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MEASURED PERFORMANCE OF SLOTTED WAVEGUIDE PHASED ARRAY ANTENNA USING FEEDING CIRCUIT OF BLOCK EXCITATION TECHNIQUE

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1. Introduction

Beam scanning antenna systems are being applied for commercial uses of highly functional antenna applications such as automotive radars and FWA (Fixed Wireless Access) systems in recent years. Since phase shifters are connected to all the elements of phased arrays, high cost is a significant problem to apply to commercial uses. Block excitation technique is proposed to reduce the number of required phase shifters to half of the number of subarrays [1]-[3]. We have reported the block excitation feeding circuit of a phased array with four slotted waveguide linear array antennas to produce beam scanning function by using only one phase shifter [4]. Here, we design the slotted waveguide phased array antenna composed of the feeding circuit and slotted waveguides. The measured beam scanning performance of the fabricated antenna is presented in this paper.

2. Structure of the Feeding Circuit

The antenna is composed of four vertical linear array antennas slotted on the broad wall of the waveguides. Beam scanning in horizontal plane is possible by controlling the phase difference between the four waveguides as is shown in Fig. 1. Three phase shifters are required in order to control phase differences of all the four linear arrays independently. But only one phase shifter is sufficient if it is connected at the input port of the both antennas 3 and 4 as is shown in Fig. 2. However, in this case, antennas 1, 2 and antennas 3, 4 are fed in phase, respectively. Therefore, a grating lobe appears when beam scans. Then, we introduce a coupling circuit between the input ports of antennas 2 and 3. When phases of antenna 1 and 4 are zero and ξ, respectively, desired phases $\xi/3$ and $2\xi/3$ of antennas 2 and 3 could be obtained by controlling the coupling factor of the coupling circuit. The top view of the actual waveguide feeding circuit is shown in Fig. 3. Adjacent two feeding circuits of antennas 1, 2 and 3, 4 are connected through the coupling window. The coupling factor can be controlled by the size and the

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location of the window.

3. Measured Characteristics of Fabricated Antenna

A slotted waveguide phased array antenna is fabricated for experiments. The design frequency is 12.0 GHz. Figure 4 shows the photographs of the fabricated antenna. A 13-slotted waveguide linear array is designed for subarrays of the phased array. All the slots are inclined 45 degrees for the polarization requirement such as automotive radar applications. Four subarrays are fed from the proposed feeding circuit as is shown in Fig. 4(a). The spacings of these adjacent slotted waveguides are 0.66 wavelengths in free space. The slotted plate is assembled on the waveguide of the aluminum alloy as is shown in Fig. 4(b).

Array factors of a 4-element linear array are calculated from the simulated scattering coefficients. They are shown in Fig. 5. Sidelobe level is approximately −4 dB in the case without the coupling circuit. On the other hand, it is reduced to −7 dB due to the coupling circuit. However, it is still 5 dB higher than the ideal case. In order to clarify the reason for increasing sidelobe, scattering coefficients of the feeding circuit is investigated. The amplitude and phase of the four antenna ports are shown in Fig. 6 when the two input ports are excited in the same amplitude and in 90 degrees phase difference for 10 degrees beam scanning. 6.5 dB amplitude difference is observed between the port 2 and 3 because the leakage from the port 3 through the window amplifies the output of port 2 in phase and that from the port 2 reduces the output of port3 out of phase. Measured output amplitude and phase almost agree well with calculation.

The measured radiation patterns in the horizontal plane (xy-plane) are shown in Fig. 7. Beam scans in 5 and 10 degrees when input phase difference is 45 and 90 degrees, respectively. Sidelobe level increases up to −11 dB when beam scans in 10 degrees. It is 4 dB lower than the simulation. The side lobe level is reduced because the size of the ground plane surrounding the fabricated antenna shown in Fig. 4(a) is much smaller than that in the simulation model where the size of the ground plane is infinite. Measured overall scattering coefficients at the two input ports are shown in Fig. 8. The reflections S_{55} and S_{66} are approximately −15 dB and the isolation S_{65} is almost −13 dB at the design frequency.

