Designing of Square Microstrip Patch Antenna using Metamaterial Structure

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***Abstract*—In this paper, we design a square microstrip patch antenna using metamaterial. It is designed with two port square microstrip antenna for operating 1-3 GHz frequency range. This provide better bandwidth of 53 MHz with return loss -19.74 dB at 10.204 GHz frequency. We use CST microwave studio for designing the square microstrip patch antenna using metamaterial structure.**

Keywords—Square microstrip antenna, Metamaterial structure, Bandwidth, Return loss.

1. INTRODUCTION

Metamaterials have a property that is not found naturally, it consists of artificial metallic structure which have negative permeability (μ) and permittivity (ε). At the present day, substrates with low dielectric constant are preferred for getting maximum radiation. Thus metamaterial is used to improve the low gain and efficiency in wireless communication. In our project microstrip patch antenna is designed with frequency range 1 to 3GHz. The performance of our fabricated antenna was analyzed and measured. CST Microwave Studio is used to design, simulation, and analyze the antenna.

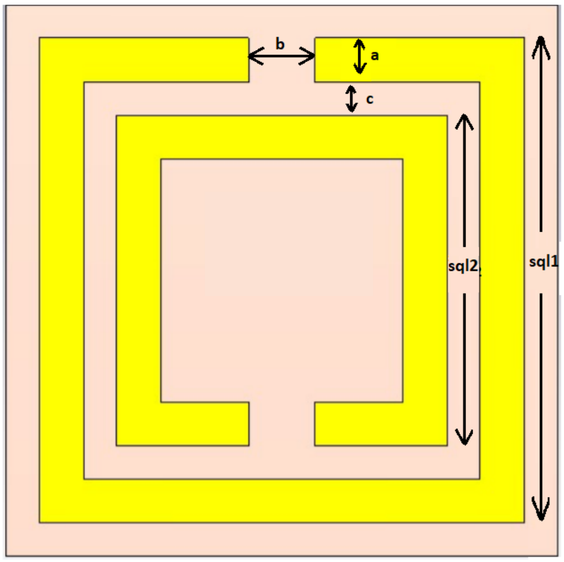

Fig. 1.Front view of unit cell metamaterial antenna structure

Now a days, wireless communication system commonly use microstrip patch antenna for wireless devices as microstrip patch antenna has low weight, low cost, design and technology. Patch antenna requires low profile thus patch antenna consists of thin conducting sheet of about 1 by 1/2 λ_o mounted on surfaces. There is a narrow gap between the patch and the ground plane. The electric field is zero at the centre of patch. The impedance bandwidth and return loss are important parameters of antenna. The disadvantage of antenna is that the bandwidth is limited to few percent. But metamaterial based microstrip patch antenna gives significant improvement in bandwidth and return loss. The proposed square microstrip patch antenna has wide impedance bandwidth. The square geometry is smaller in size for a given frequency as compared to circular geometry. The performance of microstrip antenna depends on dimensions of antenna, substrate material, feeding technique. Generally conducting material like copper or gold is used for patch. Dielectric substrate with low dielectric constant gives better radiation, wide bandwidth and good efficiency.

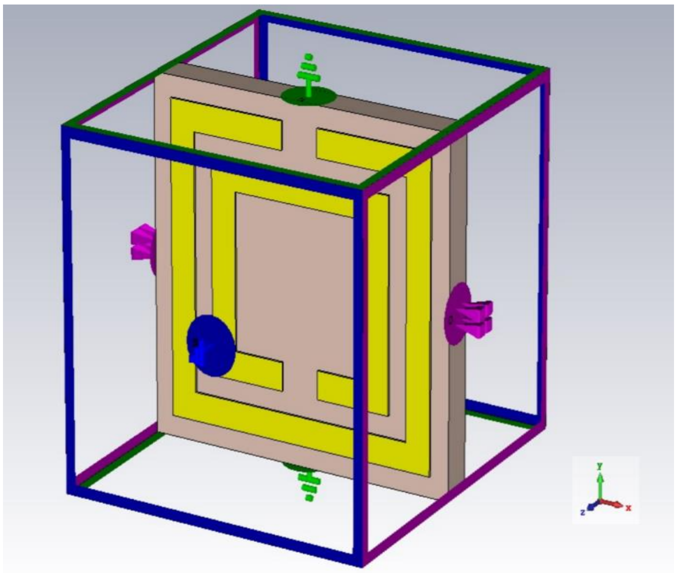

Fig. 2. Boundaries view of metamaterial structure

In this paper, the unit cell of metamaterial antenna has two square rings as shown in figure 1. There is a perfect magnetic axis towards z axis, y axis is perfect electric axis and x axis is open. Thus two waveguide ports are along x axis.

