

Design and Fabrication of a Coporate-feed Plate-laminated Waveguide Slot Array Antenna for 120GHz-band

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Abstract— We propose a double-layer slotted waveguide array antenna having a wide bandwidth and a high efficiency for 120 GHz band. The diffusion bonding of laminated thin metal plates provides high precision even in very high millimeter bands such as 120 GHz. We design a 16x16-element array antenna having 90% peak aperture efficiency with 33.4 dBi at 126.5 GHz.

Keywords- plate-laminated waveguide; diffusion bonding; double-layer; slot antenna, corporate feed

I. INTRODUCTION

Recently, there is strong demand for millimeter-wave wireless links using 120GHz and higher bands for the increase in data rate needed to catch up with the expanding broadband society [1]. We are investigating the feasibility of the corporate-feed plate-laminated waveguide slot array antenna [2][3] for this demand. A 16x16-element antenna achieves 80% antenna efficiency with more than 32dBi over a 4.8GHz bandwidth in the 60GHz band. 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 band to demonstrate the high performances. The proposed antenna shows high efficiency of 80 % over an 11.5 GHz bandwidth and the peak of the directivity is 33.4 dBi with 90 % aperture efficiency at 126.5 GHz. The 1-dB down gain bandwidth is 13.9 %.

II. ANTENNA STRUCTURE AND DESIGN

A. Structure

The structure of the proposed antenna is illustrated in Figure 1. There are 16x16 radiating slots with 0.86 wavelength interval on the top layer fed by a corporate feeding network on the bottom layer. Figure 2 shows the layer information of this antenna. The upper layer of this antenna consists of three etching patterns. Three kinds of the etching patterns are for radiating slots (0.2 mm thickness), cavities (0.6 mm thickness) and coupling slots (0.2 mm thickness). The bottom layer consists of one etching pattern for the feeding network (0.6 mm thickness). All of the etching patterns are composed by

laminating thin metal plates of 0.2 mm thickness. The total antenna size of the 16x16-element array is 41.5mm x 42.0 mm and the total thickness is 1.6 mm for the design frequency of 123GHz.

