Design of a film antenna using a cloverleaf-shaped monopole structure for WiBro and WLAN

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Abstract: This study designs a film monopole antenna for WiBro (wireless broadband internet, 2.3–2.4 GHz) and WLAN (wireless local area network, 2.4–2.48 GHz) bands. A variety of design parameters were used to optimize frequency properties, and radiating and ground- ing elements were placed on the same plane for maximized radiation efficiency. Cloverleaf-shaped radiating elements were used to induce a phase difference of 180 degrees and thus obtain improved bandwidth. This paper presents the possibility of realizing broadband by using parasitic elements. The antenna created in this study achieves a peak gain of up to 3.18 dBi and satisfies WiBro (2.3–2.4 GHz) and WLAN (2.4–2.48 GHz) bands with a bandwidth of 2.30–2.54 GHz (9.8%) at \(-10\) dB or lower.

Keywords: film monopole antenna, WiBro, WLAN, cloverleaf

Classification: Wireless circuits and devices

References

1 Introduction

With recent rapid advancement of wireless communication technologies, there is increasing need to use wireless communication bands for delivery of diverse information and to develop broadband or multiband antenna technology for higher-speed communications. In particular, the use of radio waves in the field of personal communications has been rapidly increasing with the wide diffusion of handheld computers and smart phones. There is also growing need for wireless broadband internet (WiBro) and wireless local area network (WLAN) that allow such devices to be connected to internet networks anywhere, with an increase in their availability. As the applicability of WLAN has expanded, WLAN antennas for terminal devices have been proposed to address the disadvantages of existing antennas and a wide variety of signal-transfer WLAN antennas have been designed with consideration of the installation environments.

The types of antennas that are mainly used for WLAN include planar strip antennas, meander antennas, microstrip antennas, and helix antennas [1, 2]. Among them, microstrip antennas cost less to produce and are relatively easy to build in smaller and lighter designs. They have a conductor that radiates electromagnetic waves on one side and a conductor ground plane on the other, with a dielectric material in between. Microstrip antennas using radiation from microstrip line discontinuities are easy to fabricate, lightweight, reasonable in price, and can be simply integrated with solid-state devices. Because of these advantages, microstrip antennas have been widely studied and many improvements have been documented [4]. However, they are characterized by narrowband, low radiation efficiency and low gain.

In this paper, we designed a film antenna using a cloverleaf-shaped monopole structure with characteristics of WiBro and WLAN bands, by mitigating the disadvantages of commonly used microstrip patch antennas: narrowband, low radiation efficiency and low gain. To this end, a monopole structure was configured on a plane; radiating and grounding elements were designed in a monopole configuration on the same plane to improve radiation efficiency; and a cloverleaf-shaped radiating element was used to improve the bandwidth of the structure [3].

2 Design and measurement of a monopole film antenna

The poor radiation efficiency of the existing microstrip patch antennas not only results from parasitic radiation on transmission lines, but is also a result of some input signals being induced waveguides between radiating and grounding elements that are arranged on the top and bottom of a dielectric substrate. The bandwidth of a microstrip patch antenna is proportional to the substrate thickness but in inverse proportion to the dielectric permittivity. If a low-permittivity substrate of increased thickness is used for the purpose of bandwidth improvement, it is likely to raise manufacturing costs and further decrease radiation efficiency [4, 5].

The monopole film antenna proposed in this paper uses a coplanar waveg-
uide (CPW) feed and the radiating and grounding elements are placed on the same level so as to inhibit surface current and obtain better radiation efficiency. The antenna also provides improved bandwidth and gain by using a cloverleaf-shaped monopole structure. The slot structure and inter-slot distance of the cloverleaf-shaped radiating elements were adjusted to induce a phase difference of 180 degrees between the top and bottom radiating elements from their center and achieve a broadband characteristic.

Fig. 1. Proposed cloverleaf-shaped film antenna structure
(a) Design parameters (b) Design parameters of radiating element (c) Fabricated antenna

The study used a 1-mil polyimide film with a dielectric permittivity of 3.5 and a loss tangent of 0.0027. In addition, the cloverleaf-shaped monopole radiating element and CPW feed structures are printed on the same plane of the substrate, as shown in Fig. 1 (a). Film thickness and permittivity as well as thin-film thickness to be printed, were preferentially taken into consideration as variables that influence the input impedance matching of the antenna, and the input impedance of the antenna was determined by adjusting the width and length of transmission lines on the ground and radiating planes and the distance between the cloverleaf-shaped radiating elements. The commercial EM software Ansoft HFSS was used to design the proposed antenna. Fig. 1 (a) and Fig. 1 (b) show the design parameters of proposed cloverleaf-shaped antenna and the design parameters of radiating elements, especially. We presented the appearance of the fabricated cloverleaf-shaped antenna on the flexible printed circuit board (FPCB) in Fig. 1 (c).

