Design of Zero Index Metamaterial Lens for Gain Enhancement of the Antenna array

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Abstract: A zero index metamterial layer used for the gain enhancement of the patch antenna array operating in the L band. The slotted double circular ring resonator structure acts as the metamterial for the gain enhancement of the Microstrip patch antenna array. An improved gain, compact size with Near Zero Index (NZI) patch antenna array is designed with enhanced radiation properties. Slotted Double Circular Ring Resonator structure layer is placed above the microstrip patch antenna array. Moreover, it acts as Meta Surface lens. The proposed NZI lens is designed to increase the measured gain in E- and H-plane in operating frequency band (L-band).

Key words- Metamaterial, Near Zero Index (NZI), Meta surface lens, slotted double circular ring resonator, Gain, E-plane, H-plane.

I.   INTRODUCTION

Naturally metamaterial does not exist we have to create it, by changing the properties of the material that are permittivity and/or permeability. The Electromagnetic metamaterials (MTMs) are not natural materials [4]. Materials can be characterized by electric permittivity and magnetic permeability. Metamaterial provides the field to realize the all-possible material properties by designing different cellular structure architecture. Among the several structure of the metamaterial, zero permittivity/permeability/index is a one of the method to enhance the radiation characteristic of the antenna elements [2]. The advancement in the modern wireless communication system requires high gain antennas. As the number of elements increases in an array the distance between elements reduces which lead to increase in mutual coupling between the antenna elements. As the mutual coupling increases antenna parameter like gain and radiation affected. This reduces antenna performance. To overcome this problem Near Zero index metamterial Lens layer used.

Here metamaterial Meta surface structures used for gain enhancement of the antenna array. To achieve this, Slotted double circular ring resonator Meta surface lens layer used. The advancement in the modern wireless communication system requires high gain antennas. The antenna emits radiation in free space in a different way depending upon its configuration. Transmitting antenna radiates EM energy into space and receiving antenna collects EM energy. Now a day's microstrip antennas have more importance, Because of their small size and other properties. This is very use full in wireless communication system. The properties of multiple-input and multiple-output (MIMO) like high quality used to enhance the isolation between antenna elements. Hence enhances the performance of antenna elements. The improvement in antenna properties in the field of microwave wireless communication systems provides different frontier for designers to design enhanced power, high-realized gain, compact, and low profile radiators. In this paper, zero index Metamaterial Meta surface lens layer is used for gain enhancement of the microstrip patch antenna array.

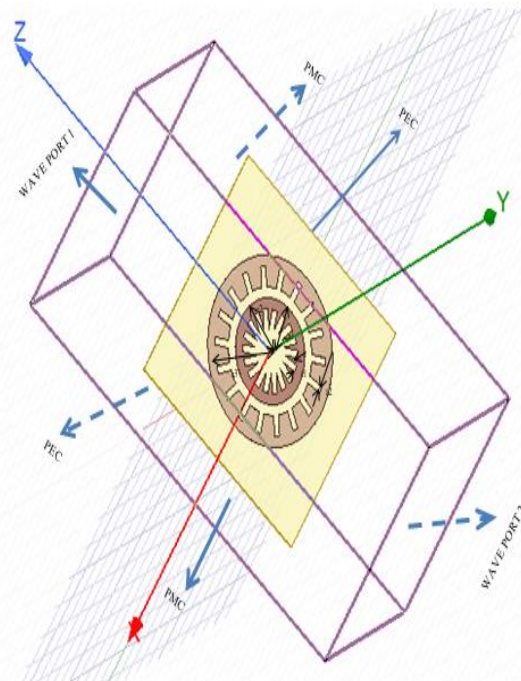## II.   DESIGN OF ZERO INDEX METAMATERIAL STRUCTURE

Figure1. Design of slotted double circular unit cell in HFSS with boundary condition

