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Improvement in Characteristics of Microstrip Patch Antenna with the Help of Zero Index Metamaterial Structure

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ABSTRACT: In this Paper, A new metamaterial unit-cell with a zero refractive index (n) is presented and employed for the gain enhancement of a microstrip antenna operating at 5.28 GHz. The unique property of the metamaterial gathers the wave radiated from the antenna and collimates it towards the normal direction when used in a superstrate layer. The design provides a gain enhancement of 8.1 dB using a single layer superstrate, when suspended above a microstrip patch at 5.28 GHz.

KEYWORDS: Metamaterial structure, Microstrip patch Antenna, Zero Index Metamaterial.

I. INTRODUCTION

In planar antennas, the metamaterial superstrate based designs are very demanding for high-gain antenna applications. As the effective permittivity or the permeability of a material approaches to zero, the phase of the electromagnetic wave freezes [1]. This property can be effectively utilized in planar antennas for focusing the antenna radiation from a conventional radiator [3]. An array of unit cell was designed with an optimum periodicity and employed as a superstrate layer for the gain enhancement [4].

II. METAMATERIAL UNIT CELL & HIGH GAIN ANTENNA CONFIGURATION

The proposed antenna is shown in Figure 3. The basic building block of the metamaterial superstrate is the ZIM unit cell as shown in Figure 1 with geometrical parameters a = 9.5, b = 4.0, c = 4.5, d = 0.5, g = 0.5 [Units = mm] [1] The unit-cells are arranged as shown in Figure 2 with periodicity of 8x8. In this design, a coaxial fed microstrip patch antenna (MPA) with dimensions W x L = 12.84 mm x 16.74 mm is constructed. Superstrate realized on FR4 laminate with dielectric constant 4.3 and thickness h2 = 0.8 mm. At the optimized design, the unit cells were arranged with a periodicity 8x8 and inter-unit-cell spacing of s = 2 mm. The superstrate loaded antenna configuration is shown in Figure 3. The superstrate layer and the antenna have dimensions of L x L = 100 x 100 mm^2 and are aligned at the center [1].

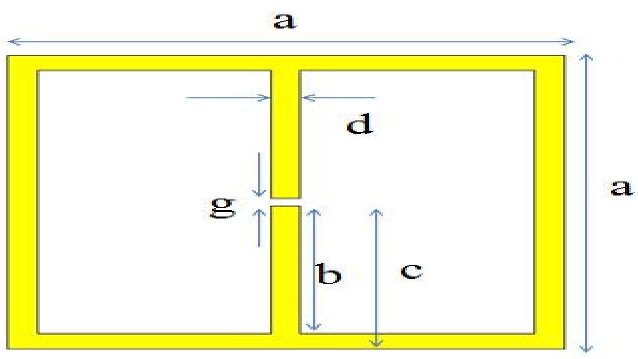

Figure 1 Proposed Unit Cell Geometry

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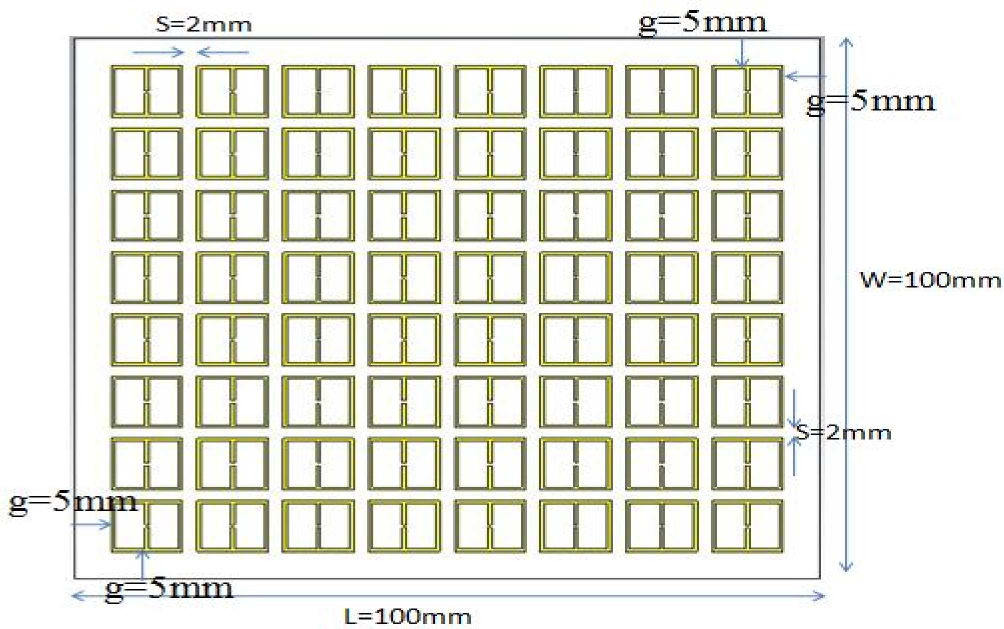

