DUAL BAND MONOPOLE ANTENNA FOR WLAN/WIMAX APPLICATIONS

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Key words: Dual band, Monopole, Bandwidth, WLAN, WiMAX.

In this paper, a single layer dual band bended strip monopole antenna is presented for WLAN and WiMAX applications. The structure of the antenna is simple, which consists of a single bended strip and a microstrip-fed line. The proposed antenna is printed on the low-cost FR4-epoxy substrate (relative permittivity is 4.4) of one side and defected ground plane on the other side of the substrate. The overall dimension of the substrate is 35x50x1.6 mm³. The antenna may cover two separate bands, the lower band of WLAN and upper band of WiMAX. The resonance frequency of lower and upper bands of the antenna can be controlled by the geometry of the bended strip. The ~ 10 dB impedance bandwidths of 450 MHz, centred at 2.41 GHz (percentage bandwidth is 18.6 %) and 990 MHz centred at 5.7 GHz, (percentage bandwidth is 20.7 %). The detail performances of the proposed antenna are demonstrated along with measured and simulated results. The results are good in agreement.

1. INTRODUCTION

In recent technology, the enormous development of wireless communication devices such as mobile, tablets, laptop, and other handheld electronic device should have lightweight, dual or multiband operability and high-speed data connectivity. The WLAN (2.4/5.2/5.8 GHz) and WiMAX (2.5/3.5/5.5 GHz) are often and widely used in commercial applications. For high-speed data connectivity, wide operating bandwidth is essentially required. Basically, microstrip antenna has low bandwidth and low gain. Researchers try to overcome these difficulties. Monopole antenna is a substitute which has high bandwidth and our target is to increase bandwidth. Microstrip antenna also have some other basic features like small size, low cost, conformal shaping, and ease of integration with microwave circuit [1, pp. 1–52].

So far, various monopole antennas and many other compact dual or multi-band monopole antennas are found in the literature for WLAN and WiMAX applications. In [2] presented a miniaturized triple band monopole antenna for WLAN and WiMAX applications with an impedance bandwidth of 140 MHz, 310 MHz and 840 MHz, respectively. In [3] presented a coplanar waveguide (CPW) fed rectangular ring monopole antenna for WLAN applications and impedance bandwidth of 490 MHz and 990 MHz, respectively. In [4] a compact monopole planar antenna with inverted F and L shaped strips for WLAN and WiMAX applications, covering three separated impedance bandwidths of 300 MHz, 400 MHz, and 800 MHz, respectively. In [5] presented a compact dual-band asymmetric coplanar strip fed printed monopole antenna for 2.4/5GHz WLAN/Bluetooth applications, with impedance bandwidths of 90MHz and 810MHz, respectively. In [6] Proposed triple band printed monopole antenna for 2.4/3.5/5.8 GHz. In [7] presented an electrically small multiband monopole antenna based on complementary split ring resonators for WLAN and WiMAX applications, with bandwidths of 300 MHz, 400 MHz, and 400 MHz, respectively. In [8] proposed compact microstrip-fed tri-band monopole antenna with hybrid strips for WLAN and WiMAX applications, which achieved the bandwidths of 190 MHz, 900 MHz, and 550 MHz, respectively.

Besides, these monopole antennas design some other structural configurations are also reported for dual or multi-band operation such [9] multiband and wideband planar antenna for WLAN and WiMAX applications with a pair of rectangular slits and an inverted U shaped slot has bandwidths of 580 MHz, 740 MHz, and 1.1 GHz, respectively. In [10] presented multiband multi input multi output (MIMO) antenna system with parasitic elements for WLAN and WiMAX application with an impedance bandwidth of 220 MHz, 220 MHz, and 350 MHz respectively. In [11] reported tri-band quasi-self complementary antenna for WLAN and WiMAX applications with impedance bandwidth of 510 MHz, 330 MHz, and 770 MHz, respectively. In [12] presented a dual band planar antenna with the compact radiator for 2.4/5/2.5/5.8 GHz WLAN applications, which cover the impedance bandwidths of 110 MHz and 1.06 GHz, respectively.

