MILLIMETER-WAVE SLOTTED WAVEGUIDE ARRAY ANTENNA MANUFACTURED BY METAL INJECTION MOLDING FOR AUTOMOTIVE RADAR SYSTEMS

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1. Introduction

Electrically beam-scanning planar antennas are required for automotive radar systems in the millimeter-wave band [1]. Slotted waveguide array antennas are expected to realize high gain and high efficiency since a waveguide has an advantage of low transmission loss in such a high frequency band [2]. However, the production cost of the general waveguide antenna is high in the case that the antenna is manufactured by conventional procedures such as metal cutting. We propose the slotted waveguide array antenna, as shown in Fig. 1 (a), for the radar system. Electrically beam-scanning in zx-plane is realized by digital signal processing of the digitized signals received from the subarrays. The RF and beamforming units are attached to the backside of the planar waveguide antenna as shown in Fig. 1 (b). In order to reduce the production cost, the metal injection molding technology [3] is

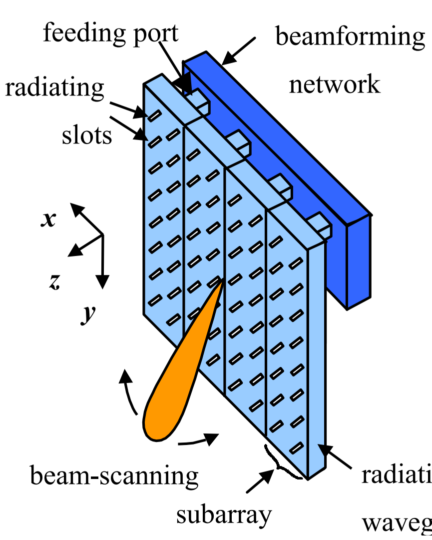

Fig. 1(a). Electrically beam scanning slotted waveguide array antenna.

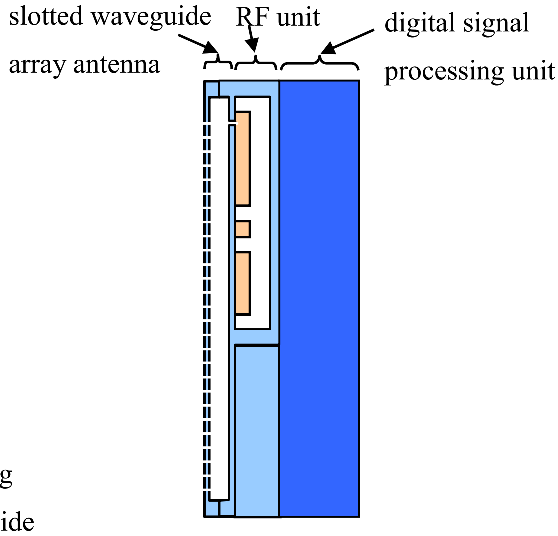

Fig. 1(b). Electrically beam-scanning radar with the slotted waveguide array.

