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ENHANCEMENT OF THE GAIN AND BANDWIDTH OF MPA USING METAMATERIAL STRUCTURE

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ABSTRACT:
In this paper, a proposed metamaterial structure with rectangular microstrip patch antenna at 2.54 GHz is represented. It shows the metamaterial property at 1.59 mm and shows the reduction in return loss with microstrip patch antenna 2.54 GHz at resonant frequency. The patch antenna is simulated in HFSS 13 and compared the result with patch antenna using proposed metamaterial structure. The analysis shows reduction in return loss and enhancement of gain which provides a bright future for analysis in this field.

KEYWORDS: Left-handed material (LHM), Microstrip patch antenna (MPA), Metamaterial (MTM), Return loss, Gain

1. INTRODUCTION:

The development of low cost, minimal weight, and low profile antennas that are capable of maintaining high performance. The future development will aim to provide reduction in size and high speed data transfer exist there. The microstrip patch antennas are genrally used in the wireless devices [1]. So the miniaturization of the antenna has become an important issue in reducing the volume of entire communication system. The patch is a low profile, Low gain antenna. The patch to ground-plane spacing is equal to the thickness t of the substrate and is typically about λ0/100.The patch antenna is inexpensive as compared to others. The return loss of patch antenna is very small that is disadvantage of patch antenna. Metamaterial based rectangular patch antenna improves the return loss as well as gain of patch antenna. HFSS version13 is a basically a software package for electromagnetic analysis and design. The software provides full flexibility for the analysis of the design and results.

1.1 Left Handed Material:

The third quadrant ($\varepsilon<0$, $\mu<0$) represents Metamaterial, which is having both permittivity and permeability negative, also called left handed material or double negative material (DNG). It follows the left handed propagation rule because propagation of wave takes place in backward direction in the medium [2]. Due to negative μ and negative ε the refractive index of the medium is calculated to be negative. Thus, it is also termed as NIM (negative index material)[3].Electric vector E, electromagnetic vector H and wave vector k form the left hand triplet and this left handed material is called Metamaterial. This word is a combination of **"**meta" and "material**"**, Meta [4] is a Greek word which directs something beyond, altered, changed or something advance Metamaterial are generally implemented in a periodic structure. It is a soft option to design and fabricate it by array structure of unit cells. A unit cell is a combination of splt ring resonator and wire structure. An array of unit cells may be used to get that structure [4].

For the plane wave these equations can be presented

$$\vec{k} \times \vec{E} = \omega\mu\vec{H} \quad ; \quad \vec{k} \times \vec{H} = -\omega\varepsilon\vec{E} \qquad (1)$$

Therefore, for positive ε and μ, $\vec{E}$, $\vec{H}$ and $\vec{k}$ form right handed orthogonal system. When ε and μ both are negative the equation (1) changes to and formed left handed orthogonal system

$$\vec{k} \times \vec{E} = -\omega\mu\vec{H} \;;\quad k \times \vec{H} = \omega\varepsilon\vec{E} \qquad (2)$$

2. DESIGN SPECIFICATION:

To design the patch antenna we use parameters such as resonant frequency, dielectric constant, and substrate [8].

2.1 CALCULATION OF PARAMETERS:

Return loss: 20 log |Γ|

Γ -Reflection Co-efficient

CALCULATION OF VSWR:

$$S = \frac{1+|\Gamma|}{1-|\Gamma|}$$

CALCULATION OF WIDTH (W):

$$W = \frac{1}{2f_r\sqrt{\mu_0 \epsilon_0}}\sqrt{\frac{2}{\epsilon_{reff}+1}} = \frac{C}{2f_r}\sqrt{\frac{2}{\epsilon_{reff}+1}}$$

C = Free space velocity of light

ε_r=Dielectric const. of substrate

EFFECTIVE DIELECTRIC CONSTANT OF MPA:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{w}}}\right)$$

Actual length of the patch (L):

$L = L_{eff} - 2\Delta L$

Calculation of length extension:

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}$$

3. ANALYSIS OF PATCH ANTENNA AND MTM STRUCTURE:

The Rectangular Microstrip Patch Antenna is designed on woven fiber glass substrate [10]., dielectric constant ε_r = 4.88 and height from the ground plane d=1.59mm.The parameter of rectangular microstrip patch antenna are L= 50 mm, W= 50 mm, radius of coax feed is 2mm at center position of (28, 20, 0) with a probe of radius 1mm at h=1.59mm.PEC material is used in probe and coax pin.

The simple metamaterial structure is inspired by metamaterial structure to get the better result in both return loss as well as bandwidth.