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2. CALCULATIONS

The parameters of square microstrip patch antenna are calculated from following formulas mention below:

a) Calculation of width:

The width W is calculated as

$$W = \frac{C}{2f_o\sqrt{\frac{\epsilon_r+1}{2}}}$$

Where,
C = velocity of light in free space
ϵ_r= dielectric constant of substrate used

b) Calculation of length:

The length L is calculated as

$$L = L_{eff} - 2\,\Delta_L$$

Where,

$$L_{eff} = \frac{C}{2Lf_o\sqrt{\epsilon_{eff}}}$$

c) Effective dielectric constant:

The effective dielectric constant is calculated from

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12sh}{sl}}}\right)$$

Where,
sl= width of substrate
sh = substrate height

d) Resonance frequency

The resonance frequency f_o for microstrip patch antenna is calculated as

$$f_o = \frac{C}{2\sqrt{\epsilon_{eff}}}\sqrt{\left(\frac{m}{L}\right)^2 + \left(\frac{sh}{sl}\right)^2}$$

Where,
m and n are mode along L and W respectively

Dimensions:

Table 1. Dimensions of square metamaterial structure

Dimension of structure	**Symbol**	**Value(in mm)**
Width and length of substrate	Sl	2.5
Width and length of outer Square	sql1	2.2
Width and length of inner Square	sql2	1.85
Gap	B	0.3
Width of ring	A	0.2
Gap between two square	C	0.15
Substrate height	Sh	0.25
Square thickness	D	0.2

3. DESIGN OF FULL STRUCTURE

Design of unit of metamaterial antenna proposed is shown above with dimensions. In full structure, unit cell repeated with periodicity for X and Y plane.

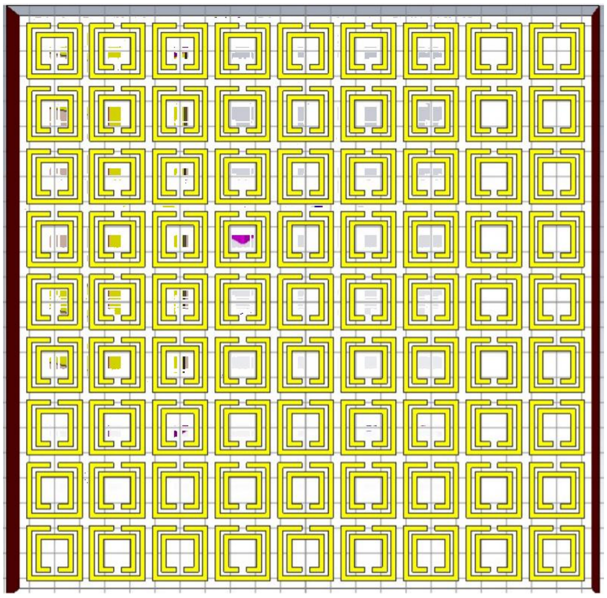

Fig. 3. Front view of metamaterial structure of antenna proposed

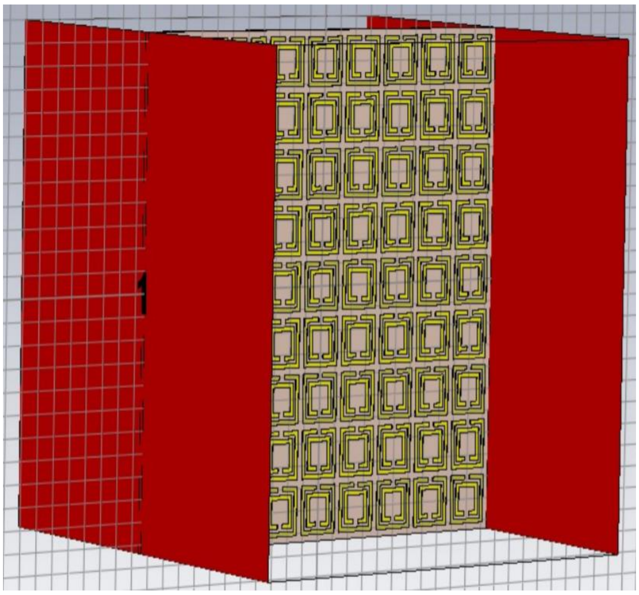

Fig. 4. Two waveguide ports of metamaterial structure of antenna proposed

Two waveguide ports are along with x axis as shown in figure 4. We have done analyze the parameters for full structure in this project. The proposed design has a wide impedance bandwidth and high isolation for both ports.