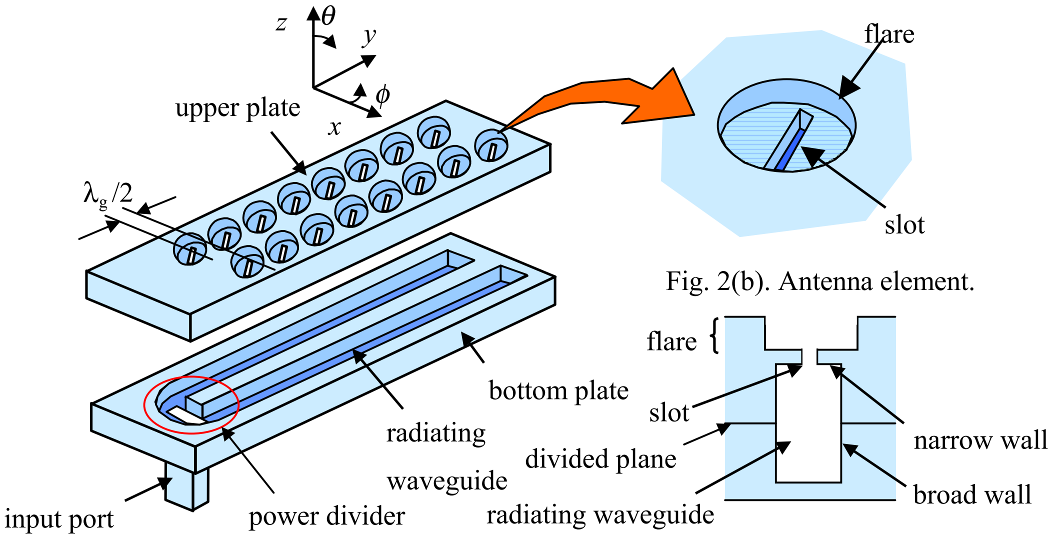

Fig. 2(a). Configuration of the developed subarray.

Fig. 2(b). Antenna element.

Fig. 2(c). Cross section of the antenna element.

adopted to manufacturing the waveguide antenna and the shielding case of the RF and signal processing units. In this paper, we introduce the antenna configuration and demonstrate performance of the developed antenna in the 76 GHz band. The performance of the antenna manufactured by the metal injection molding is compared to that of the antenna manufactured by the precision metal cutting.

2. Configuration of antenna

The configuration of the developed antenna is shown in Fig. 2 (a), (b) and (c). A subarray consists of two parallel radiating waveguides and is fed at the junction from the backside of the antenna by using a compact power divider. All the radiating slots are cut on the narrow wall of the radiating waveguide and are inclined 45 degrees from the guide axis (y-axis). The antenna is composed of the upper and the bottom plate. The waveguides are divided by the xy-plane at the center of the broad wall, where the current in the y-direction becomes almost zero. Therefore, the transmission loss of the waveguide is small.

The two radiating waveguides are fed by the divider in 180 degrees out of phase each other. Slots are arranged on both the waveguides with a half guide wavelength shift in y-direction in order to compensate the phase difference between the two waveguides and slot arrangement results in triangular lattice fashion. Grating lobes appear at the endfire direction in the plane with maximum slot spacing. In order to suppress the grating lobe level, we set a cylindrical flare around each slot, as shown in Fig. 2 (b) and (c). Since the flare shades the radiation from the slots to the endfire direction,

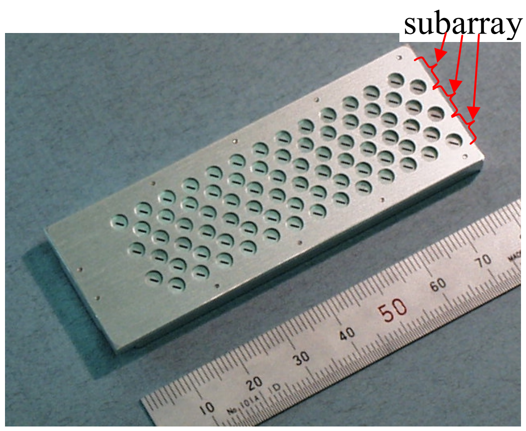

Fig. 3. Photograph of the developed antenna (MLA) which consists of three subarrays.

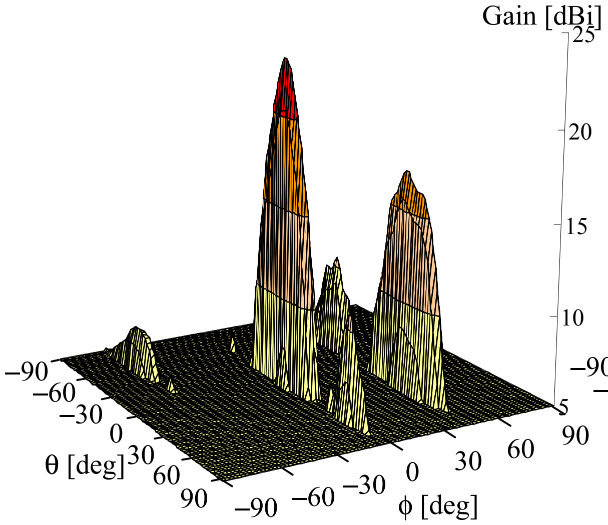

Fig. 4(a). Two dimensional radiation pattern of the antenna CTA with flare.