In the present paper, a novel compact wideband dual resonant monopole antenna is proposed for WLAN and WiMAX applications. This antenna is designed in a simple bended shaped form and fabricated on the FR4 epoxy substrate with dielectric constant of 4.4, a thickness of 1.6 mm and a partial ground plane on the other side of the substrate. The obtained impedance bandwidth (S11 ≤ −10 dB) of 450 MHz (2.2 – 2.65 GHz) and 1180 MHz (5.11– 6.29 GHz) are the main achievements of this proposed design. The wide impedance bandwidths satisfy the requirement of both 2.4/5/2.5/5.8 GHz WLAN lower band and 2.5/5.8 GHz WiMAX upper band. Though the proposed antenna is conceptualized from the previous work reported [13]. The proposed antenna has been fabricated and experimentally tested. The antenna has been also found to have good voltage standing wave ratio (VSWR) and gain.

2. ANTENNA DESIGN

The design of the antenna is performed for a single layer microstrip feed line monopole antenna with the finite ground plane on FR4 epoxy substrate. The relative permittivity (εr) of the substrate is 4.4 with loss tangent of

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0.02 and the thickness (h) of the substrate is 1.6 mm. The overall dimension of the substrate is 35x50x1.6 mm³ and the structure has been shown in Fig. 1. The 50 Ω micro strip line with \( w_f \) of 2.6 mm is used for excitation of the antenna. The width of feed line, strip widths and lengths have been optimized to obtain the desired results. The final optimized dimensions of the proposed antenna are listed as follows (in mm) \( L_s = 50, W_s = 35, L_g = 14.7, W_f = 2.6, L_1 = 22.2, L_2 = 14.5, W_1 = 1.5, L_3 = 2, L_4 = 5, g = 2.8 \). The optimum values of the parameter have been set by testing the results with different values of parameters. The required numerical analysis and determination of a geometrical parameter of the proposed antenna are obtained with the help of HFSS v.11 software which based on finite element method (FEM).

The proposed antenna contains bended strip to achieve desired resonant frequency. From current distribution, it can be observed that the bended strip is responsible for upper resonant frequency (5.46 GHz). The total length of the strip for this resonant frequency (5.46 GHz) is nearly half of the guided wavelength. Therefore, the length of the strip is calculated as:

\[
L_{total1} = \frac{\lambda_g}{2}, \quad (1)
\]

\[
\lambda_g = \frac{c}{f_r \sqrt{\varepsilon_{eff}}}, \quad (2)
\]

\[
\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2}, \quad (3)
\]

\[
L_{total1} = (L_2 + L_4) - (L_1 + L_3) + (2W_1 + W_2), \quad (4)
\]

where \( C \) is the speed of light, \( f_r \) is the desired resonant frequency and \( \varepsilon_{eff} \) is the effective relative permittivity.

On the other, the lower resonant frequency (2.47 GHz) is excited due to microstrip feed line. The effective length is calculated as:

\[
L_{total2} = \frac{\lambda_g}{4}, \quad (5)
\]

\[
L_{total2} = (L_f + W_f) - (L_f - L_g). \quad (6)
\]

3. SIMULATED RESULTS

In this section, the simulated return loss is derived from the respective graphs obtained in HFSS v.11. Figure 2 shows the return loss of the proposed monopole antenna resonant at 2.47 GHz and 5.46 GHz with the magnitude of –28.20 dB and –29.22 dB, respectively. The –10 dB impedance bandwidth of WLAN lower band is found to be 850 MHz in the range of 2.01 GHz to 2.86 GHz and for WiMAX upper band is 1270 MHz ranging from 5.00 GHz to 6.27 GHz, which implies that the proposed antenna has wide bandwidth for both the operating bands.

