Research Article
Dual-Polarized Crossed Bowtie Dipole Array for Wireless Communication Applications

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A dual-polarized array with downtilted radiation patterns is proposed for wireless communication applications. The proposed dual-polarized antenna element achieves an enhanced impedance bandwidth and compact dimensions by introducing a parasitic circular patch and vertical metal cylinders, which is a good candidate for radiating elements in base station antennas. By optimizing the amplitude and phase distribution along the feed, a radiation pattern with a downtilted angle is obtained. The dual-polarized array antenna achieves an impedance bandwidth for VSWR ≤ 1.5, covering the frequency bands for 3G/LTE systems. Moreover, the proposed array achieves high port isolation, the stable antenna gain over the entire operating band. Therefore, the proposed array antenna is very suitable for potential wireless communication applications. A prototype has been manufactured and measured. The measurements, that match the design objectives, are also presented.

1. Introduction

With the rapid development of mobile communication systems, different mobile communication systems operating in different frequency bands have been designed. The 3G systems, such as TD-SCDMA, WCDMA, and CDMA2000, operate in the 2 GHz (1880–2170 MHz) band [1], and the future LTE (Long Term Evolution, 4G) systems, such as TDD LTE and FDD LTE, will operate in the 2.3 GHz (2300–2400 MHz) and 2.6 GHz (2570–2690 MHz) bands [2, 3]. Therefore, base station antennas must have a wide impedance bandwidth covering the frequency band from 1800 MHz to 2800 MHz. In addition, for base station applications, dual orthogonal polarizations oriented at angles of +45° and −45° with respect to vertical direction are also required, as the signal on two orthogonal polarizations can help reduce the fading caused by multiple reflections [4, 5].

Recently, a great number of base station antennas have been developed. The dual-polarized antenna proposed in [6] is a combination of a modified low-profile monopole and a circular planar loop and it achieves an impedance bandwidth of about 25%, being unsatisfactory to cover the LTE frequency bands. Dual-polarized wideband antennas also are proposed in [7–11]; however, the operating frequency bands of the proposed antennas cannot cover the 3G and LTE frequency bands. The broadband dipole antenna proposed in [12] is composed of an irregular shorted patch and planar dipole elements, which obtains a bandwidth of 49.5%. The array may show grating lobes because the lateral dimension of the antenna is large. Therefore, it is difficult for these antennas to be designed as an array. Similarly, the wideband antennas proposed in [13–18] are difficult to be arrayed. Moreover, in [19], although the proposed wideband antennas have a compact size, they have a complex structure, which leads to high cost and difficulty in postfabrication tuning. In [20, 21], a downtilted radiation pattern for base station applications is achieved.

In this paper, a dual-polarized crossed bowtie dipole array is presented. The array antenna element consists of a pair of dipoles, inverted L-shaped feed strips, a parasitic circular patch for impedance enhancement, and vertical metal cylinders for decreasing the lateral dimensions. A wide impedance
Fractional bandwidth of about 45.6% (1.76–2.80 GHz) is obtained for both polarizations for VSWR $\leq 1.5$ (Port 1, $+45^\circ$ polarization, Port 2, $-45^\circ$ polarization). To achieve a downtilted radiation pattern for base station applications, a 10-element linear antenna array based on the feed network and the element described above is designed. The measured results show that the array achieves a wide impedance fractional bandwidth of about 55.3% (1.7–3.0 GHz) for VSWR $\leq 1.5$ (Port 1, $+45^\circ$ polarization), and VSWR $\leq 1.5$ (Port 2, $-45^\circ$ polarization), which is wide enough for 3G and LTE applications. Moreover, the proposed array can realize a stable peak gain of about 16.5 dB over the entire operating bands. Particularly, by optimizing the distribution of amplitude and phase distribution along the feed, radiation pattern with a downtilted angle of about $6^\circ$ is obtained. Thus, the proposed array antenna is very suitable for potential base station applications.

