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Review Paper on Metamaterial based Superstrate Antenna

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Abstract

The aim in this paper is to review a new form of micro strip Patch antenna with metamaterial based superstrate inspired by an ordinary patch antenna resonating for various applications. It is shown that by implementing innovative resonators structure into the design, there is simultaneous gain and bandwidth improvement. The results in terms of gain, bandwidth, radiation pattern and return loss are analyzed in detail, which allows us to develop a comparative study according to the distance separating the superstrate placed in the antenna. In recent decade with the use of metamaterial based superstrate the size of antenna have been drastically reduce to very small sizes and light weight for actual practical application.

Keywords: Microstrip Patch, Metamaterial, SRR, CSRR, Superstrate.

I. INTRODUCTION

In recent decades, scientists have spent a lot of time and effort researching new materials and physical phenomena to fulfill modern life. Modern communication requires a compact antenna designs as well as multiple applications in a single device. Recent years, metamaterials have attracted extensive research interests in the field of electromagnetics systems due to their unusual material properties. Microstrip patch antennas found great applications in modern wireless communication systems since they account for large number of advantages like they are low in cost, small in size, light in weight, ease of fabrication, feed line flexibility, beam scanning omnidirectional patterning, but they also suffer from problems of narrow bandwidth and low gain.

Several techniques by researchers and scientists have been employed to overcome this problem such as using dual feed network based structures, stacked patches, antennas with sequential feeding structure and multi-layered structures. Lately, researchers are also investigating the use of metamaterial to enhance The bandwidth and gain within the desired operating frequency range. It is very important to reduce the size of antenna as it limits the overall size and cost of the devices. Various techniques have been given for the size reduction, high gain and high directivity of patch such as slots, DGS (Defected Ground Structure), using fractals and electromagnetic band gap (EBG) structures but in proposed antenna the metamaterial technique has been implemented.

II. METAMATERIAL

Metamaterials are incorporated into new materials that are formed by the arrangement of metal structures on the surface of dielectric substrate. Therefore, the physical properties of the metamaterials depend on their compositions more that what they are made up.

Materials with negative permittivity and permeability were first studied in 1968 by Vaselago. It perform many functions, by implimeting metamaterial structure with patch antenna can reduce return loss, miniaturize the size of an antenna, increase bandwidth, efficiency, gain, directivity and all other parameters such as radiation pattern and VSWR. Electromagnetic metamaterials (MTMs) are artificial material that is created by arranging homogeneous metal structures and having unusual properties those natural materials are not available. On the other hand, different structures give different types of

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metamaterials and applications, which are classified based on the material permittivity and permeability values created by various structures.

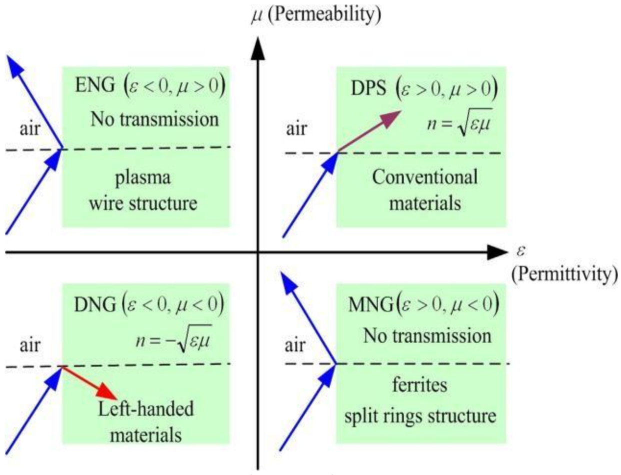

Figure:1-Classification of the materials [7].

III. SUPERSTRATE

characteristics of the superstrate layer were first studied by David. R. Jackson in 1985[9]. It was later found that if the proper parameters were taken with the superstrate, the benefit increased greatly. This method was known as the resonance gain method, and it utilized a superstratewith either relative permeability **μ>>1** or relative permittivity **e>>1**. According to this research by choosing the layer thicknesses and dipole position properly, a very large gain may be realized at any desired angle
0. This gain varies proportionally to either s or μ, depending on the configuration. However, it was found that the bandwidth was inversely proportionate to gain.

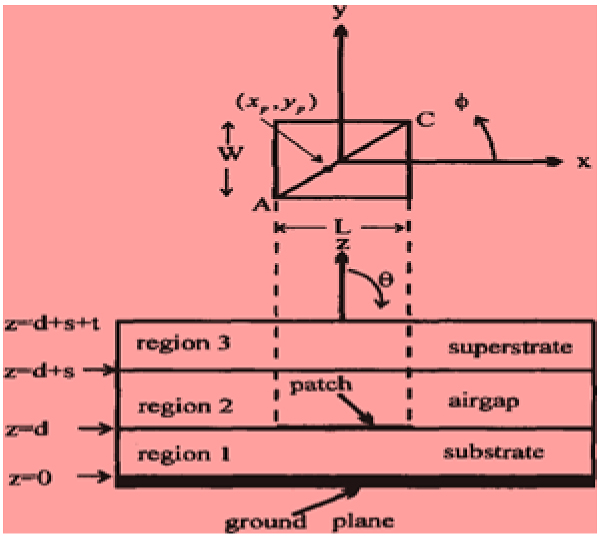

Figure:2- Geometry of the rectangular shape antenna used by the researchers [8].

Figure 2 shows The geometry of a superstrate-loaded patch antenna. Two cases of superstrate loading were discussed in this study, in the first case the superstrate layer is directly loaded on the patch and in the other case the superstrate spaced away from the patch with a distance of a half wavelength or its multiples. In the latter configuration, the superstrate acts not only to protect the layer, but also acts as a directive parasitic antenna, significantly increasing the gain of the antenna.

