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A Novel Wideband Near Zero Index Fractal Metamaterial (NZIFM) Unit Cell

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***Abstract*— In this paper, a novel wideband Fractal Metamaterial Unit Cell possessing near zero refractive index is presented. The proposed unit cell is constructed with square shaped fractal loop having compact dimension of 18.34 x 18.32 mm^2 on an FR4 dielectric substrate of thickness 0.4 mm. The resulting structure is designed and simulated using High Frequency Structure Simulator (HFSS).The parameters such as relative permittivity, permeability, refractive index, relative impedance and return loss characteristics are analyzed in the wideband region.**

***Index Terms* –Unit Cell, Wideband, NZIFM, Metamaterial, HFSS.**

I. INTRODUCTION

A kind of artificial synthetic composite material with specific structure, which reveals properties not found in natural materials are usually termed as metamaterial [1]. Basically these types of materials are developed with the aim of novel electromagnetic properties such as negative permittivity or permeability, zero refractive index and chirality with some periodicity structure in one, two or three dimensions which modifies the properties of the material [2, 3].Mandelstam [4] and veslage [5] proposed the concepts of negative refraction and double negative materials in 1945and 1967 respectively. In 2000, Smith and pendry done the experimental verification of feasibility of negative refraction was realized by [6, 7].Although there is significant progress in this era, the accurate definition of metamaterial is still a matter of debate. But there are several generally accepted features for a metamaterial. Dimensions of the unit cell and periodicity of the metamaterial plays a vital role in view of utilization of these materials in design of microwave device and antennas.Fig.1 shows the nomenclature of the metamaterial based on their real parts of permittivity and permeability. Several other types of metamaterial have also been studied [8-13].

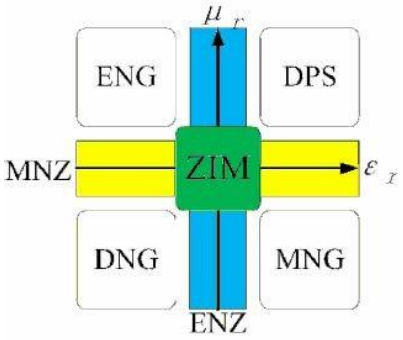

Fig.1.Metamaterial Nomenclature

The different nomenclature of metamaterial shown in the Fig.1 are abbreviated below.

DPS – Double Positive Media, ENG - ε Negative Media
MNG - μ Negative Media, DNG - Double Negative Media
ZIM –Zero Index Media, ENZ - ε Zero Media
MNZ - μ Zero Media

In this paper a wideband Near Zero Refractive Index (NZRI) Fractal Metamaterial Unit Cell is designed using HFSS. This paper is organized as follows: Section II describes the design of metamaterial Unit cell. The simulations results of the various properties of the unit cell are discussed in section III. Conclusion of the paper is convened in Section IV.

II. DESIGN OF FRACTAL METAMATERIAL UNIT CELL

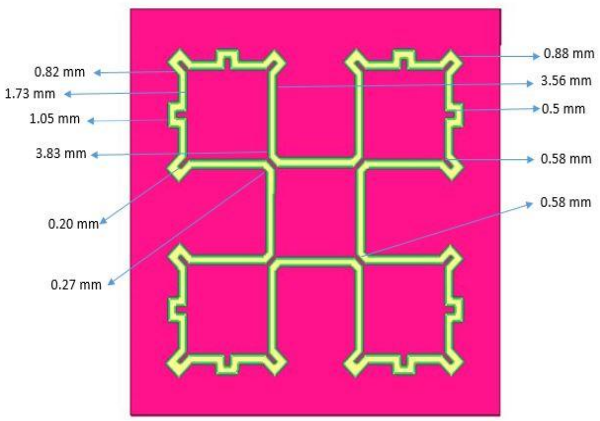

Fig.2. Structure of Proposed Novel Metamaterial Unit

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A novel metamaterial Unit cell is designed using fractal loop concept on an FR4 dielectric substrate of thickness 0.4 with dimensions of 18.34 x 18.32 mm^2 is depicted in the Fig.2.The unit cell is designed with square shaped fractal loop with minkowski like fractal structures embedded in it.

III. SIMULATION RESULTS

The proposed structure is simulated using HFSS in the frequency range of 1-15 GHz. The simulated relative permittivity and permeability of the NZIFM are shown in the Fig.3 and Fig.4 respectively.