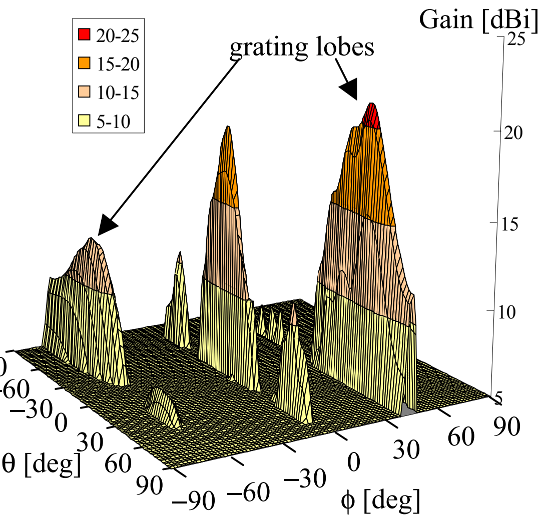

Fig. 4(b). Two dimensional radiation pattern of the antenna CTA without flare.

the grating lobe level is reduced.

We fabricated two antennas for experiment evaluating the antenna performance. One is fabricated by the metal injection molding of Magnesium alloys (MoLded Antenna: MLA). The other is fabricated by the precision metal cutting of Aluminum alloys (CuT Antenna: CTA). The photograph of MLA is shown in Fig. 3. The subarray antenna has the 26 slots. The slot spacing in the y-direction is approximately 1.2 λ_0 (λ_0: wavelength in free space). The aperture length is approximately 16 λ_0. The spacing between the two radiating waveguides is 0.84 λ_0. Therefore, the antenna element spacing in triangular lattice is 0.97 λ_0. A part of the grating lobe would appear at the endfire direction in the plane with maximum element spacing. The flare is 0.25 λ_0 in hight and 0.87 λ_0 in diameter.

3. Experimental results

Fig. 4 (a) and (b) show two-dimensional radiation patterns of CTA with and without the flare, respectively. In the case without the flare, the level of a grating lobe increases to 21.3 dBi which is 3.1 dB higher than the main lobe level. While, in the case with the flare, the levels of the grating lobes are approximately 6 dB lower than the level of the main lobe. Consequently, the gain of the main beam becomes 4.9 dB high in comparison with that of the antenna without the flare.

Fig. 5 shows the measured gain and the antenna efficiency of CTA and MLA. Those of CTA are 23.1 dBi and 54 % at 76.5 GHz, respectively. While, MLA's results are 23.2 dBi and 55 %, which are the same levels with those of CTA. Results of CTA without

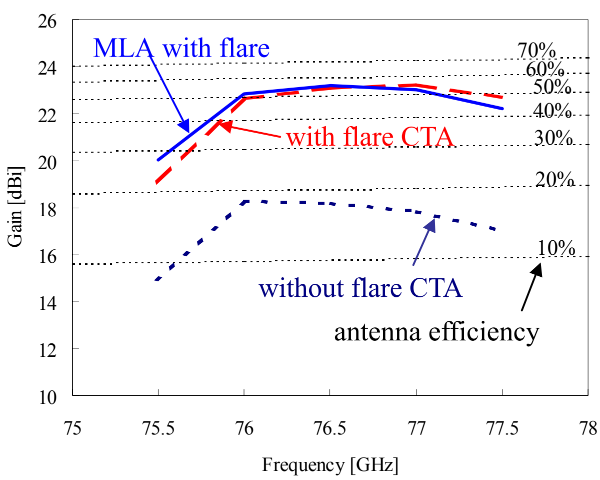

Fig. 5. Measured antenna gain and efficiency.

