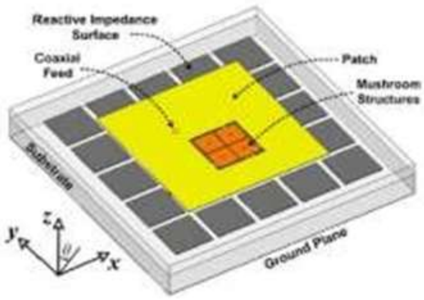

Figure 9. Proposed CP patch antenna with RIS & mushroom like CRLH[15].

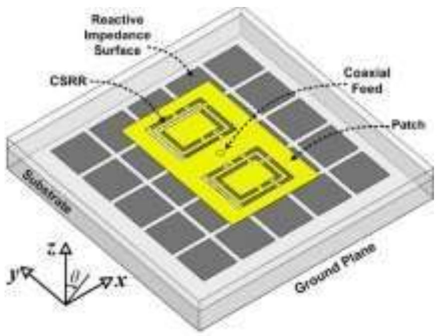

Figure 10 proposed CP patch antenna with RIS And CSRR[16].

IV. CONCLUSION

In this paper, the basics of Metamaterial with its properties have been discussed. Various configuration of metamaterial Structures over patch antenna have been discussed which improvesperformance of various antenna parameters such as gain, VSWR, bandwidth & efficiency. Among several available techniques like Increase height of substrate, multiple feed structures, use of low dielectric substrate, stacking patches over one another etc., metamaterial finds its way better in bandwidth enhancement.

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