A 76.5 GHz Microstrip Comb-Line Antenna Array for Automotive Radar System

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***Abstract*—This paper presents a 45 degree linearly polarized microstrip comb-line antenna array for the 76.5 GHz automotive radar system. The 13-element array is implemented on Rogers RO3003 substrate with a size of 20 × 2 mm^2. The measured gain of the antenna is 11.4 dBi and the sidelobe level is below -16.5 dB at 76.5 GHz.**

***Index Terms*—automotive radar, microstrip, comb-line antenna array.**

I. Introduction

The past decade has witnessed a rapid development of millimeter-wave automotive radars [1]-[3]. With latest semiconductor technology the whole radar system could be implemented with a high level of integration [4]. The development of automotive radar poses a challenge for the antenna design in terms of cost and dimension [5].

Different technologies have been applied to millimeter-wave antennas in automotive radar systems, such as waveguide slot array antennas [6]-[7], lens antennas [8], reflector antennas [9]-[10], SIW antennas [11]-[12], and gap-waveguide antennas [13]-[14].

As a low-cost solution for mass production, microstrip antennas are widely used in automotive radar industry [15]. A 27-element microstrip comb-line antenna array at 76.5 GHz was reported in [3]. The design in [3] was a traveling-wave antenna array. Therefore, the maximum beam direction is not orthogonal to the antenna surface, and changes with the frequency. This paper presents a 13-element 45° linearly polarized standing-wave microstrip comb-line antenna array for the 76.5 GHz automotive radar system, where the maximum beam direction is orthogonal to the antenna surface and does not change with the frequency in a certain frequency band. A prototype of the new designed antenna has been manufactured. The design with the simulation has been verified against the measurement.

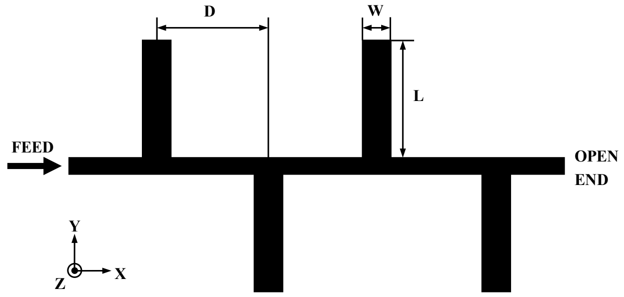

Fig. 1 90° uniform microstrip comb-line antenna array

II. Microstrip Comb-Line Antenna Array

A. Basic Configuration

The basic configuration of a 90° uniform microstrip comb-line antenna array is shown in Fig. 1. The radiating element of this array is the open-circuited stub and it has a radiation pattern similar to a dipole. The array is formed by placing stubs alternately on both sides and terminating the feedline by an open end, thus it is a standing-wave structure which works in resonant mode. The distance D between adjacent stubs is chosen as λ/2 to form a broadside radiation array and the stub length L is also λ/2 so the impedance seen from the feedline is the same as impedance at the open end.

For the automotive radar applications, the angle between each stub and feedline is adjusted to 45°. In this way the polarizations of radar signals sent by two vehicles coming from opposite directions are orthogonal to each other, therefore the interference could be minimized.

B. Array with Taylor Amplitude Taper

Sidelobe suppression is very critical for a radar system as high sidelobe level may result in false target detection. The typical sidelobe level of a uniform antenna array is approximately -13.5 dB [16]. Various amplitude taper could be applied on the array to achieve better sidelobe suppression. Here Taylor distribution is chosen since it offers optimal trade-

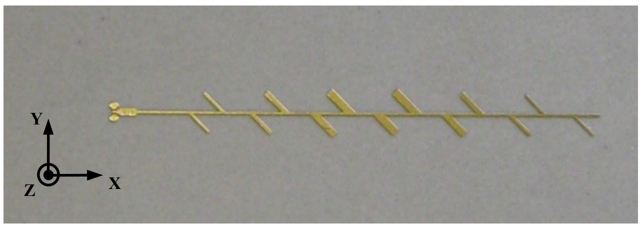

Fig. 2 Fabricated prototype of 45° microstrip comb-line antenna array with amplitude taper

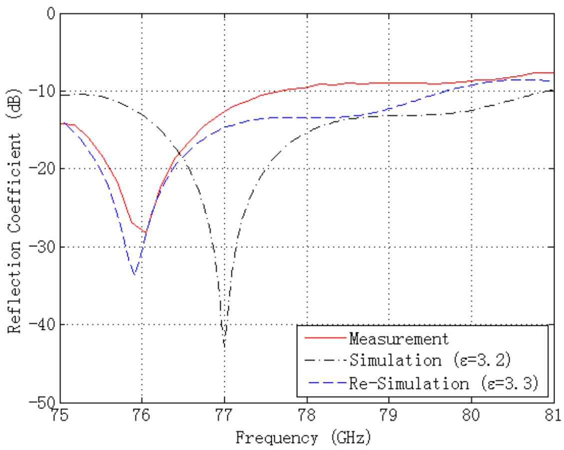

Fig. 3 Simulation and measurement results of reflection coefficient

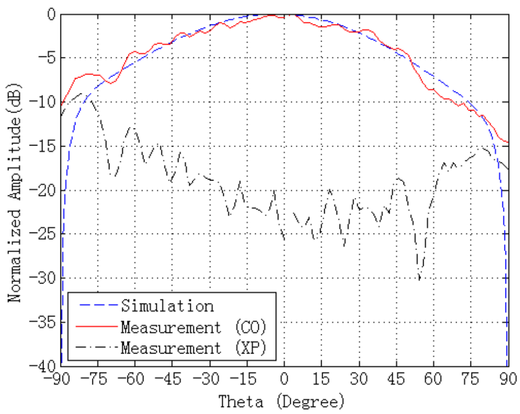

Fig. 4 Simulated and measured *yz*-plane radiation pattern at 76.5 GHz

off between sidelobe level and beamwidth.

