A Wideband Modified Loop Antenna for Wireless Application

Sapna B A¹* and Dr. G Srivatsun²
Department of Electronics and Communication Engineering
PSG College of Technology, Coimbatore, India-641004
¹sapna.psmi@gmail.com, ²srivatsunece@yahoo.co.in

Abstract

This paper presents a novel broadband loop antenna with “L” strips which is excited by capacitive coupling with a microstrip feed. The designed antenna operates in the frequency range from 3.96GHz to 6.17GHz, covering a bandwidth of 2.21GHz. The proposed antenna exhibits a peak gain of 4dBi, and has an omnidirectional radiation pattern in the operating frequency band. The average radiation efficiency of the antenna is 86%. The prototype measures 39×39 mm² (0.75λ₀ × 0.75λ₀), which is compact in size. The measured and simulated results of the designed antenna are in good proximity to each other, making it suitable for Wi-Fi, WiMAX and LTE applications.

Keywords: Monopole antenna, coplanar, microstrip feed, wideband, wireless.

1. Introduction

The portable wireless devices are expected to be compact and low profile with high data transmission capacity for modern applications. As antennas are major component of wireless devices, the antenna design is focused at low profile wideband, Ultra-Wide Band (UWB) and multiband operations. Monopole antennas are simple and inexpensive, capable of multiband and wideband operations with slight modifications using slits and slots. Coplanar Waveguide (CPW) monopole antennas are extensively used as they are easily integrated with other circuit components. Currently a number of wireless standards such as IEEE802.11 Wireless Local Area Networks (WLAN, 2.4 and 5.8GHz band), IEEE 802.11 a/b/g/n Wireless Fidelity (Wi-Fi, 2.4 GHz, 3.6 GHz, 4.9 GHz, 5 GHz, 5.9 GHz and 60GHz bands), find numerous wireless applications. The C-band (4 to 8 GHz) is used for many satellite communications services, such as cordless telephones, and radar systems. Compact CPW antennas are suitable for wireless applications like RFID and navigation [1-2]. Capacitive coupled dual band loop antennas with circular polarization is used for beam steering applications [3]. Bandwidth of loop and monopole antennas are improved with parasitic strips and asymmetrical ground planes [4-7]. Passive elements in monopoles with tapered feed and slots can further improve the frequency band to achieve UWB operations [8-10]. Multiband resonance in the monopole antennas are reported with the insertion of ring resonators [11].

In this paper, considering the advantages of CPW technique a broadband printed square loop monopole antenna with two “L” strip is proposed and investigated. This antenna has a low-profile structure with reasonable gain and wider bandwidth at lower cost. One of the design challenges in low profile loop antenna is the 50-ohm feed line. The, proposed antenna overcome this difficulty with a capacitive coupled strip feed near to the radiating element. A good impedance matching can be obtained with appropriate length of the feed strip. The organisation of this manuscript is as follows. Section 2 describes the developmental stages of the proposed antenna design with the comparative performance of
Section 3 investigates the simulated and measured results, followed by the conclusion in section 4.

2. Evolution of the Proposed Antenna Geometry

The design and developmental stages of the low profile, wideband antenna is shown in Figure 1. The antennas are designed to print on a commercially available FR-4 substrate with dielectric permittivity $\varepsilon_r$ of 4.3, and height of 1.6mm. The copper conductor printed on the dielectric has a thickness of 0.035mm. In general, the circumference of a square loop antenna is given by $4(l-w)$, where $l$ and $w$ are the length and width of the square side. The wave propagation occurs when the loop perimeter is greater than twice the guide wavelength [12]. Initially a simple square loop antenna was designed with circumference of 84mm and strip width 1mm operating at 5.8GHz frequency. All antennas are of fixed size measuring a side length ‘$L_d$’ of 39mm. The side length of the loop antenna is 22mm ($0.42\lambda_0$). The ground plane is printed on the same side of the loop forming a Coplanar Waveguide (CPW) monopole antenna. Length of the ground plane and the dielectric are fixed, but the ground width $w_g$ is varied and optimized to 5mm for maximum return loss. Feed to the antenna is provided through a microstrip line printed at the bottom of the substrate as in Figure 1(f) with width $f_w=3mm$. This provides a capacitive coupling to the loop on the other side. The optimized dimensions of the proposed antenna are listed in Table 1.

