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Substrate Height and Dielectric Constant Dependent Performance of Rectangular Micro Strip Patch Antenna

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Abstract
In this paper, Rectangular Microstrip patch antenna has been designed for different substrate heights and dielectric constants of substrate. The proposed antenna is designed at a height 3.2 mm from the ground plane. This paper proposes a new generation of antenna that applies Meta material properties at ground Plane. The paper analyzes the performance of Micro strip Patch Antenna with and without using the Meta material structure. Effect of bandwidth due to change of substrate height and dielectric constant have been investigated. Finally, bandwidth for each substrate height and dielectric constant is measured for selecting the optimal patch antenna.

Keywords - Rectangular micro strip patch antenna (RMPA), Meta material (MTM) Impedance Bandwidth, Return loss.

1. INTRODUCTION

Micro strip patch antennas get more and more importance in these days. A Patch antenna is a type of low profile Microstrip antenna, which can be mounted on a flat surface. It consists of a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane. Patch antennas are simple to design and easy to modify and customize. Factors of the patch antennas can be improved by integrating Metamaterial structure on it. Metamaterial is an artificial material which has negative permeability & permittivity hence named as double negative Metamaterial.
The unusual properties of the Metamaterials [1, 2] were utilized here in a Microstrip Patch Antenna at operating frequency in order to achieve a more efficient Antenna. Metamaterials were first introduced by Veselago [3, 6] in 1967. Veselago first analyzed theoretically the wave propagation in a material with a negative electric permittivity and a negative magnetic permeability [7]. In such a left-handed (LH) material the electric field, the magnetic field, and the wave vector of an electromagnetic wave propagating obey the left-hand rule (instead of the right-hand rule for usual materials). Metamaterials permit Patch Antenna elements to cover a wider frequency range, thus making better use of available space for small platforms or spaces. Some applications for Metamaterial Antennas are wireless communication, space communications, GPS, satellites, space vehicle navigation, and airplanes.

In this paper, we propose corporate feed Rectangular Microstrip patch antennas with three different substrate heights and two different dielectric constants. FR4 with dielectric constant 4.3 and Roger with dielectric constant is 3.0 are used to investigate the effect of bandwidth. All designed antennas are operated at 3.35GHz frequency which is used for Wireless broadband access. The paper also analyses three different frequencies to investigate the effect of bandwidth in Microstrip patch antenna design. Why the Microstrip Patch Antenna is designed at a height 3.2 mm from the ground plane is also analyzed in this paper.

2. ANTENNA DESIGN & METHOD

In this paper, a Rectangular Microstrip patch antenna using Metamaterial is designed. The Three substrate heights are 1.4mm, 1.6mm and 2.0mm with two different dielectric constants of substrates are 4.3 and 3.0 respectively are taken to design the antennas. The operating frequency is 3.35GHz. Design parameters of Rectangular Microstrip Patch Antenna can be calculated from the formulas given below, Used for Designing of RMPA [8, 9]

Calculation of Width (W)

$$w = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

Where,
c = free space velocity of light
ε_r = Dielectric constant of substrate

The effective dielectric constant of the RMPA

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

The actual length of the Patch (L)

$$L = L_{eff} - 2\Delta L \quad (3)$$

Where

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \quad (4)$$

Calculation of Length Extension

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{w}{h}+0.8\right)} \quad (5)$$

3. SIMULATION RESULTS

A rectangular micro strip patch antenna (RMPA), with design of Metamaterials, at a height of 3.2mm from the ground plane is shown in Fig1.

