IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p-ISSN: 2278-8735
PP 68-71
www.iosrjournals.org

Gain Enhancement of Rectangular Slot Microstrip Patch Antenna Using Zero Index Metamaterial

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Abstract:- *The advancement of wireless communication necessitates the design of high gain antennas with maximum possible miniaturization for developing compact systems. However, miniaturization leads to poor gain of the antenna. Thus, for effective communication it is important to enhance the gain of the antenna. In this paper the gain enhancement of a rectangular slot microstrip patch antenna with a metamaterial superstrate structure is proposed. High-gain planar antennas are drawing more and more attention because they have a low profile and can be easily fabricated by printed circuit board (PCB) technology. In addition, they are lighter than reflector antennas and are thus much easier to be installed. They have found applications in various domains such as satellite communications and wireless broadcasting. Electromagnetic metamaterials, possessing unusual properties, can be used to improve antennas performance. Among different kinds of metamaterials, the zero index metamaterials (ZIM) have been developed. These metamaterials have either the effective permittivity or the effective permeability very near to zero in a certain frequency range, which results in the refractive index being near to zero. The gain of a slot antenna can be increased with the help of a single layer metamaterial superstrate. Metamaterial is used because they have negative index of refraction and it has the ability to bend light back towards the source.*

Keywords: *zero refractive index, metamaterials, gain enhancement, patch antenna .*

I. Lntroduction

Metamaterials are artificial structures having unique electromagnetic properties which are not found in natural materials [1]. Since the first experimental realization of metamaterials [2], they have been used to improve the performance of various microwave devices, especially antennas [3].Metamaterials are artificial structures having unique electromagnetic properties which are not found in natural materials. Among the different kinds of metamaterials, near-zero index metamaterials (NZIM) have the ability to control the direction of radiation. To achieve high gain antenna array configuration is employed. Furthermore, the zero-index metamaterial (ZIM) structures can be embedded into antenna smoothly and easily for gain enhancement without any burden to the antenna .

Microstrip antennas, often called patch antennas, are widely used in the microwave frequency region because of their simplicity and compatibility with printed-circuit technology, making them easy to manufacture at low cost . Microstrip antenna typically exhibits narrow bandwidth and low gain that limits its application in practice Several approaches have been made to improve the bandwidth of the slot antenna. Metamaterials offer unprecedented flexibility for manipulating the optical properties of matter. In the case of materials possessing an effective index of zero, most work has focused on epsilon-near-zero metamaterials (ENZs) which can be realized using diluted metals or metal waveguides operating below cut-off . These materials, however, suffer from optical impedance mismatched to free-space and large reflections from the interface. Impedance-matched metamaterials have recently been demonstrated using metal based fishnet structures. However, at optical frequencies previously demonstrated zero-index metamaterials require the use of metallic inclusions, leading to large ohmic loss and an anisotropic optical response, which are impediments for numerous device applications associated with a zero-index, such as tailoring spontaneous emission and cloaking.

In this paper, a periodic structure of fish net unit cell, as superstrate, has been used for broadside gain enhancement of a slot antenna. A 3x3 periodic structure of the fish net unit cell has been placed as superstrate on top of the slot antenna. This superstrate structure results in enhancement of the gain of the slot antenna in the broadside direction without affecting the antenna radiation patterns. The Substrate Integrated Waveguide (SIW) is a subversion of a low profile planar transmission line which can be designed easily [4]. Waveguides are the best transmission line for high power and high frequency applications but it is bulky making it unsuitable for high density-integration. SIW is basically a combination of waveguide and planar transmission lines and it is also referred as the "Laminated Waveguide". In laminated waveguide the electromagnetic wave leakage can be controlled by using through hole pitch smaller than a quarter wavelength .The metamaterial can be c1assified on the basis of permittivity (ε) and permeability (μ) as shown in Fig.1.

