Wideband Waveguide Slot Array Antennas with Corporate-feed in 120GHz and 350GHz Bands

Jiro Hirokawa[#], Dongjin Kim[#], Makoto Ando[#], Tadao Nagatsuma[*], Jun Takeuchi[+] and Akihiko Hirata[+]

[#] *Department of Electrical and Electronics Engineering, Tokyo Institute of Technology*
2-12-1 Ookayama, Meguro, Tokyo 152-8552, Japan
jiro@antenna.ee.titech.ac.jp

[*] *Graduate School of Engineering Science, Osaka University*
1-3 Machikaneyama, Toyonaka, Osaka 560-8531, Japan
nagatuma@ee.es.osaka-u.ac.jp

[+] *Microsystem Integration Laboratories, NTT Corporation*
3-1 Wakamiya, Morinosato, Atsugi, Kanagawa 243-0198, Japan
hirata.akihiko@lab.ntt.co.jp

Abstract—**We design and fabricate double-layer slotted waveguide array antennas with wide bandwidths and high efficiencies for 120 GHz and 350 GHz bands. To achieve high gain and high efficiency in high frequency bands, the diffusion bonding technique of plate laminated waveguide is used as a fabrication method. The antennas with 16x16 slots show about 70% efficiency with 32 dBi gain and about 50% efficiency with 31 dBi gain in the 120 GHz and 350 GHz bands, respectively.**

I. Introduction

One of the promising techniques to increase the transmission rate is to use higher frequency band because the transmission capacity of the wireless link increases. For this reason, various millimeter-wave wireless links using 120 GHz and higher frequency bands are being widely researched [1]. High gain antennas are needed for the increasing the transmission capacity and transmission distance. Currently, most of those systems are using standard horn antennas with lens or reflector antennas. The antennas for such a high frequency are rare due to the difficulty of fabrication.

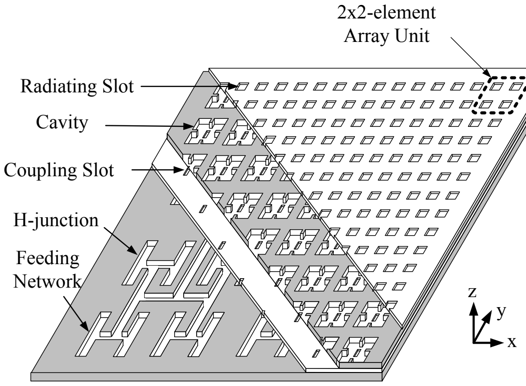

Fig. 1. Antenna Configuration

We are investigating the feasibility of the corporate-feed plate-laminated waveguide slot array antenna for these communication systems. A 16x16-element antenna achieves 80% antenna efficiency with more than 32dBi over a 4.8GHz bandwidth in the 60GHz band [2]. Etching patterns in the laminated plates can provide high precision and the diffusion bonding can give perfect electrical contacts among the plates even at such higher frequencies. In this paper, we design this antenna in the 120 GHz and 350GHz bands to demonstrate the performances.

II. Antenna Structure

The structure of the proposed antenna is illustrated in Fig.1. 16x16-radiating slots are arranged with 0.86 wavelength interval on the top layer. A corporate-feed waveguide that consists of several H-plane T-junctions is located in the lower layer. The radiating part is fed through a coupling aperture located at each end of the feeding circuit. The sizes of these antennas are 33.6 mm square with 1.6 mm height and 11.2 mm square with 0.6 mm height in the 120 GHz and 350 GHz bands, respectively.

A 2x2-element array is designed as a unit to be fed by the corporate-feed structure. Figure 2 shows the 2x2-element array on a cavity with the feed waveguide. Firstly, we design this 2x2-element sub-array to have good reflection and good radiating performance for each band. Then we combine the 2x2-element sub-arrays with the corporate-feeding network.

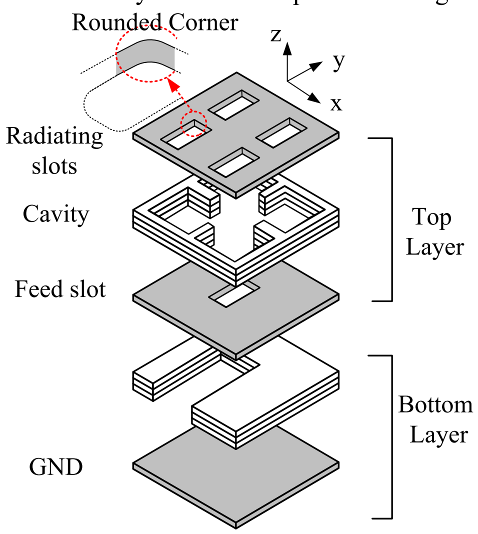

Fig. 2. 2x2-element array unit

The overall bandwidths of reflection are 8.6% and 5.6% for VSWR less than 1.5 and the antenna efficiencies are around 80% and 70% in the 120 GHz and 350 GHz bands, respectively. The narrower bandwidth in the 350 GHz band is caused by the effects of design limitations on plate thickness and rounded corner; they affect much on the 350 GHz band than the 120 GHz band. Also, the conductivity loss increases in higher frequency, the antenna efficiencies in the 120 GHz and 350 GHz bands are lower than the previous antenna with 80% antenna efficiency in the 60 GHz band.

