CPW-Fed Compact Ultra Wideband MIMO Antenna for Portable Devices

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Abstract

Background/Objectives: A novel Coplanar Waveguide (CPW) fed Multiple Input Multiple Output (MIMO) ultrawideband (UWB) antenna with a size of 26mm x 40mm x 0.8mm is proposed for portable device applications. Methods/Statistical Analysis: Two monopole elements with CPW fed are the elements of MIMO antenna and are placed perpendicular to each other to obtain pattern diversity. To enhance the isolation between elements and to improve impedance bandwidth, a long protruding ground stub is etched on the ground plane. Findings: The proposed antenna can cover the frequency band from 2.3-12.5 GHz with isolation more than -20 dB over the entire frequency band. A peak realized gain of 4.5 dBi and efficiency of more than 90% is achieved through the proposed antenna model. Applications/Improvements: High isolation of more than -20 dB is obtained from 2.3-12.5 GHz. The proposed antenna is a good candidate for portable device applications.

Keywords: Compact, Coplanar Waveguide (CPW) Feed, Multiple Input Multiple Output Antenna (MIMO), Mutual Coupling, Ultra Wideband (UWB)

1. Introduction

Ultra Wideband technology is the most promising technology because of its advantages, such as high data rate transmission, less cost, high security, and less power consumption. It uses wide bandwidths to send short pulses at lower power levels. UWB technology has wide range of applications in Wireless Personal Area Networks (WPAN), short-range high speed data transmission systems, high precision cancer detection, radar and imaging systems, etc. However, in order to reduce the interference to other wireless systems, Federal Communications Commission (FCC) authorized 3.1 to 10.6 GHz band with power level of < -41.3 dBm/MHz for UWB applications in 2002. Many antennas have been proposed in the past years for UWB system applications. However, multipath fading degrades the performance in UWB systems. It is well known that MIMO technology can be used to minimize the multipath fading effects as well as increase channel capacity for UWB systems. The MIMO uses multiple antennas at the transmitter and receiver to increase communication link quality and reliability of communication system. Early works show that, MIMO technique minimizes the limitations in ultrawideband systems and also achieves high data rates.

Since, space is a limited on portable devices, placing multiple antennas is a major challenge and will result mutual coupling which degrades system performance in terms of pattern diversity. So, the difficulty in design of UWB MIMO system is the compact size with low coupling between the antenna elements. Several methods were proposed for compact MIMO antenna design giving lower mutual coupling between radiating elements for portable UWB applications. Various decoupling structures are proposed to enhance the isolation in compact MIMO systems for UWB applications, such as protruded ground stubs, tree-like structures to enhance isolation, introducing a neutralization line, and meandered lines, defected patch structures. CPW-fed MIMO antenna provides an
isolation of about -15 dB have been reported\textsuperscript{11–14}. CPW antennas are preferred because of low volume and easy integration to MMIC.

A coplanar waveguide fed UWB MIMO antenna having small size is proposed for portable devices with impedance bandwidth from 2.3-12.5 GHz in this paper. The antenna has a size 26 mm x 40 mm, which is about 25% smaller in size as compared to the antenna one in\textsuperscript{6}. Two-planar monopole antennas with CPW-fed placed perpendicular to other and a simple stub is used on the ground to improve isolation between antenna elements and enhance the bandwidth. The proposed antenna provides larger impedance bandwidths from 2.3-12.5 GHz as compared to the one in\textsuperscript{5}.

2. Antenna Design

The design of the CPW-fed two-port ultrawideband MIMO antenna is shown in Figure 1, with an overall size of $L \times M = 26 \times 40$ mm$^2$. Antenna is printed on FR4-epoxy substrate material having thickness of 0.8 mm, dielectric constant ($\varepsilon_r$) of 4.4, and a loss tangent (tanδ) of 0.02. The proposed antenna comprises of two monopole radiating antennas, such as PM1 and PM2 in Figure 1, respectively. The coplanar waveguide is used to feed the port 1 and port 2 by 50 $\Omega$. To increase isolation between the ports, PM1 and PM2 are placed perpendicular to each other. A common ground for the whole antenna is formed by connecting two ground planes.

The ground of PM1 with size $L_g \times W_g$, the ground of PM2 having the size of $L_g \times L$, and the rectangle shaped radiating elements (PMs) having the dimensions of $L_r \times W_r$ were etched on the same side of dielectric substrate. A long stub with size $L_s \times W_s$ as shown in Figure 1 is used on the ground plane to enhance isolation and increase impedance bandwidth. The dimensions of proposed antenna are tabulated in Table 1.

<table>
<thead>
<tr>
<th>L ($mm$)</th>
<th>$L_1$</th>
<th>$F_{g1}$</th>
<th>$L_g$</th>
<th>$L_s$</th>
<th>$D_1$</th>
<th>$F_{g1}$</th>
</tr>
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<tbody>
<tr>
<td>26</td>
<td>10</td>
<td>7.5</td>
<td>8</td>
<td>18</td>
<td>5.7</td>
<td>1.5</td>
</tr>
<tr>
<td>W ($mm$)</td>
<td>$W_{g1}$</td>
<td>$W_{s1}$</td>
<td>$W_r$</td>
<td>$D_s$</td>
<td>$F_{g2}$</td>
<td></td>
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<tr>
<td>40</td>
<td>11</td>
<td>1.8</td>
<td>32</td>
<td>1</td>
<td>6.1</td>
<td>0.4</td>
</tr>
</tbody>
</table>

3. Results and Discussions

Simulation tool Ansoft HFSS is used to study, optimize and design the proposed MIMO antenna. Return loss (S11), mutual coupling (S12), current distributions, radiation patterns, peak gain, efficiency, and VSWR of antenna are analyzed.