Figure 2 Superstrate Layer

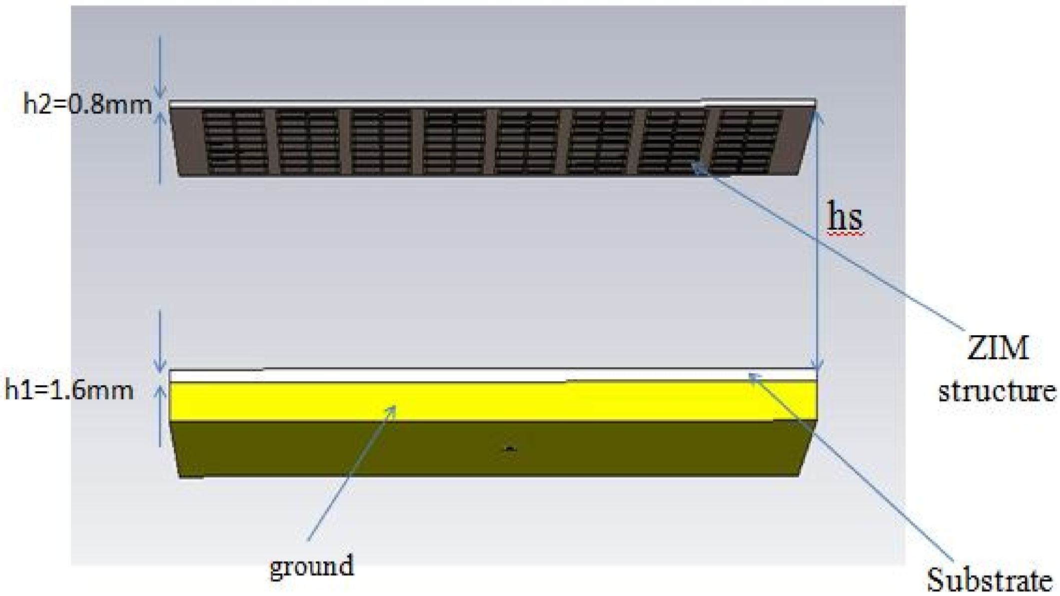

Figure 3 Microstrip Antenna with Superstrate Layer

III. OPEN BOUNDARY CONDITION RESULT

To simulate Unit cell for open boundary condition in CST Microwave software X_{min}, X_{max}= Open, Y_{min}, Y_{max}= electric ($E_t = 0$), Z_{min}, Z_{max}= magnetic ($H_t = 0$) are specified in the Open boundary condition configuration.

