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# Patch Antenna using Metamaterials for Wireless Applications: A Review

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***Abstract:*** Metamaterials are artificial engineered materials with unusual electromagnetic properties which are not found in nature. The use of metamaterial in patch antenna not only reduces the size of antenna but also improves the antenna parameters like gain, directivity, bandwidth enhancement and efficiency. In this review paper, an introduction and overview of metamaterials and its application in patch antenna is described. A comparison of literature review on the basis of size reduction, gain and bandwidth enhancement techniques for various wireless applications is presented.

***Index Terms* – Metamaterial, Patch Antenna, Wireless Applications.**

## I. INTRODUCTION

In recent years, with new inventions and the developing technology the use of wireless modernized devices is increasing day by day. Antennas are the most important part of any wireless devices. The antenna is an electronic device which acts as a transducer which will convert the electrical energy into electromagnetic energy and vice versa. The Microstrip patch antenna is widely used in these devices due to their low profile, low fabrication cost and are light in weight and have more advantages as compared to other antennas. The need of compactness, robustness and low cost of antenna is a must for the wireless devices. The metamaterial plays an important role in miniaturization and enhancing the parameters of an antenna. Metamaterial are artificial structures with the properties that are not available in nature. They are also known as engineered materials [1].

## II. METAMATERIAL AND IT'S CLASSIFICATION

In recent years, many researchers are working on metamaterial in order to enrich the antenna parameters and compactness of antenna size. Metamaterials are being widely used to design antenna and microwave devices. The classification of metamaterial was first proposed by Russian physicist Victor Veselago in his paper called the substances with simultaneously negative permittivity and permeability. The word metamaterial is a Greek word which is a combination of two words 'meta' and 'material' which means beyond or advanced. The conventional natural materials have positive permittivity and permeability and Metamaterials may have either negative permittivity or permeability or simultaneously both may be negative.

Metamaterial properties are different from the naturally occurring materials. Electric permittivity (ε) and magnetic permeability (μ) they are the two basic parameters which describe the electromagnetic property of a material. They are also called as left-handed materials. The metamaterials are classified on the basis of permittivity and permeability as shown in Figure 1.

### A. Double Positive Material:

In Quadrant 1 it represents the materials with simultaneously positive value of permittivity and permeability both. It covers mostly dielectric materials which do occur in nature and the propagation of wave is in forward direction. It follows right hand thumb rule for direction of propagation. They are also called as Right handed materials or Double positive materials.

### B. Epsilon Negative (ENG) Material:

In Quadrant 2 it represents the materials with negative permittivity below plasma frequency and positive permeability. It covers metals, ferroelectric materials, and extrinsic semiconductors. They are also called as Epsilon negative media.

### C. Double Negative (DNG) Material:

In Quadrant 3 it represents the materials with negative value of permittivity and permeability both. In this media the propagation of wave takes place in backward direction. They are called as double negative material or left handed material and no such material is found in nature so they are also called as engineered materials.

### D. Mu Negative Material:

In Quadrant 4 as shown in figure it represents the materials with negative permeability below plasma frequency and positive permittivity. It includes ferrite materials. They are known as Mu-negative materials.