2. Crossed Bowtie Dipole Antenna Element

2.1. Geometry of the Antenna Element. The geometry of the proposed dual-polarized crossed bowtie antenna element is illustrated in Figure 1. It consists of a pair of crossed bowtie dipoles, inverted L-shaped feed strips, a parasitic circular patch, four vertical metal cylinders, and a ground plane as a reflector to achieve the unidirectional radiation pattern. The crossed bowtie dipoles with colocated centers and orthogonal axes are used as radiators. Each bowtie dipole has a pair of square arms with a square hole located at the center of the arm. To improve impedance matching, the parasitic circular patch is employed on the top of the crossed bowtie dipole by adding another resonant mode in the upper band. The vertical metal cylinders have been introduced to reduce the dimensions along the array direction, which can weaken the array mutual coupling. The feed configuration, as shown in Figure 1(d), is an inverted L-shaped strip which is divided into two parts: a vertical strip and a horizontal strip. The vertical line with a hollow metal cylinder acts as a coaxial feeding line, whose outer conductor is connected to one arm of the dipole while an inner conductor is connected to the other arm. Furthermore, the inner core is shorted to the ground plane through the hollow metal cylinder, which is introduced to compensate the imbalance of the current amplitude. The feed mechanization of the other bowtie dipole is similar. Moreover, the two horizontal and orthogonal strips are staggered up and down. By adjusting the distance between the two orthogonal strips, the isolation of the two orthogonal polarizations is improved.

2.2. Discussion of Parameters

2.2.1. The Vertical Cylinder. To explore how the dimension of the vertical cylinder influences the antenna performance, parametric studies are performed as shown in Figure 2. The dependence of $H_2$ on the VSWR of the dual-polarized antenna element is shown in Figure 2(a) and the simulated results for VSWR as a function of $D_1$ are shown in Figure 2(b). The VSWR of the antenna in the upper band is hardly affected by the length ($H_2$) or the diameter ($D_1$) of the vertical cylinder, while the lower band of the antenna...
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1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8
1.0
1.5
2.0
2.5
3.0 VSWR
Frequency (GHz)

Figure 2: Simulated VSWR for different values: (a) $H_2$ and (b) $D_1$.

is affected significantly. When $H_2 = 0$ mm, which means that the vertical cylinders are removed, the resonant point of the antenna element is far from the lower band. By selecting $H_2 = 10$ mm and $D_1 = 1.5$ mm, better impedance matching is achieved for the two ports which can meet the requirement for base station application.

2.2.2. The Parasitic Circular Patch. Considering the influence of the parasitic circular patch on the impedance bandwidth of the antenna, two key parameters are studied: the diameter of parasitic circular patch ($D$) and the distance between patch and radiators ($H_3$), as depicted in Figure 3. Figure 3(a) shows the VSWR performance with different values of the diameter $D$. With a decrease in $D$, the resonant mode of the upper band is shifted to the lower band, whereas the resonant mode in the lower band changes slightly. With $D = 0$ mm, which means that the parasitic circular patch is removed, only the antenna element achieves one resonant point in the operating band. In Figure 3(b), the antenna VSWR for different values of the distance $H_3$ is presented. With an increase in $H_3$, the coupling between patch and radiators tends to weaken. Hence, the resonant mode of the upper band is shifted to the upper band, whereas the resonant mode of the lower band is almost unchanged. Therefore, $D$ and $H_2$ mainly affect the resonant mode of the upper band. The optimal results of $D$
and $H_3$ are 32 mm and 7 mm obtained by simulation for the proposed antenna. All other geometrical parameters of the dual-polarized crossed bowtie antenna element have been optimized with using the Ansoft HFSS 13.

2.3. Simulated and Measured Results. The dual-polarized crossed bowtie dipole antenna element is fabricated by die casting technique as shown in Figure 4. With using Agilent E8363B network analyzer the proposed antenna element is measured in the anechoic chamber. Figure 4 shows that the measured impedance fractional bandwidth for VSWR $\leq 1.5$ is 46.1% (1.76–2.81 GHz) for both polarizations. Obviously, wideband impedance characteristic is achieved. Both of the simulated and measured port isolations are better than 28 dB over the operating band. The discrepancy between the simulated and measured results is probably caused by fabrication tolerance.