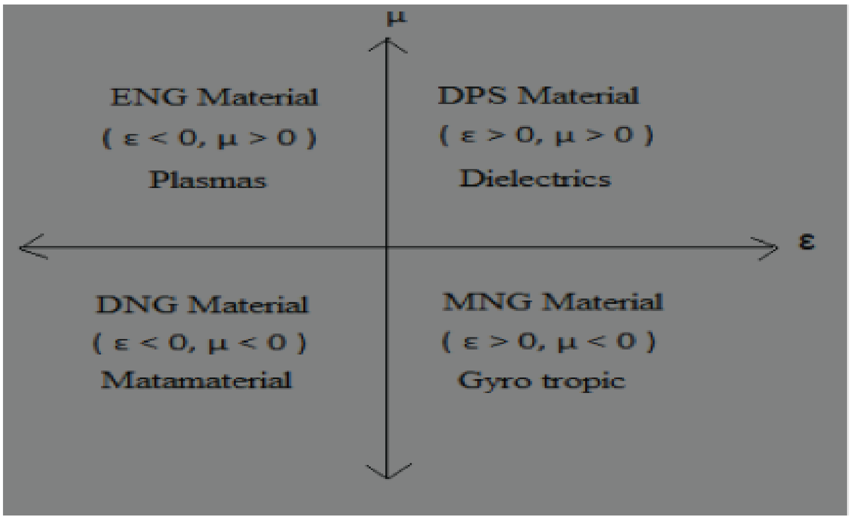

Fig. l . classification of metamaterials

(i) Double positive material for double positive (DPS) material both the permittivity and permeability are greater than zero ($\varepsilon > 0$, $\mu > 0$).The dielectric comes under this designation.
(ii) Negative permittivity material- The material which has permittivity less than zero and permeability greater than zero ($\varepsilon < 0$, $\mu > 0$). Plasma exhibits these characteristics.
(iii) Negative permeability material -The material which has permittivity greater than zero and permeability less than zero ($\varepsilon > 0$, $\mu < 0$).The gyro tropic material exhibit these characteristics.
(iv) Double Negative Material -The metamaterial which have both permittivity and permeability less than zero ($\varepsilon < 0$, $\mu < 0$).These material are not found in nature. It is artificial material.

II. Zero Index Metamaterial

An integrated metamaterial with an index of refraction approaching zero. Most natural materials have an index greater than one, meaning that the wavelength shrinks when light enters from the outside. By contrast, the wavelength is larger inside a material with index less than one, ultimately growing to infinity as the index approaches zero. The result is uniform phase throughout the material. The fields inside oscillate synchronously in time, and any wave fronts incident on the crystal are immediately communicated to the far side with infinite phase velocity. Recently demonstrated such a material using a silicon photonic crystal, surrounded by polymer, and sandwiched between two layers of gold. Here, silicon pillars are arranged in a square lattice, and the radius and pitch is carefully tuned to drive the index to zero. The physics behind the zero index requires infinitely tall silicon pillars. By placing the structure between conductive plates, the fields approximate the infinite case even when the structure is finite. This allows us to fabricate 2D metamaterials on a chip, and feed them from the side with integrated silicon waveguides. In negative-index metamaterials (NIM), both permittivity and permeability are negative, resulting in a negative index of refraction. These are also known as double negative metamaterials or double negative materials (DNG).

In optical materials, if both permittivity and permeability **μ** are positive, wave propagates in the forward direction. If both ε and μ are negative, a backward wave is produced. If ε and μ have different polarities, waves do not propagate. Mathematically, quadrant II and quadrant IV have coordinates (0,0) in a coordinate plane where ε is the horizontal axis, and μ is the vertical axis. In negative-index metamaterials (NIM), both permittivity and permeability are negative, resulting in a negative index of refraction. These are also known as double negative metamaterials or double negative materials (DNG). Other terms for NIMs include "left-handed media", "media with a negative refractive index", and "backward-wave media".

III. Antenna Design

Parameters Of Rectangular Slot Antenna

In this section parameters of a rectangular slot antenna has been designed which is printed on a dielectric substrate of FR4 with relative permittivity (ε r) of 4.4.

The three essential parameters for the design of a rectangular microstrip patch antenna are:

- Frequency of operation (0 *f*): The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for design is 4.2 GHz.

- Dielectric constant of the substrate (*r* □ □): The dielectricmaterial selected for the design is FR4-epoxy which has a dielectric constant of 4.4. A substrate with a high dielectric constant reduces the dimensions of the antenna.
- Height of dielectric substrate (h): For the microstrip patch antenna it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6mm.

