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Single Layer Dual Circularly Polarized Series-fed Gap Waveguide Based Slot Array for 77 GHz Automotive Radar

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1. Abstract

A series-fed single layer dual circularly polarized slot array antenna fed by stepped ridge gap waveguide is proposed at the 77 GHz band. The antenna generates dual circularly polarized waves, which shows potential to be used in next-generation polarimetric radar for automotive applications. The antenna contains 8 columns of linear arrays and two feeding ports for exciting the columns of the slots. The design process and measured results are described in this paper. The measured results show that the realized gain of the proposed antenna is above 27.3 dBi and the axial ratio is about 2 dB over the proposed 76-79 GHz with dual CP patterns. The measured S_{11} and S_{22} for the proposed antenna is below -10 dB and the measured port isolation is above 17.5 dB.

2. Introduction

Polarimetric radars have been widely investigated in recent years for autonomous vehicles to realize target classification [1]–[3]. A full polarimetric radar utilizes two antennas at Tx/Rx channels, with linear/ circular polarization (LP/CP), to analyze the correlation of signals and, furthermore, classify the low-cross-section objects precisely. A dual CP polarimetric radar has the advantages of lower multi-path interference and a higher probability of target detection because the signal level is independent of scattering object orientation. However, from the antenna design point of view, challenges such as multiple-layer geometry, complex feeding networks, etc. need to be addressed for a dual CP antenna.

To solve these challenges, a single-layered series-fed waveguide slot array is a good candidate to realize the dual CP antenna with a potential for 1D beam scanning [4]. The dual CP performance is realized by separately exciting both ports on the opposite side. To decrease the grating lobe and avoid dielectric loss, the slot array is built based on gap waveguide (GW) technology [5]. The parallel top and bottom metal plates in GW are contactless, which provides a less complex geometry. Ridges or grooves are built on the bottom plate to guide the propagating waves. Periodic pins are placed surrounding the ridges/ grooves, to create a stopband.

The proposed planar slot array consists of 8 columns linear array and each linear array has 18 slot elements. Two 1-to-8 power dividers are integrated with two RWG-WG transitions to feed the slot array. The model geometry and the prototype are shown in Fig. 1.

The simulated and measured S-parameters results are shown in Fig. 2 (a) and Fig. 2 (b). The measured impedance bandwidth ($S_{11} \leq -10$ dB) covers the 76-81 GHz frequency band. The measured S_{22} shows a 2 dB difference from the simulation, which is reasonable because of manufacturing tolerance at mmWave. For the S_{21}, the measured results are below -17.5 dB, which agrees well with simulations. Fig. 2 (c) and Fig. 2 (d) show the realized gain, measured radiation efficiency, and axial ratio of the proposed array. The measured realized gain is around 27 dBi within the band of interest from 76-79 GHz. There is about a 0.8-1.5 dBi discrepancy between simulated and measured results, which could come from the imperfect impedance matching. The misalignment during the measurement decreased the gain also. The measured efficiency is from 71.2 %-84.9 %. About the axial ratio, the measured AR is smaller than 1.77 dB at the specification frequency band (76-79 GHz).

The simulated and measured RHCP patterns on *yz* plane and at 76 GHz, 77 GHz, 78 GHz, and 79 GHz are shown in Fig. 3. The measured relative cross polarization level (X-pol. level) is below -22 dB. The measured normalized side lobe level (SLL) is below -15 dB. The main beam scans about 6 degrees from 76 GHz to 79 GHz due to the characteristic of a traveling wave array.

3. Conclusion

A dual CP waveguide slot array antenna has been proposed and measured based on stepped RGW technology. Both good CP performance and far-field results have been achieved. Measured isolation of ports and polarization purity show the potential of this antenna to be used in polarimetric radar. The whole design process is explained in this paper.
Such a dual CP antenna array can be integrated with a commercial radar board using the already published integration concept and a complete radar front-end can be built in the future.

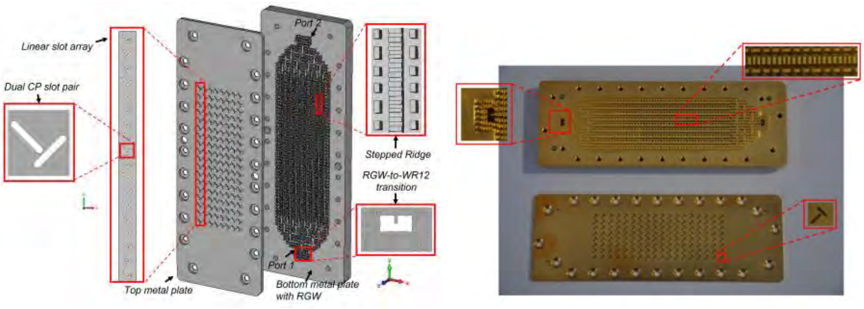
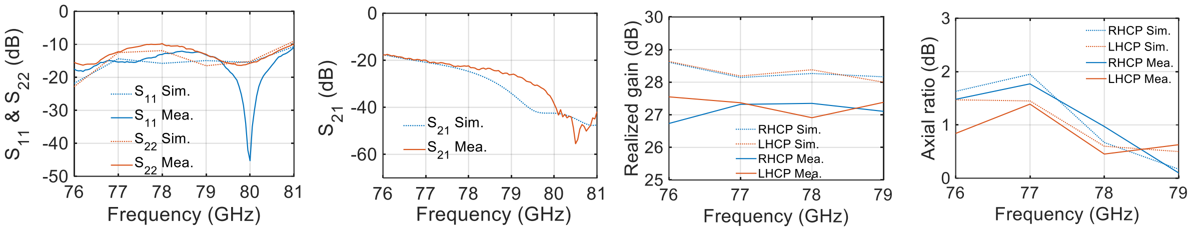
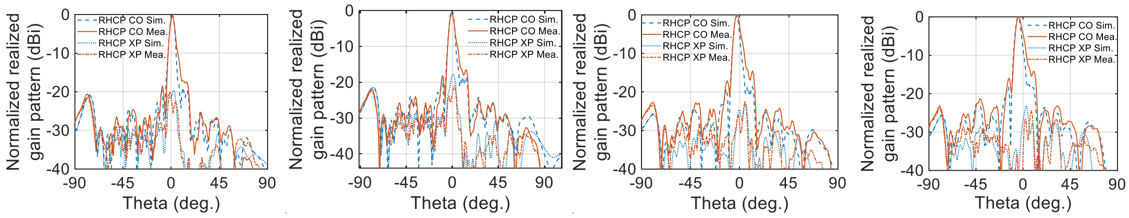


Figure 1. The model geometry and the prototype picture.



(a) (b) (c) (d)

Figure 2. Comparasions of simulated and measured results.



(a) (b) (c) (d)

Figure 3. Simulated and measured patterns of RHCP on yz plane at different frequencies. (a) 76 GHz. (b) 77 GHz. (c) 78 GHz. (d) 79 GHz.

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