4. SIMULATION RESULTS

The square microstrip antenna is designed on dielectric material FR-4(lossy) and height from ground plane is sh = 0.25mm. The block of square patch having dimensions 2.2mm x 2.2mm. is cut.

Simulation result with return loss and bandwidth of square antenna is shown in figure 5 and 6.

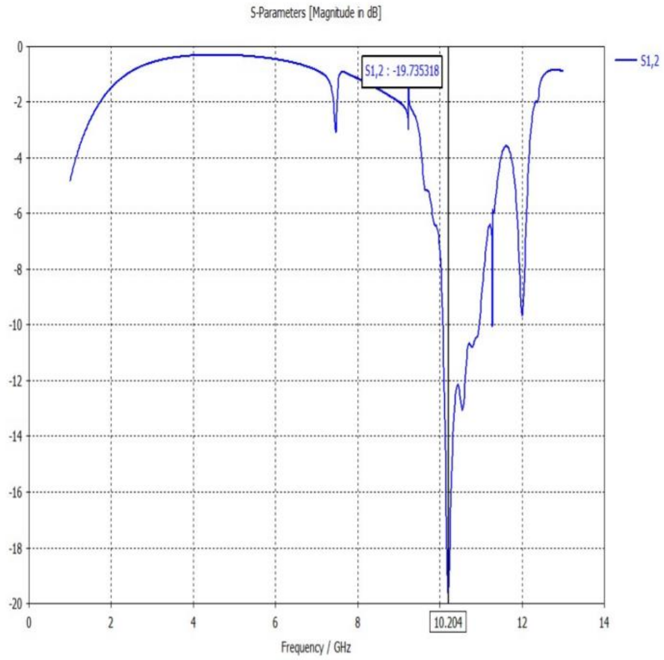

Fig. 5. Simulation result of return loss

Thus the return loss of proposed square antenna is -19.74 dB at 10.204 GHz frequency as shown in figure 5. This is power transmission graph plot from port 1 to port 2 (S1,2).

