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Research Article

Rectangular Microstrip Patch Antenna having New '4 square' Shaped Metamaterial Structure at 7.33 GHz

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Abstract

We present microstrip patch antenna incorporated with left-handed metamaterial at 7.33 GHz. The proposed antenna uses metamaterial structure in the height of 1.6mm from the ground plane. This paper shows the comparison between the microstrip patch antenna theoretical calculation and practical calculation metamaterial structure with the enhancement in antenna gain and reduction in return loss at the same resonant frequency. By use of this combination it has been seen that there is a step up of return loss. These structures are simulated using IE3d Electromagnetic simulator of Zeland software incorporation.

Keywords: *Metamaterial Structure (MTMS), Rectangular Microstrip Patch Antenna, Return Loss, VSWR.*

1. Introduction

There has been a lot of studies published on the improvement of performance of microstrip patch antenna and where metamaterial provides the improvement in desired characteristics without changing in resonant frequency. Paper published in 1986.The concept of a medium having both negative permittivity and permeability was theoretically given and predicted that electromagnetic plane waves in such a medium would have dramatically different characteristics (S.K Chowdhury, 2009). However there was not much progress until the year 1999. Then Prof. J.B.Pendry proposed the design of thin wire structure that exhibits the negative value of permittivity and split ring resonator (SRR) exhibits the negative permeability (P.P Sarkar, 2011). After that Dr.Smith combined the two structures and also fabricated the first structure of metametarial (S.H Chang, 2004). In fact many researches were done to increase the response of microstrip antenna as this type of antenna is desired for its low cost properties but compromises in gain and directivity. According to few studies done the LH MTM could actually increase the directivity (P. P. Sarkar, 2011; R. Wongsan, 2013). The plan metamaterial-based transmission line has attracted much attention since it can be designed to have unusual characteristics (negative phase constant and so on) with abroad pass band and can also be easily constructed on PCBs (Yu Tao, 2011; Andrew R. Weily, 2011).

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2. Theoretical calculation

2.1 Design of the patch antenna

Based on the simplified formulation that has been described, a design procedure is outlined which leads to practical design of rectangular microstrip patch antenna. The procedure assumes that the specified information includes the dielectric constant of the substrate (ε_r), the resonant frequency (f_r), the height of the substrate (h) and the loss tangent (δ).

2.2 Design Calculation

1) Dielectric Constant of the Substrate (ε_r)

The dielectric material that is used in my design of the Microstrip Patch Antenna is Alumina with $\varepsilon r = 4.4$, as this one of the maximum values of the dielectric substrate has been taken in order to reduce the size of the antenna.

2) The frequency of the operation (f_0)

The frequency of operation for the Patch antenna I am trying to design has been selected as 7.33GHz.

3) Height of the dielectric substrate (h)

Microstrip Patch antenna has been designed in order to rule out the conventional antenna as the patch antennas are used in most of the compact devices.

Therefore the height of the antenna has been decided as 1.6mm.

4) Calculation of width formula (w)

$$W = \frac{c}{2f0\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

With the substituting the values of c= 3x108 m/s
fr = 7.33GHz and h = 1.6mm
Width w =0.0205m = 20.5mm

5) Calculation of Effective dielectric constant (εreff)

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

With the substituting the values εr=4.4, h=1.6mm, w=20.5mm Effective Dielectric Constant εreff= 2.74

6) Calculation of effective length (Leff)

$$L_{reff} = \frac{c}{2fr\sqrt{\varepsilon reff}}$$

The values ε_{reff} = 2.74, c= 3x108m/s f_r = 7.33GHz
Leff= 0.012396m = 12.3mm

7) Calculation of the length extension (L) with h=1.5mm, w=30.7mm

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

With the values from h, w and ε_{reff} the L is being calculated as 0.5mm
L= 0.5mm

8) Calculation of the length of the patch (L):

$L = L_{eff} - 2 L$

Where L= 0.5mm, L_{eff}= 12.3mm, L=12.3mm.

3. Simulation Result

The software used to model and simulate the Microstrip patch antenna is Zeland IE3D. which is a full-wave electromagnetic simulator based on the method of moments. It analyses 3D and multilayer structures of general shapes. It has been widely used in the design of MICs, RFICs, patch antennas, wire antennas, and other RF/wireless antennas. It can be used to calculate and plot the parameters, VSWR, current distributions as well as the radiation patterns.