Table 1 Parameters of Rectangular Slot Patch Antenna

Parameters	Substrate Dimensions	Superstrate Dimensions
Length	-26.8mm	-26.8mm
Breadth	-23.6mm	-23.6mm
Thickness	1.6mm	1.6mm
Dielectric Constant Of Substrate	4.4	4.4
Tangent Loss	.02	.02

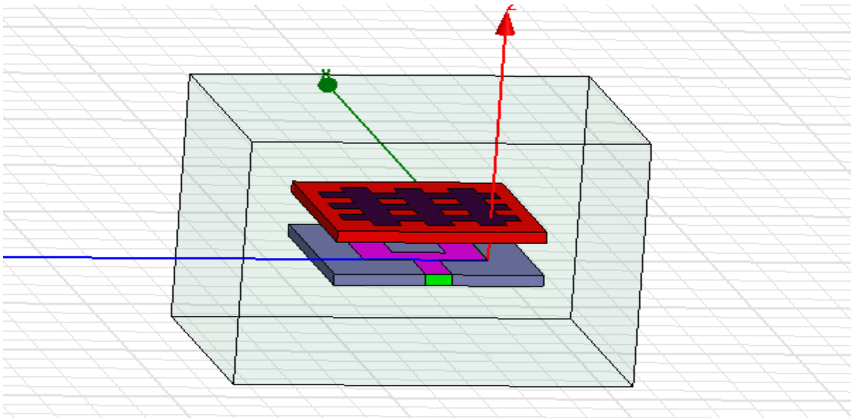

Fig.2. Structure of metamaterial superstrate loaded rectangular slot microstrip patch antenna.

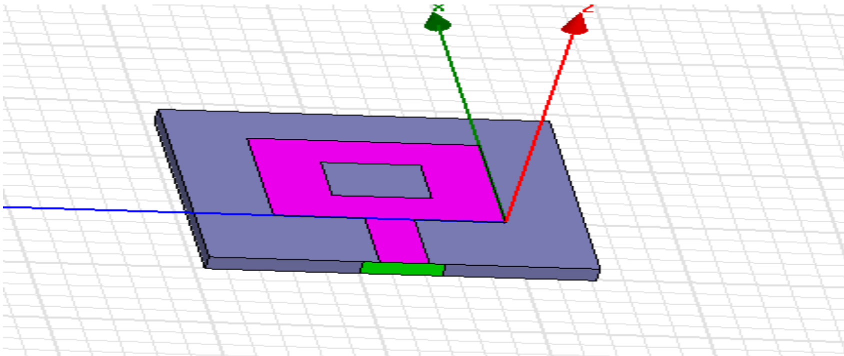

Fig.3. Structure of rectangular slot microstrip patch antenna

IV . Simulated results

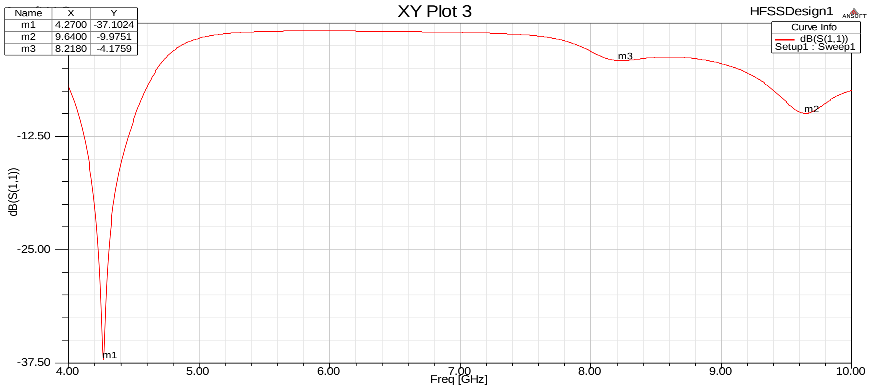

Fig.4. Simulated return loss characteristics of the rectangular slot antenna

This figure shows the Simulated return loss characteristics of the rectangular slot antenna. In this graph three dips are formed. The first dip is formed at the frequency of 4.2GHz. The second dip is formed at the frequency of 8.2GHz. The third dip is formed at the frequency of 9.2GHz. In the first frequency the return loss is -37.10dB. So 4.2GHz is selected as the best resonant frequency.

