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Microstrip Patch Antennas using Metamaterials: A Review

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Abstract: Microstrip patch antenna is the low volume, low weight means low profile antenna. Metamaterial is an unreal or synthetic material which does not exist in nature. Its properties are not defined by its material composition but by the structure which can be elliptical, rectangular, triangular, and circular or any perpetual shape. Engineers can cull the congruous category of materials for the categorical applications. Metamaterials (MTMs) presence has exhorted the enhancement in the engineering and also in electromagnetic theory. Metamaterials are becoming utilizable for low profile antennas and RF & Microwave bands. The structures used can be of any type of conductor i.e. Artificial Magnetic conductor, electromagnetic band gap, frequency selective surface. In this research paper importance of Metamaterials (MTMs) in Microstrip patch antennas (MPAs) has been discussed. MTM antennas possess sundry applications and have wide scope in the communication engineering and other fields.

Keywords- Metamaterials, Electromagnetic Band Gap, Artificial Magnetic Conductor, Microstrip Patch Antennas.

I. INTRODUCTION

The curious nature of humans has shown the way to research and innovation of the materials with novel properties, even the properties "not engendered by God". With all this research the metamaterials come into existence.

Over the year's lot of techniques have been advised in order to enrich the properties such as gain and return loss of patch antennas. According to the conventional approach, the radiator can be set on high dielectric substance and the antenna size can be miniaturized. But these conventional approaches results into the drawbacks [1]. First problem is that in high permittivity medium, characteristic impedance is quite low which engenders difficulties in the impedance matching and another is the high permittivity region due to which the e.m.f. remains highly concentrated. So, the MTMs is an exhilarating research area and it magnetized the interest of the electronics engineer.The meta materials result into the ameliorations in electromagnetic replication functions like high gain profile, efficiency, low loss and gratified bandwidth requisite that offer exhilarating possibilities of future design of contrivances, component.

A. *Microstrip patch antenna*

In today's world of the wireless communication, low profile, light weight and low cost antennas are required. The MPA is used recurrently because of its simple design, ease in installation, variety of shapes and its compatibility with microwave and Millimeter Wave Integrated Circuit (MIMC) [2]. MPA comprises of a dielectric substrate whose one side has radiating patch and other side has a ground plane. The patch is made of the matter like gold or copper and it reform into any shape, it can be rectangular, circular triangular, elliptical etc.

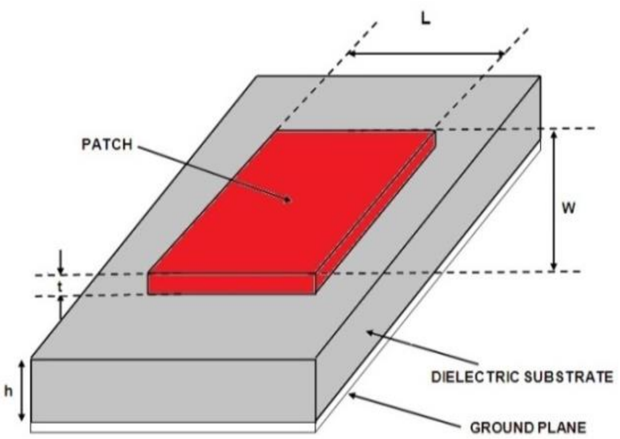

Figure 1: Microstrip Patch Antenna

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The first work done on MPA was by Deschamps, Engleman and Greig in 1960. The layout of rectangular MPA is as shown in Fig.1.

The microstrip patch antennas also have some limitations like narrow bandwidth, low gain and less power handling capability. There is the direct connection between all the parameters of antennas as if we try to advance the one parameter it affects the other one. There are the vast applications for MPA such as: mobile systems, Global Positioning System (GPS), satellite communication, Wi-Fi, Wi-Max, radar systems, biological imaging, and radio frequency identification.

B. Metamaterials

The word Meta Material is an amalgamation of “meta” and “material”, Meta is a Greek word which betokens something beyond, altered, transmuted or something advance [3]. Metamaterials are incipient unreal matters with the eccentric EM properties that are not found in natural occurring materials. Betokens metamaterials are the artificial structures designed to have properties not obtainable in nature [4].The natural materials have positive electrical permittivity, magnetic permeability and index of refraction whereas the metamaterials have been termed as negative index materials (NIM) or double negative (DNG) media or left handed materials (LHM) or backward wave (BW) media- having all these parameters negative. With these metamaterials new kind of the microwave component/devices and miniaturized antennas can be created for wireless communication and defense industries. The metamaterials is first theoretically proposed by the Russian physicist Victor Veselago in 1968.