A slotted double circular ring resonator as shown in figure1 is act like zero index metamaterial structure, because the permittivity and permeability of this structure is close to zero. In this structure the slots in the circular rings acts like capacitors and whole ring like inductors. These capacitive slots are created to achieve the compactness having band pass center frequency in the defined frequency range [1]. After designing the Zero index metamaterial structure the boundary box is designed to that slotted double circular ring resonator structure as shown in figure1. Boundary box has total six faces in that two faces are made as perfect magnetic conductor (PMC), two faces are made as perfect electric conductor (PEC) and other two faces are made as wave port-1 and wave port-2. The purpose of doing this is to make that slotted double circular ring resonator structure as unit cell, to know that how that slotted double circular ring resonator structure behaves in infinite array. Then that whole design is simulated in the HFSS.
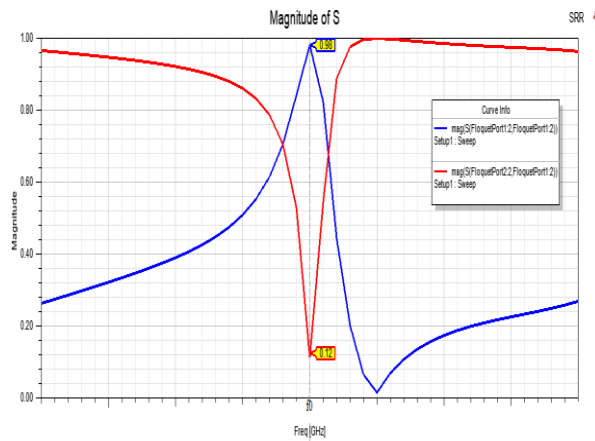
Figure2 and figure3 shows the magnitude and phase of the S-parameter generated by metamaterial Unit Cell. From these two graph it is observed that the magnitude and phase of the S-parameters are near zero at the operating frequency.
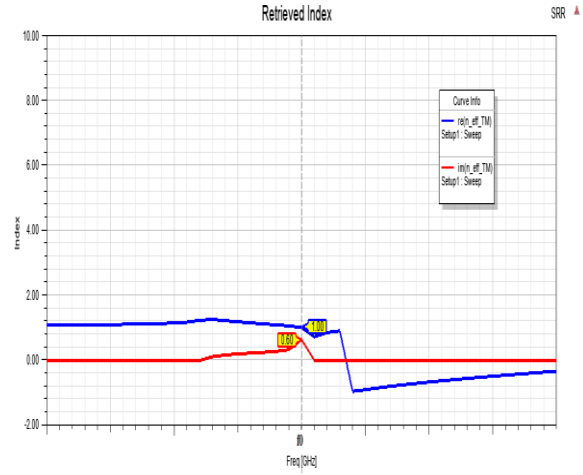

Figure4. Retrieved index of the Unit Cell

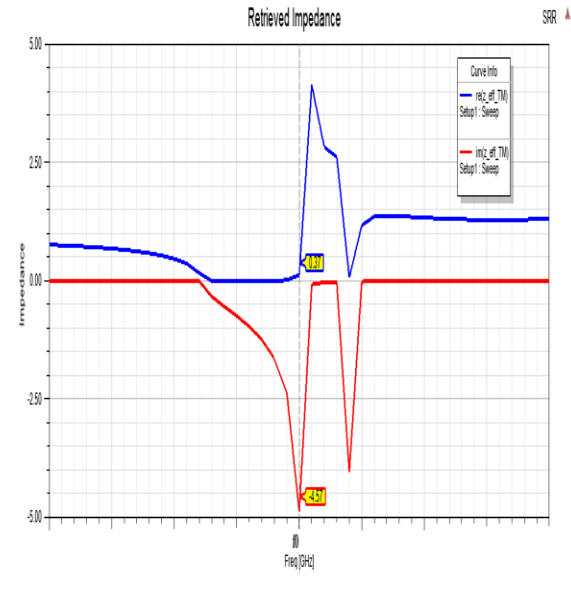Figure2. Magnitude of S-parameters of Unit Cell in HFSS

Figure5. Retrieved impedance of Unit Cell

From the figure4, we can see that the retrieved index of the slotted double circular metamaterial structure is near zero. Now this structure converted to 4×4 element layer. Moreover, this layer is placed above the patch antenna array.

