Design of a Corporate-fed 2×2-element Slot Array on a Hollow Rectangular Coaxial Line

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***Abstract*—In order to realize a single-layer corporate-fed slot array, a hollow rectangular coaxial line is adopted as a feeding line. A 2×2-element subarray on a hollow rectangular coaxial line for the corporate-fed array is designed for the 60-GHz band. For the wideband operation, a cavity-backed wide slot is adopted as a radiating element. The 5.7% bandwidth for the reflection less than −20 dB is obtained in the subarray by simulation. The performance of a 16×16-element array is evaluated using the result of the designed subarray.**

I. Introduction

Slotted waveguide array antennas [1] are promising candidates for millimeter-wave band applications such as fixed wireless access systems and radar systems. The fabrication technique of diffusion bonding of laminated thin metal plates [2], [3] expects low-cost fabrication of complicated multi-layer structure. The diffusion bonding technique was applied to a double-layer corporate-fed slot array [4], and the gain more than 32 dBi and the about 80% antenna efficiency above 4.8 GHz were achieved in the 60-GHz band. However, the antenna is relatively thick because of its double-layer structure. This is because the broad wall of the hollow rectangular waveguide has to be larger than half-wavelength, and therefore, the feeding circuit on the rectangular waveguide and the radiating part are separated in two different layers.

A single-layer corporate-fed slot array can be realized by adopting a TEM transmission line such as a rectangular coaxial line [5] as the feeding line because the width of a TEM transmission line has no limitation in size reduction in principle. Although the conductor loss of a rectangular coaxial line is generally larger than that of a rectangular waveguide, the rectangular coaxial line is suitable as a low-loss and compact feeding line [6].

In this paper, we present the radiation unit (2×2-element subarray) of the single-layer corporate-fed array on a hollow rectangular coaxial line for the 60-GHz band.

II. Antenna Configuration

Fig. 1 shows the configuration of the proposed single-layer corporate-fed slot array on a hollow rectangular coaxial line. The radiation unit (2×2-element subarray) shown in Fig. 2 is fed through a narrow rectangular coaxial line. The conductor loss of the feeding coaxial line calculated by the WII rule [7] is 0.067 dB/cm at 60 GHz, which is still smaller than the transmission loss of the post-wall waveguide (0.13 dB/cm) of PTFE ($\varepsilon_r = 2.17$, $\tan\delta = 6.50\times10^{-4}$) [8].

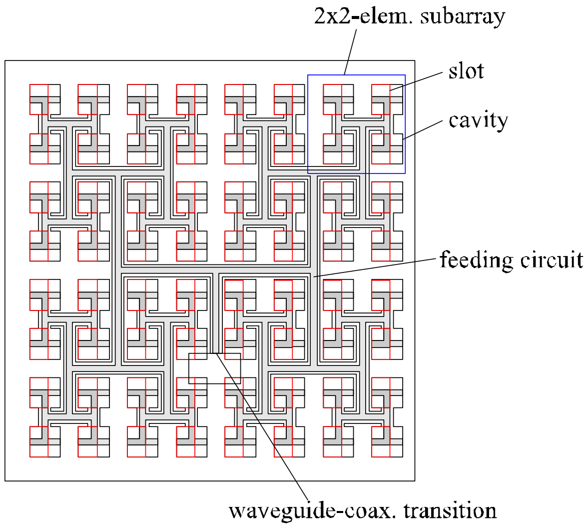

Fig.1. Configuration of the corporate-fed slot array on a rectangular coaxial line.

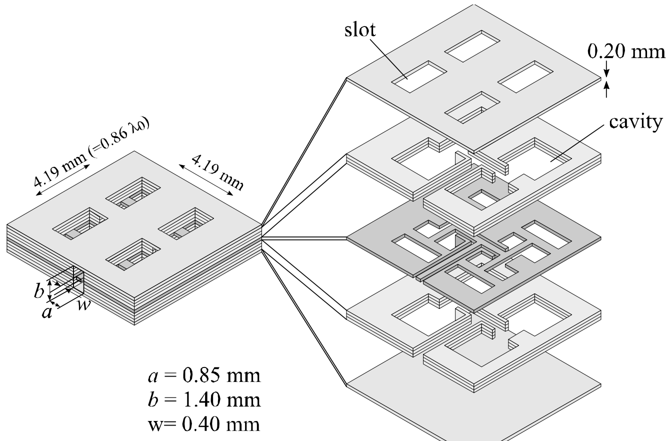

Fig.2. A 2×2-element subarray of wide slots.

III. Subarray Design

Fig. 3 shows the analysis model of the 2×2-element subarray. Wide slots and cavities are adopted for the wideband operation. In order to reduce the inner mutual couplings to the adjacent slot and the junctions, the cavity-backed slots are connected with narrow rectangular coaxial lines. Two pairs of periodic boundaries are placed so as to take into account the external mutual coupling in the uniformly-excited infinite array. The parameters are determined to maximize the bandwidth for the reflection below −20 dB. The frequency characteristic of the reflection coefficient is shown in Fig. 4. The bandwidth for the reflection less than −20 dB is 5.7%.

The radiation patterns of the 16×16-element array are calculated using the designed 2×2-element subarray and the array setup option of HFSS. The radiation patterns at 61.5 GHz of the 16×16-element array are shown in Fig. 5. The grating lobes of about −20 dB at ±35 degrees and the asymmetric radiation pattern are observed in the E-plane. This is because the excitation of the slots is not uniform due to the asymmetric structure of the subarray. In the H-plane, the grating lobes of cross-pol. are confirmed, which comes from the cross-pol. component (y-component) of the electric field on the wide slot.