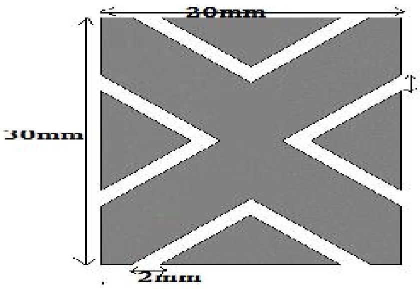

Fig.1: Dimension view of Rectangular micro strip patch antenna at a height of 3.2mm from the ground plane. (Source: CST)

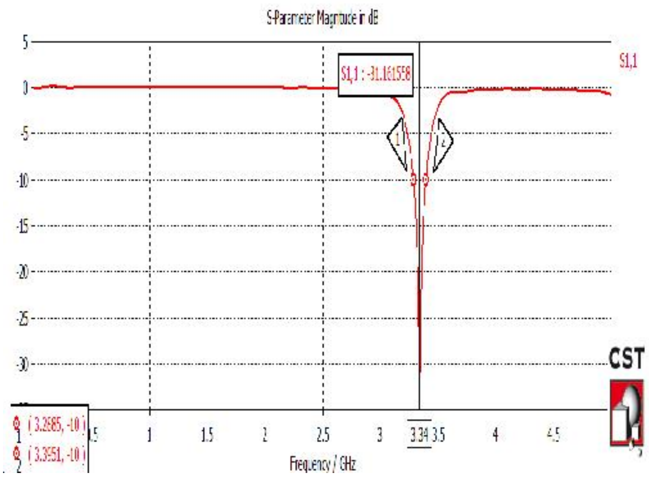

Fig.2: Simulated result of the RMPA along with proposed meta material cover showing Return Loss of -31.16dB & Bandwidth is 106.6MHz. at a height of 3.2mm from the ground plane,with dielectric substrate ROGER.

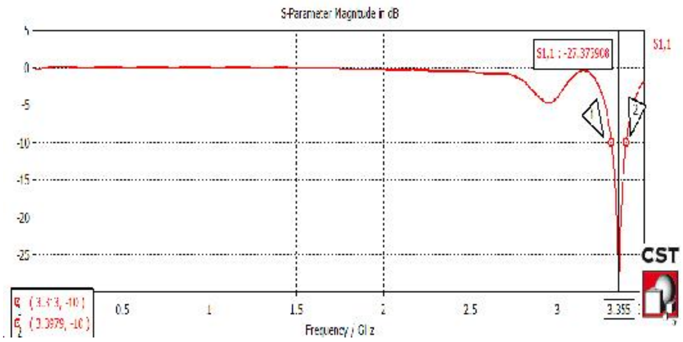

Fig.3: Simulated Result of RMPA with Metamaterials with FR4 dielectric substrate showing Return loss of -27.37dB & Bandwidth is 84.9MHz.

In fig.2&3, we show the comparison of Different dielectric constants, The dielectric constant of the substrate is typically in the range $2.2 \leq \varepsilon r \leq 12$. While increasing the Dielectric constant with the dimension of the antenna so small, the Bandwidth & the efficiency of the system decreases. This comparison is shown in Table1.

Table1: Comparison result at Different Dielectric Constant

Substrate Height	Dielectric constant	Bandwidth	Return loss
1.6	3.0	106.6	`-31.16
1.6	4.3	84.9	-27.37

It is seen from the fig2, with substrate height 1.6mm & Dielectric constant 3.0 the return loss is -31.16dB at frequency of 3.35 GHz, and with substrate height 1.6mm & Dielectric constant is 4.3 the return loss is -27.37dB at frequency of 3.35 GHz. A negative value for return loss shows that this antenna had not many losses while transmitting the signals. The return losses are changed due to the change of substrate heights.