III.   DESIGN OF PATCH ANTENNA ARRAY
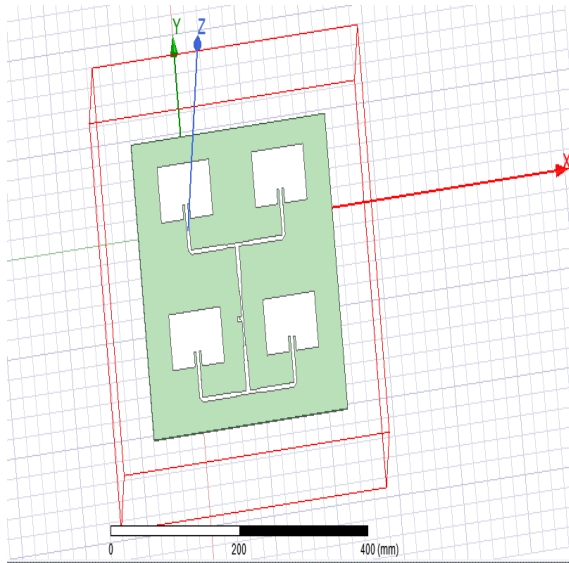

Figure3. Phase of S-parameters of Unit Cell in HFSS

Figure6. Design of Microstrip patch antenna array in HFSS

Patch antenna works on the principle of fringing field effect. Fringing field effect is the enhancement of Electric field near three-layer material, due to the discontinuity in the material properties at the triple layer. In the Figure6 the rectangular patch is the radiating element. The power is supplied by the coax feed with the help of power divider. The feed connects the ground plane to the radiating element (rectangular patch). The rectangular patch antenna optimized to operate in L-band with good return loss. The results for normal patch antenna array having four patch elements are noted.
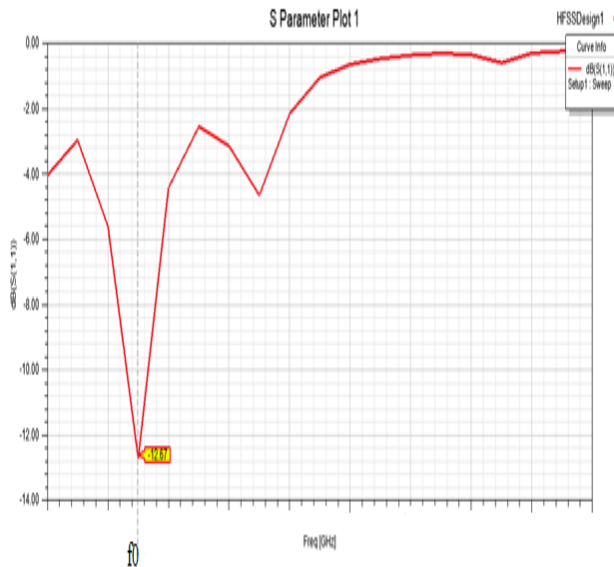

Figure7. S-parameter of the patch antenna array without Meta surface lens layer
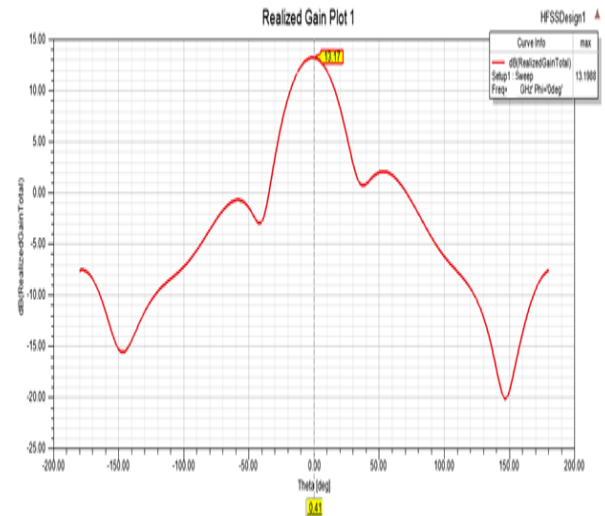

Figure8. Realized gain of the patch antenna array without Meta surface lens layer

Figure7 and figure8 shows the S-parameter and Realized gain of the Microstrip patch antenna array without Meta surface lens layer respectively. Initially four patch elements for operating frequency is in L-band are designed in HFSS side by side as shown in figure6, power divider designed in ADS and imported to HFSS, and then both are combined in HFSS. The total realized gain of the patch array is around 13.17dB   for operating frequency is in L-band.

IV. IMPLEMENTATION OF ZERO INDEX METAMATERIAL META SURFACE LENS FOR GAIN ENHANCEMENT OF THE ANTENNA ARRAY
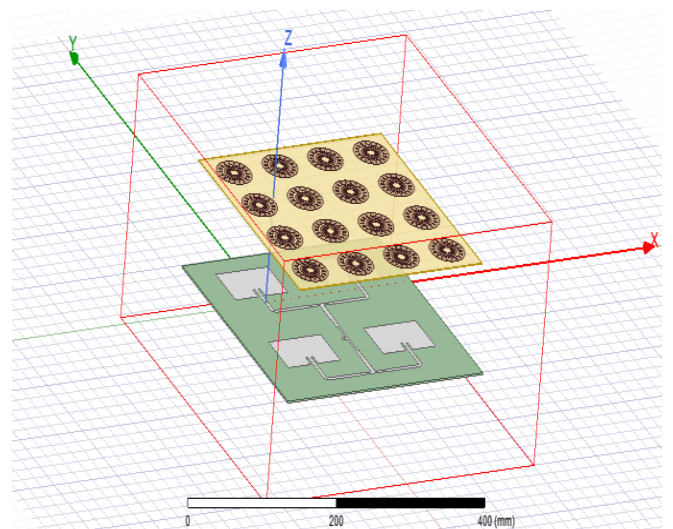

Figure9. Design of Microstrip patch antenna array with Meta surface lens layer in HFSS

