The International Conference on Advanced Wireless, Information, and Communication Technologies (AWICT 2015)

Dual Band Slotted Antenna For Radar And Automotive Applications

Meriem Ben Abdallah\textsuperscript{a}, Jamal Bel Hadj Tahar\textsuperscript{b}

\textsuperscript{a}National School of Engineers of Sousse, BP 264, Erriadh 4023 Sousse, Tunisia
\textsuperscript{b}National School of Engineers of Sousse, BP 264, Erriadh 4023 Sousse, Tunisia

Abstract

This paper presents the design of a new rectangular microstrip patch antenna on a low resistivity silicon substrate fed by microstripline to operate for millimeter band applications. The slots are used to achieve good impedance matching to increase bandwidth. The proposed antenna is designed and optimized based on 3D EM simulations studies, presents a low profile dual band antenna with small size of 0.64mm x 1mm operating at 60 GHz and 77 GHz with a relatively significant gain for radar applications and communication at very high speed in an automotive environment.

Keywords: microstrip patch antenna; dual band; impedance bandwidth

1. Introduction

The rapid development of wireless communication systems at millimeter band has increased the demand for compact antenna with high gain and wideband operating frequencies. Microstrip patch antenna has advantages such as low profile, light weight and low cost fabrication. Moreover, development on silicon technology has made millimeterwave applications achievable for mass production. However, microstrip patch antenna designed on silicon shows performance degradation due to excitation of surfaces waves in high-index materials which causes lower efficiency, reduced bandwidth and degraded radiation pattern. There are numerous and well-known methods to increase the bandwidth of antennas, including increase of thickness, the use of low dielectric substrate, slotted patch antenna, the use of various impedance matching and feeding techniques, and the use of multiple resonators[1]
The design of multi-band antennas was the subject of several research studies [2],[3]. The technology insertion slots is used [4],[5]. In [6], a triple band h shape slotted microstrip patch antenna is presented for working for dual GSM and single ISM band frequency at 0.9 GHz, 1.8 GHZ and 2.45 GHz. In 7, the authors propose a microstrip patch antenna composed of two slots of different dimensions and fed by 50ohm coaxial feed for millimeter wave wireless applications at 26 GHz, 31 GHZ and 35 GHZ. This paper presents a new modified rectangular microstrip patch antenna with inverted T shaped slot for dual band operation at 60 GHz and 80 GHz suitable for automotive applications. The design employs 50 Ω microstrip line feeding and simulated using High Frequency Structure Similator (HFSS).

2. Antenna design

The theoretical analysis is based on the transmission lines model [8]. The antenna is designed with silicon substrate of 200m thickness and relative permittivity of 11.9. The length and width of the patch were calculated approximately

\[ W = \frac{1}{2f_r \sqrt{\mu \varepsilon_0}} \times \sqrt{\frac{2}{\varepsilon_r + 1}} \]  

(1)

And the length of the antenna

\[ L = \frac{1}{2f_r \sqrt{\varepsilon_{eff} \mu \varepsilon_0}} - 2\Delta L \]  

(2)

Where

\[ \Delta L = 0.41h \frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258} \times \frac{W}{h} + 0.264 \]  

(3)

And

\[ \varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2 \sqrt{1 + 12 \frac{h}{W}}} \]  

(4)

Where \( f_r \) (in Hz) is the resonant frequency, \( L \) and \( W \) are the length and width of the patch, in mm, respectively and \( \varepsilon_r \) is the relative dielectric constant.

The simulation has been done using HFSS based on Finite Element Method (FEM).

3. Parametric study

The geometry of the proposed antenna is shown in figure 1

![Fig. 1. Geometry of the proposed slotted microstrip patch antenna](image-url)
The dimensions are given in table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value(mm)</th>
<th>Parameter</th>
<th>Value(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_p$</td>
<td>0.64</td>
<td>$W_s^2$</td>
<td>0.2</td>
</tr>
<tr>
<td>$W_p$</td>
<td>1</td>
<td>$P_2$</td>
<td>0.16</td>
</tr>
<tr>
<td>$L_f$</td>
<td>0.85</td>
<td>$L_s^3$</td>
<td>0.13</td>
</tr>
<tr>
<td>$W_f$</td>
<td>0.17</td>
<td>$W_s^3$</td>
<td>0.12</td>
</tr>
<tr>
<td>$Y_0$</td>
<td>0.27</td>
<td>$P_3$</td>
<td>0.78</td>
</tr>
<tr>
<td>$L_s^1$</td>
<td>0.32</td>
<td>$L_s^4$</td>
<td>0.13</td>
</tr>
<tr>
<td>$P_1$</td>
<td>0.6</td>
<td>$P_4$</td>
<td>0.02</td>
</tr>
<tr>
<td>$L_s^2$</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Geometric Parameters of the proposed antenna.