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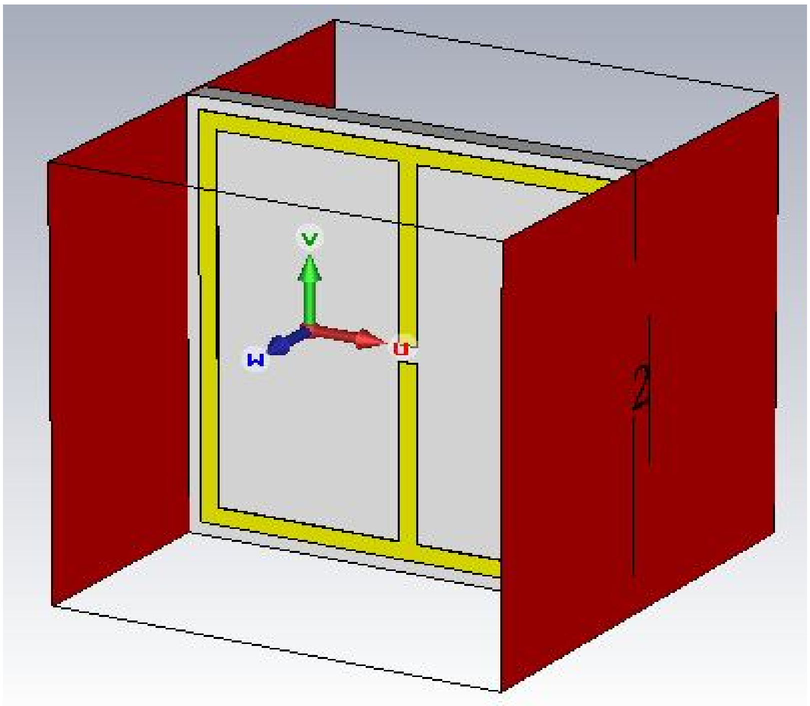

Figure 4 Unit Cell Configuration for Open Boundary Condition

The figure 5 shows the result of S-parameters [Magnitude in dB] for Open boundary condition of Unit Cell.

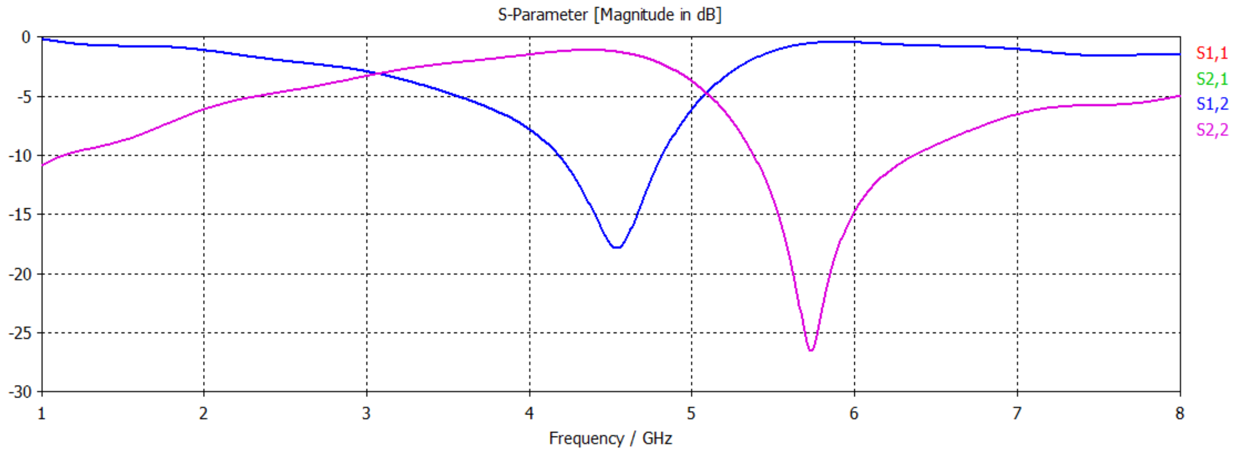

Figure 5 S-Parameters of the metamaterial Unit Cell [Magnitude in dB]

IV. SIMULATION RESULTS WITH & WITHOUT METAMATERIAL STRUCTURE

(1) The scattering parameter is calculated over the band 4-6 GHz and it is shown in Figure 6. Scattering parameter's result shows that at resonant frequency metamaterial antenna attains (S11<-10dB) better figures compared to conventional antenna's response.