Figure 1. Developmental stages of modified square loop antenna (a) Loop antenna (b) Antenna 1 (c) Antenna 2 (d) Antenna 3 (e) Proposed antenna (f) Bottom view of the proposed antenna.

Table 1. Optimised design parameters of proposed antenna

<table>
<thead>
<tr>
<th>Parameters</th>
<th>$L$</th>
<th>$w$</th>
<th>$l_v$</th>
<th>$l_h$</th>
<th>$s$</th>
<th>$w_g$</th>
<th>$l_g1$</th>
<th>$l_g2$</th>
<th>$f_w$</th>
<th>$f_l$</th>
<th>$h$</th>
<th>$L_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value(mm)</td>
<td>22</td>
<td>1</td>
<td>22.75</td>
<td>25.75</td>
<td>0.5</td>
<td>5</td>
<td>13</td>
<td>25</td>
<td>3</td>
<td>14.8</td>
<td>1.6</td>
<td>39</td>
</tr>
</tbody>
</table>
The loop antenna is modified into four different stages of antennas namely Antenna 1, Antenna 2, Antenna 3 and the proposed antenna. First modifications in the loop antenna is an additional vertical strip of length \( l_v \) of 22.75mm and width \( s \) of 0.5mm, placed across the loop with 3mm offset from the centre as in Figure. 1(b). The second modification stage is the Antenna 2 represented in Figure. 1(c). The Antenna 2 is constructed with an additional horizontal strip of length \( l_h \) 25.75mm attached at the vertical strip forming a reverse “L” structure. Feed length of loop antenna, Antenna 1, and Antenna 2 are maintained at 30mm. Antenna 3 as depicted in Figure. 1(d), has an additional vertical strip of same dimension which is placed opposite to the first vertical strip at the lower edge of the dielectric. Ground plane of antenna with three strips is modified for convenience with two asymmetric rectangular sections making it as a defective ground structure, isolating from the 2nd vertical strip with different length \( l_{g1} \) and \( l_{g2} \). Finally, the proposed antenna illustrated in Figure.1(e) comprised of a square loop and two “L” strips placed with an optimal offset value from the origin of the loop. As the ground plane is modified for antenna 3 and proposed antenna, the feed length is also optimized for better impedance match. Proposed antenna is compact in size with lateral dimension measuring 0.75\( \lambda_0 \) x 0.75\( \lambda_0 \) at the designed frequency of 5.8GHz.

![Graph showing return loss performance](image)

**Figure 2. Return loss performance of the different antenna configurations**

The return loss performance of all antenna configurations is analysed using the 3D electromagnetic software. Comparative return loss performance of different stages of the antenna designs are exhibited in Figure.2. The return loss plot of the loop antenna has two resonant bands with 930MHz and 970MHz bandwidth covering the frequency range from 2.61GHz to 3.54GHz and from 4.99GHz to 5.96GHz. In figure 2, the antenna with single strip exhibits three resonant bands respectively at 2.7GHz, 4.8GHz and 5.8GHz. The antenna 2, with loop and two strips broadens the upper band covering a bandwidth of 1.02GHz ranging from 4.38GHz to 5.4GHz. The lower band of antenna 2 has a bandwidth of 640MHz between 2.56GHz and 3.19GHz. The third modified antenna with shorter feed length, the antenna 3 has dual band resonance but shifts the resonance bands to the right with lower band at 3.96GHz with a return loss magnitude of 35dB. The upper band is centred at 5.3GHz and has a return loss of 29.1dB. With the additional strip forming the cross cross loop the proposed antenna with four strips achieved a broader bandwidth of 2.21GHz in comparison with other four designs of Figure.1. Thus, the proposed antenna which is a simple modified loop provides wider bandwidth with good impedance match within the microwave standard reference magnitude of \( S_{11} \leq -10dB \).
3. Performance Analysis of the Antenna

Proposed antenna has been fabricated and tested to validate the performance. Photograph of the proposed antenna prototype is portrayed in Figure 3. Antenna characteristics like return loss, VSWR, radiation patterns and gain are simulated and the results are compared with the measured values. Impedance characteristics are measured using vector network analyser and the radiation characteristics are measured in a partial anechoic chamber against a standard wideband horn antenna operational within 1-12GHz frequency band. Figure 4 depicts the simulated and measured return loss of proposed antenna. With reference to -10dB, measured $S_{11}$ has an impedance bandwidth of 2.21GHz ranging from 3.96GHz to 6.17GHz. VSWR performance of proposed antenna is displayed in Figure 5, and is within the acceptable ratio of 2:1. Measured results of return loss and VSWR shown in Figures 4&5 are in close proximity to the simulated graphs, validating the simulated performance of the antenna.

