A DUAL BAND ANTENNA FOR WLAN APPLICATION USING DOUBLE RECTANGULAR PATCH

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Abstract

Rectangular patch has been investigated for the dual band antennas in the wireless communication systems. Microstrip antennas are increasingly being used for many communication applications because of its low profile and light weight advantages. This paper demonstrates a novel and simple dual-band design of the printed rectangular patch antenna. Double rectangular patch with four bridges is investigated for solution of IEEE 802.11b/g (2.4GHz) and 802.11a (5.5GHz). Rectangular patch for 5.5GHz frequency band is printed on the PCB substrate and connected to another rectangular patch for 2GHz frequency band with four bridges to obtain dual band operation in an antenna element. 4-bridges can modify the desired frequency band from its original frequency band by changing its width. The proposed antenna has a low profile and is fed by 50 coaxial line.

Key Words : Dual band antennas, WLAN, Frequency band.
1 INTRODUCTION

Microstrip antennas are the promising candidates for microwave and millimeter applications where low profile, low cost, conformability and ease of manufacture are found out to out-weigh the electrical disadvantages such as narrow bandwidth and low power capability. In arrays, they allow easy integration with active and passive circuits for beam control and signal processing. One major application is design of microstrip antenna arrays which are attractive candidates for adaptive systems in the present and future communication systems.

A microstrip antenna is a light weight structure in the form of printed circuit board like radiating element widely used in high frequency application starting from HF band to microwave and millimeter wave bands. Particularly this is found useful in telemetry, satellite communications, GPS and various military radar systems operating in microwave band. Integrating with the solid state receiver ad transmitter module opens up the possibility of building large antenna array systems with each element being an active individually controlled element. Therefore various forms of low cost signal processing antennas are thus possible. Most radiations from a microstrip line occur when there is discontinuity in the line, there is mismatch of one sort or the other. By enhancing the radiations it is possible to design a compact MSA with reasonable efficiency and a low physical profile. Although this technique is suitable mainly for frequencies above 1GHz, these are used even at low frequencies as low as 100MHz or even less but the surface area tends to become unwieldy while handling.

A microstrip patch antenna is a wide-beam, narrowband antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulting substrate. Because such antennas have a very low profile, they are often mounted on the exterior of the laptops. Microstrip antennas have several advantages compared to conventional microwave antenna, therefore many applications cover the broad frequency range from 100MHz to 100GHz.
Design of microstrip antenna

For a given frequency, there is variety of patch sizes that will resonate at that frequency. But there is always an optimum size which will exhibit a good radiation pattern as well as reasonable efficiency. The actual size of the patch will depend on a number of
factors, such as the relative permittivity of the dielectric $r$ and its thickness $t$-cm, the shape of the patch (usually circular or rectangular) and the overall bandwidth required. The bandwidth required largely determines the thickness of the dielectric but because the dielectric is usually available only in certain thickness, then the width $w$ of the patch may have to be varied from optimum if a particular band is required[1].

**Characteristics of MSA**

They are extremely low profile and conformal to the structure where it is mounted /installed. It is extremely light in weight and structurally robust. The radiation characteristics are easily predictable clearly and very convenient for mass produced at very low manufacturing cost. Easy to achieve dual frequency performance. Ideally suited for MMIC fabrication which makes integration of radiator and feeding systems simpler. Linear polarized MSAs do not need matching sections or thick resonant cavity. Can be easily modified for shaped beam and desired polarizations. since the height of that patch is above the ground plane is small, resonator exhibits a Q of 25 to 100.

**Practical MSA**

MSAs can be used as a standard transmitting or receiving antenna. Transmitting or receiving characteristics can be calculated from the geometry and that its driving point impedance. The transfer function, the driving point input impedance and resonant frequency of MSAs are strongly dependant on its intrinsic properties such as permittivity $r$ effective loss tangent $\tan \delta$ and coaxial feed line characteristics , effective width etc. impedance measurements largely help to perfect the antenna design. Intrinsic properties can be determined by the theory based on cavity model. These two approaches [2] were found useful to design standard MSAs for transmitting and receiving purposes.

Aerospace vehicles, missiles and satellite borne vehicles are some of the practical antennas where MSA has been found very helpful and useful. Here particularly radiation characteristics of MSA get altered significantly in plasma medium and two modes of waves are considered. The electro acoustic wave generated and the EM wave generated by the antenna[3]. For small values of electro acoustic wave propagation constant $Ba$ there is a significant change in the relative shape of radiation pattern due to plasma. However for
higher values of Ba the level of side lobe decreases to a great extent. There is change in magnitude of field intensity in plasma as compared to free space.