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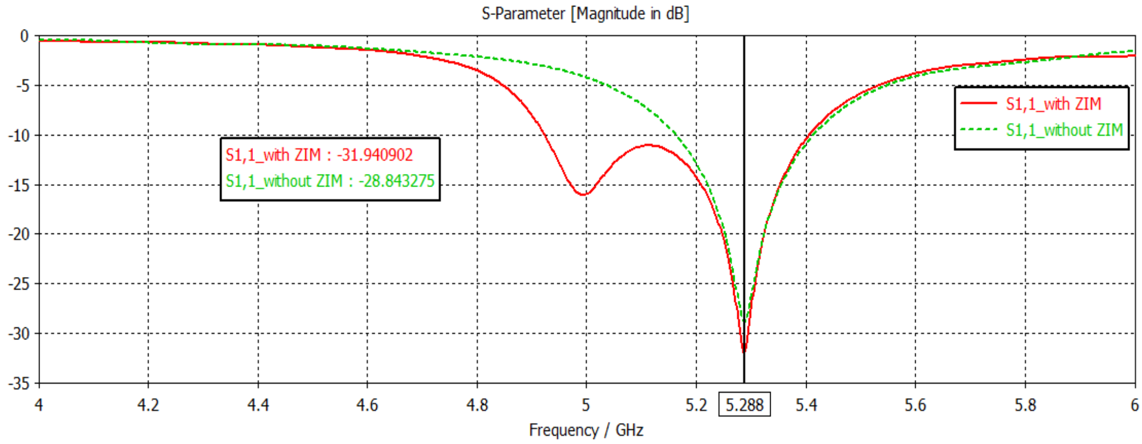

Figure 6 S parameter with & without Metamaterial structure

(2) The Gain result shows that at resonant frequency metamaterial antenna has approx 10.9 dB gain whereas the conventional antenna attains gain of only 2.8 dB. Thus the proposed design exhibits a gain enhancement of 8.1 dB with a single superstrate layer.

