A Circular Microstrip Antenna Radiating Circularly Polarized Conical Beam for SDARS Applications

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1. Introduction

Recently, wireless communication systems such as wireless local area networks (WLAN), mobile communications and Digital Audio Radio Service (DARS) have been growing enormously. Especially, Satellite Digital Audio Radio Service (SDARS) is the most popular type of DARS operating in United States and Canada. The SDARS is operated in the 2.3 GHz S-band from 2.332 to 2.345 GHz. SDARS uses satellite broadcasting to provide the signal in environments having line-of-sight to the satellite base station broadcasting primarily for urban areas. The requirements of the SDARS antenna include a conical-beam radiation pattern (satellite communications) with maximum gain over 20-60 degree of elevation angles (with respect to the horizon). Moreover, for sufficient performance of base station reception, lower angle elevation reception (at about 0 degree elevation) with vertical polarization is desired. From the literature [1]-[6], a conical-beam radiation pattern with circular polarization is obtained by using a circular microstrip antenna. Therefore, this paper proposes a circular microstrip antenna for SDARS applications. The circular microstrip antenna is designed to meet SDARS requirements. It is found that simulation results of the proposed antenna are well-suited for SDARS specifications. The prototype antenna was fabricated to validate the simulation results.

Table 1 Antenna parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Electrical Size</th>
<th>Physical Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>0.66λ</td>
<td>8.5 mm</td>
</tr>
<tr>
<td>h</td>
<td>0.025λ</td>
<td>3.17 mm</td>
</tr>
<tr>
<td>α</td>
<td>-</td>
<td>45°</td>
</tr>
</tbody>
</table>

Figure 1: Antenna configuration.
2. Antenna Configuration

For a typical circular microstrip antenna [1], the fundamental mode can only generate a broadside and linearly polarized radiation pattern. However, exciting higher order current modes can generate a conical beam pattern. In order to achieve circular polarization characteristics, multiple feeds with proper angular separation are required. The geometry of the substrate is of a circular shape in order to enhance the radiation symmetry.

Figure 1 illustrates the configuration of the circular microstrip antenna used in this paper, where $a$ is the diameter of the circular substrate and ground plane, $d$ is the diameter of the circular patch, $h$ is the thickness of the substrate with dielectric constant of $\varepsilon_r$, and $\alpha$ is the angle between adjacent feed points.

![Prototype antenna](image)

Figure 2: Prototype antenna.

![S-parameters as a function of frequency](image)

Figure 3 S-parameters as a function of frequency.
3. Results

In this paper, the circular microstrip antenna is designed to meet the system requirement for SDARS applications. The parameters of the circular microstrip antenna are tabulated in Table 1 with \( \varepsilon_r = 2.2 \), where \( \lambda = 128 \text{ mm} \). The operating frequency of 2.34 GHz is used and the all feed points are excited with TM\(_{21}\) mode by using proper phase arrangement for each feed point (0°, 0°, 90°, 90°). The distances from the center of the patch to all feed points are 0.325\( d \). The photograph of the fabricated prototype antenna is depicted in Fig. 2.

The S-parameter characteristic of the antenna is shown in Fig. 3. It is found that the trends of measured S-parameters of each port reasonably agree with the simulation results. At the 2.34 GHz operating frequency, the \(|S_{11}|, |S_{22}|, |S_{33}|, |S_{44}|\) are lower than -10 dB as shown in Fig. 3(a). It is noticed that the \(|S_{21}|, |S_{12}|, |S_{43}|\) and \(|S_{34}|\) in Fig. 3(b) are higher than -10 dB. The other S-parameters in Fig. 3(c) are reasonable for the operating frequency of 2.34 GHz.

![Photograph of the fabricated prototype antenna](image1)

(a) 4-ports power divider.

![S-parameter characteristic of the antenna](image2)

(b) Return loss and insertion loss.

![Phase of insertion loss](image3)

(c) Phase of insertion loss.

**Figure 4** Four-port power divider.

In practice, a power divider is used to divide the power to all feed points for multi-feed excitation. Therefore, the four-port Wilkinson power divider [7] is employed in this paper. It is designed for four-feed points of the circular microstrip antenna of Fig. 1 with proper phase arrangement for each feed point. Fig. 4 shows the photograph of the four-port Wilkinson power divider for this work and its characteristics.

Figure 5 illustrates the characteristics of the circular microstrip antenna. The measured radiation patterns in both \( \phi = 0^\circ \) and \( \phi = 90^\circ \) as shown in Fig. 5(a) and Fig. 5(b) respectively are reasonably in good agreement with the simulated ones. Although almost of measured axial ratios in both \( \phi = 0^\circ \) (Fig. 5(c)) and \( \phi = 90^\circ \) (Fig. 5(d)) are larger than 3 dB, but the trends of measured axial ratios reasonably agree with the simulation results for SDARS applications.

4. Conclusions

The proposed antenna is designed based on the requirements of SDARS applications. The conical-beam pattern with the circular polarization is obtained by using the circular microstrip antenna with four-feed points designed with suitable parameters. At 2.34 GHz operating frequency,
the $|S_{11}|$, $|S_{22}|$, $|S_{33}|$, $|S_{44}|$ are lower than -10 dB and the other S-parameters are acceptable except the $|S_{21}|$, $|S_{12}|$, $|S_{43}|$ and $|S_{34}|$ that are larger than -10 dB, which may affect to the characteristics of the antenna. For the characteristics of the proposed antenna, the measured radiation patterns are reasonably in good agreement with the simulated ones, and the trends of measured axial ratios reasonably agree with the simulation ones. However, almost measured axial ratios are more than 3 dB. This may be caused by either the imperfect power divider and fabricated antenna or the effects of the $|S_{21}|$, $|S_{12}|$, $|S_{43}|$ and $|S_{34}|$ that are larger than -10 dB.

![Radiation pattern at $\phi = 0^\circ$.](image1)

![Radiation pattern at $\phi = 90^\circ$.](image2)

![Axial ratio at $\phi = 0^\circ$.](image3)

![Axial ratio at $\phi = 90^\circ$.](image4)

**Figure 5** Radiation patterns and axial ratios.

### References