The measured copolarization and cross-polarization patterns of the antenna element in the XOZ and YOZ planes at 1.8, 2.2, and 2.6 GHz are shown in Figure 5. In the operating band, the half-power beam widths of the copolarization pattern in the XOZ plane (the horizontal plane) are about 66°. Moreover, the measured results have maximum cross-polarization level of about $-18$ dB in the XOZ plane; the front-to-back ratio is better than 22 dB over the entire band. Note that both of the two ports can achieve a gain over 8.3 dB with a variation of 1 dB over the entire band.

### Table 1: Amplitude and phase distribution along the feed.

<table>
<thead>
<tr>
<th>Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<td>Amplitude</td>
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<td>0.801</td>
<td>0.978</td>
<td>1.0</td>
<td>0.960</td>
<td>0.723</td>
<td>0.871</td>
<td>0.825</td>
<td>0.609</td>
<td>0.631</td>
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<td>255</td>
<td>212</td>
<td>174</td>
<td>147</td>
<td>124</td>
<td>107</td>
<td>67</td>
<td>50</td>
<td>0</td>
</tr>
</tbody>
</table>

3. Dual-Polarized Array

#### 3.1. Array Antenna Configuration. The configuration of the proposed array antenna is shown in Figure 6. The array antenna is composed of a wideband feed network, a ground plane, and ten dual-polarized antenna elements as described in Section 2. The array antenna is mounted on the center of the ground plane with dimensions of $1135 \times 55$ mm$^2$ and the space between neighboring elements is 115 mm as shown in Figures 6(a) and 6(b). A pair of side walls is also introduced to reduce the backside radiation and septum is used to improve the isolation performance between the neighboring elements. For the feed network in Figure 6(c), it is fabricated on a PTFE substrate with a thickness of 0.93 mm, a relative dielectric constant of 2.6, and a loss tangent of 0.001. To achieve a downtilted pattern for base station applications, amplitude and phase distribution along the feed are optimized with using the adaptive differential evolution algorithm, which incorporated a new select operator and an adaptive parameter and is introduced to search the global solutions. Finally, the optimal results about the amplitude and phase of the feed network are tabulated in Table 1.

#### 3.2. Results of Simulation and Measurement. The simulated and measured VSWR against frequency are shown in Figure 7. For VSWR $\leq 1.5$, the measured impedance fractional bandwidth is about 55.3% ranging from 1.7 to 3 GHz for both polarizations. Additionally, both simulated
Figure 5: Measured radiation patterns for the element at (a) 1.8, (b) 2.2, and (c) 2.6 GHz.
and measured port isolations are better than 30 dB over the 3G and LTE bands. The difference between simulated and measured values is due to fabrication tolerances and measurement environment.

Figure 8 shows the measured radiation patterns of the proposed array at 1.8, 2.2, and 2.6 GHz. A downtilted radiation pattern of 6° for the two ports is obtained in the XOZ plane by application of adaptive differential evolution algorithm. Moreover, the cross-polarization component of radiation pattern is better than −20 dB and front-to-back ratio is better than 30 dB over the operating band. Thanks to the existence of the side walls, the side lobe level of the array is less than −10 dB. Additionally, the half-power beam width of the copolar patterns in the YOZ plane is about 66° over the whole band. Measured gains for the two ports are shown in Figure 9. It was observed that measured gain is better than 16 dB over the entire band. The measurements prove that the array antenna can be widely used in the mobile communication service.

4. Conclusion
A wideband dual-polarized crossed bowtie dipole array with downtilted pattern is proposed. The array consists of a wideband feed network, a ground plane, and ten dual-polarized antenna elements. To achieve a downtilted radiation pattern for base station applications, amplitude and phase distribution along the feed are optimized by application of adaptive differential evolution algorithm. The measured results show that the dual-polarized array achieves a wide impedance bandwidth and good radiation characteristics covering the frequency bands for 3G and LTE systems. Therefore, the proposed array antenna is very suitable for potential wireless communication applications.

Conflict of Interests
The authors declare that there is no conflict of interests regarding to the publication of this paper.
Figure 8: Measured radiation patterns for the dual-polarized antenna array at (a) 1.8, (b) 2.2, and (c) 2.6 GHz.
Acknowledgments

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