A Compact Four Concentric Rectangular Rings Slot Antenna for Mobile Handset Applications

Zhen YU\textsuperscript{1,2,*}, Jian-guo YU\textsuperscript{2} and Xiao-ying RAN\textsuperscript{1}

\textsuperscript{1}North China Institute of Science and Technology (NCIST), China
\textsuperscript{2}Beijing University of Posts and Telecommunications (BUPT), China

*Corresponding author

Keywords: Four concentric rectangular rings, Slot antenna, Dual-band, Compact microstrip antenna.

Abstract. A novel compact four concentric rectangular rings slot broadband microstrip antenna is proposed for mobile handset applications. The antenna has a circular radiator with four concentric rectangular rings slot structure. The antenna can cover more than ten mobile applications with -10dB bandwidth of 88.7\% (1.6-4.15GHz) for DCS1800(1710-1880MHz), TD-SCDMA(1880-2025MHz, 2300-2400MHz), WCDMA(1920-2170MHz, 1755-1880MHz), LTE33/41/42/43 (1900-2690MHz, 3400-3800MHz), Bluetooth, GPS, COMPASS, GLONSS, GALILEO, WLAN (802.11b/g/n:2.4-2.48GHz), and WiMAX(3.3-3.8GHz) wireless applications. The proposed antenna is fabricated on a 1.6 mm-thick FR4 substrate with dielectric constant of 4.4, and the size is 50*40mm\textsuperscript{2}. The good agreement between the measurement results and the simulation validates the proposed design approach and meets the requirements for mobile handset applications.

Introduction

With the rapid development of mobile communication systems, miniaturized multiband planar antennas have been widely used in wireless mobile handsets because of its light weight, low profile, low cost, high manufacturing precision, easy to load, easy integration, etc. Resonance antennas, such as half-wave dipoles or quarter-wave monopoles are difficult to achieve multiband and miniaturization\cite{1}. In order to better achieve the multiband and miniaturization, many technologies have been studied, such as coupling feed technology \cite{2-3}, slot loaded technology \cite{4-5}, loading the matching network \cite{6}, and fractal technology \cite{7}. A square slot, a pair of L-strips, and a monopole radiator are used to excite three different resonances in \cite{8}. A microstrip feed line, a substrate, and a ground plane on which some simple slots are etched to achieve triband operation in \cite{9}. A monopole antenna with two rectangular corners cut off and two inverted-L slots are etched to achieve three resonant modes for triband operation is presented in \cite{10}. Inverted L-slot patch with a defected ground plane is used for triple-band operation in \cite{11}, whereas three circular-arc-shaped strips whose whole geometry looks like “ear”-type antenna are reported to cover the desirable bands for WLAN/WiMAX wireless communication terminal in \cite{12}.

In this paper, a compact four concentric rectangular rings slot band microstrip antenna is proposed and designed for wireless communication systems that can support broadband applications. The antenna covers more than ten mobile applications of DCS1800(1710-1880MHz), TD-SCDMA(1880-2025MHz, 2300-2400MHz), WCDMA(1920-2170MHz, 1755-1880MHz), LTE33-41/42/43 (1900-2690MHz, 3400-3800MHz), Bluetooth, GPS, COMPASS, GLONSS, GALILEO, WLAN(802.11b/g/n:2.4-2.48GHz), and WiMAX(3.3-3.8GHz) wireless applications.
Antenna Structure and Design Procedure

Characteristics of Antenna Structure

The configuration of the proposed antenna is shown in Figure 1 with dimensions in Table 1. The antenna has a circular radiator with four rectangular concentric rings slot and gound on the back of substrate. The antenna is designed on FR4 substrate with height of 1.6mm, dielectric constant ($\varepsilon_r$) of 4.4 and loss tangent ($\delta$) of 0.02.