The effect of the geometric parameters is investigated in this part. The following parameters are selected for this study: horizontal slot length $L_s^1$, horizontal slot width $W_s^1$, vertical slot length $L_s^2$ and vertical slot width $W_s^2$. To accurately understand the influence of these parameters, only one parameter is studied at each time while others are kept constant. At the beginning, only one slot is considered. Figure 2 shows the effect of varying the horizontal length slot $L_s^1$ placed at $P = 0.9 \text{mm}$ with $W_s^1 = 0.03 \text{mm}$. It can be found that the resonant frequencies at higher band decreases and the resonant frequency at the lower band is kept almost unchanged.

![Fig. 2. The effect of varying the length of the first slot on antenna return loss](image)

Figure 3 shows the effect of varying the position of this horizontal slot with length fixed as $L_s^1=0.32 \text{ mm}$ .It shows that the two resonant frequencies at higher band are most influenced. This variation affects mainly their return loss.

![Fig. 3. The effect of varying the position of the first slot on antenna return loss](image)
Figure 4 shows that changing in horizontal slot width substantially affects the return loss of the frequency at 67 GHz. It affects little the other two frequencies.

![Figure 4. The effect of varying the width of the first slot on antenna return loss](image1)

Figure 5 and figure 6 show the effect of adding a second vertical slot. A parametric study is made to arrive at the best dimensions of the T-shaped slot as shown in table 2.

![Figure 5. The effect of varying position of the second slot on antenna return loss](image2)

![Figure 6. The effect of varying the width of the second slot on antenna return loss](image3)

Two others slots have been inserted and optimized in the same manner as the inverted T shaped slot to achieve more bandwidth in the W band. The optimal dimensions found for those slots are shown in table 2. The return loss comparison between the microstrip antenna with and without the third and fourth slots is shown in figure 7.
4. Results of simulation and discussions

The parametric study and simulation has achieved an antenna operating in two bands frequency. These frequencies fit well with several transmission applications in free space in the band $60\,\text{GHz}$ and $77\,\text{GHz}$ where integrability is a required parameter to a relatively small size of $1\,\text{mm} \times 0.64\,\text{mm}$.

Figure 8 shows the effect of slots insertion on the bandwidth enhancement and the return loss.

<table>
<thead>
<tr>
<th>HFSS</th>
<th>Frequency(GHz)</th>
<th>S11(dB)</th>
<th>Bandwidth(GHz)</th>
<th>Bandwidth(%)</th>
<th>Gain(dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60.3</td>
<td>-38.6</td>
<td>2.45</td>
<td>4.06</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>77.5</td>
<td>-26.6</td>
<td>4.45</td>
<td>7.03</td>
<td>2.57</td>
</tr>
</tbody>
</table>

Table 2. Characteristics of operating frequencies of the proposed antenna

The inverted T shaped slot insertion provides 50% bandwidth enhancement at lower band at $60\,\text{GHz}$ and provide a second operating frequency at W band with $1.8\,\text{GHz}$ bandwidth which correspond to 2.33%. S3 and S4 slots insertion provides more bandwidth enhancement at this band. It allows more than $4\,\text{GHz}$ bandwidth which corresponds to more than 6% bandwidth which means 122% enhancement.
This proposed antenna provides more bandwidth at both V and W band than in [2] but lower gain. This work can be extended to provide better gain by enhancing the substrate performance through micromachining technology and other techniques.

5. Conclusions

A novel slotted rectangular microstrip patch antenna fed by 50 Ω microstripline has been studied, modeled and simulated. The proposed antenna operates in two frequency bands V and W. The developed structure is small in size with the characteristics of operation and radiation desired for applications in the automotive environment.

6. References