III. ANTENNA MEASUREMENT

Figure 3 shows the frequency characteristic of the reflection at the feed aperture of the 120 GHz band antenna. We measure the reflection using a vector network analyzer. The measured reflection is quite different from the design result. In order to identify the factors for the degrading and frequency shifting in the measurement, we have done calculations for various values of over-etching. The result assuming 30 μm over-etching for all layer patterns is added into Fig.3 and Fig.4 which show good agreement with the measured one. Figure 4 shows the frequency characteristic of the gain and the antenna efficiency. The measured gain is compared with a standard gain horn antenna. In design, the peak of the gain including the conductor loss and reflection is 33.1 dBi with 84% antenna efficiency at 126.5 GHz. But in measurement, we have 32.9 dBi of the gain with 80% antenna efficiency.

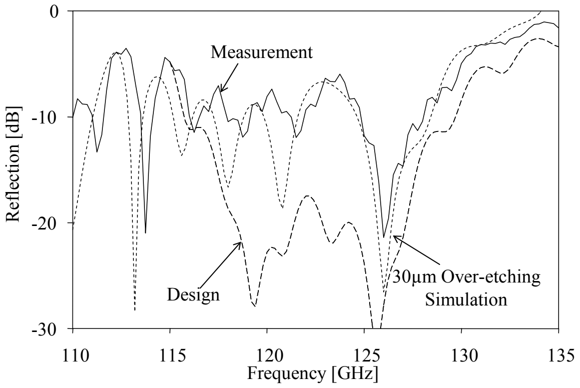

Figure 3. Reflection of 120 GHz band antenna

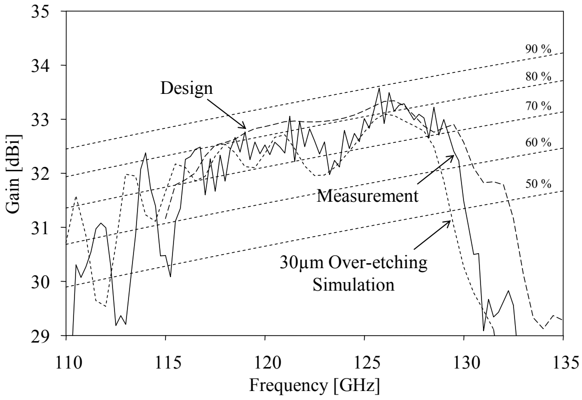

Figure 4. Gain and antenna efficiency of 120 GHz band antenna

The antennas for the 350 GHz band are also fabricated. In this frequency band, three antennas are fabricated by adding ±10 μm into all the parameters, assuming over/under etching. Figure 5 shows the frequency characteristics of the gain and the antenna efficiency. The frequency dependence is shifted qualitatively lower by increasing all the parameters among the three antennas. Even though we fabricated the three antennas considering with over/under etching, the over-etching was occurred much more than we expect. Also various values of over-etching were calculated to find out the over-etching value in the 350 GHz band and the calculation results are added in Fig.5. The measured three antenna gain values of +10μm, 0μm and -10 μm are well matched with over-etching simulation assumed +40 μm, +30 μm and +20 μm in Fig.5. Thus we confirm that the over-etching value in the 350 GHz band also 30 μm. In design, the peak of the gain including the conductor loss and reflection is 32.2 dBi with 75% antenna efficiency at 350 GHz. But in measurement, we have about 32.0 dBi of the gain with 74% antenna efficiency.

Since the fabrication errors such as over-etching much effect on the antenna performance in a high frequency such as 120 GHz and 350 GHz, we should consider the fabrication error properly when we design an antenna using diffusion bonding method.

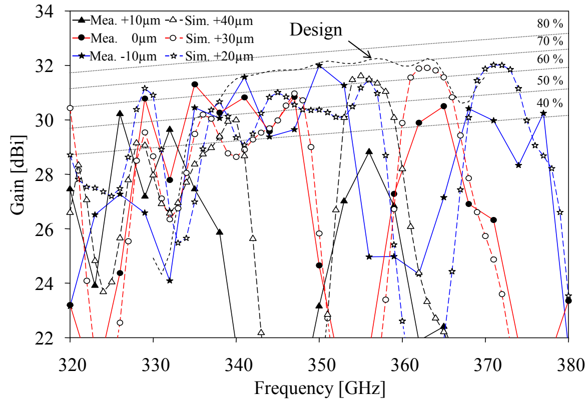

Figure 5. Gains and antenna efficiencies of 350 GHz band antennas

IV. CONCLUSION

A double-layer waveguide slot array antennas with high gain and broad bandwidth are designed and fabricated for 120 GHz and 350GHz bands. In the presentation, we will show the latest measured results of the 350GHz antenna with revising the fabrication errors.

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