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After design of the patch antenna array the zero index metamaterial layer is created above the patch antenna array at height of $\lambda/2$ as shown in figure9. The height of the lens optimized to get maximum gain. This layer acts as zero index meta surface lens and designed in such way that it converges the radiated beam from the antenna array so that beam width of the antenna array reduces and results enhancement in the radiation characteristics.
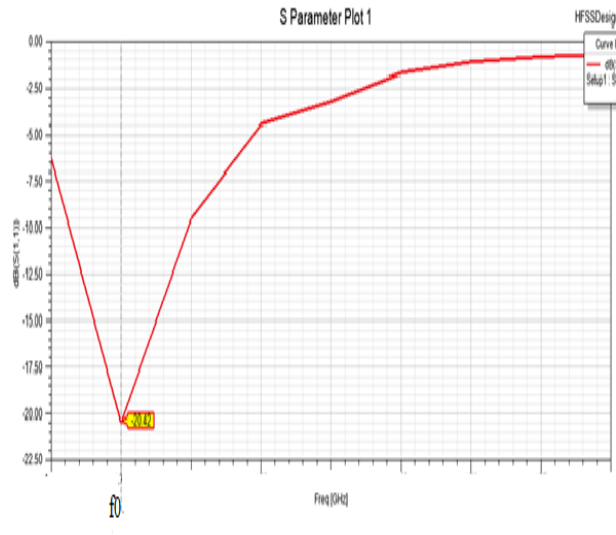

Figure10. S-parameter of the patch antenna array with Meta surface lens layer
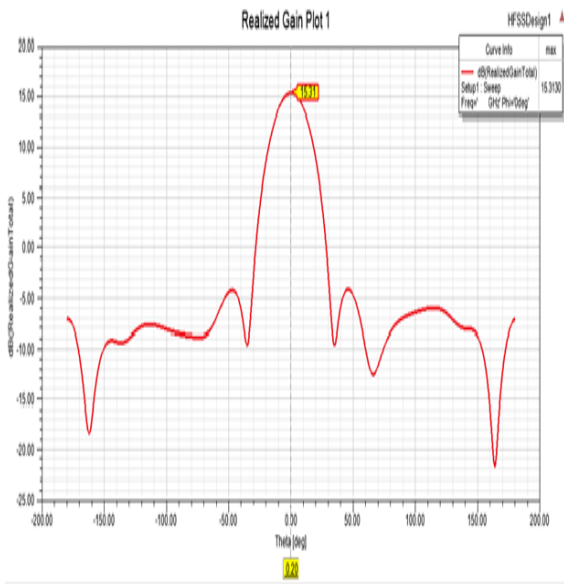

Figure11. Realized gain of the patch antenna array with Meta surface lens layer

Figure10 and Figure11 shows the S-parameter and total realized gain of the microstrip patch array after placing the metamaterial Meta surface lens layer above the patch array at the height of $\lambda/2$ distance. The realized gain of the antenna array is 15.31dB. the performance of the antenna array improves after applying the zero index metamaterial lens layer above the patch antenna array.

Table1. Comparison between Microstrip patch antenna array with and without zero index metamaterial lens layer

Antenna Parameter	Microstrip Patch antenna array without metamaterial lens layer	Microstrip Patch antenna array with metamaterial lens layer
S-parameter	-12.67dB	-20.42dB
Realized gain	13.17dB	15.31dB

Table1.Shows the comparison between Microstrip patch antenna array with zero index metamaterial lens layer and without zero index metamaterial lens layer. The gain of the patch antenna array increases by 2.14dB after applying slotted double circular ring resonator metamaterial Meta surface structure layer above patch antenna at the height of $\lambda/2$ and also there is improvement in S-parameter .

V.   CONCLUSION

In this paper, the gain of the patch antenna array is increased by 2.14dB after applying the zero index metamaterial lenses, compared to normal patch antenna array working on the same frequency band (L-band). This zero index metamaterial layer acts as lens, the EM wave from the antenna array passes through the metamaterial layer without any deviation. This results to reduction in beam width, hence gain of the patch antenna array increases.

References

[1] Amit Kumar Singh1 , Mahesh P. Abegaonkar1, Shiban K. Koul "Compact near zero index metasurface lens with high aperture efficiency for antenna radiation characteristic enhancement" IET Microw. Antennas Propag., 2019, Vol. 13 Iss. 8, pp. 1248-1254

[2] Yahong Liu, Xiaojing Guo, Shuai Gu, and Xiaopeng Zhao "Zero Index Metamaterial for Designing High-Gain Patch Antenna" International Journal of Antennas and Propagation Volume 2013, Article ID 215681, 12 pages http://dx.doi.org/10.1155/2013/215681

[3] Christophe Caloz "Ten Application of Metamaterials" 2016 IEEE international symposium on Antennas and propagation.

[4] Ahmad B. Numan and Mohammad S. Sharawi "Extraction of Material Parameters for Metamaterials Using a Full-Wave Simulator" IEEE Antennas and Propagation Magazine, Vol. 55, No. 5, October 2013.