格子状金属板を装荷した逆相給電一層構造導波管平面アンテナの設計法に関する研究

A study on design of an alternating-phase fed single-layer slotted waveguide array with a latticed plate

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1. INTRODUCTION

High-gain and mass-producible planar antennas are strongly demanded in accordance with development of millimeter wave applications such as fixed wireless access (FWA) systems in 20–40 GHz and automotive radar systems in 76 GHz. A single-layer slotted waveguide array is an attractive candidate for these applications. Figure 1 presents a configuration of an alternating-phase fed single-layer slotted waveguide array with a wide choke. An outstanding feature of the alternating-phase fed array is that the electrical contact, such as brazing, between the slotted plate and the feed structure can be dispensed with because the currents on the narrow walls do not cross the contacting surface, as shown in Fig. 1 (b). Therefore, the slotted plate is simply tacked on the feed structure and is fixed by screws at the periphery, since the choke surrounding the waveguides eliminates the leakage at the periphery without electrical contact.

In order to enhance the performance of the alternating-phase fed array for millimeter wave use, it is proposed that a latticed plate with a relatively large thickness is stacked on the slotted plate and that they are fixed by screws tightly on the feed structure, as shown in Fig. 1. Thickness of the latticed plate is not negligible in millimeter wave because, for examples, 1 mm is corresponding to a quarter wavelength in 76 GHz. This paper presents design of the slot array for the proposed antenna. The element of the array is regarded as a waveguide slot with a cavity. An analysis model to take effects of the cavity as well as mutual couplings in the external region into account is solved by MoM to obtain the slot coupling for the array design [1], [2]. The slot array with 25 elements is designed for uniform aperture distribution at 76.5 GHz [3]. A prototype antenna is manufactured and validity of the design is confirmed by the near field measurement.

2. SLOT COUPLING ANALYSIS

Fig. 2 presents an analysis model for slot coupling for design of the slot array and its structural parameters, respectively. The element of the slot array is regarded as a waveguide slot antenna with a rectangular cavity. It is important to take into account effects of the cavity and the mutual couplings via the external region for design of the planar array. In order to simulate the mutual couplings, PEC and periodic boundary conditions (PBC) are assumed in the external region. This model is analyzed by the method of moments (MoM).

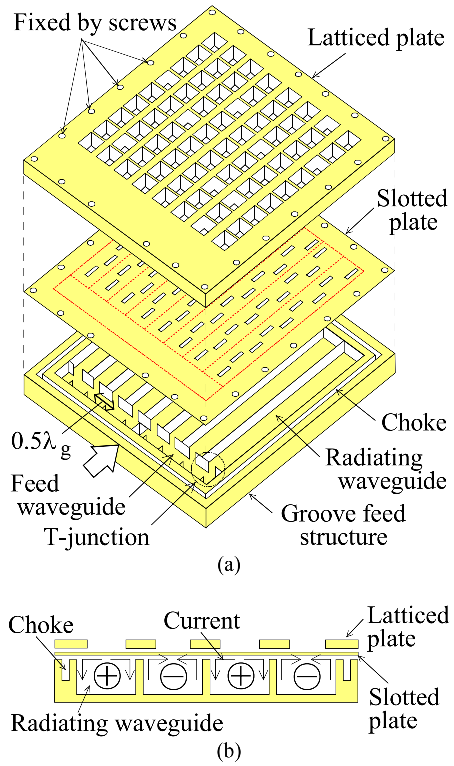

Fig. 1: Alternating-phase fed waveguide slot array with a latticed plate. (a) Bird's eye view. (b) Cross-sectional view of the radiating waveguides.

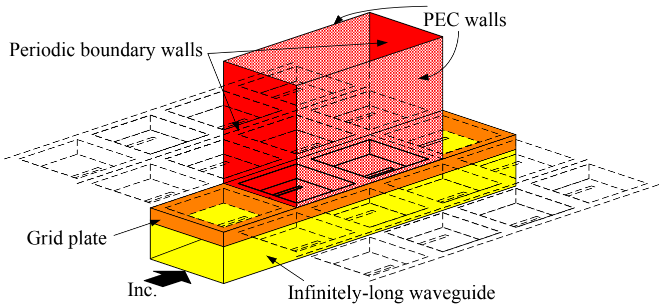

Fig. 2: Analysis model of slot coupling for the array design.

3. ARRAY DESIGN

A slot array with a rectangular cavity is designed for uniform aperture distribution by using the results of the slot coupling analysis. The conventional design method for a resonant shunt slot array is available for this array because the radiation power can be controlled by the slot offset while the slot length is chosen to be a resonant slot.

