Abstract

This paper highlights the proposed design for a dual band slotted frequency reconfigurable microstrip patch antenna fed through a 50Ω coaxial feed using inset type of a feeding system over the FR4 substrate for resonating between Wi-Fi and Wi-Max frequency bands. The patch antenna is proposed to tune between two frequencies i.e. Wi-Fi frequency (2.4GHz) and the Wi-Max (3.5GHz) with the help of slots. The proposed structure resulted in a gain of 1.94dBi and 3.31dBi for the lower and the upper frequency bands respectively. The measured radiation patterns were Omni directional in the higher band.

Keywords: Wi-Fi, Wi-Max, slotted,

INTRODUCTION

Traditionally wireless systems were designed for single predefined mission. Therefore, the antennas used in these systems also possessed some fixed parameters such as frequency band, radiation pattern, polarization, and gain. Recently reconfigurable antennas (RAs) have gain tremendous research interest for many different applications, for example, cellular radio system, radar system, satellite communication, airplane, and unmanned airborne vehicle (UAV) radar, smart weapon protection. In mobile and satellite communications, reconfigurable antennas are useful to support a large number of standards (e.g., UMTS, Bluetooth, WiFi, Wi-MAX, DSRC). A single multifunctional antenna can replace multiple single functional antennas. In [6] various types of Reconfigurable Antennas and their realization using electronic switches such as PIN diodes have been discussed. However such designs suffer from biasing problems. Planar antennas have been most widely used in wireless communication systems, especially in wireless local area network (WLAN), Worldwide Interoperability for Microwave Access (WiMAX) and Long Term Evolution (LTE) applications. In order to satisfy the WLAN/WiMAX/LTE standards, multiband antennas which operate at 2.4–2.484 GHz/5.15–5.825 GHz for WLAN, 2.5–2.69 GHz/3.4–3.69 GHz/5.25–5.85 GHz for WiMAX are required where in independent tuning can be obtained for a particular frequency bands of interest. In [1], a dual band slotted antenna with Co-planar waveguide feed has been presented for WLAN and Wi-Max applications. The structure resulted in a gain of 2.4dBi and 2.7dBi and a bandwidth of 400MHz and 1.02GHz for the lower and the upper frequency bands respectively. The structure has been simulated on a FR4 substrate of permittivity 4.4 and thickness 1mm. In [2], a tri band slotted Bow tie antenna has been designed targeting 2.5GHz, 3.5GHz and 5.5GHz wireless applications. The structure resulted in a Gain of 2.4dB, 3.0dB and 3.55dB for the lower, middle and the upper frequency bands respectively. The structure has been simulated on a FR4 substrate of permittivity 4.4. The peak boresight gains reported were negative for all the three frequency bands of interest. In [3], a tri band antenna targeting Wireless LAN and WiMAX frequency bands were presented The structure resulted in Gains of about 1dBi, 2dBi and 1.25dB for the lower, middle and the upper frequency bands respectively. The measured radiation patterns were nearly omni directional under azimuth plane and were characterized by the presence of nulls under elevation plane. In [4], a tri-band antenna targeting WLAN and Wi-MAX applications were presented using a Dual U shaped slot. The structure has been simulated on a FR4 substrate of permittivity 4.4. The fractional bandwidths reported were 3.14%, 4.96% and 2.56% for the lower, middle and the upper frequency bands respectively. The simulated radiation patterns were directional. In [5], a dual band antenna has been fabricated on a FR4 substrate of permittivity 4.4 targeting WLAN frequency bands. The structure resulted in two different resonant frequencies of 2.45GHz and 5.8GHz. The peak gains reported were 1.6dBi and 2.33dBi for the lower and the upper frequency bands respectively. The measured radiation pattern was characterized by the presence of nulls under both the lower and the upper frequency bands respectively. In [6], a comparative analysis of various reconfigurable and multiband antenna concepts was presented. The different techniques for realizing Multiband Antennas such as PIN diodes, MEMS switches, and varactors were discussed. In [7], a dual band antenna based on metamaterial planar structure operating in S band and C band is designed and developed for Space and Radar communication Applications using CSRR in the Ground plane. The structure has been designed on a FR4 substrate of permittivity 4.4 with a dimension of 21.7mm X 20.4mm with a substrate thickness of 1.6mm along with Microstrip line feeding technique.
resonates at 2.7GHz, 7.5GHz with the return loss of -17.27dB, -29.63dB, respectively with a -10dB impedance Bandwidth of 6.8GHz. The average Gain of the Antenna is 5.82dB. In [8], a metamaterial based dual band Antenna has been proposed for Wi-Max Application using CSRR. The radiating structure resonates at two different frequencies of 3.5GHz and 5.5GHz. The radiating structure resulted in a return loss of -24.5dB, -31dB, a Bandwidth of 112.1MHz and 92.1MHz for both the lower and the upper bands respectively. The structure has been designed on a Rogers substrate of permittivity 2.2 and resulted in a Gain of 4.5dBi and 5.0dBi for both the lower and the upper bands respectively. In [9], a multiband monopole antenna has been designed on a Rogers substrate of permittivity 3.23 using CSRR. The structure resulted in a gain of -1.0 dBi, 1.0dBi and 4.0 dBi, a return loss value of -25dB, -15.0dB and -20.0dB respectively for 2.4GHz, 3.5GHz and 5.2GHz frequency bands respectively. The radiating structure resulted in a Bandwidth of 440MHz, 200MHz and 200 MHz for the lower, middle and the upper bands respectively. In [10], a dual band patch antenna is designed by loading a U-slot metamaterial structure on the surface of the rectangular patch. The structure has been designed on a FR4 substrate with a thickness of 6mm. The structure resulted in a resonant frequency of 3.58GHz and 5.74 GHz with a return loss value of -16.0dB, -12.5dB and a Bandwidth of 490MHz and 650 MHz for the lower and the upper frequency bands respectively.