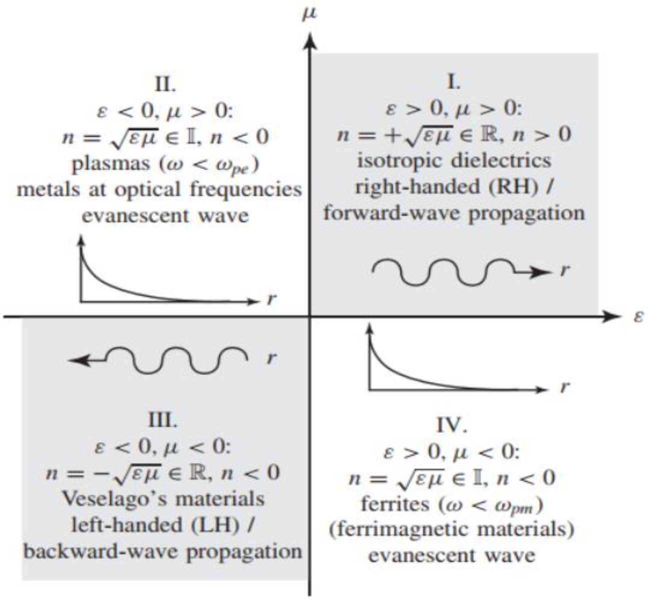


Fig. 1 Classification of Metamaterial [1]

## III. RING RESONATOR STRUCTURES:

### A. Split Ring Resonator Structure:

The split ring resonator structure consists of a pair of concentric metallic rings etched in a dielectric substrate having splits at opposite sides. The shapes of these rings can be circular, square or even U shaped. When the time changing magnetic field penetrates through the metallic rings, it induces an electromotive force which in turn produces a rotating current. Through the capacitive gaps, the induced current line passes from one ring to another in the form of displacement currents. The split ring behaves as an LC circuit. The split ring resonator (SRR) and its equivalent LC circuit is shown in the below figure:

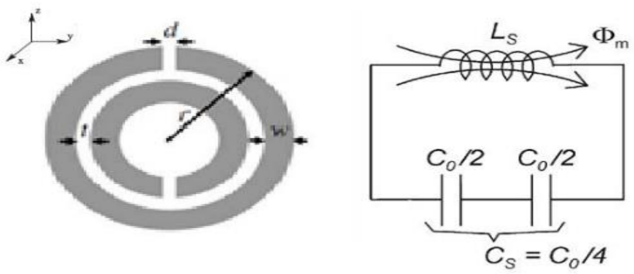


Figure 2 Split ring resonators with equivalent LC circuit [7]

### B. Complementary Split Ring Resonator Structure:

The Complementary split ring resonators (CSRR) are complementary of SRR by applying the Babinet's principle where the rings are etched on a metallic surface and its magnetic and electric properties are interchanged w.r.t SRR. The resonant frequency remains same for same physical dimensions for both SRR and CSRR. In the equivalent circuit model of CSRR in place of the inductance of SRR the capacitance is substituted [7]. The CSRR with its equivalent circuit model is shown:

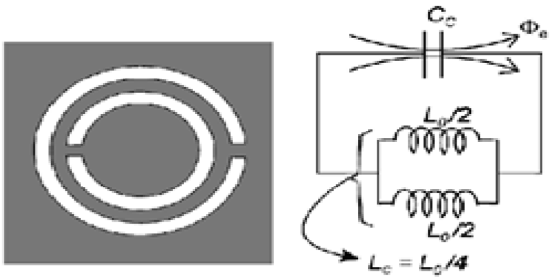


Figure 3 Complementary Split ring resonators with its equivalent circuit [7]

## IV. LITERATURE SURVEY

In this paper [2], a compact triband antenna with split ring resonator array using microstrip feedline and FR4 substrate is proposed. The bandwidth of antenna was optimized by introducing slots on the top of the patch. At the bottom face of the antenna the split ring resonators with partial ground plane strips are used to improve the antenna radiation characteristics. Here the antenna resonates at the frequencies of 2.45 GHz, 3.5 GHz and 5.5 GHz with the bandwidths of 12.5%, 7.42% and 6.36% and having gain of 2.25dBi, 3.72dBi and 2.71dBi. This antenna has an omnidirectional radiation pattern which is appropriate for WLAN and WiMAX applications.

In this paper [3], a triband patch antenna with Defected ground structures in the ground plane and the slots introduced in the patch with Rogers RO3003 substrate is presented. Multifrequency response was obtained by defected ground structures etched in the ground plane. To improve the antenna performance slots of different shapes were used. The complementary split ring resonator was modified with an open circuited stub joint to it and was etched in the ground plane to create additional resonant frequencies. L, E and U shape slots were introduced in the patch to increase the initial patch resonance. The proposed antenna resonates at the frequencies of 2.42 GHz, 5.22 GHz and 5.92 GHz which is compatible with Bluetooth, WLAN, Wi-Fi and Zigbee applications.