Table1. Rectangular Microstrip Patch Antenna Specifications

Parameters	Dimension	Unit
Die-electric constant	4.88	-
Loss tangent (tan)	.001	-
Thickness (h)	1.59	Mm
Operating frequency	3.2	GHz
Length L	50	Mm
Width W	50	Mm
Radius of probe	1	Mm
Radius of coax feed	2	Mm
Type of feed	Co axial line	-

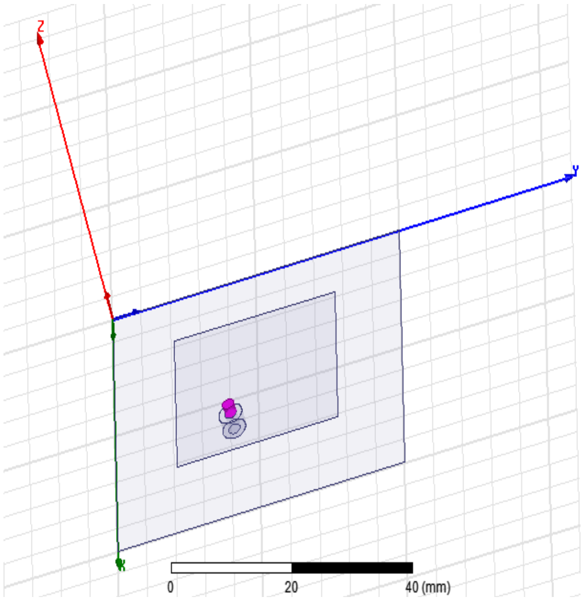

Fig.1: Rectangular microstrip patch antenna

HFSS 13 software is used to design the Rectangular microstrip patch antenna (MPA) at operating frequency at 2.54 GHz.

Simulated result of Return loss and bandwidth of Rectangular Microstrip Patch antenna (MPA) which will provide the base for comparison of parameter is shown in fig 2.

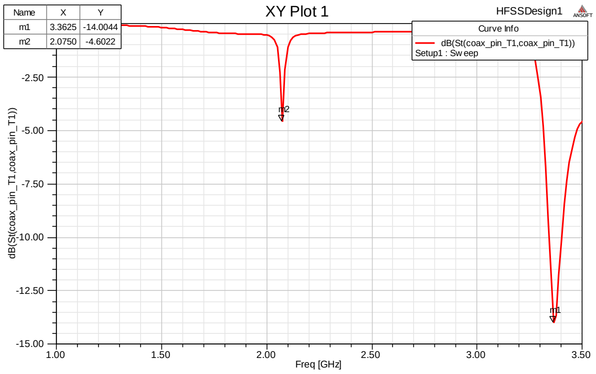

Fig. 2: Simulation of return loss and bandwidth of MPA

The bandwidth of simple MPA is at 72 MHz and Return loss is **-14 dB** at 3.62 GHz and it return loss is at 2.36 GHz is **-5 dB** The microstrip patch antenna has 3D Radiation pattern in HFSS. Return loss or reflection loss is the reflection of signal power from the insertion of a device in a transmission line or optical fiber. It is expressed as ratio in dB relative to the transmitted signal power.

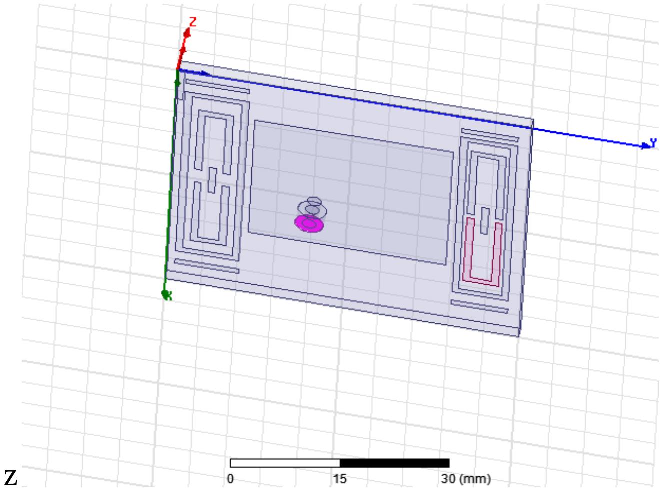

Fig. 3: Design of proposed metamaterial structure at the height of 3.2 mm from ground plane.

This design provides a better bandwidth and return loss[11]. Simulation result of bandwidth and return loss of MPA loaded with metamaterial structure is shown in fig.4. it will touch the return loss of -34.95 dB at 2.4175 GHz. This result is far better than MPA in terms of both parameters. We can see that graph of fig 4 becomes broader at -10 db. So bandwidth will be greater than former simulated graph of fig. 2. So we got the desirable result

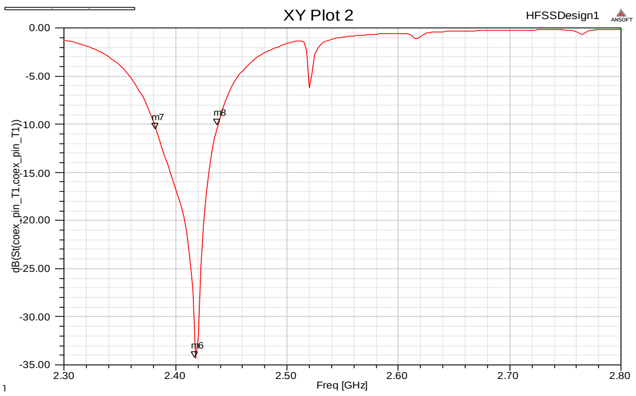

Fig.4: Simulation of Return loss and bandwidth of MPA with proposed metamaterial structure