**ANTENNA DESIGN**

**METHODOLOGY**

In the proposed work, a dual band Antenna has been designed, simulated and Fabricated on a FR4 substrate of permittivity 4.4 and thickness 1.6mm to tune between Wi-Fi (2.4GHz) and Wi-Max 3.5GHz Frequency band. The length and the width of the patch antenna are selected so as to tune to 2.4GHz frequency band. The length of the patch has been kept at half the guide wavelength corresponding to 2.4GHz. Two symmetrical slots of length 3.5mm by 8.5mm have been cut on the surface of the patch so as to tune to 3.5GHz frequency band of interest. Inset type of feeding technique has been employed for impedance matching between the port and the antenna. The length of the inset feed is kept at 10mm from the edge of the patch to get the required 50 ohms impedance point.

**DESIGN EQUATIONS**

\[ L = \frac{\epsilon}{2f_{c}\sqrt{\varepsilon_{reff}}} - 2\Delta L \]  

\[ L_{p} = L = \text{Length of the patch} \]
\( f_r \) = resonant frequency corresponding to 2.4GHz frequency band
\( \Delta L \) = patch length extension
\( h \) = substrate thickness
\( W \) = width of the patch
\( \varepsilon_{reff} \) = effective permittivity of the substrate

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

\( f_1 = \frac{c}{\sqrt{\varepsilon_{reff} x 4 x l_{slot1}}} \)  

Where
\( f_1 \) = Resonant Frequency corresponding to 3.5GHz.
\( l_{slot1} \) = slot length corresponding to 3.5GHz.

\[
\Delta L = h \times 0.412 \times \left( \frac{\varepsilon_r + 0.3}{\varepsilon_r - 0.258} \right) \left( \frac{h}{W} + 0.8 \right)
\]  

