DESIGN AND ANALYSIS OF RECTANGULAR MICROSTRIP PATCH ANTENNA USING METAMATERIAL FOR BETTER EFFICIENCY

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Abstract

In this present work, “Design and analysis of patch antenna using metamaterial (MTM) structure” is proposed for better improvement in the impedance bandwidth and reduction in the return loss at operating frequency 1.89 GHz. The proposed antenna is designed at a height 3.2 mm from the ground plane. This design is operated at 1.89 GHz and 2.553 GHz. At 1.89GHz, the bandwidths are increased up to 29.2 MHz and 19.8 MHz in comparison to 10.1MHz of RMPA alone. The Return loss of proposed antenna are reduced by -32.64dB and -29.26dB at dual band frequency as comparison to -10.26 dB of RMPA alone. Microstrip Patch antenna has advantages than other antenna is lightweight, inexpensive, easy to fabricate and achieve radiation characteristics with higher return loss. CST MICROWAVE STUDIO is used to design the metamaterial based rectangular microstrip patch antenna.

Keywords- Rectangular microstrip patch antenna (RMPA), Metamaterial (MTM), Directivity, Impedance Bandwidth, Return loss, Gain.

I. Introduction

In the recent years the development in communication systems requires the development of low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. The future development of the personal communication devices will aim to provide image, speech and data communications at any time, and anywhere around the world. This indicates that the future communication terminal antennas must meet the requirements of multi-band or wideband operations to sufficiently cover the possible operating bands. The performance of the fabricated antenna was measured and compared with simulation results [1]. Moreover, we have also indicated the appropriate choice of particular metamaterial for different specific purposes like antenna size reduction and other mode modification-related applications [2]. The performance of a rectangular patch antenna array on a metamaterial substrate was studied relative to a similar array constructed on a conventional FR4 substrate [3]. In modern wireless communication systems, the microstrip patch antennas are commonly used in the wireless devices. Therefore, the miniaturization of the antenna has become an important issue in reducing the volume of entire communication system [4].

In modern wireless communication systems, the microstrip patch antennas are commonly used in the wireless devices. The demand in commercial and military wireless systems is due to capabilities of proposed Antenna such as low weight, low profile, low cost, easily combined with design and technology, and relatively simple fabrication. All these antennas can also fabricate using CST simulation software and get very sharp characteristics. Proposed RMPA can be largely used in many wireless communication systems because of their low profile and light weight Microstrip antennas are largely used in many wireless communication systems because of their low profile and light weight [5]. The “patch” is a low-profile, low –gain, narrow – bandwidth antenna. Aerodynamic considerations require low-profile antenna on aircraft and many kinds of vehicles. Typically a patch consists of thin conducting sheet about 1 by 1/2λo mounted on Substrate. Radiation from the patch is like radiation from two slots, at the left and right edges of the patch. The “slot” is the narrow gap between the patch and the ground plane. The patch –to-ground-plane spacing is equal to the thickness t of the substrate and is typically about λo/100. Advantage of patch antenna than several antenna is lightweight and inexpensive. The electric field is zero at the center of patch, maximum at one side, minimum on the opposite side. The important parameters of any type antenna are impedance bandwidth and return loss. The impedance bandwidth depends on parameters related to the patch antenna element itself and feed used. The bandwidth is typically limited to a few percent. This is a disadvantage of basic patch antenna. Metamaterial based rectangular microstrip patch antenna improves the bandwidth and return loss in significant way. CST MICROWAVE STUDIO is a software package for the electromagnetic analysis and design, use to design the metamaterial based rectangular microstrip patch antenna. The software contains four different simulation techniques like transient solver, frequency domain solver, integral equation solver, Eigen mode solver and most flexible is transient solver.
V.G. Veselago in 1968 provided a theoretical report on the concept of metamaterial (MTM) [6]. A Left-Handed metamaterial or double-Negative Metamaterial exhibits negative permittivity and permeability [7]. The currently popular antenna designs suitable for the applications of wireless local area network (WLAN) and world-wide interoperability for microwave access (Wi-MAX) have been reported [8].

II. Design specifications

The RMPA parameters are calculated from the following formulas. Desired Parametric Analysis [9],[10].