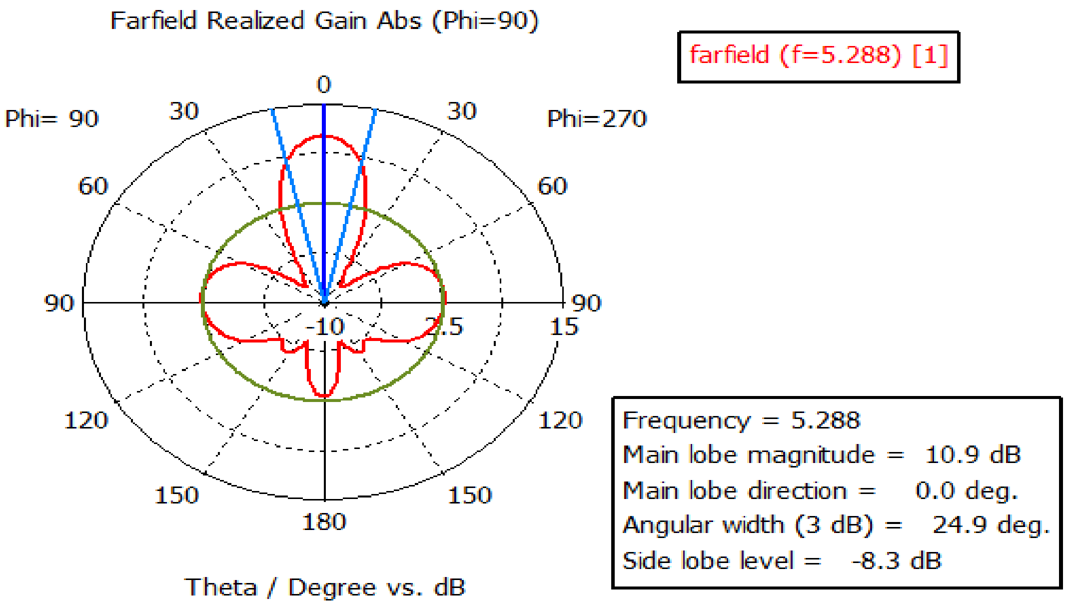

Figure 7 Gain with Metamaterial structure

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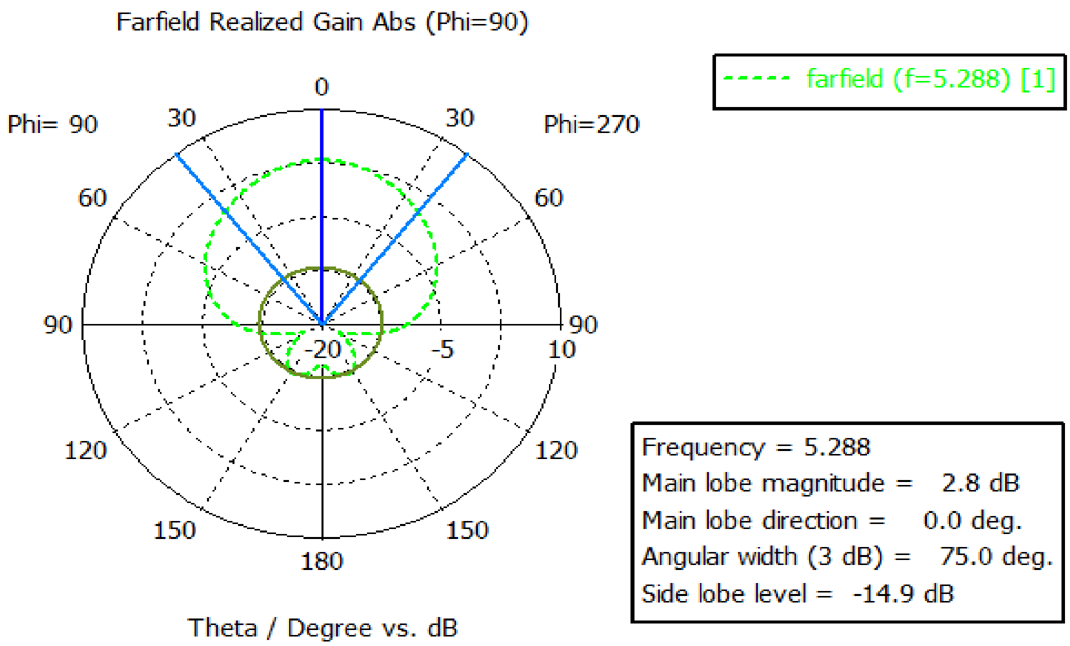

Figure 8 Gain without Metamaterial structure

(3) The polar plot shows that metamaterial antenna has higher directivity 12.6 dBi compare to conventional antenna has only 4.7 dBi.

