e-Shaped Slot Antenna for WLAN Applications
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Abstract—This paper presents an e-shaped slot antenna for wireless communications. The antenna is designed for dual frequency bands 2.4–2.52 GHz and 4.82–6.32 GHz, which support WLAN communications coverage IEEE 802.11b/g (2.4–2.4835 GHz), IEEE 802.11j (4.90–5.091), IEEE 802.11a (5.15–5.35 GHz), and IEEE 802.16d (5.7–5.9 GHz). The bandwidth at low resonant frequency and high resonant frequency are about 0.12 GHz and 1.5 GHz, respectively. The simulation results of e-shaped slot antenna are analyzed by using Method of Moment (MoM) from IE3D Software.

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1. INTRODUCTION
The e-shaped slot antenna fed by microstrip line is one type of microstrip antenna which has advantages such as: low profile, lightweight and easy to fabrication \[1\]. The antenna was designed for two frequency bands and referred to the guided wavelength. The IE3D software as referred in \[2\] was used to analyze the proposed antenna.

In this paper, a microstrip fed e-shaped slot antenna is presented. The design objective is to satisfy Wireless Local Area Network (WLAN) of IEEE 802.11b/g/j/a and IEEE 802.16d. Method of Moment was applied to evaluate the characteristics of the proposed antenna. Although many researchers have studied the other shape of antenna, but this e-shaped slot antenna is the new shaped which we will purpose and controlled for dual frequency with matching resonant frequency was rarely investigated. Therefore, the effect of varying width of slot antenna was investigated in this paper by using simulation software. The simulation results show that this antenna can be applied to serve WLAN applications.

2. ANTENNA STRUCTURE
This antenna was designed on RT/Duroid 5880 with 1.575 mm of thickness, \(h\), and 2.2 of dielectric constant, \(\varepsilon_r\). The width of microstrip feed line (\(w\)) is designed to match impedance of characteristic impedance of transmission line 50 ohms which can be calculated by following:

\[
\frac{w}{h} = \frac{2}{\pi} \left\{ B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r} [\ln(B - 1)] + 0.39 - \frac{0.61}{\varepsilon_r} \right\}
\]

(1)

where

\[
B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}}
\]

In this case, \(w = 4.7\) mm.

The wave length (\(\lambda_g\)) in the substrate of this antenna can be calculated from following equations

\[
\lambda_g = \frac{c/f}{\sqrt{\varepsilon_{eff}}}
\]

(2)

where \(\varepsilon_{eff}\) is the effective dielectric constant:

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

(3)
In this case, $\lambda_g$ at frequency 2.4 GHz is 91.66 mm and $\varepsilon_{\text{eff}}$ is 1.86.

The configuration of this antenna is shown in Figure 1 which has dimension of $27 \text{ mm} \times 17.3 \text{ mm}$. ($A \times B$)

3. FINDING THE DUAL FREQUENCY FOR WLAN

The length/dimension of e-shaped slot antenna in each side are $A = 0.3 \lambda_g(27 \text{ mm})$, $B = 0.2 \lambda_g(17.3 \text{ mm})$, $C = 17 \lambda_g(15.85 \text{ mm})$, and $D = 0.1 \lambda_g(9.2 \text{ mm})$. The parameters in width of slot antenna are:

- $S_{B1}$ = width of upper slot in $y$-axis
- $S_{B2}$ = width of lower slot in $y$-axis
- $S_{A1}$ = width of upper slot in $x$-axis
- $S_{A2}$ = width of middle slot in $x$-axis
- $S_{A3}$ = width of lower slot in $x$-axis

In this case, we fixed the widths of three slots ($S_{A1}$, $S_{A2}$, $S_{A3}$) in $x$-axis to 1 mm. To find the dual frequency which match to the 50 ohms transmission line, we propose 2 steps for achieving the WLAN covering IEEE 802.11 a/b/g/j and IEEE 802.16d are as follows:

**Step 1:** $S_{B1} = S_{B2}$

Varying $S_{B1}$ and $S_{B2}$ to 1 mm, 2 mm, 3 mm, 4 mm, 5 mm. (The length of microstrip line is adjusted for match impedance of 50 ohms.)

The simulation result of return loss ($S_{11}$) is shown in Figure 2. Table 1 displays the results of return loss and bandwidth. The results show that when increasing the width of slot, the bandwidth...
and resonant frequency are increased, while low resonant frequency is slightly increased as shown in Figure 2. The simulation of low resonant frequency and high resonant frequency are shown in Figure 3, when varying S\textsubscript{B1} and S\textsubscript{B2}.