**SIMULATION AND MEASURED RESULTS**

**Figure 3.** Simulated return loss plot of the slotted Antenna resonating at 2.3GHz and 3.5 GHz indicating a value of -13.68dB and -25.2dB for the lower and the upper frequency bands respectively as indicated by markers m1 and m2 on FR4 substrate of permittivity 4.4. The Horizontal Axis represents the Frequency(in GHz) while the vertical axis represents the reflection coefficient(in dB).
Figure 4. Simulated VSWR plot of the slotted Antenna resonating at 2.3GHz and 3.5 GHz indicating a value of 1.47 and 1.11 for the lower and the upper frequency bands respectively as indicated by markers m1 and m2 on FR4 substrate of permittivity 4.4. The Horizontal axis represents the Frequency(in GHz) while the vertical axis represents the normal value of vswr.

<table>
<thead>
<tr>
<th>Name</th>
<th>Freq</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>m1</td>
<td>2.3719</td>
<td>2.3719</td>
<td>1.4768</td>
</tr>
<tr>
<td>m2</td>
<td>3.5628</td>
<td>3.5628</td>
<td>1.1160</td>
</tr>
</tbody>
</table>

Figure 5. Simulated bandwidth of the slotted antenna resonating at 2.4GHz indicating a value of 0.038GHz. The -10dB impedance bandwidth is extending from 2.34GHz to 2.38GHz. The Horizontal axis represents the Frequency(in GHz) while the vertical axis represents the reflection coefficient(in dB).
**Figure 6.** Simulated bandwidth of the slotted antenna resonating at 3.5GHz indicating a value of 0.08GHz. The -10dB impedance bandwidth is extending between 3.52GHz to 3.6GHz. The horizontal axis represents the Frequency (in GHz) while the vertical axis represents the reflection coefficient (in dB).

**Figure 7.** Simulated radiation pattern of the antenna resonating at 3.5GHz under H plane indicating a peak gain of 2.7dB. The radial axis represents the Antenna Gain (in dB) while the angular axis represents the scan angle (in degrees)
Figure 8. Simulated radiation pattern of the antenna resonating at 3.5GHz under E plane indicating a peak boresight gain of -7dB under E plane. The radial axis represents the Antenna Gain (in dB) while the angular axis represents the scan angle (in degrees).

Figure 9. Simulated radiation pattern of the antenna resonating at 2.4GHz under H plane indicating a peak boresight gain of 2.34dB. The radial axis represents the Antenna Gain (in dB) while the angular axis represents the scan angle (in degrees).
Figure 10. Simulated radiation pattern of the antenna resonating at 2.4GHz under E plane indicating a peak boresight gain of 2.34dB. The radial axis represents the Antenna Gain (in dB) while the angular axis represents the scan angle (in degrees).

Figure 11. Measured radiation pattern of the slotted Antenna on FR4 substrate (permittivity 4.4) indicating a peak boresight gain of 3.31dB under E plane at 3.5GHz, as shown by marker m1. The radial axis represents the Gain (in dB) while the angular axis represents the scan angle (in degrees).
Figure 12. Measured radiation pattern of the slotted Antenna on FR4 substrate (permittivity 4.4) indicating a peak boresight gain of 3.14dB under H plane at 3.5GHz, as shown by marker m1. The radial axis represents the Gain (in dB) while the angular axis represents the scan angle (in degrees).

Figure 13. Measured radiation pattern of the slotted Antenna on FR4 substrate (permittivity 4.4) indicating a peak boresight gain of 2.63dB under E plane at 2.4GHz, as shown by marker m1. The radial axis represents the Gain (in dB) while the angular axis represents the scan angle (in degrees).
Figure 14. Measured radiation pattern of the slotted Antenna on FR4 substrate of permittivity 4.4 indicating a peak boresight gain of 1.94dB under H plane at 2.4GHz, as shown by marker m1. The radial axis represents the Gain (in dB) while the angular axis represents the scan angle (in degrees).