**Special MSAs**

Antenna for subsurface radars have mutually conflicting requirements such as low frequency operation for better penetration, broadband characteristics for finer resolution, small size for pinpointing the antenna location and sufficient sensitivity for good SNR of the image. A flat plate antenna pasted/ mounted on building wall is cheaper solution to satellite dish antenna. Here the flat plates and the focal length are chosen such that diffraction effect causes a maximum signal to be delivered to the feed horn. The feed horn aperture is large to capture all energy in the diffraction pattern. In practice, an aperture width approximately equal to the width of a plate is adequate.

**Application of microstrip antenna** Microwave engineering plays very important role in the development of microwave antennas and high resolution radar systems capable of detecting and locating enemy planes and ships. Even today radars into many varied forms such as missile tracking radars, fire control radars, weather detecting radars, air traffic control radars etc., represent a major use of microwave frequencies. In the modern age, microwaves increasingly used in industrial, scientific, domestic and medical applications.

**Losses in microstrip line**

Microstrip transmission lines consisting of a conductive ribbon attached to a dielectric sheet with conductive backing are widely used in both computer and microwave technology. Because such lines are easily fabricated by printed circuit manufacturing techniques, they have technical and economic merit. For a nonmagnetic dielectric substrate, two types of losses occur in a dominant microstrip mode: i) dielectric loss in the substrate and ii) ohmic skin loss in the strip conductor and the ground plane. The sum of these two losses per unit length is in terms of the attenuation factor. The mechanism leading to the power losses and parasitic coupling effects in the microstrip lines are Conductor losses, Dissipation in the dialectical of the substance, Radiation losses, Surface wave propagation. The first two are dissipative effects, where as the other two are parasitic phenomena.
2 EXISTING MICROSTRIP ANTENNA

Currently there are many microstrip antennas available but they have significant disadvantages. They are complex due to the inherent inhomogeneity of the dielectric materials used, multilayered dielectric structures, periodic loading of the substrate to prevent surface waves, aperture coupling of the field to the antenna, use of stacked configuration to achieve larger bandwidth, loading of the antenna to achieve desired antenna characteristics, and integration of the circuit functions with antenna functions. Other problems include narrow band, lower gain, lower power handling capability etc.

3 PROPOSED MICROSTRIP ANTENNA

The current wireless and mobile communication systems have presented new challenges to the design of high-quality transmission antennas and size reduction has been an important issue. The proposed design let the designers reduce the size, weight, and the cost of the components and system for low signal level applications by replacing the more cumbersome waveguide assemblies and components. The fabrication process is well suited for series production of circuits and antennas. Here in order to increase the bandwidth parameter the substrate thickness has been increased and permittivity is reduced. In this case, however antenna can no longer be directly connected with transmission lines and the models derived from microstrip line theory are no longer valid as they assume the substrate is thin. The analysis progress was implemented using SONNET software which provides commercial EDA solutions for high frequency electromagnetic (EM) analysis.

4 BASIC MATERIALS REQUIRED FOR CIRCUIT DESIGN

The basic materials required for monolithic microwave integrated circuits in general, are subdivided into four categories.

Substrate Materials

A substrate of microwave circuit is a piece of substance on which electronic devices are built. The ideal substrate material
should have the following characteristics: high dielectric constant (9 or higher), low dissipation factor or loss tangent, dielectric constant should remain constant over the frequency range of interest and over the temperature range of interest, high purity and constant thickness, high surface smoothness, high resistivity, dielectric strength, and high thermal conductivity.

**Conductor Material**

The ideal conductor materials for microwave circuits should have the following properties: high conductivity, low temperature coefficient of resistance, good adhesion to the substrate, good etchability and solderability, easily deposited or electroplated.

It is possible to obtain good adhesion with high conductivity materials by using a very thin film of one of the poor conductors between the substrate and the good conductor.

**Dielectric and resistive materials**

Dielectric materials are used in monolithic microwave integrated circuits for blockers capacitors and from couple line structures. Resistive materials are used in microwave circuits for biased networks, terminations and attenuators.

### 5 CONSTRUCTION OF A DOUBLE RECTANGULAR PATCH

A practical yet computational rigorous structure was chosen in order to demonstrate the effectiveness and accuracy of the linear elements. The structure is a rectangular patch antenna with center frequency of GHz 7.01. Arlon AD 260A dielectric material with a dielectric constant 2.6 was chosen as the substrate for this antenna. The same material with same dielectric constant is used as the grounded material.