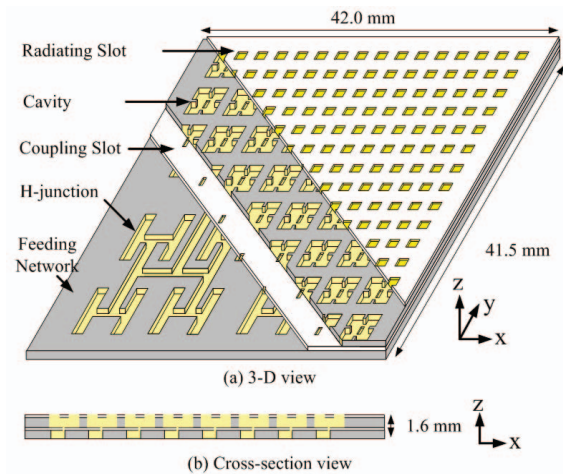


Figure 1. Antenna Configuration

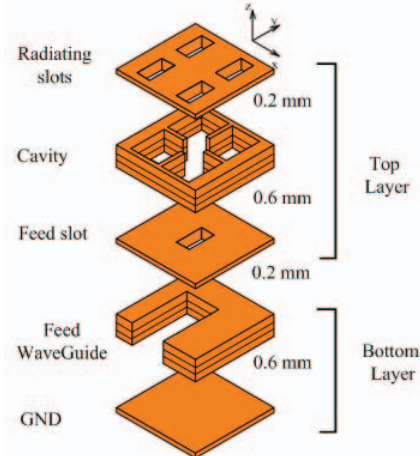


Figure 2. Layer Information of the Antenna

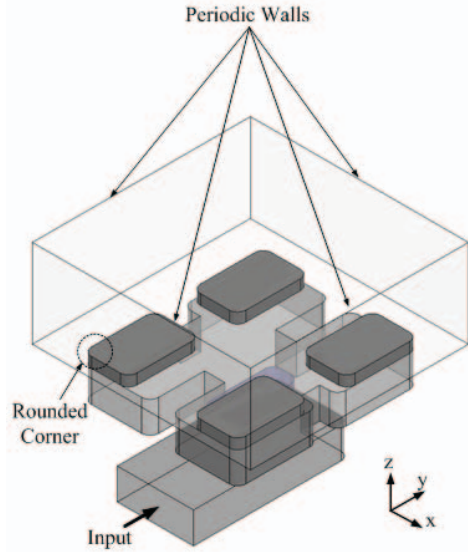


Figure 3. 2x2-element Array Unit Configuration

B. 2x2-element Design

A 2x2-element array is designed as a unit to be fed by the corporate-feed structure. Figure 3 shows the 2x2-element array on a cavity with the corporate-feed waveguide. Since the coupling slot and the cavity under the radiating slots provide same magnitude and same phase from the antenna input to each radiating slot, this antenna shows the broad bandwidth and the high efficiency. Two sets of periodic boundary walls are placed in the external region to include the mutual coupling in an infinite two-dimensional array of the radiating slots. This 2x2-element antenna dimension is basically based on the previous designed antenna for 60 GHz [3], however it can not be scaled down because the fabrication method using plate-laminating has a limitation of the plate thickness. The minimum thickness which can be fabricated using plate-laminating is 0.2 mm; this antenna is redesigned for 120 GHz band with a 0.2 mm plate. Furthermore, there is one more limitation for the fabrication using plate-laminating. It is impossible to make a rectangular for each corner of the slot by etching. Thus each corner of the slot must be rounded as marked in Figure 3. Basically, this 2x2-element unit has a wide bandwidth due to its dual-resonance caused by the slot self-resonance and the external mutual coupling [4]. Because the periodic structure of this slot is dependent on the ratio between the width and the length of the slot, the radius of the corner is a quite important parameter for the bandwidth. As shown in Figure 4, the slot shape is changed according to the radius of the corner, the ratio between the width and the length of the slot is also changed. It is not needed to consider the effect of this rounded corner in the previous research such as 60 GHz band because the antenna structure is large enough to ignore the effect of the rounded corner. However in this research, we must consider the effect of this rounded corner since the antenna structure is relatively much smaller than the previous research. Figure 5 shows the simulated results of various radius of the rounded corner. According to the change of the radius of the corner, the local

maximum values and bandwidths of the reflection are changed. We evaluate the bandwidth and the local maximum value at VSWR of 1.5 and VSWR of 1.2, respectively. The local maximum value must be low just in case some error occurs in fabrication. As shown in Figure 5, the local maximum value and the bandwidth of the reflection shows a trade-off relation. We determine the radius of the corner as the size of 0.16 mm. This 0.16 mm for the radius of the corner is also the minimum value to fabrication. The bandwidth of this 2x2-element array is 8.4% and the local maximum value of the reflection is -23 dB when the radius of the corner is 0.16 mm

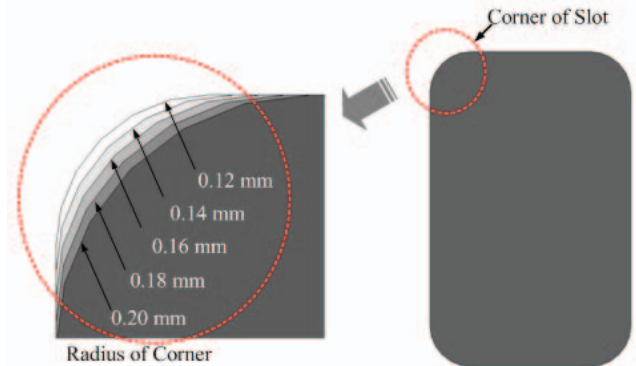


Figure 4. Slot Shape according to the Radius of Rounded Corner

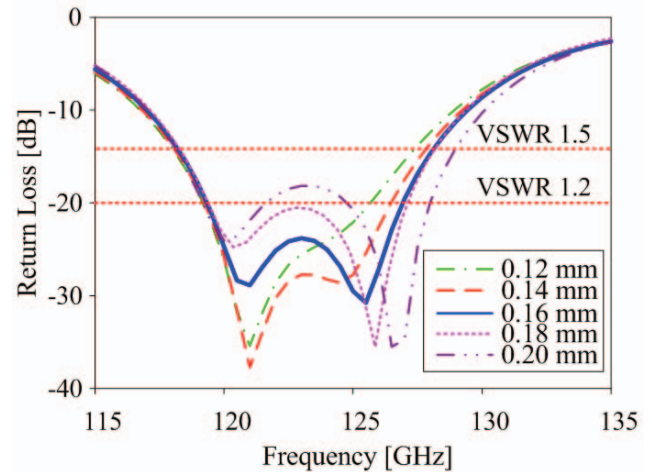


Figure 5. Frequency Response of the 2x2-element Antenna Array according to the Radius of the Rounded Corner

