UWB Radar Antenna with Emission Notch in Restricted Frequency Band

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1. Introduction

To improve road safety and reduce traffic deaths, automotive radars using ultra-wideband (UWB) technology are being developed worldwide [1]. A UWB radar antenna is required to achieve wideband characteristics, compact structure, and mass production at low cost. In addition, it is preferable to have a function that can suppress emissions in the restricted frequency band from 23.6 to 24.0 GHz in order to mitigate interference with other services using this band [2], [3]. Furthermore, since circular polarization (CP) might suppress multiple scattering between multiple targets, CP antennas with good polarization discrimination may be useful for automotive radar. This paper proposes a novel planar antenna composed of a cavity with rim that achieves wideband characteristics, emission rejection in the restricted band, and excellent CP isolation.

2. Rimmed-Cavity-Back Spiral Antenna (RCBSA)

It is widely known that the conventional microstrip antenna (MSA) has low profile and low cost, but its bandwidth is very narrow due to its thin dielectric substrate. To widen the bandwidth, we adopted a relatively thick substrate and a single-arm rectangular spiral antenna, which is known as a wideband printed antenna [4]. However, a thick substrate generates surface waves that disturb the aperture distribution, causing a degraded radiation pattern and poor antenna gain. To reduce surface-wave generation, we developed a square cavity with rims enclosing the spiral antenna (Fig. 1). The cavity consists of a square conducting wall composed of a lot of via arranged periodically and a metallic rim printed on the substrate top surface. The width of the rim (Lr in Fig. 1) is approximately one quarter of the guide wavelength ($\lambda g/4$).

Figure 2 shows the surface-wave cavity-suppression effect. An antenna with only a via-wall cavity or no cavity has insufficient suppression characteristics, resulting in a distorted radiation pattern and low directive gain, Gd. On the other hand, the RCBSA achieves a radiation pattern with good symmetry and high Gd.

Since the antenna consists of a cavity, it may have resonance. At the fundamental resonance frequency, f_R, the input impedance becomes very large, so large reflection occurs at the antenna input terminal and a sharp notch may appear in the antenna gain, causing the antenna to function as a band-rejection filter. We can obtain an antenna that mitigates interference by matching f_R with the restricted band.

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The value of f_R can be controlled by changing parameters of the cavity and spiral exciter. From a practical viewpoint, the rim width, Lr, may be most appropriate. Figure 3 shows the band rejection characteristics of RCBSAs for several Lr variants.

3. Development and performance of 8-element array antenna

3.1 Array configuration

Based on the above design concept, we developed a 2 x 4-element array antenna. Figures 4 (a) and (b) show the top and bottom views of the antenna. Rogers RO4003 with a dielectric constant, ε, of 3.38 was used as the substrate. The structural parameters are summarized in Table 1.

Each element antenna radiates CP because a spiral antenna is used as an exciter. However, the polarization characteristics are insufficient, so we applied the sequential-rotation-array technique [5] to improve the CP characteristics as an overall array antenna. The four elements are rotated sequentially in 90° steps in the array column and fed with differential phase shifts corresponding to the element rotation. The same technique is applied to the two-element arrays in the array row.

3.2 Measured results

Figures 5 (a) and (b) show the radiation patterns at 26.5 GHz—a typical frequency in the UWB radar band—in the horizontal- and vertical-planes, respectively. Solid lines show co-polarization (RHCP in our case), and broken lines show cross-polarization (LHCP). Within the half-power beam width, the cross-polarization level is held below -20 dB.

Figure 6 shows the reflection coefficient, S_{11}. It is less than -13 dB within the specified band from 25 to 29 GHz. The major cause of reflection is probably the coaxial connector. The broken line shows S_{11} when this reflection is ignored by using the time-gate function of a vector network analyzer; the reflection becomes less than -18 dB.

Figure 7 shows the gain versus frequency. A gain of more than 14 dBi was obtained over the specified band. The gain includes connector loss of 0.5 dB. A sharp notch is clearly seen in the restricted band where the gain is reduced to 10 to 15 dB lower than the gain at 26.5 GHz.

4. Conclusions

We developed a novel planar antenna for automotive radars. The 2 x 4-element array antenna composed of rimmed-cavity-back spiral antennas achieved a gain of more than 14 dBi over the specified frequency band. A notch for emission rejection in the restricted band was effective in mitigating interference. In addition, the antenna has excellent polarization isolation characteristics by using the sequential-rotation-array technique, which is useful for automotive radars.