In this paper [4], a triangular complementary split ring resonator for multiband operation based compact metamaterial antenna is proposed. In a single device, metamaterial technique is used for achieving desired compactness and multiband antenna characteristics. The triangular complementary split ring resonator was loaded in the trapezoidal radiating patch with partial ground plane with a FR4 substrate. The proposed antenna resonates at the frequencies of 2.5 GHz, 5.25GHz, 7.35 GHz, and 8.2 GHz with the gain of 0.81dBi, 0.54dBi, 0.55dBi, 3.04dBi which is suitable for WLAN, WiMax, X-band downlink and ITU applications.

In this paper [5], a multiband antenna for GPS/WLAN/WIMAX applications loaded with metamaterial and slots are proposed. A dual band antenna is designed by etching the trapezoidal shaped slots in the patch and rectangular slots in the ground plane. Additional resonant frequencies are created by introducing metamaterial unit cells in the ground plane. An omnidirectional pattern is created in H-plane and a bi-directional pattern is created in E-plane. This antenna resonates at the frequencies of 1.5 GHz, 2.4 GHz, 3.5 GHz and 5.2 GHz with the gain of 2.4dBi, 2.1dBi, 2.7dBi and 1.8dBi which is suitable for GPS, WLAN and WiMax applications.

In this paper [6], a tripleband Microstrip antenna based with complementary split ring resonator with Rogers RT/duroid 5880 substrate with the thickness of 1.575mm is proposed. Two different shaped complementary split ring resonators are used, one is circular shaped and the other one is square shaped. The complementary split ring resonators are etched in the ground plane. The circular unit cell is designed to produce a resonance of 5.6 GHz and the rectangular cell resonating at 2.45 GHz. This antenna resonates at the frequencies of 2.45 GHz, 3.56 GHz and 5.62 GHz with the gain of 1.03dBi, 5.1dBi and 5.41dBi which is suitable for WLAN and WiMax applications.

TABLE 1 COMPARISON TABLE FOR LITERATURE SURVEY PAPERS

| Parameter | Paper-2 | Paper-3 | Paper-4 | Paper-5 | Paper-6 |
|---|---|---|---|---|---|
| **Resonant Frequency (GHz)** | 2.4, 3.5, 5.5 GHz | 2.42, 5.22, 5.92 GHz | 2.5, 5.25, 7.35, 8.2 GHz | 1.5, 2.4, 3.5, 5.2 GHz | 2.45, 3.56, 5.62 GHz |
| **Frequency Ban d** | S & C Band | S & C Band | S ,C & X Band | L, S & C Band | S & C Band |
| **Substrate material** | FR4 | Rogers RO3003 | FR4 | FR4 | Rogers RT/duroid 5880 |
| **Size Reduction, Gain & bandwidth enhancing techniques** | Differently shaped slots, SRR array | DGS, L, U & E shape slots, CSRR with stub | TCSRR | Trapezoidal & rectangular slots, metamaterial unit cell in ground plane | Double circular CSRR different shapes |
| **Applications** | WLAN, WiMax | WLAN, Wi-Fi, Zigbee | WLAN, WiMax, X-band downlink and ITU applications | GPS, WLAN WiMax | WLAN, WiMax |

## IV. CONCLUSION

In this review paper, the use of metamaterial in patch antenna has been studied for wireless applications. Microstrip patch antennas are one of the widely used antennas in the field of wireless communication systems. Metamaterial are either loaded on the substrate or etched on the patch. The antenna miniaturization also reduces the fabrication cost. The size reduction, gain, bandwidth enhancement techniques and improvement of various other antenna parameters for wireless applications have been studied.

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