![Figure 1. Layout of proposed antenna.](image)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>12mm</td>
</tr>
<tr>
<td>L1</td>
<td>5mm</td>
</tr>
<tr>
<td>s1</td>
<td>0.8mm</td>
</tr>
<tr>
<td>fw</td>
<td>1mm</td>
</tr>
<tr>
<td>fh</td>
<td>35mm</td>
</tr>
<tr>
<td>H1</td>
<td>15mm</td>
</tr>
<tr>
<td>W</td>
<td>40mm</td>
</tr>
<tr>
<td>Gh</td>
<td>16mm</td>
</tr>
</tbody>
</table>

Performance of Simulation

The simulation is conducted by Ansoft HFSS 15.0. Figure 2 illustrates the reflection loss (S11) curves at different RI and L1 values.

![Figure 2. Combined simulated reflection loss curves at different RI and L1 values.](image)
It can be seen that the proposed antenna can operate at a broadbands with two resonance frequencies centered at 2.05GHz with -37.6dB reflection loss and 3.55GHz with -32.9dB reflection loss. The simulated -10dB bandwidth (1.6-4.15GHz) is 88.7%. These bands cover several commercial application bands of 2G, 3G, 4G, WiFi, Navigation, Bluetooth and WiMAX, as given in Table 2.

Table 2. -10dB frequency bands covered by antenna.

<table>
<thead>
<tr>
<th>-10dB Bandwidth</th>
<th>Covered Commercial Bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6-4.15GHz</td>
<td>DCS1800(1710-1880MHz),TD-SCDMA(1880-2025MHz,2300-2400MHz), WCDMA(1920-2170MHz,1755-1880MHz), LTE33-41/42/43 (1900-2690MHz,3400-3800MHz), Bluetooth,GPS, COMPASS, GLONSS, GALILEO, WLAN(802.11b/g/n:2.4-2.48GHz),WiMAX(3.3-3.8GHz)</td>
</tr>
</tbody>
</table>

The surface current amplitude distribution on radiator of the proposed antenna that work at the center frequency of 2.05GHz and 3.55GHz, respectively, are shown in Figure 4. For 2.05GHz frequency, the current is more concentrated at the bottom of the radiator, as shown in Figure 4(a), as the frequency increase, the outer edges of radiator and slots has more current, as shown in Figure 4(b), 3.025.

Figure 4. Current distribution of the antenna at different center frequencies.

The simulated 3D and E/H-plane radiation patterns of the proposed antenna at the center frequencies of 2.05GHz and 3.55GHz are shown in Figure 5. It can be seen that the patterns are close to omnidirectional at all bands.

Figure 5. 3D and E/H- plane radiation patterns at two center frequencies.
**Fabrication and Measured Results**

To verify the dual-broadband performance of the planar antenna, a prototype antenna is fabricated and measured. The antenna is built on 1.6mm thick FR4 substrate with loss tangent=0.02 and 30μm copper on both sides, as shown in Figure 6(a). The antenna is tested by antenna measurement system of PNA3621, as shown in Figure 6(b).

![Fabricated antenna prototype and testing scenario.](image)

The measured reflection loss ($S_{11}$) and Voltage Standing Wave Ratio (VSWR) have better agreement with the simulated results, as shown in Figure 7. This makes the antenna compatible for mobile communications applications.

![Measured $S_{11}$ and VSWR curves.](image)

**Conclusions**

A novel compact four concentric rectangular rings slot broadband microstrip antenna is developed for DCS1800, TD-SCDMA, WCDMA, LTE, Bluetooth, Navigation, WLAN, and WiMAX applications. The better agreement between the measurement results and the simulation validates the proposed antenna meets the requirements for various wireless applications.
Acknowledgements

This work was financially supported by the National Natural Science Foundation of China (No.61372035), LangFang city Science, Technology Research and Development Program (No.2016011007), Scientific Research Project of Central Universities of NCIST (No. 3142013050) and Virtual Laboratory Project of NCIST.

References


