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Metamaterial based Microstrip Patch Antenna Using Unit Cell Array for Gain Enhancement

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***Abstract*—**Role of Antenna in Wireless communication is really vital whether it is point to point wireless communication or Wi-Fi. The size of antenna should be compact. In this work a novel design of the metamaterial based unit cell 7X7 arrays has been used as superstrate for the gain enhancement of a microstrip patch antenna operating at 7.1 GHz frequency. This frequency lies in the C-band which is normally used in satellite communication. Due to the unusual properties, metamaterial can change the electric and magnetic property of electromagnetic wave passing through it. Hence metamaterial is used in the fabrication of antenna enhanced the required properties. The proposed design provides a high gain of 9.4 dB using a superstrate, when suspended above a microstrip patch at 7.1 GHz. Simulation and measurement results confirm that near-zero index metamaterial (NZIM) array significantly improves the gain (by more than 1.8 dBi) and reduces the half power beamwidth in both E-plane and H-plane by 20^o. The S parameters are extracted using HFSS,which is a Finite-Element-Method (FEM)-based full-wave simulator.

***Keywords*—** Microstrip Patch Antenna, Frequency 7.1GHz, NZIM cell array, ANSOFT HFSS Software, Gain, Return loss.

I. INTRODUCTION

Metallic structures with negative permittivity (ε) and permeability (μ), are referred as metamaterial and thus leads to negative refractive index. Due to this it supports those waves having antiparallel velocities (phase and group velocity). Metamaterial doesn't obey Snell's law, Doppler effect, Vavilov-Cerenkov radiation etc [1]-[3]. No other material in the world shows such wonderful properties like metamaterial. Due to this, metamaterials have capabilities to change the electric and magnetic characteristics of EM waves passing through it and this helps in getting enhanced properties when applied to antenna design [2].The basic building block is known as the unit cell, and it defines the basic properties of the metamaterial. The uni-directional broadside radiation characteristics of a microstrip patch antenna (MPA), the beam focusing property of a novel NZIM array has been explored to enhance the gain and reduce the half power beam width (HPBW) of an microstrip patch antenna [4],[5]. A near-zero index metamaterial unit cell design on a both side of the substrate and a layer consisting of 7X7 unit cell array has been used as superstrate over an MPA for enhance the broad side performance.

II. DESIGN METHAODOLOGY

A. Reference Patch Antenna

Construction wise microstrip patch antenna is very simple It is fabricated by conventional microstrip fabrication technique. An antenna consists of conducting patch on a ground plane separated by dielectric substrate. A microstrip fed has used in rectangular patch antenna operating frequency (f_o) =7.1 GHz. The schematic diagram of proposed microstrip patch antenna is shown below fig.1. The substrate of the patch antenna is realized on Rogers RT/Duroid 5880 (tm) with dielectric constant (ε_r) =2.2 and loss tangent (δ) = 0.0009, the thickness of proposed substrate hight h= 1.6mm with copper thickness of 30μm proposed patch antenna is used. The width W_p and length L_p of patch are optimized to given the 7.1 GHz operating frequency. HFSS used for the patch antenna simulations. The patch antenna has HPBW of $\Theta_E=90^0$ in E-plane and HPBW of $\Theta_H= 72^0$ in H plane [6].

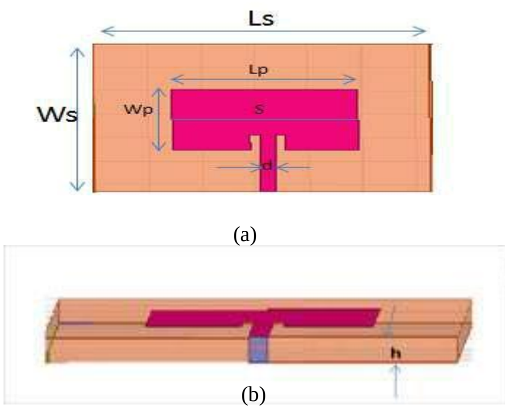
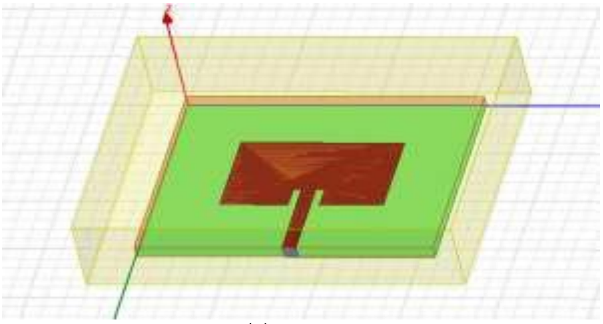


Fig. 1. Schematic diagram of microstrip patch antenna: (a) Top view. (b) Side view; L_p= 12.8635 mm, W_p= 17.3181 mm, L_s= 31.5 mm, W_s= 31.5 mm, S= 3 mm, d=1.4798mm.