Figure 15. Measured bandwidth of the slotted antenna resonating at 4.1GHz (marker 2). The -10dB impedance bandwidth is extending between 3.94GHz to 4.43GHz as indicated by markers 1 and 3 giving a bandwidth of 0.49GHz. The Horizontal axis represents the Frequency (in GHz) while the vertical axis represents the nominal value of the standing wave ratio.
Figure 16. Measured return loss plot of the antenna resonating at 2.6GHz (marker 1) and 4.1GHz (marker 2) indicating a value of -9.0dB and -44.0dB as shown by markers 1 and 2. The Horizontal axis represents the Frequency (in GHz) while the vertical axis represents the reflection coefficient (in dB).

Figure 17. Measured VSWR plot of the antenna resonating at 2.6GHz (marker 1) and 4.1GHz (marker 2) indicating a value of 2.11 and 1.02. The Horizontal axis represents the Frequency (in GHz) while the vertical axis represents the normal value of vswr.
RESULTS AND DISCUSSIONS

Table 1. Comparison between the simulated and measured value of the Dual band Slotted Microstrip patch Antenna simulated on a FR4 substrate ($\varepsilon_r=4.4$ & thickness 1.6mm) for resonating between Wi-Fi & Wi-Max

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Antenna parameters</th>
<th>Simulated</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Resonant Frequency</td>
<td>2.36GHz</td>
<td>3.5GHz</td>
</tr>
<tr>
<td>2</td>
<td>Return Loss</td>
<td>-14.3dB</td>
<td>-25.2dB</td>
</tr>
<tr>
<td>3</td>
<td>Bandwidth</td>
<td>38.0MHz (2.34GHz to 2.38GHz)</td>
<td>80.0MHz (3.524GHz to 3.609GHz)</td>
</tr>
<tr>
<td>4</td>
<td>VSWR</td>
<td>1.47</td>
<td>1.18</td>
</tr>
<tr>
<td>4</td>
<td>Gain</td>
<td>2.34dB (E &amp; H)</td>
<td>2.7dB (H)</td>
</tr>
</tbody>
</table>

![Figure 6.19](image)

Figure 6.19 Comparison of the Simulated and measured Antenna performance parameters using FR4 substrate for Resonating between Wi-Fi(2.4GHz) and Wi-Max(3.5GHz).

RESULTS AND DISCUSSIONS

The Results of the slotted antenna have been reported in Table 1. The simulated return loss values were close to -14.3 dB & -25.25dB in the lower and upper frequency bands respectively indicating that the antenna radiates more efficiently in the higher band when compared to lower Frequency band of interest. The simulated vswr values were close to 1.47 in the lower band as against 1.1 in the higher band indicating a poor impedance matching in the lower Frequency band of interest. The simulated and the measured Gains agree well. The lowest reported measured Gain were 1.94dB under H plane at 2.4GHz while the highest reported Gain were 3.31dB under E planes at the upper band. The measured Gain variation was between the range of 1.94dB to 3.31 dB across both the bands. The measured Bandwidths reported were 0 MHz and 490MHz for the lower and the upper frequency bands respectively. The measured bandwidths were high in the upper band when compared to lower band. The measured radiation pattern were characterized by the presence of nulls in both the upper and the lower frequency bands of interest. The measured gains were comparatively higher when compared with simulated across both the frequency bands of interest.

CONCLUSION

The Antenna resonates weakly in the Wi-Fi band when compared to the Wi-Max band. The measured peak Gains were in the range of 1.94dB to 3.31dB. The measured radiation patterns were nearly omnidirectional in the upper band when compared to the lower frequency band of interest.
ACKNOWLEDGMENT

The Authors would like to thank Dr. Chandrika Sudheendra Group Director, ADE and Mr. Diptiman Biswas Scientist F, FTTT division ADE, DRDO for having permitted to carry out Antenna characterization and measurement of radiation pattern in the Anaechoic Chamber.

REFERENCES