The surface current distribution is described more in detail about the working principle of the radiating patch at a different resonant frequency of the proposed antenna. Figure 3 shows that at 2.41 GHz the strong current flows along the feed line only. On the other hand, at 5.7 GHz the most of the current is distributed on the bended strip of the monopole, which is shown in Fig. 4. So, it is clear that the two modes are excited at the two different position of antenna surface.

![Fig. 1 – Geometry of the proposed antenna from top view.](image1)

![Fig. 2 – Simulated return loss vs. frequency based on optimal value.](image2)

![Fig. 3 – Simulated current distribution [A/m] at 2.41 GHz.](image3)
4. PARAMETRIC ANALYSIS

In Figs. 5 to 7 are derived the parametric study of proposed antenna. Fig. 5 shows the effect of length $L_4$ of bended shaped strip on the resonant frequency. As $L_4$ increases from 4 mm to 6 mm, the center frequency of the upper band moves from 5.6 GHz to 5.4 GHz. The reason behind this the increased of $L_4$ prolongs the total length of the strip and hence the increase the current path on the strip length. Instead of this, the impedance bandwidth of the upper band becomes narrower (from 1.37 GHz to 1.03 GHz) with the increment of $L_4$. On the other hand, the lower band kept fixed. So $L_4$ is set to 5 mm.

In Fig. 6 depicts the return loss for different values of $L_g$. It is clear to see that the impedance bandwidth and the characteristic of return loss both are affected while $L_g$ changed from 14 mm to 15.5 mm. As the increase of $L_g$ from 14 mm to 15.5 mm, both the resonant frequency has been shifted upper side and reduced the magnitude of return loss. Interestingly the bandwidth of the upper band is increased by increasing the value of $L_g$ but it also affects the characteristic of impedance. So for proper impedance matching, $L_g$ set to 14.7 mm.

In Fig. 7 depicts the parameter effects on the magnitude of the return loss with varying $W_f$. It is clear from the Figure that both resonant frequencies do not alter. At $W_f$ is 2 mm the magnitude of return loss at lower band is higher than the upper band. As $W_f$ increased to 3 mm, now the magnitude of return loss of higher band is relatively more than the lower band. So, $W_f$ is selected to 2.6 mm for convenient results.

5. RESULTS AND DISCUSSION

The fabricated prototype of the proposed monopole antenna is shown in Fig 8. The measured data have been obtained using Rohde and Schwarz ZVA 40 at Kalyani University, West Bengal. The comparison of simulated and measured return loss is shown in Fig. 9, when it is clear to see that the measured return loss is in good agreement with simulated return loss. The small discrepancies are observed between the measured and simulated results both in the
value of return loss and the resonant frequency of the upper band. This may be due to fabrication tolerance and/or soldering effect of SubMiniature version A (SMA) connector. But the antenna structure still exhibits dual band behavior for WLAN and WiMAX.

In practice, the required bandwidth is 84 MHz (from 2.4–2.484 GHz) for WLAN lower band and 600 MHz (from 5.25–5.85 GHz) for WiMAX upper band. From the measured results it can be observed that the proposed antenna is resonant at two different frequencies of 2.41 GHz and 5.7 GHz with the magnitude of –19.5 dB and –16.06 dB, respectively. The –10 dB impedance bandwidth in WLAN band is 450 MHz (2.2 GHz–2.65 GHz, 18.6 % centred at 2.41 GHz) and in WiMAX the bandwidth is 1180 MHz (5.11–6.29 GHz, 20.7 % centred at 5.7 GHz). So, the measured impedance bandwidth is more than the practical requirement bandwidths. Figure 10 shows the VSWR versus frequency (GHz) graph and it shows that the value of VSWR is ≤ 2 over the whole operating band. The VSWR is 1.23 at 2.41 GHz and 1.37 at 5.7 GHz, which is a well-accepted value for both resonant frequencies.