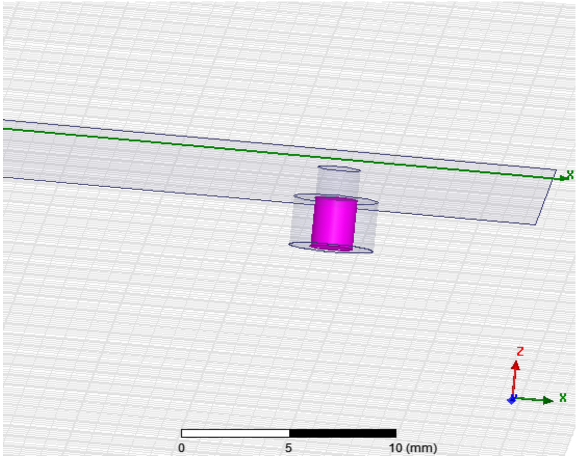

Fig.5: Coaxial feed inserted in the patch

Coaxial feed is used in the analysis with inner radius 1 mm and outer radius 2 mm. Fig 5 shows the side view of insertion. We cut out the substrate part for insertion of coaxial cable. While using feeding, leakage and insertion loss of the structure should be in mind.

Antenna gain is the ratio of maximum radiation intensity at the peak of gain beam to the radiation intensity in the same direction [16] which would be produced by an isotropic radiator having the same input power. Simulation result of MPA is in fig given below. The gain of MPA is 3.612 at 2.54GHz while simulated on HFSS 13. Antenna gain can be increased by cutting the slot technique.it can increase the gain at same frequency also.

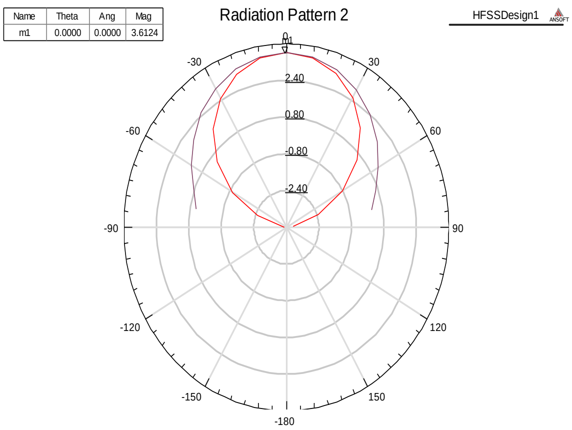

Fig.6: Antenna Gain of MPA

Metamaterial structure already increased the gain of metamaterial antenna up to the mark. We can also increase gain further by cutting the slot in the structure. This is the technique which is widely used in MTM field to get the better result.

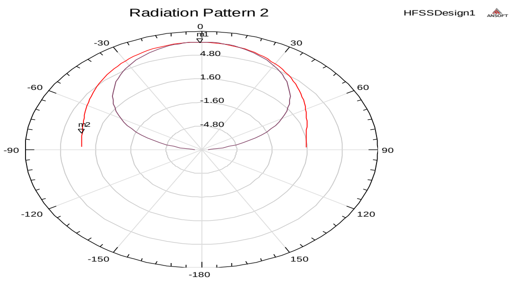

Fig.7: Antenna Gain of MPA with proposed metamaterial structure

4. SIMULATION RESULT AND DISCUSSION:

In this paper, Rectangular microstrip patch antenna loaded metamaterial structure is simulated using HFSS13 software. The proposed design in comparison of MPA alone is far better. This design is operated at 2.54 GHz and it provided bandwidth enhancement. Similarly return loss increases more than 10 dB with metamaterial loaded structure. The reduction of Return Loss ultimately improves the Gain as well as the Directivity of Rectangular Microstrip Patch Antenna. by the slot cutting in the structure, we can increased the gain of antenna.so it is found that the insertion of Meta material structure on Rectangular Microstrip Patch Antenna ultimately Reduce the Return Loss[17] as discussed in the above figure 4.

5. CONCLUSION:

The patch antenna has less bandwidth. So MPA using metamaterial structure has been proposed and discussed in this paper. Better return loss shows that very small amount of waves returned to source so radiated power will increase. The reduction of return loss ultimately improves gain of patch antenna which makes patch antenna more directive as discussed in simulated result. MTM structure reduces the size of antenna which is the demand of current technology. This had been proven metamaterial loading effect enhance the crucial parameter like return loss, gain and directivity etc. of the patch antenna. In future metamaterial will be helping tool in every field from electronics to agriculture. The negative property of metamaterial makes it different from others. Now we can say the dream of veselgo is getting true. Metamaterial has now entered in the optical field which shows the possibility of invisibility name as cloaking. So there is a possibility of using MTM in every field for better result.

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