B. Simulated Result of the Patch Antenna

C. Design and Characterization of Unit Cell Array



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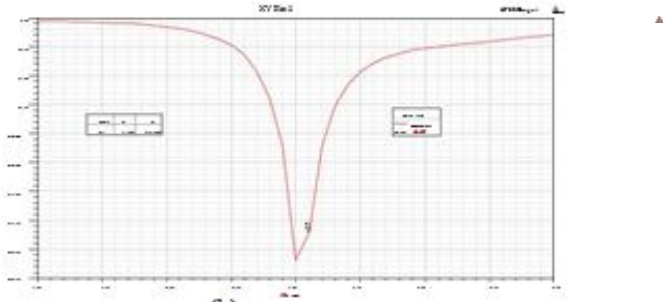

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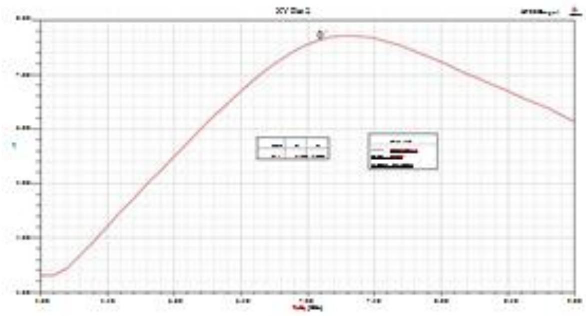

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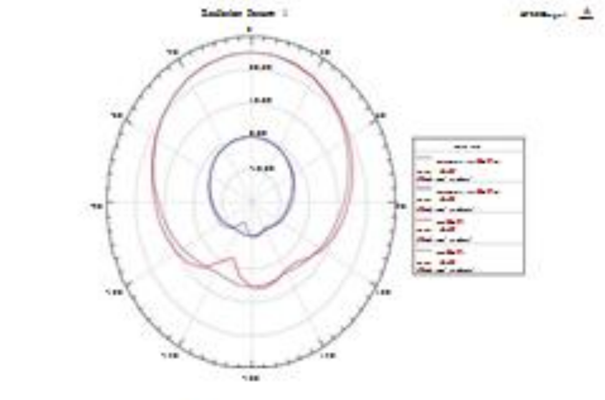
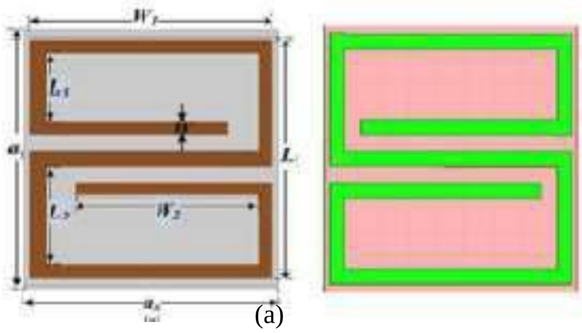


(d)

Fig. 2. (a) Show the Proposed patch antenna with HFSS (b) Show the return loss S11 of the patch antenna (c) Show the directivity of the patch antenna.(d) Show the Radiation Pattern of the patch antenna.

C. Design and Characterization of Unit Cell Array

The metamaterial unit cell array superstrate of the MPA used for the gain enhancement. Fig. 3 show the single unit cell parameter printed on both side with the FR4 substrate ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$). The unit cell array is arranged with periodicity of 7X7 and spacing between two unit cells is 4.5mm. The periodicity of the unit cells has represented by a_x and a_y in the x and y direction show in fig.4.The single unit cell as well as metamaterial unit cell array is simulated in the ANSOFT HFSS with the both PMC and PEC boundary condition. If the parameter of metamaterial unit cell has been changed than the refractive index can also be changed [7],[8].