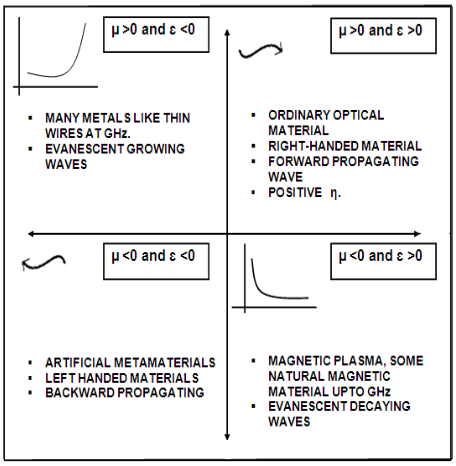

Fig.2. Classification of the Materials.

The emergence of MTMs in antenna designing: In conventional materials, the properties are derived from the constitute atoms and are characterized by the chemical and Atomic structures of the matter whereas in metamaterials the properties are derived from the constitute unit cell. Materials are relegated on the sub- structure of the permittivity & permeability. Depending on the values μ and ε, quadrant belongs to which material is decided. The metamaterials belongs to third quadrant having Re(μ) <0 and Re(?) <0 as shown in Fig.2 [5] as both are negative it satisfies dispersion condition [6]. The field vectors viz. Magnetic vector(H), Electric vector(E) and Wave vector(k) form a left handed triad, hence it is also called Left-Handed Materials(LHM).

II. ROLE OF METAMATERIALS IN PATCH ANTENNA

Many exotic applications of the metamaterials exist. Many researchers are endeavoring to amend the accomplishment of microwave, wireless communications, microelectronics and optical contrivances utilizing these incipient metamaterials. By utilizing metamaterials, the radiated power of the antenna could be enhanced. The main features of metamaterial like negative permittivity and permeability can be exploited for making electrically small, highly directive and reconfigurable antennas. These antennas also demonstrate the improved efficiency, bandwidth performance and ameliorate the beam scanning range of antenna arrays. These antennas also support navigation systems, communication links, surveillance sensors and command & control systems [7]. Light emanating is rejected and controlled by wide angles, for aerospace applications using nano-composites utilizing metamaterial technology [8]. Thin film technology advanced with metamaterial nano-composites is utilized to amplify the solar cell efficiency by amassing light from wide angles and by absorbing it over the spectrum of interest. The Extraordinary properties of MTMs and their latent applications in cloaking expeditiously drew attention from agencies like DARPA & NATO. Immensely colossal scale metamaterials with customized electromagnetic properties have been utilized for shipboard applications as well.

The efficiency, bandwidth and the gain of the MPA has been embellished by using the metamaterial lens [9]. The MPA have been of any type i.e. conformal patch antenna, array of antennas. The Artificial Magnetic Conductors (AMC) surfaces, Electromagnetic Band Gap (EBG) surfaces also help in improving the gain, efficiency and reduction of return loss [10] [11].

As MPA has many properties and has been used from past years. So, here the patch antenna along with the metamaterials will be used to achieve the best results using the properties of the both. Patch antennas can be functioned at various frequencies for wireless communication. The MTM lens designed using Split Ring Resonator (SRR) and wire, combined as a unit cell. MTM lens ameliorate the gain and efficiency, directivity &main lobe level is strengthened. The MTM lens improves the performance at lower resonant frequencies. The MTM lens can also be helpful in enhancing the performance of conformal patch antenna (CPA). The CPA is better than that of the planar patch antenna. MTM lens along with the CPA improves the gain, bandwidth and efficiency [12].

For the reduction of the dimensions of MPA the SRR along with the MTM is very helpful. By using this technique [13] 6dB gain over an impedance band over 600 MHz at 1.8GHz is obtained, and the radiation pattern remains unchanged irrelevant of the changes in the dimensions of antenna. The high impedance EBG Patterns are also useful in the performance enhancement of MPA [14]. The numerous EBG Structures either circular or rectangular can be used.The analysis done on horn antenna in [15] results into the side lobe reduction.

The use of Artificial Magnetic Conductor (AMC) ground plane results into the amelioration of the input impedance bandwidth and gain [16]. MTM based AMC surface plane gives better results [17].The other structures which help in improving the performance of MPA is EBG structure and the reduction in side and back lobe helps in improving the efficiency of antenna [18]. Along with these structures, the patch antenna can also be designed backed by the Frequency Selective Surface (FSS) structures. The results of all these structures compared on the basis of return loss and gain with that of the conventional antenna. The simulation in proves that the AMC ground plane gives the highest efficiency as compared to other structures.

III. CONCLUSION

MPA have been one of the most pioneering topics in antenna theory and design. Existing solutions escort to the tribulations of spurious radiation and high complexity. Out of the numerous structures used the AMC gives better performance and MTM lenses are also valuable for patch antennas. Metamaterials offer impending for electrifying new technologies, faster as well as for existing devices to be made smaller and more effectual. MTMs properties and its emergence in patch antenna are delineated with varied applications. It shows very captivating feasibility in radiation characteristics of an antenna. Communication Engineering is at new level to create life additional luxuries and cozy with the encouragement of analysis within the field of metamaterials.

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