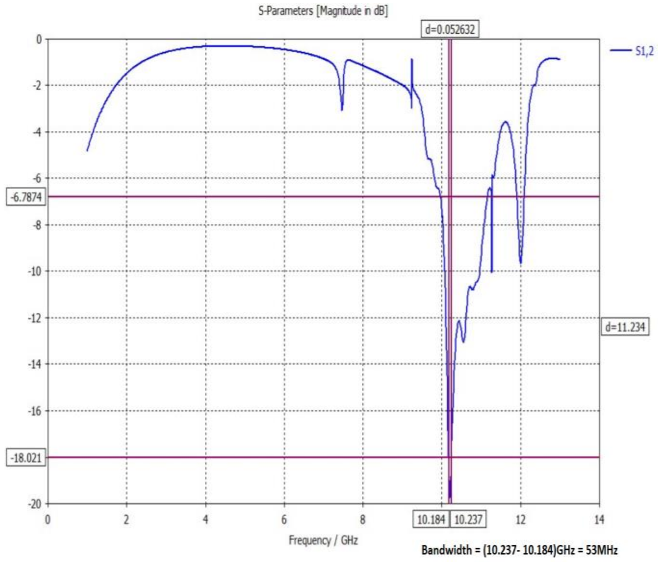

Fig. 6. Simulation result of Bandwidth

Figure 6 shows the impedance bandwidth of 53MHz, which is calculated as

$$\text{Bandwidth} = 10.237\text{ GHz} - 10.184\text{ GHz} = 53\text{MHz}$$

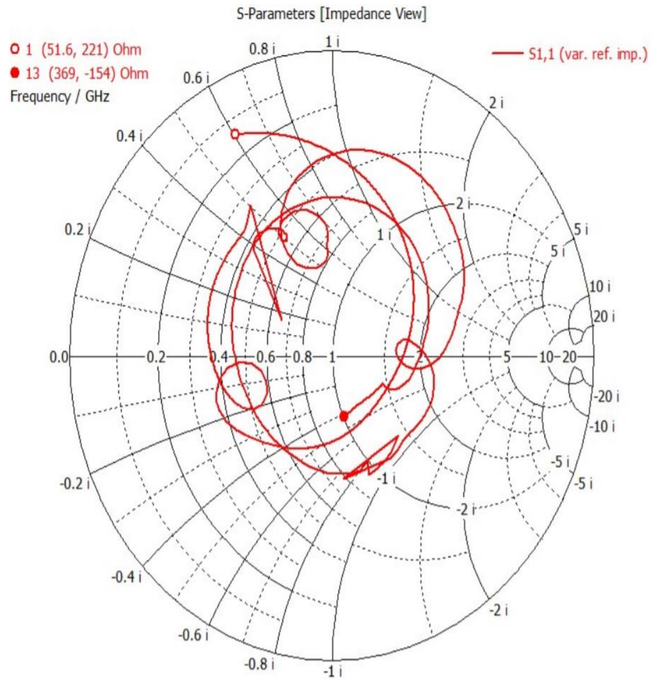

Fig. 7. Z smith chart of s parameter S1,1

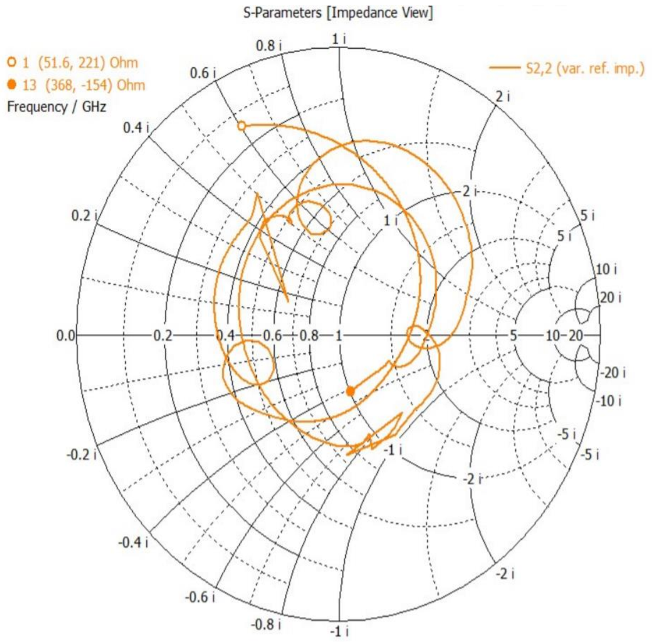

Fig. 8. Z Smith Chart of s parameter S2,2

Smith chart plot represents antenna impedance variation with frequency. Figure 7 and 8 shows the smith chart of S parameter S1,1 and S2,2. Smith chart can be used to convert reflection coefficient to normalized impedance. The smith chart is very helpful for power transmission analysis.

5. APPLICATIONS

Among the antenna applications of microwave and radio frequency substrate materials, the metamaterial is most relevant. The metamaterial antenna is used to design low profile and compact antenna system. Metamaterial can also be used as part of feeding part of antenna system. Metamaterial gives utilization to upgrade the radiation and coordinating properties. At present time the popular application of microstrip antenna design is suitable for

a) wireless local area network (WLAN)

b) world- wide interoperability for microwave access (Wi-MAX)

c) mobile wireless base station

6. FUTURE SCOPE

Square microstrip patch antenna with metamaterial provides wide band and high gain which is almost achieve in this project work. This technology may lay the foundation for anywhere wireless transferring in future.Followings are future scope for improvement and further research

a) metamaterial unit cell be implemented in fractal antennas for frequency independent applications.

b) Metamaterial antenna can be design for ultra wide band applications.

c) Square microstrip patch antenna with metamaterial can be investigated based on SRR wires and ferrites, superconductor, MEMS

d) Reducing the size of microstrip element.

e) Effect of shape parasitic patch

f) This project work can be further taken in research in order to enable tracking systemand other advanced application

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8. CONCLUSION

The design of square microstrip patch antenna using metamaterial structure has completed in CST microwave studio software. We achieved good simulation result to satisfy our requirements. Most of the antennas has main drawback of impedance bandwidth. Our design and analysis of square antenna with metamaterial has focused on impedance bandwidth. Thus simulation results provide wide bandwidth with low return loss and increase total efficiency.

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