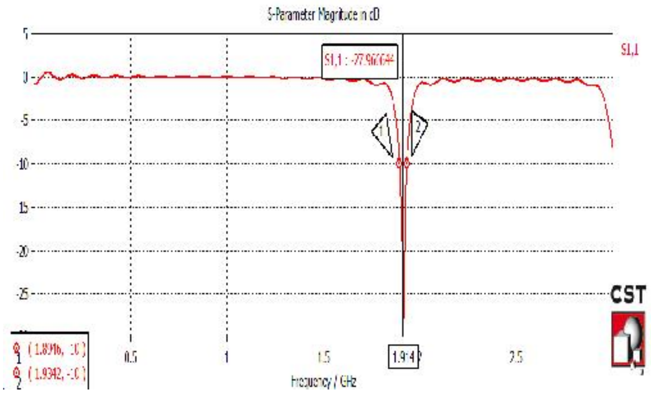

Fig.4: Simulated Result of RMPA with Metamaterials showing Return loss of -27.96dB & Bandwidth is 39.6MHz at a frequency of 1.91GHz.

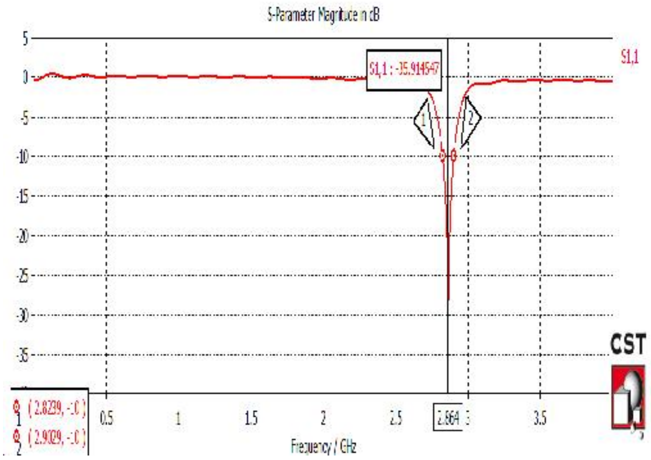

Fig.5: Simulated Result of RMPA with Metamaterials showing Return loss of -35.91dB & Bandwidth is 79.0MHz at a frequency of 2.86GHz.

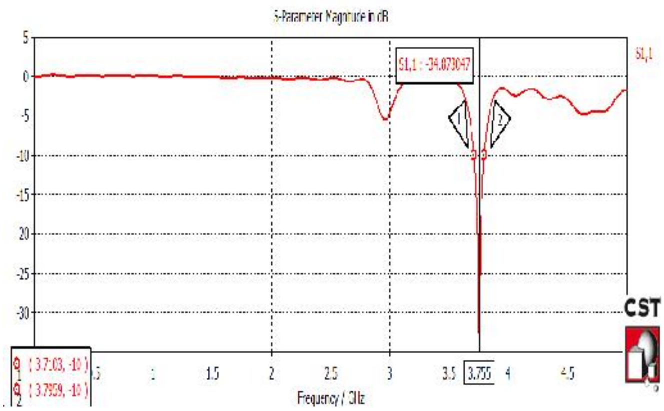

Fig.6: Simulated Result of RMPA with Metamaterials showing Return loss of -34.87dB & Bandwidth is 85.6MHz at a frequency of 3.755GHz.

In fig4, 5 & 6 shows the simulated result of Rectangular Microstrip patch antenna along with Metamaterials with Different Frequency. When the frequency of the antenna is increasing the Bandwidth of the antenna is also increasing. The three fig. show the comparison of three different frequencies at a height of 3.2mm from the ground plane. This comparison result is shown in Table2.

Table2: Comparison Result at different frequency

Substrate Height	Dielectric Constant	Frequency	Bandwidth
1.6mm	4.3	1.91	39.6
1.6mm	4.3	2.86	79.0
1.6mm	4.3	3.75	85.6

It is seen from the fig4, 5 & 6, with dielectric constant 4.3 the Bandwidth is 39.6MHz & return loss is -27.96dB at frequency of 1.91GHz, with dielectric constant 4.3 the Bandwidth is 79.0MHz & return loss is -35.91dB at frequency of 2.86 GHz, and with dielectric constant 4.3 the Bandwidth is 85.6MHz& return loss is -34.87dB at frequency of 3.75GHz.