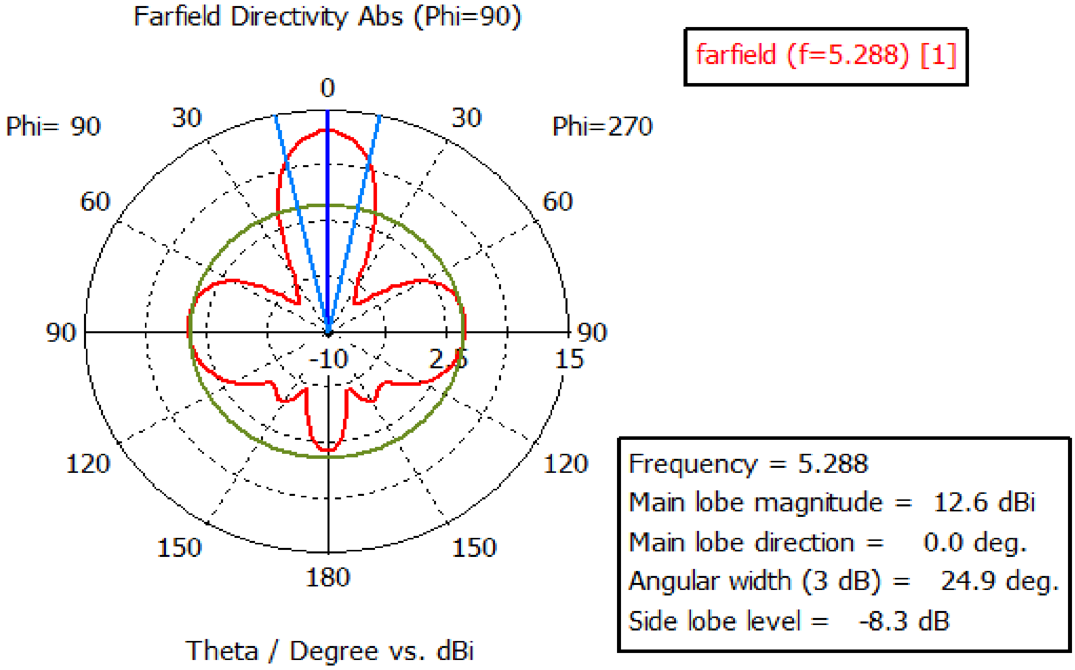

Figure 9 Far-field Directivity with Metamaterial structure

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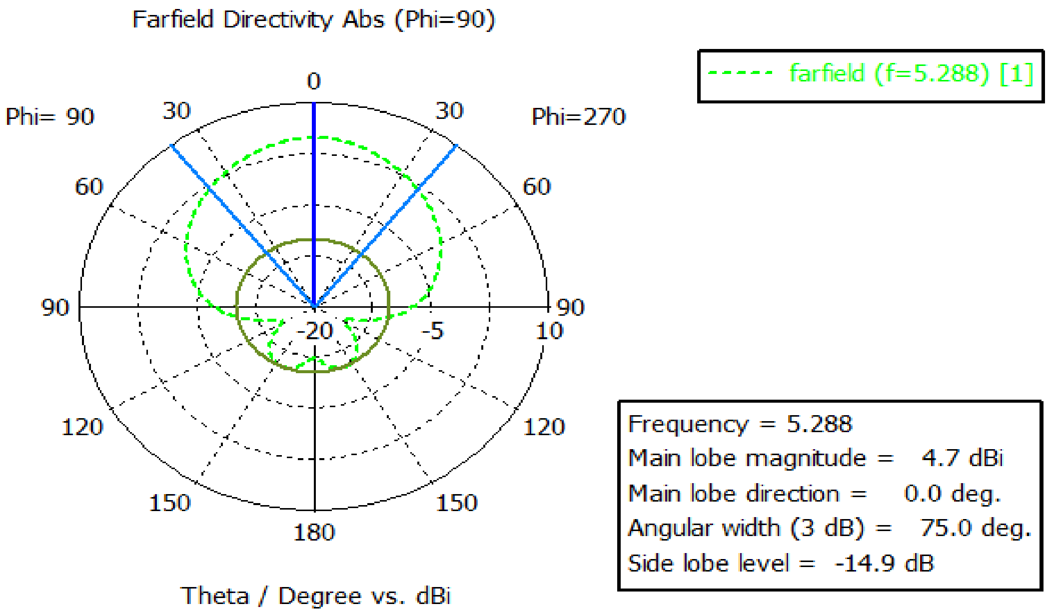

Figure 10 Far-field Directivity without Metamaterial structure

(4) The below Calculations for Efficiency of Microstrip Antenna with and without Metamaterial structure shows that with metamaterial antenna has 86.50% higher efficiency compared to conventional microstrip antenna without metamaterial structure has only 59.57% efficiency.

Efficiency of MPA with Metamaterial:-

$$= \frac{Gain}{Directivity} = \left[\left(\frac{10.9}{12.6}\right)(100)\right] = 86.50\%$$

Efficiency of MPA without Metamaterial:-

$$= \frac{Gain}{Directivity} = \left[\left(\frac{2.8}{4.7}\right)(100)\right] = 59.57\%$$

V. SIMULATION RESULT SUMMARY

Parameter	MPA With Metamaterial Structure	MPA without Metamaterial Structure
Return loss	-31.94 dB	-28.84 dB
Gain	10.90 dB	2.8 dB
Directivity	12.6 dBi	4.7 dBi
Efficiency	86.50 %	59.57 %

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VI. HARDWARE & TESTING RESULT

Figure 11 shows ZIM structure in Superstrate Layer & Microstrip Antenna with ZIM structure.Figure 12 shows hardware testing setup.