Calculation of Width (W):

\[
W = \frac{1}{2f_0 \sqrt{\epsilon_r \epsilon_f + 1}} = \frac{C}{2f_0 \sqrt{\epsilon_f + 1}}
\]  

(1)

Where

\(C\) = free space velocity of light,
\(\epsilon_r\) = Dielectric constant of substrate

The effective dielectric constant of the rectangular microstrip patch antenna:

\[
\epsilon_{\text{eff}} = \frac{\epsilon_f + 1}{2} + \frac{\epsilon_f - 1}{2} \left( \frac{1}{1 + \frac{12h}{W}} \right)
\]  

(2)

Actual length of the patch (L):

\[
L = L_{\text{eff}} - 2\Delta L
\]  

(3)

Calculation of length extension:

\[
\frac{\Delta L}{h} = 0.412 \left( \frac{\epsilon_{\text{eff}+0.3}}{W} + 0.264 \right)
\]  

(4)

III. Analysis of Patch Antenna and Metamaterial Structure with Simulated Results

The Rectangular Microstrip Patch Antenna is designed on FR-4 (Lossy) substrate at 50Ω matching impedance, dielectric constant \(\epsilon_r = 4.3\) and height from the ground plane \(d=1.6\)mm. The parameter of rectangular microstrip patch antenna are \(L=35.8462\) mm, \(W=46.0721\) mm, Cut Width= 5mm, Cut Depth= 10mm, length of transmission line feed= 35.58mm, with width of the feed= 3mm shown in figure1.

The simple RMPA is inspired by metamaterial structure at 1.89 GHz.

Table1. Rectangular Microstrip Patch Antenna Specifications

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Dimension</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric constant</td>
<td>4.3</td>
<td>-</td>
</tr>
<tr>
<td>Loss tangent (tan )</td>
<td>.02</td>
<td>-</td>
</tr>
<tr>
<td>Thickness (h)</td>
<td>1.6</td>
<td>Mm</td>
</tr>
<tr>
<td>Operating frequency</td>
<td>1.89 and 2.553 GHz</td>
<td></td>
</tr>
<tr>
<td>Length L</td>
<td>35.85</td>
<td>Mm</td>
</tr>
<tr>
<td>Width W</td>
<td>46.07</td>
<td>Mm</td>
</tr>
<tr>
<td>Cut width</td>
<td>5</td>
<td>Mm</td>
</tr>
<tr>
<td>Cut depth</td>
<td>10</td>
<td>Mm</td>
</tr>
<tr>
<td>Path length</td>
<td>35.57</td>
<td>Mm</td>
</tr>
</tbody>
</table>

Figure1. Rectangular microstrip patch antenna at 1.89 GHz.

CST-software is used to design the Rectangular microstrip patch antenna (RMPA) at operating frequency 1.89 GHz.
However, their employment raises some problems, such as, difficulty impedance matching or increasing of surface waves in the Substrate that could decline the radiation efficiency and the radiation pattern. Bandwidth of the antenna may be considerably becomes worse [8].

Simulated result of Return loss and bandwidth of Rectangular Microstrip Patch antenna(RMPA) is shown in fig 2.

The bandwidth of simple RMPA is 10.1MHz and Return loss is -10.26 dB. The Rectangular microstrip patch antenna has 3D Radiation pattern at 1.89 GHz as shown in figure8. The radiation pattern shows the directivity of simple RMPA is 6.832 dBi. 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. The return loss is given by:

\[
R_L \ dB = 10 \log \left( \frac{P_r}{P_t} \right) \quad (5)
\]

In this metamaterial design, a split RMPA is design on substrate with 6 mm width. This design gives the better improvement in impedance bandwidth and reduction in return loss.
Figure 5. Simulation of Return loss and impedance bandwidth of RMPA with proposed metamaterial structure at operating frequency 1.89 GHz.

The Return loss of proposed antenna are reduced to -32.64dB and -29.26dB at dual band frequency as comparison to -10.26 dB of RMPA alone. The bandwidths are increased up to 29.2 MHz 19.8 MHz in comparison to 10.1MHz of RMPA alone.