**Design Calculations for rectangular microstrip patch antenna**

The operating frequency, \( f_r = 6.5 \text{GHz} \), \( r = 2.6 \). Thickness of the dielectric medium for arlon medium, \( h \) is given by:

\[
h \leq 0.3 \times \frac{c}{2\pi f_r \sqrt{\epsilon_r}}
\]  

(1)
Width of metallic patch,

\[ W = \left[ \frac{c}{2f_r} \right] \times \left[ \frac{\epsilon_r + 1}{2} \right]^{1/2} \] (2)

length of the metallic patch is

\[ L = \frac{c}{2f_r \sqrt{\epsilon_{reff}}} - 2\Delta l \] (3)

Thus a rectangular microstrip patch antenna was designed theoretically and the design values obtained by using above formulas and the 3D-view of rectangular microstrip patch antenna is shown in the Figure 3.

Figure 3: 3-D view of the rectangular patch microstrip antenna

6 CONSTRUCTION OF A RECTANGULAR PATCH ANTENNA WITH 4-BRIDGES

Microstrip patch antenna was designed by attaching 4-bridges to the rectangular patch with the center frequency of 1.8GHz. Arlon AD260A dielectric material with a dielectric constant 2.6 was chosen as the substrate for this antenna. The same material with same dielectric constant is used as the grounded material.
Design Calculations for rectangular patch antenna with 4-bridges

The operating frequency, $f_r = 7.01\text{GHz}$, $r = 2.6$. Thickness of the dielectric medium for Arlon AD260A, $h$ is given by

$$h \leq 0.3 \times \frac{c}{2\pi f_r \sqrt{\epsilon_r}} \quad (4)$$

Width of metallic patch is given by,

$$W = \left[ \frac{c}{2\pi f_r} \right] \times \left[ \frac{\epsilon_r + 1}{2} \right]^{-1/2} \quad (5)$$

The length of the metallic patch is,

$$L = \frac{c}{2\pi f_r \sqrt{\epsilon_{reff}}} - 2\Delta l \quad (6)$$

Thus a microstrip patch antenna was designed theoretically and the design values are obtained by using equation (4), (5) and (6). Dimensions of the Rectangular patch antenna and 3-D view of the microstrip patch antenna with 4-bridges are shown in the figure.4 and figure.5.

Figure 4: Dimensions of the Rectangular patch antenna with FR-4 as the dielectric substrate
COMPARISON OF DOUBLE RECTANGULAR AND RECTANGULAR PATCH ANTENNA

Table-1. Comparison of Double Rectangular Patch Antenna and Rectangular Patch Antenna With 4-Bridges

<table>
<thead>
<tr>
<th>Comparison of antennas</th>
<th>Double rectangular patch antenna</th>
<th>Rectangular patch antenna with 4-bridges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of runs</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Computer</td>
<td>COMPAQ-PC</td>
<td>COMPAQ-PC</td>
</tr>
<tr>
<td>Frequency Band</td>
<td>6.5 – 10.5 GHz</td>
<td>6.5 – 10.5 GHz</td>
</tr>
<tr>
<td>Estimated Memory</td>
<td>1 MB</td>
<td>1 MB</td>
</tr>
<tr>
<td>Subsections</td>
<td>91</td>
<td>185</td>
</tr>
<tr>
<td>Analysis Time</td>
<td>13 seconds (0 seconds per analysis)</td>
<td>4 minutes 18 seconds (0 seconds per analysis)</td>
</tr>
</tbody>
</table>

Graphical representation of Frequency response of double rect-
angular and VSWR of double Rectangular patch antenna with ArlonAD260A as the base materials is shown in the figure.6, figure7 and figure 8.

Figure 6: Frequency response of double rectangular patch antenna with ArlonAD260A as the base material

Figure 7: VSWR of double Rectangular patch antenna with ArlonAD260A as the base materials

Figure 8: Phase response of double Rectangular patch antenna with Arlon AD260A as the base materials
Magnitude response, VSWR and input impedance graph of double rectangular patch antenna with 4-bridges is shown in the figure 9, 10 and 11.

Figure 9: Magnitude response of rectangular patch antenna with 4-bridges

Figure 10: VSWR graph of a rectangular patch antenna with 4-bridges

Figure 11: Input impedance graph of double rectangular patch antenna
8 CONCLUSION

The design, simulation and experimentation of microstrip patch arrays with beam-steering capabilities are discussed. A 33 square patch array is designed with approximately 35$^\circ$ beam-width and up to 60$^\circ$ electronic scanning capability. Initial design is done via an analytical approximate approach (i.e., the transmission-line model), and then accurate characteristics are determined via numerical simulations. Finally, the parameters of the designed array are measured.

An FDTD based simulation package M-PATCH is prepared and calibrated against other powerful simulators, as well as on canonical microstrip patch structures that are investigated in the literature. The M-PATCH package is then used in performance evaluation of the arrays designed for 1.8 GHz cellular wireless Communication systems. The M-PATCH package is designed to calculate network parameters which requires near field simulations, as well as to obtain radiation patterns which requires near-to-far-field transformation. It is shown here that the package is very effective in simulating microstrip patch structures.

References