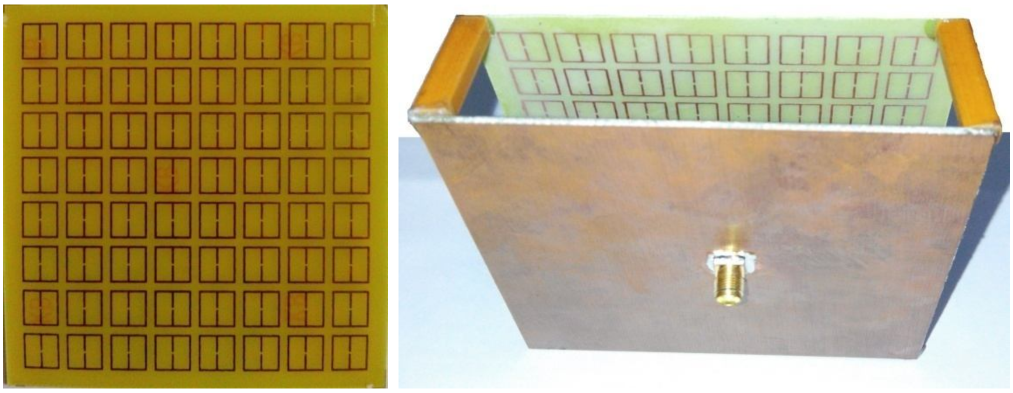

Figure 11 ZIM structure in Superstrate Layer & Microstrip Antenna with ZIM structure

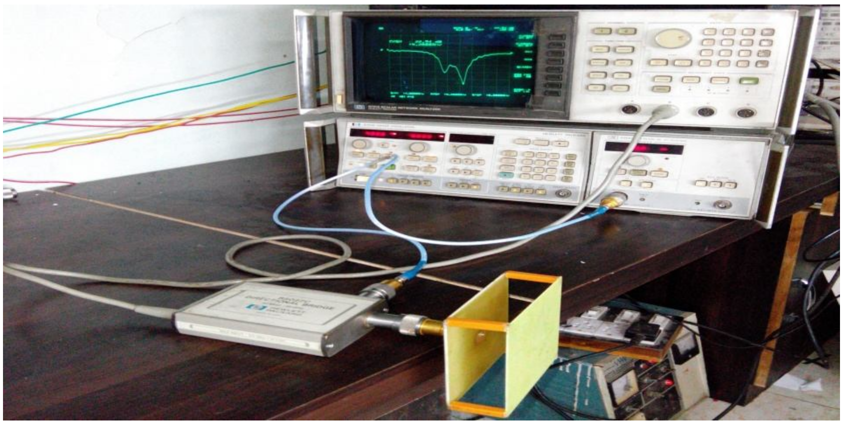

Figure 12 Hardware Testing Setup

Figure 13 S-parameter Testing Result

As seen in figure 13 measured value of S-parameter is -26.57 dB at resonant frequency.

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VII. CONCLUSION

We have proposed a high gain antenna based on zero index metamaterial structure for WLAN applications. The gain enhancement is achieved by loading a microstrip antenna operating at 5.28 GHz WLAN band with single layer superstrate metamaterial structure. Compared to existing designs, the proposed antenna configuration provides reasonably good gain enhancement of 8.1 dB.

VIII. FUTURE SCOPE OF WORK

The antenna parameters can also be made improve with the help of multi-layer metamaterial structure in the superstrate layer. The design may also be done with the help of SRR (Split Ring Resonator) or defected ground structure of different shapes to reduce overall size of antenna while maintaining improvement in other antenna parameters like return loss, gain, directivity etc.

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BIOGRAPHY

Darshansinh N. Patel completed his B.E in Electronics and Communication from Gujarat Institute of Technical Studies, Moyad, Gujarat, India in 2013. Currently, he is pursuing his M.E. in Electronics and Communication Engineering in Silver Oak College of Engineering and Technology, Ahmedabad, Gujarat, India. His area of interest is research work in **Antenna Technology.**

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