3.1 Effects of Long Ground Stub

In the proposed antenna, long ground stub is placed between the PM1 and PM2 as shown in Figure 1. This
stub plays a key role for obtaining the desirable performance in terms of mutual coupling. The simulated S11 and S12 with and without stub are depicted in Figure 2 (a) and (b).

From the Figure 2 (a), when stub is employed, the antenna resonates at about 4.7 GHz and 7 GHz frequencies. The resonance at 4.7 GHz tends towards the frequency band from 4.7 GHz to 2.3 GHz. Similarly, the strong resonance at 7 GHz moves towards the higher cutoff frequency band from 7 GHz to 12.5 GHz. Thus, when ground stub is used, two resonances are generated with lowest and highest frequencies at 2.3 GHz and 12.5 GHz respectively, giving impedance bandwidth from 2.3 GHz to 12.5 GHz.

Generally mutual coupling S12 less than -15 dB is enough for good isolation. Figure 2 (b) indicate that the mutual coupling S12 with and without long ground stub is less than -20 dB and -15 dB respectively, in the entire UWB band specified by FCC. Thus, proposed UWB MIMO antenna with long ground stub can operate in the frequency band from 2.3 to 12.5 GHz with good isolation of less than -20 dB.

Current distribution is also used to analyse the antenna performance. Figure 3 indicates the proposed antenna current distributions with and without long ground stub at 3 GHz, 7 GHz, and 10 GHz respectively. Without using long ground stub, when port1 is excited and port2 is terminated with 50 Ω, Figure 3 (a), (e), and (i) indicate that current is coupled to radiating element of PM2 and goes into the port 2. So, mutual coupling increased between the antenna elements.

With using long ground stub, when port1 is excited and port2 is terminated with 50 Ω, Figure 3 (b), (f), and (j) show that, considerably large amount of current is coupled to radiating element of PM2.
coupled to the long stub which acts as parasitic monopole element and give off radiation.

Without using long ground stub, when port2 is excited and port1 is terminated with 50 Ω, Figure 3 (c), (g), and (k) indicate that current is coupled to the radiating element of PM1 and flow to the port2. Thus, mutual coupling increased between antenna elements.

Figure 3. Current distributions at 3GHz: (c) Port2 excited without stub, (d) Port2 excited with stub. Current distributions at 7 GHz: (e) Port1 excited without stub.
With using long ground stub, when port2 is excited and port1 is terminated with 50Ω, Figure 3 (d), (h), and (l) indicate that large amount of current is coupled to long stub. So, mutual coupling between antenna elements reduced.

The prototype and measured S11 and S12 of the proposed MIMO antenna are shown in Figure 4 (a), (b), and (c). The measured S11 in Figure 4 (b) indicate that proposed antenna providing impedance bandwidth from...
Figure 3. Current distributions at 10 GHz: (i) Port1 excited without stub, (j) Port1 excited with stub, (k) Port2 excited without stub, (l) Port2 excited with stub.
2.5-10 GHz for $S_{11}<-10$ dB. And also, measured mutual coupling $S_{12}$ between port1 and port2 is shown in Figure 4 (c). As from the Figure 4 (b) and (c), the measured $S_{11}$ and $S_{12}$ parameters are slightly worse than the simulated results because of fabrication tolerances.

The 3D-patterns proposed antenna at 3, 7, and 10 GHz are shown in Figure 5. It can be seen that 3D-radiation patterns excited by port1 and port2 are complementary to each other. Thus, the proposed antenna provides pattern diversity to reduce multipath fading.

Figure 4. (a) Prototype. (b) Measured $S_{11}$-parameter. (c) Measured $S_{12}$-parameter.

Figure 5. 3D-Radiation patterns at 3 GHz: (a) Port1 excited, (b) Port2 excited. 3D-Radiation patterns at 7 GHz: (c) Port 1 excited, (d) Port2 excited.
Figure 5. 3D-radiation patterns at 10 GHz: (e) Port1 excited, (f) Port2 excited.

Figure 6. (a) Antenna Peak gain (b) Antenna Efficiency. (c) VSWR of antenna. (d) Measured VSWR.
Figure 6 (a) show that gain of the antenna ranging from 1.7-4.5 dBi in the band from 2.3-12.5 GHz. Figure 6 (b) shows that the antenna has a good efficiency of more than 90% in the entire UWB. From the Figure 6 (c) and (d), it can be observed that the antenna is giving VSWR of less than 2 in the entire frequency range.

4. Conclusion

A novel MIMO antenna with compact size of 26 mm x 40 mm x 0.8 mm for portable devices is proposed in this paper. The antenna consisting of two rectangular monopole antennas (PMs) placed perpendicular to each other. A long ground stub printed on ground to enhance isolation between the antennas. The simulated and measured results show that proposed antenna will work in ultrawideband from 2.3-12.6 GHz with low mutual coupling <-20 dB. The results giving strong motivation that presented UWB MIMO antenna is suitable for portable devices.

5. Acknowledgment

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6. References