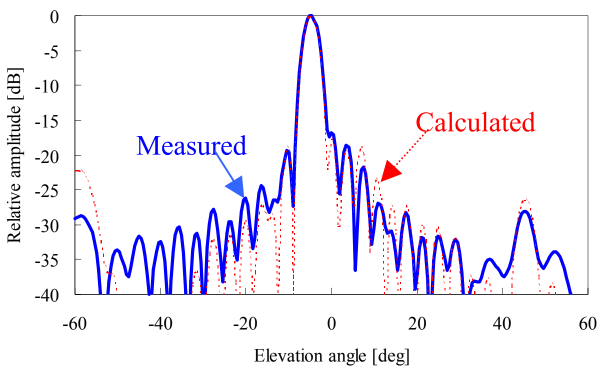

Fig. 6(a). Radiation pattern of MLA with flare in yz-plane.

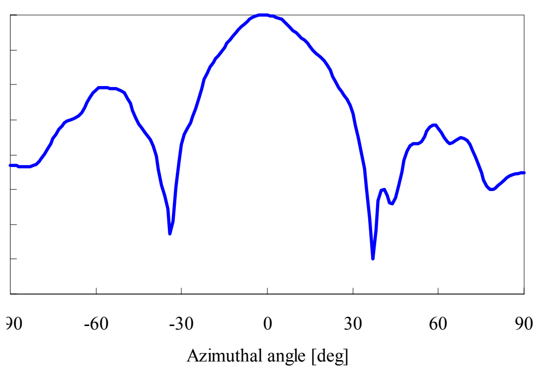

Fig. 6(b). Measured radiation pattern of MLA with flare in xy-plane.

the flare are also shown in Fig. 5 and are 18.2 dBi and 17 % at 76.5 GHz, respectively.

Fig. 6 (a) shows the radiation pattern of MLA in yz-plane. The tilting angle and half-power beam width are 5 degrees and 3.4 degrees, respectively. The measured highest sidelobe level is –17 dB. These results agree with calculations quite well. Fig. 6 (b) shows the measured radiation pattern in the zx-plane. The half-power beam width is 23.2 degrees. The highest sidelobe level is –12 dB. Fig. 7 shows the reflection characteristics. The measured reflection level of the subarray is –21 dB at 76.5GHz, which is small enough to ignore the antenna gain reduction.

4. Conclusion

We have proposed the slotted waveguide array antenna with the flare in order to obtain high performance. The antenna is fabricated by the metal injection molding. As a result of the experiments, the high efficiency of 55 % is realized in the 76 GHz band. It is confirmed that the metal injection molding technique can be applied to the mass production of the slotted waveguide antenna.

References

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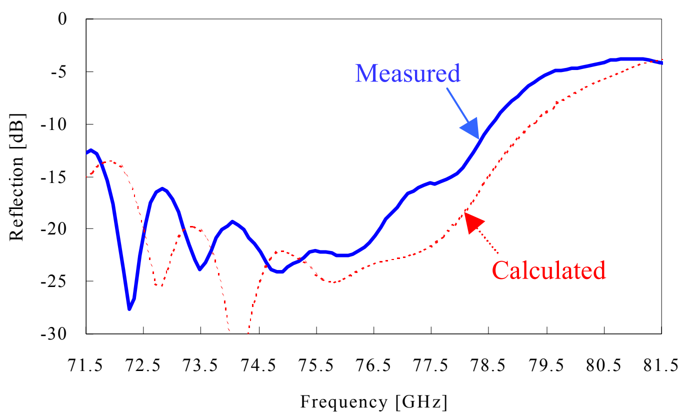

Fig. 7. Reflection from MLA with flare.