C. 8x8-way Corporate Feeding Network

The corporate feeding network is designed to obtain uniform aperture distribution of the 16x16-element array antenna [4]. Figure 6 shows the structure of the 8x8-way corporate feeding network. The feeding network consists of several H-junctions, T-junctions and the feeding-aperture. These feeding elements are also redesigned with 0.2 mm plates for the fabrication. Several irises are used to improve the reflection of each element. As seen in Figure 7, the reflection of the feeding network is suppressed below -20 dB over a wide bandwidth.

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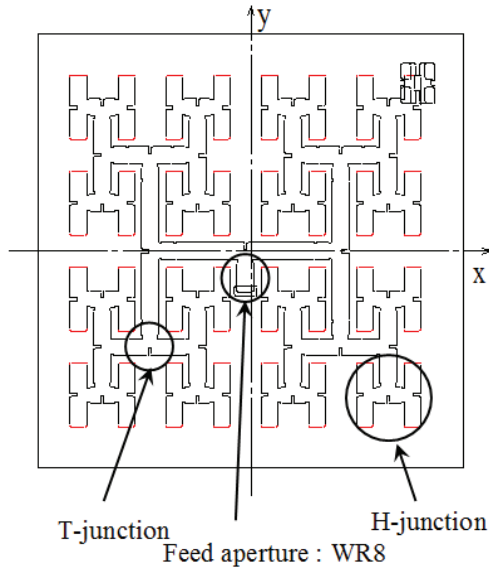


Figure 6. 8x8 way Full-corporate Feeding Network

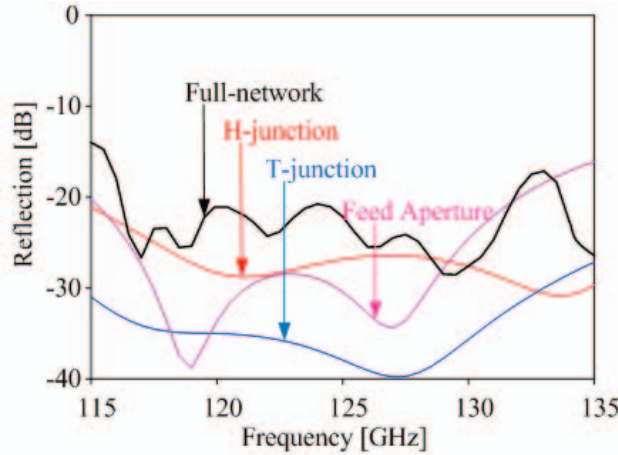


Figure 7. Reflection of the Feeding Elements

III. 16X16-ELEMENT FULL SIMULATION RESULTS

The radiating slots and the corporate-feed circuit are designed to obtain uniform aperture distribution for a broad bandwidth and high efficiency. Figure 8 shows the aperture field distribution of the full model simulated at 123 GHz. Uniform aperture field distribution is obtained by adopting the corporate feeding network. Figure 9 shows the frequency characteristics of the 8x8-way feeding network and the full model together with the antenna at the input point. The bandwidth of the full model is 8.6% for VSWR less than 1.5. This result is well matched with the frequency response of the 2x2-element array model. Figure 10 shows the frequency characteristic of the gain. The peak of the directivity is 33.4 dBi with 90% aperture efficiency at 126.5 GHz. The 1-dB

down gain bandwidth is 13.9%. Figure 11 shows the co-polarization radiation patterns of the full model in the E-plane and H-plane at 123 GHz. The radiation patterns in the both planes have symmetry because of the symmetric structure of antenna. The 3-dB down beamwidth is 3.92 degrees. The cross-polarization is suppressed below -60 dB for the both of E-plane and H-plane.