The simulated E-plane and H-plane radiation pattern at 2.41 GHz and 5.7 GHz are shown in Figs. 11 and 12. The E-plane radiation patterns at 2.41 GHz and 5.7 GHz is shaped of 8 but slightly tilted in nature.
The measured gain versus frequency for both operating bands is shown in Fig. 13. The achievable gains are 2.2 dBi and 1.55 dBi for 2.41 GHz and 5.7 GHz, respectively. The simulated radiation efficiency is also shown in Fig. 14. The average efficiency for both the bands is 96%.

The performance comparison of the proposed antenna with some other dual or multi-band reference antenna is shown in Table 1. It is found that the proposed microstrip-fed monopole dual-band antenna has more impedance bandwidth compared with the earlier ones.

### Table 1

<table>
<thead>
<tr>
<th>Antenna</th>
<th>Size</th>
<th>Frequency bands</th>
<th>Impedance bandwidth(MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed</td>
<td>35×50×1.6</td>
<td>2.4/5.2/5.8</td>
<td>450(2.2-2.65) 1180(5.11-6.29)</td>
</tr>
<tr>
<td>[2]</td>
<td>20×30</td>
<td>2.4/5.2/5.8</td>
<td>140(2.38-2.52) 310(3.34-3.68) 840(5.08-5.92)</td>
</tr>
<tr>
<td>[4]</td>
<td>20×25.5</td>
<td>2.4/5.2/5.8</td>
<td>300(2.2-2.5) 500(3.3-3.8) 800(5.1-5.9)</td>
</tr>
<tr>
<td>[5]</td>
<td>15×24</td>
<td>2.4/5.2/5.8</td>
<td>900(2.4-2.49) 810(5.07-5.88)</td>
</tr>
<tr>
<td>[7]</td>
<td>30×34×0.76</td>
<td>2.4/5.8</td>
<td>300(2.3-2.6) 400(3.3-3.7) 400(5.1-5.5)</td>
</tr>
<tr>
<td>[8]</td>
<td>20×38×0.8</td>
<td>2.4/5.8</td>
<td>1900(2.32-2.51) 900(3.38-3.71) 550(5.4-5.95)</td>
</tr>
<tr>
<td>[11]</td>
<td>29×40×1</td>
<td>2.4/5.2/5.8</td>
<td>510(2.25-2.76) 330(3.38-3.71) 770(5.1-5.87)</td>
</tr>
<tr>
<td>[12]</td>
<td>40×30×0.8</td>
<td>2.4/5.2/5.8</td>
<td>1100(2.39-2.5) 1060(5.07-5.6)</td>
</tr>
<tr>
<td>[14]</td>
<td>30×40×0.8</td>
<td>2.4/5.2</td>
<td>300(2.4-2.7) 680(3.32-4.00) 1040(4.76-5.8)</td>
</tr>
<tr>
<td>[15]</td>
<td>23×38×1.6</td>
<td>2.4/5.2/5.8</td>
<td>240(2.28-2.56) 920(3.29-4.21) 860(5.05-5.91)</td>
</tr>
<tr>
<td>[16]</td>
<td>22×12</td>
<td>2.4/5.2/5.8</td>
<td>1000(2.38-2.48) 310(3.37-3.68) 640(5.48-6.12)</td>
</tr>
<tr>
<td>[17]</td>
<td>9×14.8</td>
<td>2.4/5.2/5.8</td>
<td>340(2.39-2.73) 560(3.23-3.79) 910(5.05-5.96)</td>
</tr>
</tbody>
</table>

### 6. CONCLUSIONS

In this paper, a single layer microstrip-fed bended monopole antenna has been designed. The proposed antenna has been excited two separated bands with wide impedance bandwidth. The measured –10dB bandwidth has been covered a range of frequency from 2.2 – 2.65 GHz (450 MHz).
MHz) and 5.11 – 6.29 GHz (1180 MHz), which is the key feature of this proposed antenna. Also, the measured VSWR is found to be below 2 and peak gain (> 1.5 dBi) for both operating bands. So it can be justified that the proposed antenna is suitable for the applications in WLAN lower band and WiMAX upper band properly. The practical data obtained from hands-on experimentation have been graphically plotted with the help of MATLAB software.

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