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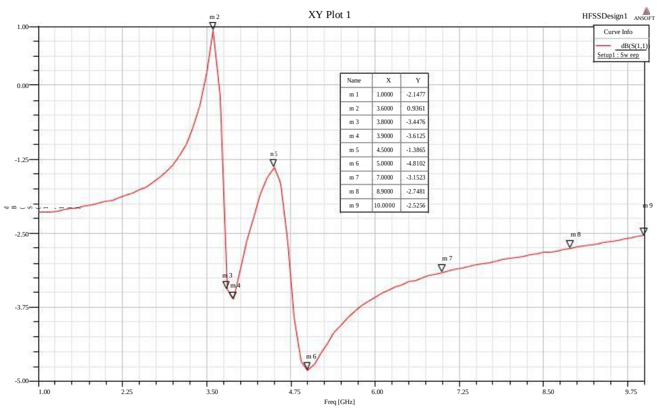
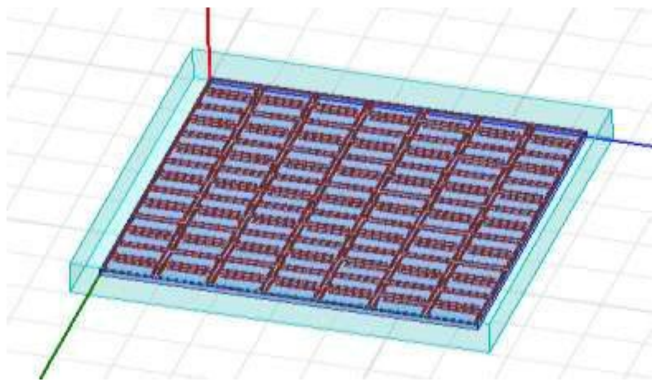


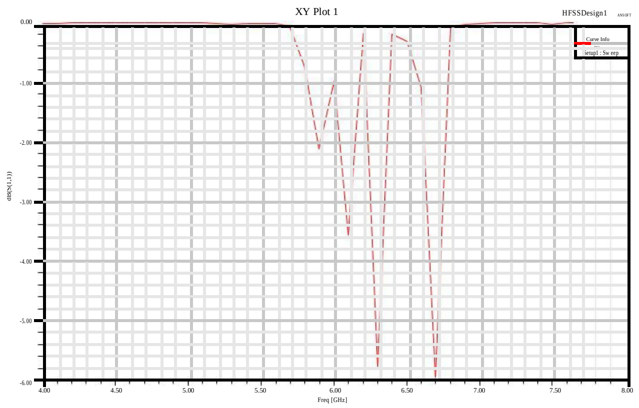
(b)

Fig. 3. The schematic diagram of NZIM cell: (a) Top view, and Bottom view; ax=ay=4.5mm, L1= 4.2mm, L2= 1.725mm, L3=1.2mm, W1=4.3mm, W2=3.5mm, W=0.25mm. (b) Show the refractive index for the proposed metamaterial single unit cell.



(a)

According to the materials with negative refractive index can convert the diverging wave to plane wave. Thus the superstrate array of metamaterial unit cells enhances the gain of patch antenna.

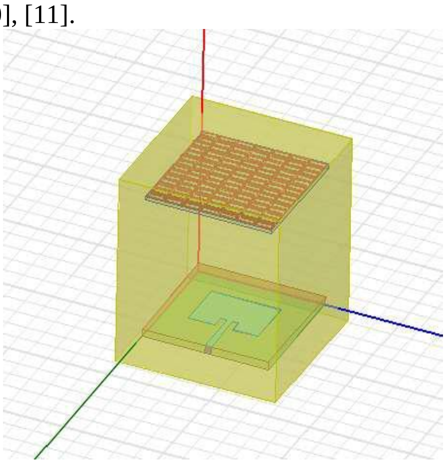


(b)

Fig. 4. The schematic diagram of the metamaterial unit cell 7X7 array: (a) Top view of array surface, (b) Graph show the negative refractive index of the metamaterial unit cell 7X7 arrays.