Figure 6. Delivered power to reduced size RMPA is showing above .90 watt

Figure 7. Delivered power to reduced size RMPA loaded with metamaterial structure.

The maximum power deliver to rectangular microstrip patch antenna is above .90 watt. As compared to RMPA alone, maximum power deliver to proposed antenna is increased up to 1 watt.

Figure 8. Radiation pattern of RMPA at 1.89 GHz showing directivity of 6.550 dBi.
The Directivity plot (3D View) represents amount of radiation intensity i.e is equal to 6.9 dBi. The simulated antenna radiates more in a particular direction as compared to the isotropic antenna which radiates equally in all directions, by an amount of 6.9 dBi. From polar plot view of the directivity, it can be seen that at a frequency of 1.89 GHz, directivity is 6.9 dBi, radiation pattern obtained is omnidirectional with main lobe directed at an angle of zero degree, having angular beam-width of 84.5 degree. The magnitude of the main lobe is 6.9 dBi.
The gain plot of RMPA alone gives the gain = 1.531dB at a frequency of 1.89GHz. As compared to RMPA alone the gain of proposed patch antenna is increased up to 4.154 dB at dual band frequency.

Antenna gain is the ratio of maximum radiation intensity at the peak of gain beam to the radiation intensity in the same direction which would be produced by an isotropic radiator having the same input power.

The Smith chart plot represents that how the antenna impedance varies with frequency. The circle cuts the resistive part at 2 on x axis for RMPA alone and cuts resistive parts at 1 and 2.35 on x axis for proposed antenna, which is normalized at 50 ohm for perfect matching. The real utility of the Smith chart, it can be used to convert from reflection coefficients to normalized impedances (or admittances), and vice versa. The smith chart is very useful when solving transmission problems. Above Fig. shows the impedance variation in the simulated frequency range and received impedance matching for proposed antenna at characteristic impedance.

The design of RMPA for 2 GHz has been done. To fabricate the microstrip patch, screen printing is done on the substrate layer by the designing on the AutoCAD, coated with copper.
layer and the ground plane is well covered by tape in order to protect from etching. Etching of the printing plate is done by dilute solution of FeCl₃ till the required substrate is obtained. To get better response care is taken to obtain sharp corners. The plate is taken out and wipe. Drilling and soldering is done in order to connect to the connector.

IV. Simulation Results

In this paper, Rectangular microstrip patch antenna loaded metamaterial structure is simulated using CST-MWS software. The proposed design in comparison to RMPA alone, found that the potential parameters of the proposed antenna is increased. This design is operated at 1.89 GHz and 2.553 GHz. At 1.89GHz, the bandwidths are increased up to 29.2 MHz and 19.8 MHz in comparison to 10.1MHz of RMPA alone. The Return loss of proposed antenna are reduced by -32.64dB and -29.26dB at dual band frequency as comparison to -10.26 dB of RMPA alone. The gain plot of RMPA alone gives the gain = 1.531dB at a frequency of 1.89GHz. As compared to RMPA alone the gain of proposed patch antenna is increased up to 4.154 dB at dual band frequency. The directivity of proposed antenna is increased up to 6.9dB as compared to RMPA alone. The maximum power deliver to proposed rectangular microstrip patch antenna is 1 watt.

V. Conclusion

The main drawback of Patch Antenna was less impedance bandwidth. For this purpose, Design and analysis of patch antenna using metamaterial structure has been proposed and analyzed in this paper. This reduction of return loss indicates that only small amount of reflection waves were returned back to the source and most of the power will be radiated from the patch. The reduction of return loss ultimately improves gain of patch antenna which makes patch antenna more directive. The development of system such as satellite communication, highly sensitive radar, radio altimeters and missiles systems needs very light weight antenna which can be easily attached with the systems and which does not make the system bulky. These requirements are main factors for the development of proposed RMPA. The simulated results provide that, improvement in the bandwidth is 16.9 MHz and the Return loss of proposed antenna is reduced by 20.7 dB. It is clear that we can easily overcome the drawbacks of RMPA by using the properties of Metamaterial (MTM). By using Metamaterial, the maximum power delivered to proposed antenna is 1 watt as compared to the RMPA delivered power of 0.9 watt.

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VII. References


Biographies

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