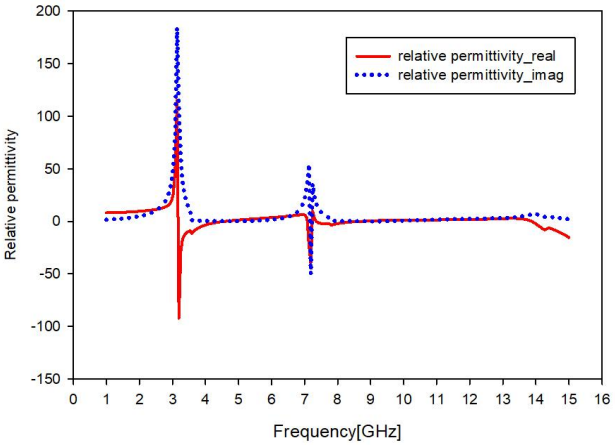

Fig.3. Real and Imaginary part of Relative Permittivity of proposed Unit Cell

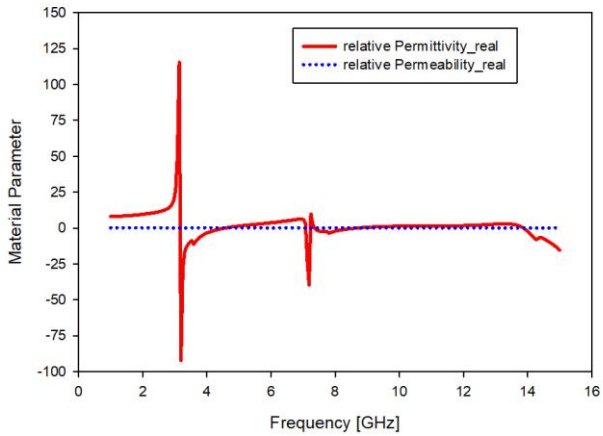

Fig.4. Real and Imaginary part of Relative Permeability of proposed Unit Cell

It is observed that the unit cell possess negative relative permittivity in the frequency range of 3.19-4.54 GHz, 7.4-8.4GHz and 13-15 GHz and almost near to zero in the other frequencies the bandwidth of 3-15 GHz.Similar to that the values of relative permeability varies from 0.05- 0.15 in the entire bandwidth of 1-15 GHz.Fig.5 shows the real and imaginary part of the refractive index of the proposed structure.

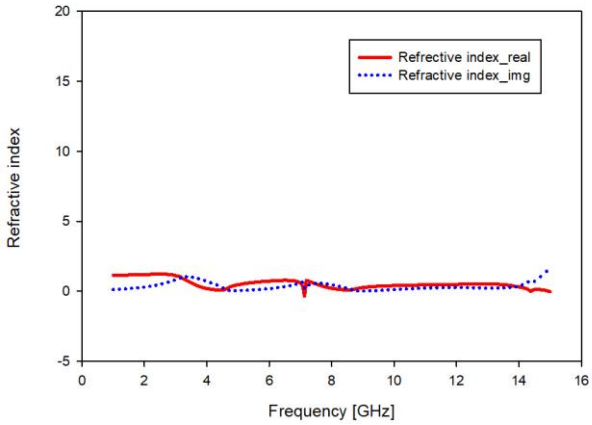

Fig.5. Real and Imaginary part of Refractive Index of proposed Unit Cell

It should be noted that the refractive index of the proposed unit cell is almost less than 0.56 in the band of 3-5.26 GHz and 7.44-14.92 GHz, varies between 0.56 – 0.75 in the band of 5.26-7.10 GHz and -0.35 in the band of 7.15-7.77 GHz. Hence it is witnessed that the proposed unit cell possesses near zero refractive index in the entire bandwidth of 3-15 GHz except at 7.1-7.7 GHz.

The reflection and transmission characteristics resulting from the simulation of the metamaterial unit cell are shown in the Fig.6.

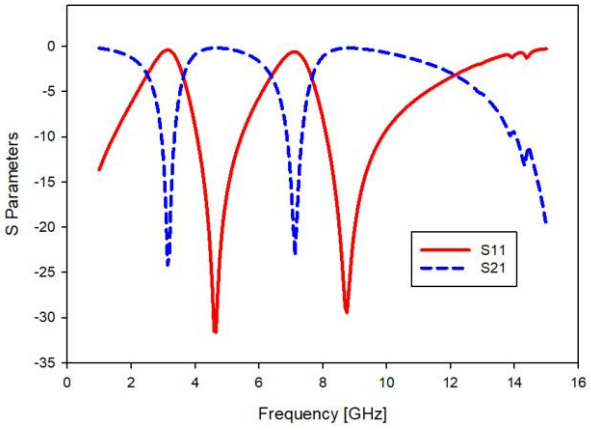

Fig.6.S – Parameters of Proposed Unit cell

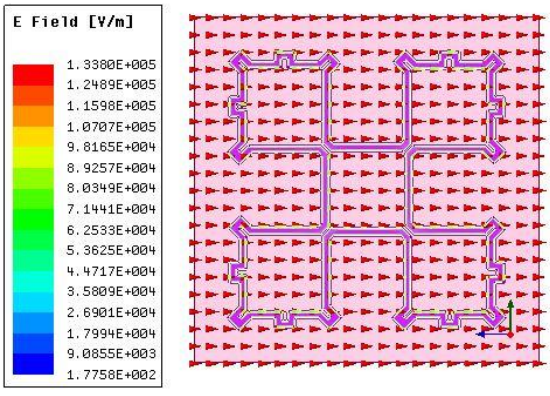

Fig.7.Fied distributions of Proposed Unit cell

The field distributions of the proposed Unit cell using Floquet port analysis method using HFSS is shown in the Fig.7.

IV. CONCLUSION

A novel metamaterial unit cell has been designed and analyzed. The simulated results proves that the structure exhibits Wideband Near Zero Index Property (NZIM) in the entire bandwidth of 1-15 GHz except at 7.1-7.77 GHz. The dimensions of the unit cell are compact and can be fabricated easily with readily available FR4.NZIM tends to focus the electromagnetic rays towards normal vector which have been proved to have significant gain increment. Hence the proposed Near Zero Index Fractal Metamaterial (NZIFM) Unit Cell can be integrated with the conventional planar antenna for enhancing the gain property.

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