In order for the antenna to have optimal characteristics at its resonant frequency and bandwidth, this study set as variables the design parameters that have the greatest influence on characteristics in the antenna structure represented in Fig. 1 (a). In Fig. 1 (a), the transmission line length (TL) was found to influence the resonant frequency characteristics of the antenna, and accordingly this study set the transmission line length as the design...
variable to examine changes in the resonant frequency and bandwidth. The resonant frequency becomes higher as the transmission line length becomes shorter and the bandwidth varies with changes in the inter-element distance. Based on the relationship between the bandwidth and resonant frequency depending on changes in the design variable $TL$ and the relationship between the input impedance and the resonant frequency depending on the design variable $Angle$, this study obtained optimal variables that could achieve the resonant frequency corresponding to the purpose of the antenna design and the greatest possible bandwidth. Table I lists the parameters of the designed antenna.

Table I. Design parameters of proposed antenna

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Value[mm]</th>
<th>Design Parameter</th>
<th>Value[mm]</th>
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<tbody>
<tr>
<td>L1</td>
<td>110</td>
<td>FW</td>
<td>3</td>
</tr>
<tr>
<td>GL</td>
<td>10</td>
<td>GW1</td>
<td>44</td>
</tr>
<tr>
<td>PL</td>
<td>15.09</td>
<td>GW2</td>
<td>30</td>
</tr>
<tr>
<td>TL</td>
<td>63.22</td>
<td>TW</td>
<td>1.5</td>
</tr>
<tr>
<td>W1</td>
<td>60</td>
<td>PW</td>
<td>4.5</td>
</tr>
<tr>
<td>L2</td>
<td>20</td>
<td>S1-2</td>
<td>8.75</td>
</tr>
<tr>
<td>W2</td>
<td>20</td>
<td>S2</td>
<td>3</td>
</tr>
<tr>
<td>S1-1</td>
<td>10</td>
<td>S3</td>
<td>3</td>
</tr>
</tbody>
</table>

This study could obtained multiband or broadband characteristics by placing parasitic components around a previously proposed monopole antenna [6, 7]. The study added parasitic elements of $PL \times PW$ to evaluate how the bandwidth changes according to the transmission line length. It was found that the proposed antenna achieved broadband characteristics represented by a bandwidth. Fig. 2 (a) and Fig. 2 (b) show E-field and H-field distribution, respectively. From the field distributions, upper radiating element and lower radiating element have $180^\circ$ phase difference for current and voltage, which means that it can decrease the reactive energy and can increase the radiation efficiency. Fig. 2 (c) shows the simulated and measured return loss of the proposed antenna in a comparative manner. The measured return loss was $-27.35\, \text{dB}$ almost similar to the simulated one at a center frequency of 2.45 GHz, and the bandwidth was measured to be 240 MHz (9.8%) for VSWR of $<2.0$.

Fig. 2 (d) and Fig. 2 (e) show a comparison of the calculated and measured radiation patterns of the proposed antenna. In the figure, (d) and (e) represent the x-y plane and y-z plane, respectively, and the measured peak gain of the antenna is 3.18 dBi, which is consistent with the simulated value.

3 Conclusion

The present study proposed a cloverleaf-shaped monopole film antenna for use in the WiBro and WLAN bands with a center frequency of 2.45 GHz. The return loss and gain of the fabricated antenna were measured, and its bandwidth and gain was 240 MHz (9.8%) and 3.18 dBi, respectively, at a re-
turn loss of $-10\text{dB}$ or lower. The antenna proposed in this paper achieved improved radiation efficiency by arraying radiating and grounding elements on the same plane and enhanced the bandwidth by using cloverleaf-shaped radiating elements. Further, the study findings suggest that the proposed antenna could be employed as a broadband antenna by adding parasitic ele-
ments. One disadvantage of the proposed antenna is its relatively large size. Therefore, future studies should focus on how to make the antenna smaller. In addition, studies focused on realizing broadband and multi-resonance characteristics using parasitic elements should be carried out. The proposed planar dipole antenna will be applicable to WiBro and WLAN services and other mobile communication services that require electrical characteristics such as broadband.

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