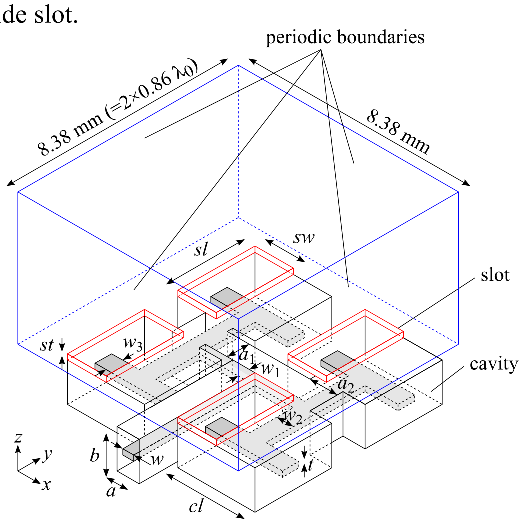

Fig. 3. Analysis model of the 2×2-element subarray.

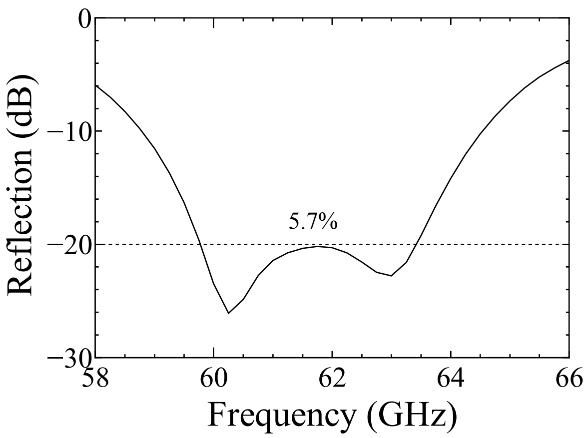

Fig. 4. Reflection of the designed 2×2-element subarray.

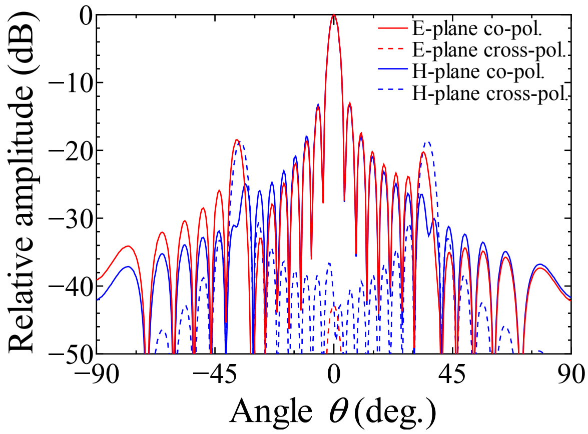

Fig. 5. Radiation patterns of the 16×16-element array simulated using the array setup.

IV. Conclusion

We have proposed the single-layer corporate-fed slot array on a hollow rectangular coaxial line for the 60-GHz band. The designed radiation unit (2×2-element subarray) for the antenna has been presented. The 5.7% bandwidth of the subarray for the reflection below −20 dB has been obtained by simulation. The radiation patterns of the 16×16-element subarray have been evaluated using the array setup option of HFSS. The grating lobes of about −20 dB with respect to the main lobe are confirmed in both the E- and the H-planes.

We are now working on the designs of the feeding circuit and the transition to form the 16×16-element array. The proposed antenna will be fabricated by diffusion bonding of laminated thin metal plates.

References

[1] R. C. Johnson and H. Jasik, Antenna Engineering Handbook, ch.9, McGraw-Hill, 1984.

[2] R. W. Haas, D. Brest, H. Mueggenburg, L. Lang, and D. Heimlich, "Fabrication and Performance of MMW and SMMW Platelet Horn Arrays, " *International Journal of Infrared and Millimeter Waves*, vol. 14, no. 11, pp. 2289-2294, Sep.1993.

[3] M. Zhang, J. Hirokawa and M. Ando, "Design of a Partially-Corporate Feed Double-Layer Slotted Waveguide Array Antenna in 39 GHz Band and Fabrication by Diffusion Bonding of Laminated Thin Metal Plates," *IEICE Trans. Commun*., vol. E93-B, no. 10, pp. 2538-2544, Oct. 2010.

[4] Y. Miura, J. Hirokawa, M. Ando, Y. Shibuya, and G. Yoshida, "Double-layer full-corporate-feed hollow-waveguide slot array ntennain the 60 GHz-band," *IEEE Trans. Antennas Propag*., vol. 59, no. 8, pp. 2844-2851, Aug. 2011.

[5] M. Ke, Y. Wang, M. Lancaster, "Design and Realization of Low Loss Air-Filled Rectangular Coaxial Cable with Bent Quarter-Wavelength Supporting Stubs," *Microwave and Optical Technology Letters*, vol. 50, pp. 1443-1446, May 2008.

[6] M. Ohtsuka, T. Takahashi, Y. Konishi, S. Urasaki, and K. Harada, "A dual-polarized planar array antenna for Ku-band satellite communications", in Proc. *IEEE AP-S Int. Symp*., vol. 1, pp. 16-19, June 1998.

[7] D. M. Pozar, Microwave Engineering, 4th Ed., John Wiley & Sons, 2011.

[8] Y. She, T. H. Tran, K. Hashimoto, J. Hirokawa and M. Ando, "Loss of Post-wall Waveguides and Efficiency Estimation of Parallel-Plate Slot Arrays Fed by the Post-wall Waveguide in the Millimeter-wave Band," *IEICE Trans. Electronics*, vol. E94-C, no.3, pp. 312-320, Mar. 2011.