Table 1: The simulation results of S\textsubscript{11} and bandwidth in the case of Step 1.

<table>
<thead>
<tr>
<th>S\textsubscript{B1}, S\textsubscript{B2} (mm)</th>
<th>S\textsubscript{11}\textsubscript{B1} (dB)</th>
<th>Low Resonant Freq. (GHz)</th>
<th>Bandwidth (GHz)</th>
<th>S\textsubscript{11}\textsubscript{B2} (dB)</th>
<th>High Resonant Freq. (GHz)</th>
<th>Bandwidth (GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-30.41</td>
<td>2.26</td>
<td>0.04 (2.24-2.28)</td>
<td>-30.06</td>
<td>3.98</td>
<td>0.12 (3.90-4.02)</td>
</tr>
<tr>
<td>2</td>
<td>-30.45</td>
<td>2.34</td>
<td>0.08 (2.30-2.38)</td>
<td>-30.12</td>
<td>4.36</td>
<td>0.22 (4.22-4.44)</td>
</tr>
<tr>
<td>3</td>
<td>-28.67</td>
<td>2.40</td>
<td>0.10 (2.36-2.46)</td>
<td>-26.62</td>
<td>4.72</td>
<td>0.38 (4.48-4.86)</td>
</tr>
<tr>
<td>4</td>
<td>-31.20</td>
<td>2.46</td>
<td>0.12 (2.40-2.52)</td>
<td>-22.92</td>
<td>5.06</td>
<td>0.58 (4.72-5.30)</td>
</tr>
<tr>
<td>5</td>
<td>-28.59</td>
<td>2.50</td>
<td>0.12 (2.44-2.56)</td>
<td>-17.59</td>
<td>5.34</td>
<td>0.70 (4.98-5.68)</td>
</tr>
</tbody>
</table>

Figure 3: Effect of varying S\textsubscript{B1}, S\textsubscript{B2} in the case of Step 1.

**Step 2: S\textsubscript{B1} ≠ S\textsubscript{B2**

Choosing the appropriate value of S\textsubscript{B1} and S\textsubscript{B2} from step 1 that are S\textsubscript{B1} = 4 mm and S\textsubscript{B2} = 4 mm. Adjusting S\textsubscript{B1} to 5 mm for wideband at high frequency.

The simulation result of return loss (S\textsubscript{11}) is shown in Figure 4 and Table 2. The bandwidth of low resonant frequency is same as step 1 that is 0.12 GHz (2.4 GHz–2.52 GHz), and bandwidth of

Figure 4: Characteristics of return loss in the case of Step 2.
high resonant frequency is 1.50 GHz (4.82 GHz–6.32 GHz), which is wideband frequency.

Finally, the bandwidth at $S_{11} = -10$ dB of lower resonant frequency is 4.88% and higher resonant frequency is 26.9%.

Table 2: The simulation results of e-shaped slot antenna in the case of $S_{B1} = 5$ mm and $S_{B2} = 4$ mm.

<table>
<thead>
<tr>
<th>Low Resonant Freq. (GHz)</th>
<th>$S_{11(L)}$ (dB)</th>
<th>Bandwidth (GHz)</th>
<th>Gain (dBi)</th>
<th>High Resonant Freq. (GHz)</th>
<th>$S_{11(H)}$ (dB)</th>
<th>Bandwidth (GHz)</th>
<th>Gain (dBi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.46</td>
<td>-40.31</td>
<td>0.12 (2.4-2.52)</td>
<td>2.1</td>
<td>5.3</td>
<td>-34.10</td>
<td>1.5 (4.82-6.32)</td>
<td>4.7</td>
</tr>
</tbody>
</table>

4. RADIATION PATTERN

Figure 5(a) and 5(b) present the radiation pattern on $y$-$z$ plane cut at phi = 90° at 2.46 GHz and 5.3 GHz, respectively. This antenna is linear polarization at low resonant frequency 2.46 GHz and is circular polarization at high resonant frequency around 5.8 GHz.

Figure 5: The simulation results of radiation pattern on $y$-$z$ plane. (a) At resonant frequency 2.46 GHz. (b) At resonant frequency 5.3 GHz.

Figure 6: Characteristic of axial ratio represent the polarization of e-shaped slot antenna.
5. CONCLUSION
The e-Shaped slot antenna was designed to support WLAN communications at frequency band 2.4–2.52 GHz and 4.82–6.32 GHz for standards IEEE 802.11b/g/j/a and IEEE 802.16d. Varying the width of slot $S_{B2}$ will affect on the match impedance at low frequency band and $S_{B1}$ will affect on high frequency band.

REFERENCES