The patch is with a dimension of L x W. It is located on a grounded substrate at z = d. The substrate (region1) is of thickness d and the relative permittivity $\varepsilon 1$. The superstrate (region 3) is of thickness t and relative permittivity $\varepsilon 3$. The air is in region 2 and 4 with permittivity $\varepsilon 0$ and permeability μ0. The patch is also assumed to be probe-fed at the position xp, yp which corresponds to at the position AC on the diagonal line.

It was found that when the superstrate layer was spaced away from the patch, the loading effects on the antenna were considerably reduced. In this case the centre frequency for the CP radiation was slightly varied, and the 3 dB bandwidth and optimal feed position were almost not affected. For higher air gap thicknesses, the main-beam polarization property was also better [8].

Metamaterial surface inspired superstrate are periodic structures where resonating metamaterial unit cells are arranged in a systematic geometrical order. a periodic Square Closed Ring (SCR) structure is used to convert a single band microstrip antenna operating at 3.6 GHz to a dual band antenna system at 3.4 GHz and 5.5 GHz. SCR is behaving as a periodic superstrate to enhance the radiation performance of the antenna. Significant improvement in the gain performance of the overall antenna system with a pick gain of 5.8dBi and 6.4dBi at 3.4 GHz and 5.5 GHz respectively. Observed that the gain of antenna can be significantly improved when the superstrate is oriented at a distance d=0.5 mm above the microstrip antenna[1].

The gain improvement is achieved based on metamaterial-based superstrate layers which have 4×4 metamaterial unit cells and multiband antenna. Superstrate antenna are used to achieve the gain enhancement in the lower frequency bands. The air gap distance for both superstrate layers are fixed based on parametric study and placed over the multiband antenna. The antenna has positive gain in all the desired frequencies. Superstrate based metamaterials can be used for WLAN/WMAX/ITU applications, and it has gain of 0.40, 0.70, 2.64 and 1.7 dB at 2.4, 3.5, 5.5 and 8.3 GHzrespectively in the lower frequency region[2].

Zero-index metamaterial (ZIM) superstrates have been comprehensive employed for gain enhancement of various antennas. A printed metallic wire array ZIM superstrate was used to enhance the directivity of a patch antenna. Two nested CLLs (capacitively loaded loops) are used to achieve dualband operation without increasing the electrical size of the unit cell. From the measurements ZIM enhances its gain by2.8 dB and 3.8 dB at 2.4 GHz and 3.5 GHz[3].
A superstrate consisting of capacitive, inductive and capacitive layers is introduced to enhance the gain of circularly polarized antenna and Reactive Impedance Surface (RIS) is inserted below the patch antenna to improve the bandwidth of circularly polarized antenna[4].

Gain improvement is obtained by using superstrate of three metallic layers and two dielectric sheets. Impedance bandwidth is enhanced by reactive impedance surface (RIS) having an array of square patches sandwiched between two FR4 dielectric sheets. This reactive impedance surface (RIS) will add extra inductive and capacitive effect to improve the impedance bandwidth of antenna to 12% (4.90GHz - 5.53GHz). Circular polarization is obtained by pentagonal microstrip patch antenna[4].

To overcome power loss due to misalignment between transmitting and receiving antennas, now days the designers are preferring antennas with circular polarization (CP)[4].

The metasurface consists of an array 8x8 of corner truncated square patches which is placed as superstrate at an optimized distance over the antenna. The truncated corner of driving patch helps to get resonance frequency along the diagonal to be higher as compared to that ofunchopped diagonal and helps to achieve circular polarization. It is clear that metasurface can be used to improve the overall radiation characteristics of the antenna. A maximum gain of 6.08dB is achieved at 7.24GHz for proposed antenna with superstrate. The overall radiation performance of the proposed antenna is improved by the employment of metasurface. With the advantages of low profile, and circular polarization[5].
maximize the gain along with maximum amount of side lobe suppression. Optimization technique is incorporated in the antenna for further enhancement in the antenna performance. In order to obtain the higher gain and directivity with the same proposed antenna, Genetic Algorithm and Pattern Search optimization techniques is incorporated. The Genetic Algorithm is considered as one of the most commonly used algorithm for optimization process. In order to reduce the run time, Pattern Search optimization technique is used. The Pattern Search algorithm is a non-random method. It is a direct, efficient and derivative free optimization method for searching the optimal value. the pattern search algorithm provides better result with less time compared to Genetic Algorithm[6].

The antenna is designed with the normal array of microstrip patch antenna and fed up by a microstrip line. After that metamaterial is placed as a superstrate and slots are made on both the layers with different sizes in the uniform structure. In this arrangement, the return loss improvement of about - 21.5133 dB and gain of about 9.9386 dB. it can be observed that the metamaterial superstrate antenna along with optimization technique provides enhanced gain as compared to the conventional method[6].

IV. RESULTS AND DISCUSSION

The antenna is designed with the various technique of microstrip patch antenna and fed up by a microstrip line. After that metamaterial is placed as a superstrate and slots and unit cell are made on number of the layers with different sizes in the uniform structure. it can be observed that the metamaterial superstrate antenna along with diverse technique provides enhanced gain, bandwidth, etc and compact size as compared to the conventional method.

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V. CONCLUSION

The different method of superstrate base metamaterials play important role in the antenna design due to its interesting and unusual properties is reviewed[10]. A metamaterial antenna is created by loading the metamaterial structure over the substrate. The analysis of antenna models with various superstrate positions and technique study for improving various parameters for a superstrate antenna. Different techniques such as different thickness, height between two substrates and dielectric constant of materials. The advantages of superstrate antenna are low profile, light weight and low power handling capacity. Furthermore, the artificial superstrate helps in tilting the main beam towards boresight [11].

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