The design frequency is 76.5 GHz. The dimensions of the waveguide are a = 2.53 mm × b = 1.47 mm. The thickness of the slotted plate t is 0.1 mm. The number of slots in the array is set to be 25. The slot spacing is 3.36 mm, where forward beam tilting is adopted and the main beam is tilted by 2.5 degree from the boresight. The dimensions of the cavity (a_h = b_h =2.21 mm and c_h = 1.0 mm) and the slot width (w = 0.24 mm) are identical for all the slots. Figure 3 presents the final parameters of the designed slot array. They are corresponding to the change of conductance for uniform distribution. Figure 4 presents the aperture field distribution predicted by the array analysis. Uniform aperture distribution is confirmed. The deviations in the amplitude and phase distribution are within 2 dB and 40 degrees, respectively.

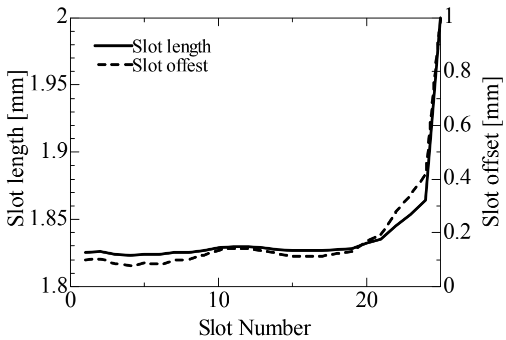

Fig. 3: Designed slot length and offset of the slot array.

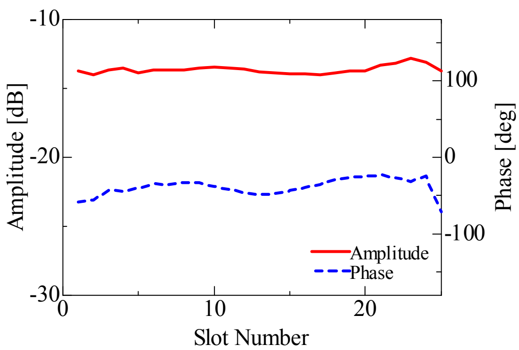

Fig. 4: Predicted aperture distribution of the slot array.

4. EXPERIMENTAL RESULTS

In order to verify the design of the slot array with the cavity, a prototype antenna with 24 waveguides and 25 slots on each waveguide is fabricated in 76 GHz. The aperture area occupied by the slots is approximately 84 mm (along the slot array) × 80 mm (along the feed waveguide). The slotted plate and the latticed plate are tacked and fixed by screws on the groove feed structure with a choke corrugated at the periphery.

Figure 5 (a) and (b) illustrate amplitude and phase distributions over the aperture at 76.5 GHz obtained by near field measurement. As shown in the figures, uniform distribution is observed for both the amplitude and the phase. The radiation pattern of the slot array calculated from the measured near field is plotted in Fig. 6. The measured pattern agrees well with the predicted one. Validity of the slot design is confirmed by the measurement.

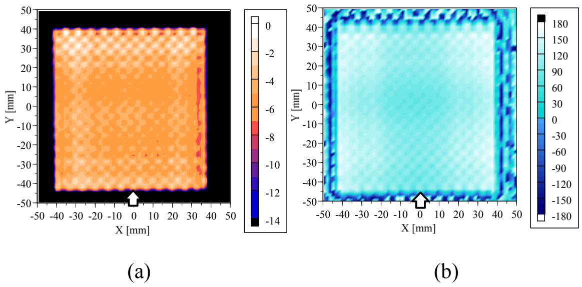

Fig. 5: Measured aperture field distribution at 76.5 GHz. (a) Relative amplitude (in dB). (b) Phase (in degree).

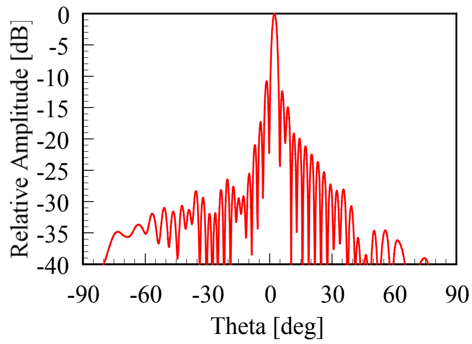

Fig. 6: Radiation pattern of the slot array calculated from the near field measurement.

5. CONCLUSION

Design of the slot array for the alternating-phase fed array with the latticed plate is presented. The analysis model with PEC and PBC walls in the external region is solved by MoM to obtain the slot coupling for the array design, where effects of the cavity as well as the mutual couplings are taken into account. The slot array with 25 elements is designed at 76.5 GHz and uniform aperture distribution within 2 dB deviations in amplitude and 40 degree in phase is predicted. The validity of the slot design is confirmed by the near field measurement.

REFERENCES

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