D. Patch Antenna with the NZIM superstrate for Gain Enhancement

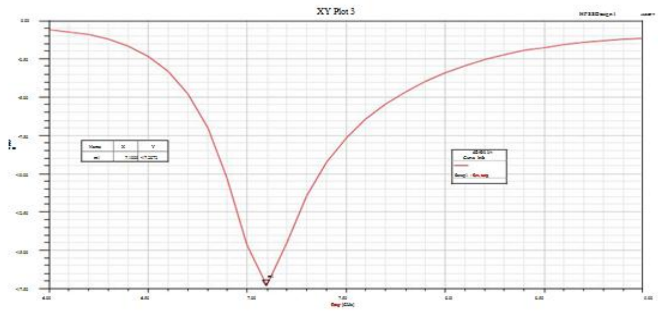
In this section, the metamaterial based 7X7 unit cell array is employed to design of the microstrip patch antenna as superstrate and performance of the overall metamaterial based microstrip patch antenna is studied. The schematic diagram of the proposed antenna with NZIM unit cell array 3D view of the antenna shown in fig. 5. The distance h between antenna and supertrate lens is h=30mm which is approximately $\lambda_0/2$ where λ_0 is the operating wavelength of the patch antenna. The length and width of the proposed metamaterial 7X7 unit cell array can effectively cover the broadside radiation of the patch antenna.The variation of S_{11} and gain of the proposed metamaterial based patch antenna with frequency for a unit cell array superstrate. It can observe that the peak gain is 9.4 dbi [5], [9],[10], [11].



(a)

III. CONCLUSION

In this paper, by observing the simulated results it can be easily analyzed that the compact microstrip metamaterial antenna gives better gain and efficiency compared to an ordinary patch antenna. This is only possible due to the unique characteristics of Metamaterials. Also due to the miniaturization it is very convenient to use it in wireless networks. Due to the unusual properties of the Metamaterials by using a single unit cell the antenna gives



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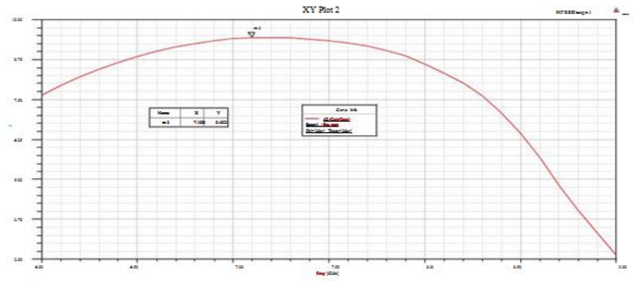

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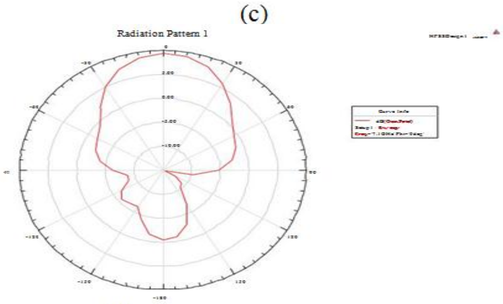

(d)

Fig. 5. (a) Show the Proposed metamaterial superstrate array based patch antenna with HFSS (b) Show the return loss S11 of the proposed antenna (c) Show the Gain of the proposed antenna.(d) Show the Radiation Pattern of the proposed antenna.

IV. RESULT AND DISCUSSION

Thus the results show that the performance of antenna is improved with the metamaterial superstrat array. Table I shows the comparision between the patch antenna and proposed patch antenna with superstrate. Thus a metamaterial unit cell array increase the peak gain by 7.6 dbi to 9.4 dbi more than 1.8 dbi gain enhance the patch antenna [12].

Table 1

Antenna Parameter	**Microstrip patch antenna without superstrat**	**Microstrip patch antenna with superstrat**
Operating frequency	7.1GHz	7.1GHz
Return loss	-18.52dbi	-17.28dbi
Gain	7.6dbi	9.4dbi

gain 1.8 dB, overall efficiency of 98.76 at 7.1 GHz frequency which is very good for point to point wireless

communication and wireless LANs. This antenna has better gain and radiation efficiency compared to an ordinary patch antenna. The results obtained through "HFSS" design software and are very good for wireless access network resources at home and elsewhere with up to 7.1 GHz performance, like IEEE 802.11a, widely available IEEE 802.11b, downward compatible IEEE 802.11g, and advanced IEEE 802.11n.