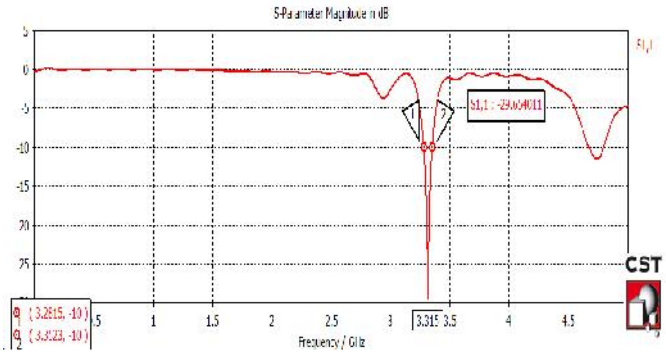

Fig.7: Simulated Result of RMPA with Metamaterials showing Return loss of -29.65dB & Bandwidth is70.8MHz at a height of 2.8mm from the ground plane.

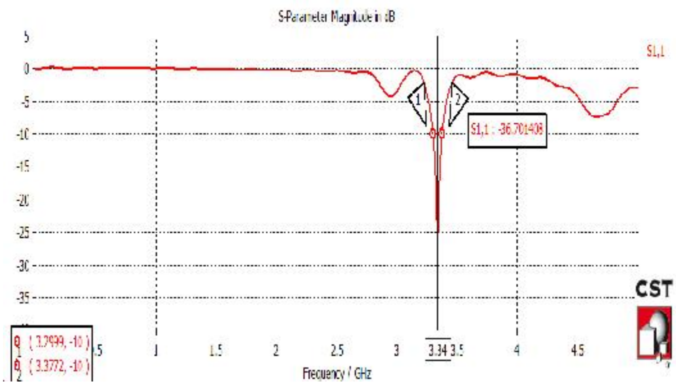

Fig.8: Simulated Result of RMPA with Metamaterials showing Return loss of -36.70dB & Bandwidth is 77.3MHz at a height of 3.2mm from the ground plane.

It is seen from the fig7 & 8, with dielectric constant 4.3 the Bandwidth is 70.8 return loss is -29.65dB at frequency of 3.35 GHz at a height of 2.8mm from the ground plane and with dielectric constant 4.3 the return loss is -36.70dB at frequency of 3.35GHz at a height of 3.2mm from the ground plane.

Table3: Comparison of Different Substrate Height at same frequency

Substrate Height	*Dielectric Constant*	*Frequency*	*Bandwidth*
2.8	*4.3*	*3.35*	*70.8*
3.2	*4.3*	*3.35*	*77.3*
4.0	*4.3*	*3.35*	*No effective*

Table3 shows that when the substrate height is increasing the bandwidth of the antenna is also increasing, because the bandwidth of the antenna is directly proportional to the substrate Height. When the Height of the design is 1.4mm above from the ground plane the bandwidth is approximately 70MHz, but when the Substrate Height is increased shown in Table3 to 1.6mm above the ground plane the Bandwidth is increased upto 7MHz. When we used Height more than 1.6mm the result is not more effective for Microstrip antenna that is why the height of the substrate is taken 1.6mm above the ground plane.

4. CONCLUSION

The Rectangular micro strip antennas can be designed successfully with the variation of substrate heights and dielectric constants at a frequency of 3.35GHz. The observation shows the antenna bandwidth increases with the increase of substrate heights and with the decrease of dielectric constants.

Table1 shows the comparison of different Dielectric Constants at same substrate Height. When the dielectric constant is decreased the Bandwidth of the antenna is increased. The Table2. Shows the comparison of different frequency at 1.6mm height from the ground plane. When the frequency of the antenna is increased the bandwidth of the antenna is also increased because bandwidth is directly proportional to frequency. Table3. Shows the comparison of different substrate height. When we are increasing the substrate height the bandwidth of the antenna is also increasing.

5. REFERENCES

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