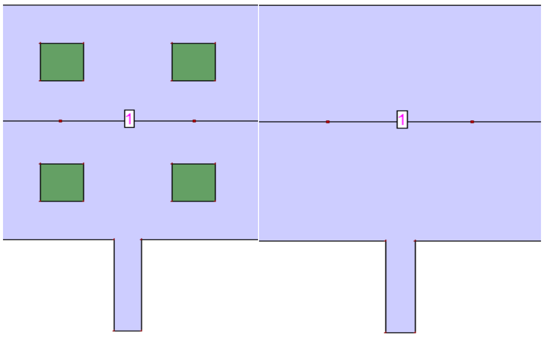

Fig 1: Front view & Back view of microstrip antenna

1) Current Distribution

The 3D current distribution plot gives the relationship between the co-polarization (desired) and cross-polarization (undesired) components. Moreover it gives a clear picture as to the nature of polarization of the fields propagating through the patch antenna.

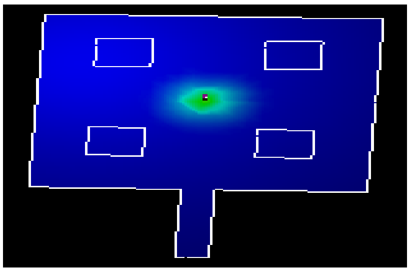

Fig 2: Distribution of current in microstrip patch antenna

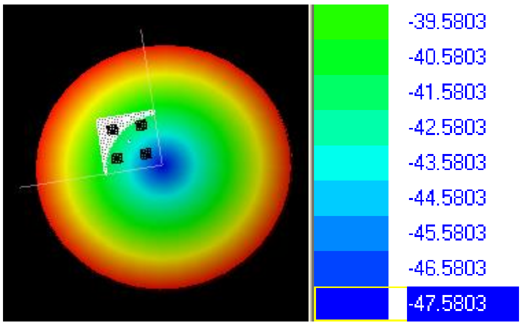

Fig 3: 3-D Radiation pattern of current distribution (Top View)

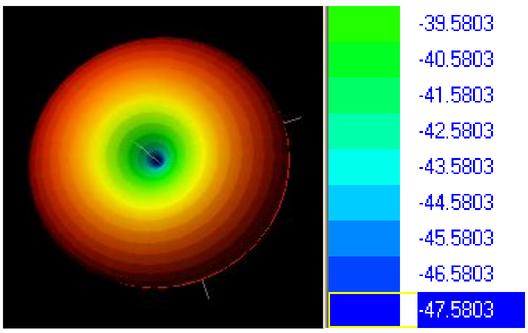

Fig 4: 3-D Radiation pattern of current distribution (Ground View)

2) Return Loss

This is the best and convenient method to calculate the input and output of the signal sources. It can be said that when the load is mismatched the whole power is not delivered to the load there is a return of the power and that is called loss, and this loss that is returned is called the 'Return loss'. This Return Loss is determined in dB as follows:

RL = -20log |Γ| (dB)

During the process of the design of the rectangular patch antenna there is a response taken from the magnitude of S11Vs the frequency (this is known as the return loss), as shown in the figure, just as the verification of the design.

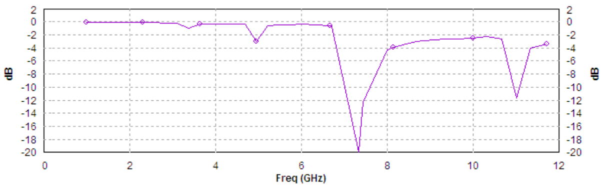

Fig 5: S-Parameter Display

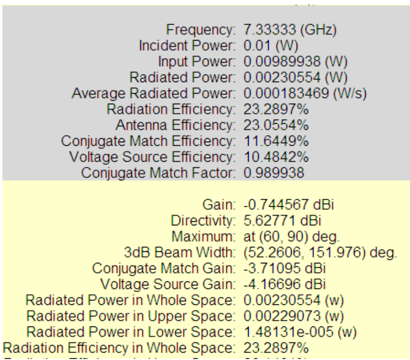

Fig 6: Design Parameter

3) Directivity Vs Frequency

The directivity v/s frequency graph is shown below. The directivity of antenna measures the power density which the antenna radiates in the direction of its strongest emission, versus the power density radiated by an ideal isotropic radiator (which emits uniformly in all directions) radiating the same total power.