[References]

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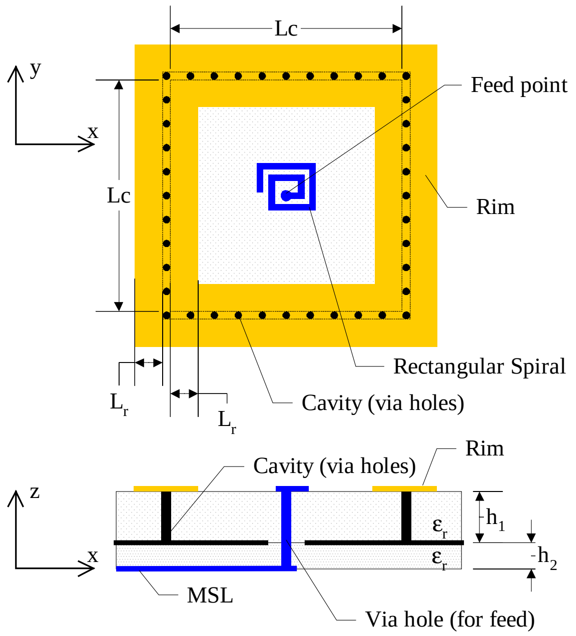


Fig. 1 Structure of rimmed-cavity-back spiral antenna

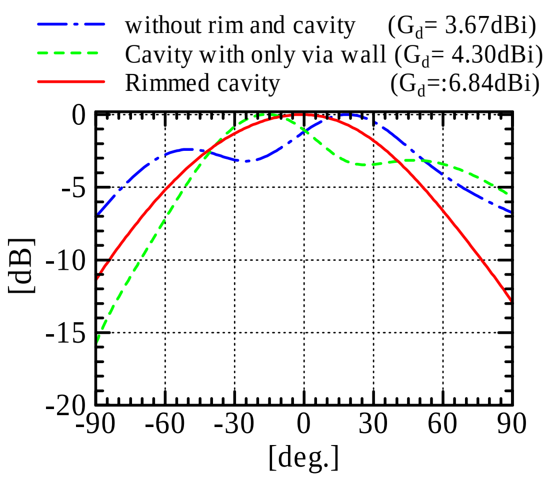


Fig. 2. Simulated radiation patterns in vertical plane (RHCP)

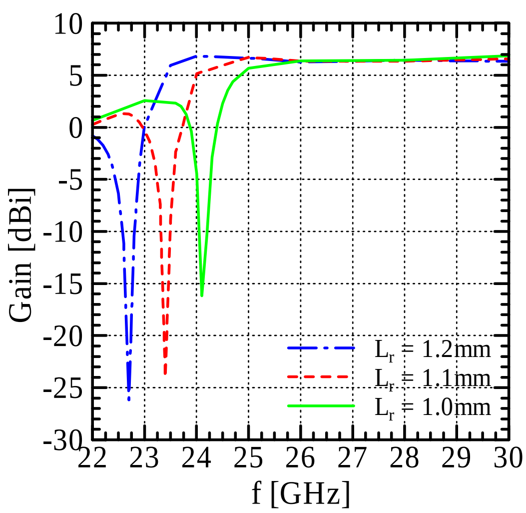


Fig. 3 Band rejection characteristics of RCBSA (Simulation)

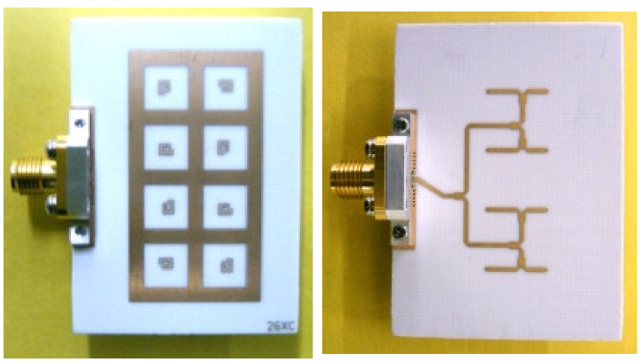
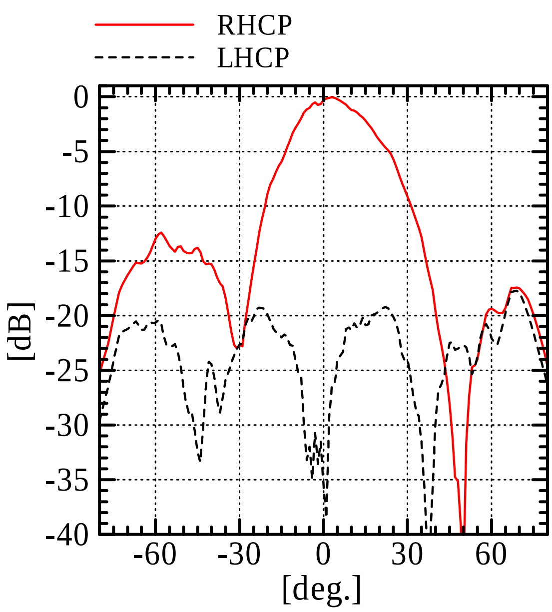