The array with Taylor amplitude taper shows a radiation pattern whose first several sidelobes close to the main beam are at the same level while the rest of lobes decay monotonically. Both the number n and level R of first few minor lobes could be specified by the designer. In this design the value n is set to 3 with the chosen sidelobe level of -20 dB, the number of open-circuited stubs in the array is N=13. The amplitude distribution over the array is controlled by radiation conductance of each individual stub which is determined by the stub width W_i.

C. *Simulation and Implementation*

The fabricated 13-element 45° microstrip comb-line antenna array is shown in Fig. 2. It was simulated by Agilent Advanced Design System (ADS) and implemented on 0.127 mm thick Rogers RO3003 substrate. At 76.5 GHz the measured dielectric constant and loss tangent of the substrate are 3.2 and 0.0168, respectively. The approximate dimension of this array is 20×2 mm^2. The width W_i (i=1, 2…, 13) of each stub are listed in Table I.

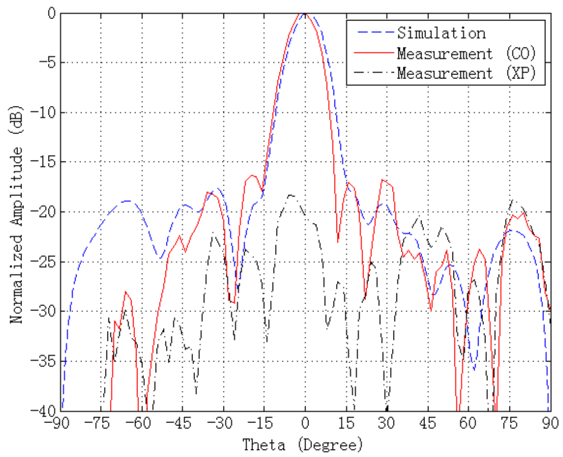

Fig. 5 Simulated and measured *xz*-plane radiation pattern at 76.5 GHz

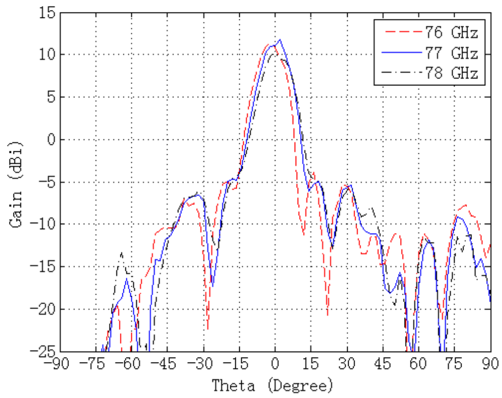

Fig. 6 Measured *xz*-plane radiation pattern at 76, 77, 78 GHz

D. *Measurement*

The measurement was performed on a probe-based setup [17]. Fig. 3 shows the comparison of reflection coefficient between simulation and measurement results. A displacement is found between simulated and measured reflection coefficient, one possible cause is that the initial value of permittivity used in simulation (ε=3.2) may not be very accurate. Therefore, the antenna is re-simulated with a new permittivity value ε=3.3 and the result shows better agreement with measurement. The radiation patterns in *yz*- and *xz*-planes at 76.5 GHz are shown in Fig. 4 and Fig. 5, respectively. Both patterns are normalized by their own maximum values. A blind region exists on the measured *xz*-plane pattern from -90° to -75° due to the space limitation of the measurement setup. The measured gain at 76.5 GHz is 11.4 dBi and the measured sidelobe level is -16.5 dB. To present the frequency response of the antenna, the *xz*-plane radiation patterns from 76 to 78 GHz with 1 GHz spacing are plotted in Fig. 6.

E. *Comparisons and Analysis*

In 2011, a 27-element microstrip comb-line antenna array at 76.5 GHz was reported in [3]. It was designed for traveling-

TABLE I. OPEN-CIRCUITED STUB WIDTHS OF FABRICATED 13-ELEMENT 45° MICROSTRIP COMB-LINE ANTENNA ARRAY

i	1	2	3	4	5	6	7	8	9	10	11	12	13
Width (mm)	0.10	0.11	0.15	0.21	0.28	0.33	0.35	0.33	0.28	0.21	0.15	0.11	0.10

wave excitation so the feedline was terminated by a matching element. To suppress the reflection, a reflection-canceling slit structure was implemented on the feedline around each radiating element. The measured reflection of antenna was -12.9 dB at 76.5 GHz and the sidelobe level was -17.9 dB.

The performance of the standing-wave antenna array presented in this paper is comparable to the above-mentioned traveling-wave array. However, one disadvantage of the traveling-wave array is that the maximum radiation beam direction is tilted respect to the antenna surface; on the other hand, the maximum beam direction of standing-wave array is orthogonal to the antenna surface and fixed within a certain frequency range. Another advantage of standing-wave array is that it does not have any reflection-canceling slit so the whole structure is much simpler compared with the traveling-wave array and more suitable for industrial applications.

III. CONCLUSION

A 76.5 GHz microstrip comb-line antenna array is developed for automotive radar system. It is implemented with 45° linear polarization to avoid interference of vehicle from opposite direction. Compared with uniform array, lower sidelobe level is achieved by applying Taylor amplitude taper. The measurement results show good agreement with the simulation.

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