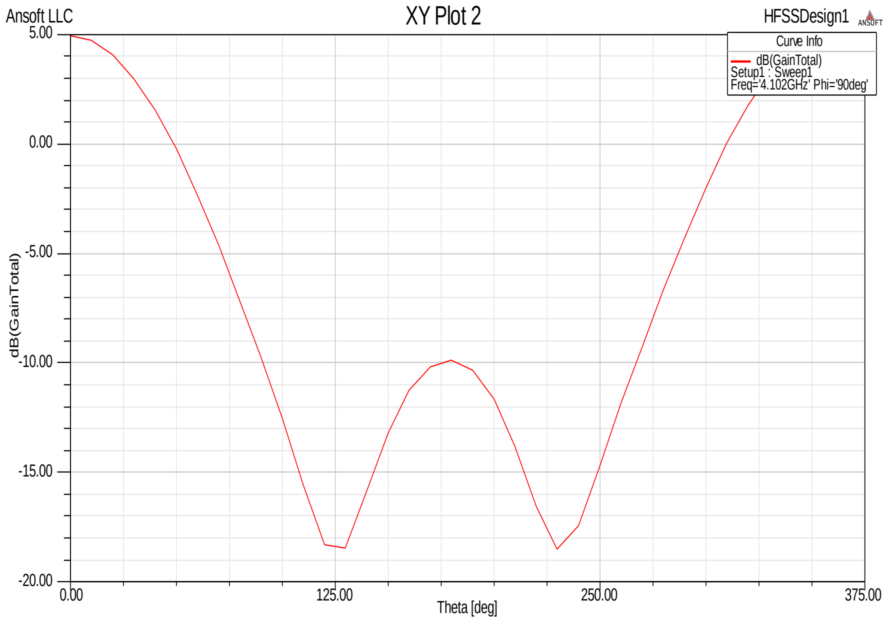

Fig.5. Gain plot of rectangular slot antenna

Figure shows the gain plot of rectangular slot antenna. The gain can be enhanced up to 2.7dB by using zero index metamaterial. The theta value ranges from 0 to 360 and resonant frequency is 4.2GHz. The phi value is 90 degree.

V. Conclusion

slot technique and near zero index metamaterial have been discussed and analyzed. Metamaterial structures have been designed and simulated. In all relevant parameters the measured values are in very good agreement with the simulated ones. Zero index metamaterial can enhance the gain of rectangular slot microstrip patch antenna over a frequency range. A periodic structure of fishnet unit cell, as zero index metamaterial superstrate has been used for broadside gain enhancement of a slot antenna. The gain can be enhanced up to 2.7dB.

References

[1]. C. Caloz and T. Itoh, “Electromagnetic metamaterials: transmission line theory and microwave applications,” John Wiley & Sons, 2005.

[2]. D. R. Smith, W. J. Padilla, D. C. Vier, S. C. Nemat-Nasser, and S.Schultz, “Composite medium sith simultaneously negative permeability and permittivity,” Physical Review Letters, Vol. 84, No. 18, pp. 4184- 4187, 2000.

[3]. Y. Dong and T. Itoh, “Metamaterial-based antennas,” Proceedings of the IEEE, Vol. 100, No. 7, pp. 2271-2285, 2012.

[4]. D.Deslendes and K.Wu, " Single-Substrate integrated Technique of planar circuits and waveguide filters," IEEE Trans.on Microwave Theory and Tech. , vo1.51, no.2, pp. 593-596, Feb 2003.

[5]. Deepanjan Bhattacharjee, Tarakeswar Shaw, Tarakeswar Shaw, DebasisMitra "Gain enhancement of a slot antenna with a metamaterial superstrate structure"2015 IEEE.

[6]. Tianmin Zeng, Dongying Li, Wenxian Yu School of Electronic Information and Electrical Engineering, Shanghai Jiao Tong University, Shanghai, China" Using Zero-Index Metamaterial to Enhance the Gain of an Broadband Microstrip Patch Antenna" 2016 IEEE