(a) Top view (b) Bottom view

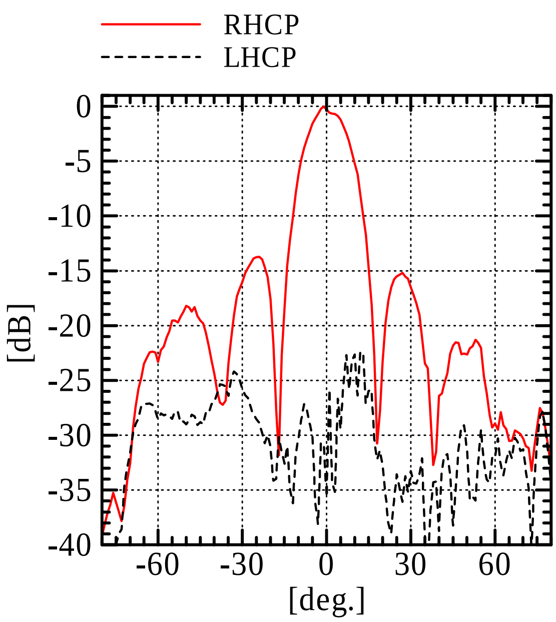
Fig. 4 Array structure (Sequential rotation array for circular polarizations)

Table 1 Parameters of 8-element RCBSA array

Specified frequency band	25 – 29 (GHz)
Substrate (dielectric constant)	Rogers RO4003C (ε_r=3.38)
Size of substrate, thickness	36.3 x 50.0, h_1= 1.21, h_2= 0.3 (mm)
Wall via (diameter, pitch)	d= 0.3 ϕ, p = 0.9 (mm)
Cavity size	Lc = 9.0, Lr = 1.08 (mm)
Exciter	Single-arm rectangular spiral
Array structure	Sequential-rotation-array
Step of rotation and phase shift	90°



(a) Horizontal plane



(b) Vertical plane

Fig. 5 Measured radiation patterns (26.5GHz)

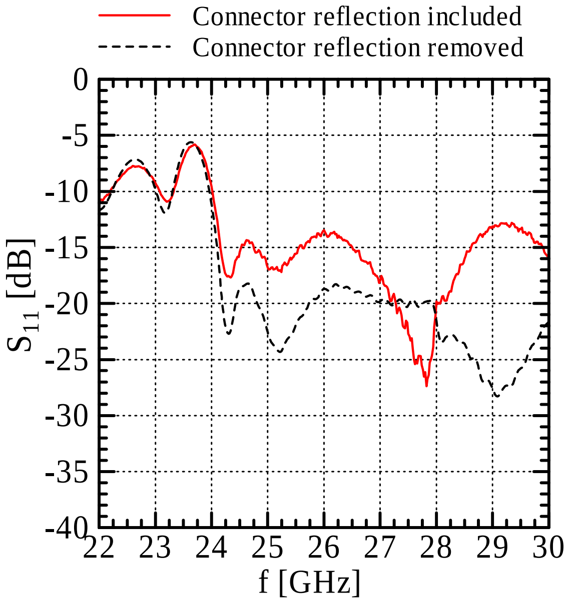


Fig. 6 S_{11} of RCBSA

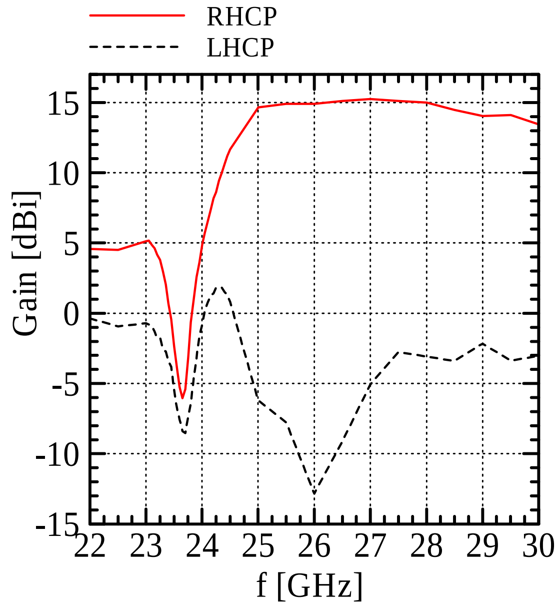


Fig. 7 Gain of RCBSA