IV. FUTURESCOPE

Microstrip patch antennas are increasing day by day for use in wireless applications due to their low profile structure. The proposed work Gain also improved by superstate substrate .Therefore, they are highly compatible for embedded antennas in handheld wireless device such as cellular phones, pagers etc. Another area where they will be used successfully is in satellite communication. Metamaterial unit cells can be formed in the form of Sierpinski Gasket and can be implemented in fractal antennas for frequency independent applications.

ACKNOWLEDGMENT

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REFERENCES

[1] Hemant Suthar et al.,"*Gain Enhancement of Microstrip patch antennausong near-zero index Metamaterial (NZIM) Lens*", IEEE Twenty First National Conference on Communications (NCC), Mumbai, India, 2015.

[2] Gijo Augustin et al., "*A zero index metamaterial unit cell for Antenna Gain Enhancment*",IEEE Antennas and Propagation Society International Symposium (APSURSI), USA, 2013.

[3] Ahmed B. Numan et al.,"*Extraction of Material Parameters for Metamaterials Using a Full-Wave Simulator*", IEEE Antennas and Propagation Magazine, Vol. 55, No. 5, October 2013.

[4] C. Caloz et al., "*Electromagnetic metamaterial Transmission line theory and microwave applications*," John Wiley & Sons, 2005.

[5] D. R. Smth et al.,"*Composite medium with simultaneously negative permeability and permittivity*" Phy. Review Lett., Vol. 84, No. 18, pp. 4184-4187, 2000.

[6] M. A. Antoniades et al., "*Multiband Compact Printed Dipole Antennas Using NRI-TL Metamaterial Loading*," IEEE Transactions on Antennas and Propagation, Vol. 60, No. 12, pp. 5613-5626, 2012.

[7] Anwer Mekki et al., "*Gain Enhancement of a Microstrip Patch Antenna Using a Reflecting Layer*," International journal of Antennas and Propagation, 2015.

[8] Arvind Kumar and Mithilesh Kumar, "*Gain Enhancement in a Microstrip Patch Antenna Using metallic ring at 10 GHz* ," International journal of Computer Application, 2014.

[9] Ashmita et al., "*Gain Enhancement in a Microstrip Patch Antenna Using H shaped defected ground structure* ," Advances in Intelligent System and Computing, 2017.

[10] Sandeep Kumar Singh, Himanshu Parasar, Rajendra Singh, Vepakomma Kavya "*Design of Compact UWB Rectangular Patch Antenna for WiMax/WLAN Applications*," International Journal of Computer Sciences and Engineering, vol. 6, issue.3, pp. 157-160, 2018.

[11] Anand Mohan, Ashok Kumar "Cylindrical Dielectric Resonator Optical Antenna (CDROA) & its Applications for Convenient Technology," International Journal of Computer Sciences and Engineering, vol. 7, issue.1, pp. 283-286, 2019.

[12] R. Luo et al., "*Negative index material composed of electromagnetic resonators*," Appl. Phys.Lett., vol. 90, pp. 263504-263504-3, 2007.

Authors Profile

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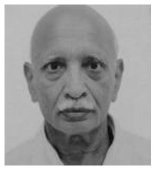

Dr. Y.K. Jain, served as Professor at BRCM Behal in ECE department from Feb 2008 to April 2008 and Principal of BMIET, Sonepat from May 2008 to Jan 2013 after retirement from Central Electronics Engineering Research Institute Pilani as Scientist-G , where he was involved in setting up of Thick- Film laboratory and developed Thick- Film Technology for manufacturing HMCs for SPACE for the first time in India. He transferred thick- film process technology to three Indian industries for manufacturing HMCs for telecommunication and industrial applications. HMCs developed at CEERI were used in SROSS- I, SROSS- II, INSAT-II A,B,C & D Satellites. He worked on more than 24 sponsored projects from ISRO, Defense, MIT ,DST and industries He has about 65 papers, 10 patents and 29 technical reports. He invented a new thick film component called VTR. He visited USA, UK and Germany under various programmes . .He headed HMC group and worked on packaging of ISFET sensors, microelectrodes for sensors, design & development of Pt. heater for sensors, development of thick film sensors and applications of LTCC technologyHe has been awarded ISHM Best paper award, NRDC Independence Day Award, A.N. Chatterjee Memorial Award and various Institutional Awards He has guided about ten M. Tech Electronics and seven Ph.D students, three students have been awarded Ph. D degree . He is Fellow member IETE, life member of IMAPS and Semiconductor Society of India.