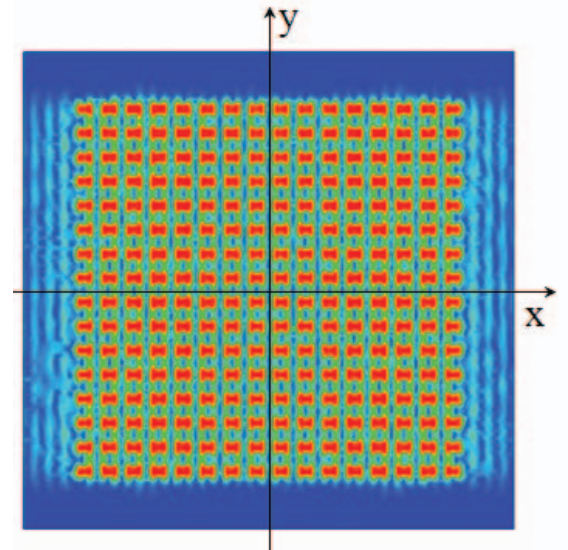


Figure 8. Aperture Field Distribution in Amplitude

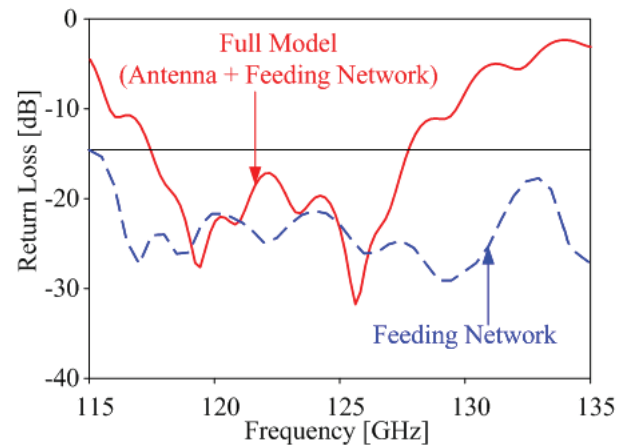


Figure 9. Frequency Response of the Full Simulation Model

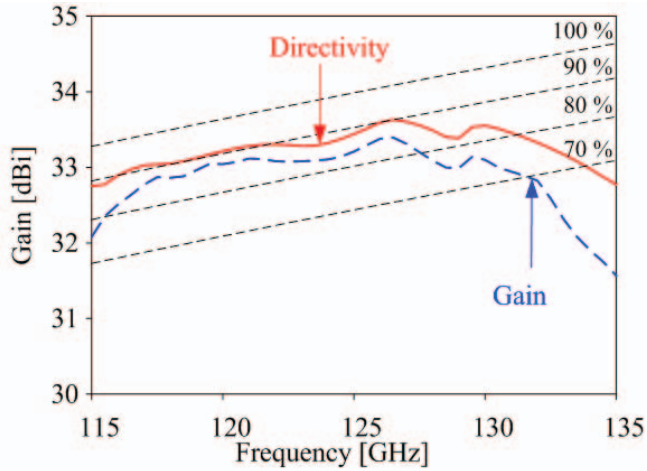


Figure 10. Gain and Efficiency of the Full Simulation Model

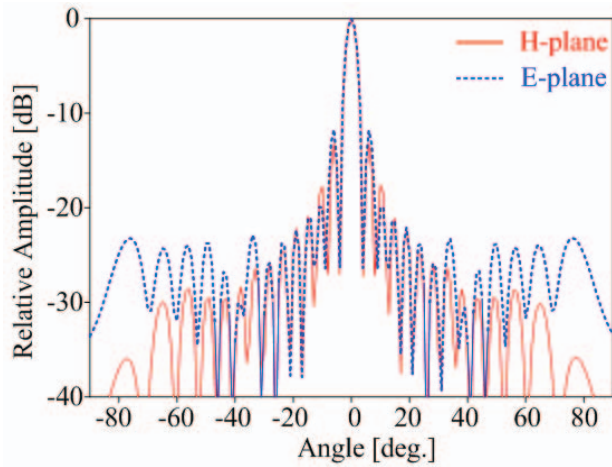


Figure 11. E-plane and H-plane Radiation Pattern

IV. CONCLUSION

A double-layer waveguide slot array antenna with a high gain and a broad bandwidth is proposed for 120 GHz band. The 16x16-element array antenna is designed and it shows high efficiency of 80 % over a 11.5 GHz bandwidth. These antennas have been under fabrication and the measured results will be presented in the conference.

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