![Prototype of the fabricated antenna](image)

**Figure 3. Prototype of the fabricated antenna**

![Return loss performance comparison](image)

**Figure 4. Return loss performance comparison of proposed antenna.**
Figure 5. VSWR performance comparison of proposed antenna.

The normalized farfield radiation patterns of the antenna in E and H plane for various frequencies like 4.2GHz, 4.68GHz, 5.2GHz and 5.8GHz are presented in Figure 6 and Figure 7. Simulated radiation pattern in the E plane maintain a smooth bidirectional pattern in all frequencies of interest. The measured E plane patterns follow the simulated patterns. The 3dB beamwidth of the antenna ranges from 65°-70° in the maximum direction. The H plane patterns are omnidirectional. The magnitude level of measured E and H plane patterns are slightly lower compared to the simulated results. The uneven edges and the variations in magnitude levels of the measured radiation patterns account to the misalignment, material losses and cable losses during measurement.

Figure 6. E-plane radiation patterns of the proposed antenna.
The gain of the antenna is calculated from the measured $S_{21}$ parameters. Figure 8 represents the simulated and measured gain of the proposed antenna. The measured plots show a peak gain of 4dB at 4.8GHz frequency. The simulated antenna has a maximum gain of 4.12dBi at 5.2 GHz. Within the operational band the average gain of the proposed antenna is 3.6dBi. The antenna shows a stable gain in the operational band with less than 1dB deviation. The
simulated radiation efficiency of the proposed antenna ranges from 70.2% to 92.6% and is plotted in Figure 9. Table 2 shows the performance comparison of the proposed antenna with earlier proposed. The proposed antenna outperforms with wider bandwidth and smaller size with a marginal gain of 3.6dB.

![Simulated radiation efficiency of the proposed antenna](image)

**Figure 9. Simulated radiation efficiency of the proposed antenna**

**Table 2. Performance comparison of proposed antenna with few existing reference antennas**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Operating Frequency range (Bandwidth)</th>
<th>Antenna dimension (mm³)</th>
<th>Gain (dBi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[3]</td>
<td>3.8GHz, 4.7GHz (120MHz)</td>
<td>80 x 80 x 3.04</td>
<td>9.3</td>
</tr>
<tr>
<td>[5]</td>
<td>1.48-4.24GHz (2.76GHz)</td>
<td>55 x 50 x 1</td>
<td>3.5dBi</td>
</tr>
<tr>
<td>[6]</td>
<td>2.21-2.7GHz (490MHz) &amp; 5.15-5.825GHz (675MHz)</td>
<td>21.4 x 59.4 x 1.6</td>
<td>2</td>
</tr>
<tr>
<td>[10]</td>
<td>1.71-1.88GHz (170MHz) &amp; 3.3-4.2GHz (900MHz)</td>
<td>36 x 48 x 1.6</td>
<td>2.4</td>
</tr>
<tr>
<td>Proposed</td>
<td>3.96-6.17GHz (2.21GHz)</td>
<td>39 x 39 x 1.6</td>
<td>3.6</td>
</tr>
</tbody>
</table>

4. Conclusion

A wideband modified loop antenna with two “L” strips offset from the centre is designed and the results are validated with the fabricated prototype. The proposed antenna is compact and measures $0.75\lambda_0 \times 0.75\lambda_0$. Realized peak gain of the antenna is 4dBi at 4.8GHz. Average radiation efficiency of the antenna is 86%. Measured results of return loss, VSWR and radiation plots are in good agreement with the simulated results. The proposed antenna has a wide impedance bandwidth of 2.21GHz, ranging from 3.96GHz to 6.17GHz frequency making it as a suitable candidate for Wi-Fi, WiMAX and LTE applications.
References