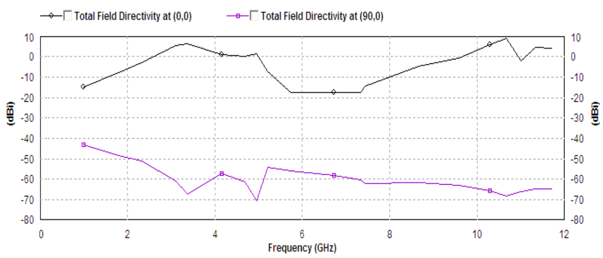

Fig 7: dbi v/s Frequency Graph

In the figure it is shown that the total field directivity at point (0,0) for the required frequency range is between -10dB to -20dB.Similarly the total field directivity at point (90,0) for the required frequency range is between -60dB to -70dB.

4) Field Gain Vs Frequency

The graph given below shows the relation between field gain v/s frequencies. Field gain I usually defined as the ratio of the power produced by the antenna from a far-field source on the antenna's beam axis to the power produced by a hypothetical lossless isotropic antenna, which is equally sensitive to signals from all directions. From the figure it clear that the total field gain at point (0,0) for the required frequency range i.e. 7.33GHz lies between -20dB to -30dB and the total field gain at point (90,0) is between -60dB to – 70dB.

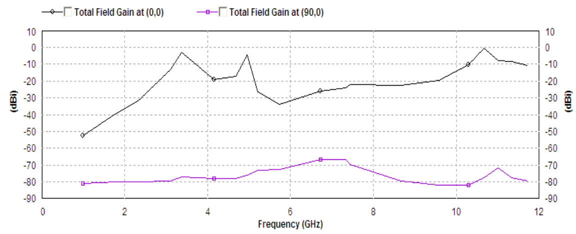

Fig 8: Total field gain v/s Frequency Graph

5) Axial Ratio Vs Frequency

Given below is the graph of axial ratio v/s frequency. The axial ratio is defined as the ratio between the major and minor axis of the polarization ellipse. The axial ratio at (0,0) for the required frequency range i.e. 7.33GHz lies between 80dB to 90dB and that at (90,0) lies at 60dB.

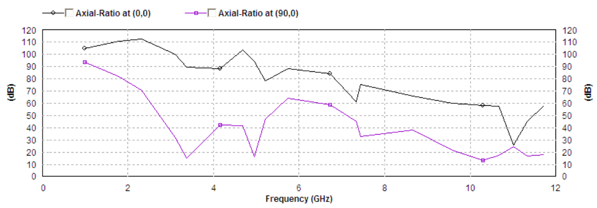

Fig 9 Axial ratio v/s Frequency Graph

4. Result & Discussion

After designing and simulating the Antenna, ensuring that it operates at the desired frequency and recording its Return Loss. The New '4 Square' Shaped Metamaterial Structure is placed on the Rectangular Microstrip Patch Antenna at a height of 1.6 mm from ground plane. Subsequently, the simulation was done on varying distance between the MTMS and Patch Antenna to observe the gain of the Antenna. The Return Loss was also obtained at the same time and been analysed. The simulated results of Rectangular Microstrip Patch Antenna with new '4 Square' Shaped Metamaterial Structure are shown in figure 1 and 9 at 7.33GHz frequency simulation exhibits rectangular microstrip patch antenna alone shows the return loss of -20dB, that ultimately improve the quality of communication. Other supporting plots for various parameters like VSWR are shown here that shows the quality of simulated antenna using metamaterial structure is improving without making variations in other parameters.

5. Application

This antenna appear to be useful for wireless systems that continue to decrease in size, such as emergency communications devices, micro-sensors and portable ground-penetrating radars to search for tunnels, caverns and other geophysical features. Various metamaterial antenna systems can be employed to support surveillance sensors, communication links, navigation systems, and command and control systems.

Conclusions

In this paper, we have investigated the enhancement of the Rectangular Microstrip Patch Antenna performances using new '4 Square' Shaped Metamaterial Structure. We have shown that left handed Metamaterial improves the gain as well as reduces return loss of this Patch Antenna. On making some variations in antenna parameters, gain can be improved up to desired limit but some practical limitation should be taken care while simulating the structure on IE3D Simulation Software.

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