4. Conclusion

We designed the waveguide feeding circuit and the slotted waveguide linear array to realize a phased array composed of four subarrays whose phases can be controlled by only one phase shifter. Reasonable beam scanning performance is obtained in the experiments.

References

[1] N. Goto, Natl. Conf. IEICE, B-1-110, Mar.'98. [2] J. Hirokawa, et al., Natl. Conf. IEICE, B-1-174, Mar.'98. [3] J. Hirokawa, et al., Natl. Conf. IEICE, B-1-82, Sep.'98. [4] K. Sakakibara, et al., 2003 IEEE Topical Conference on Wireless Communication Technology, Hawaii, USA, Oct. 2003

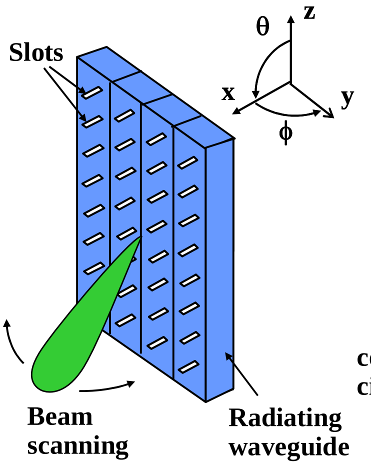


Fig.1 Phased array composed of slotted waveguide antenna.

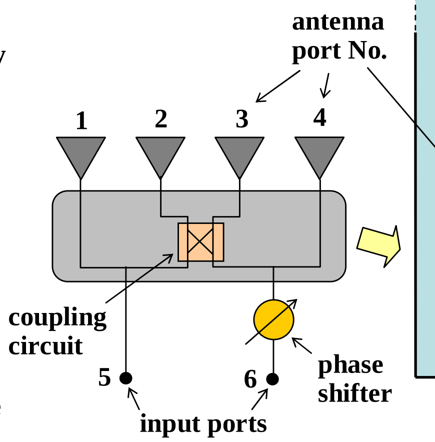


Fig.2 Configuration of phased array.

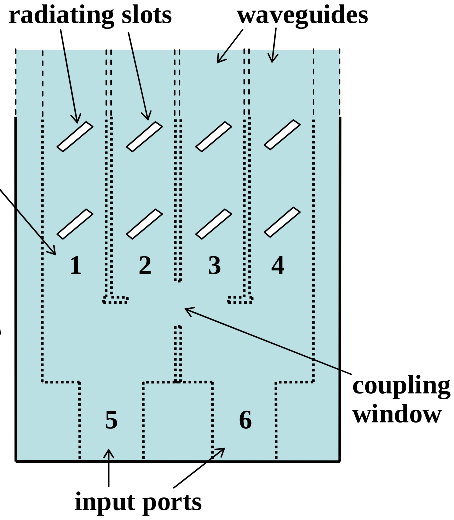
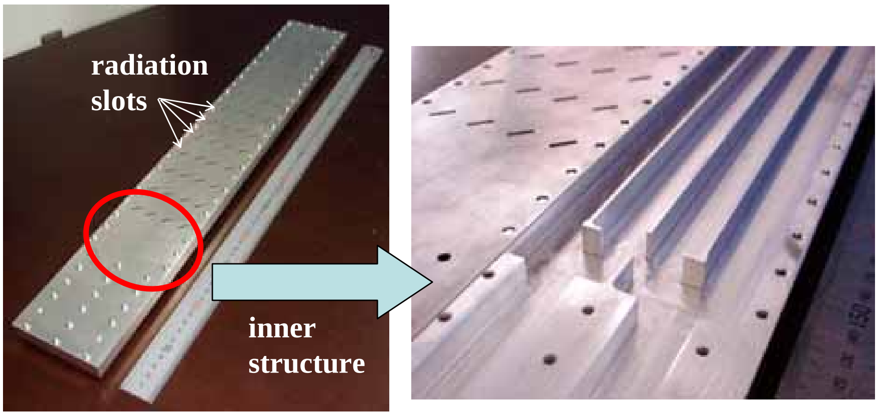


Fig.3 Top view of waveguide feeding circuit.



(a) Slotted waveguide phased array antenna. **(b) Feeding circuit.**

Fig.4 Photograph of the fabricated antenna.

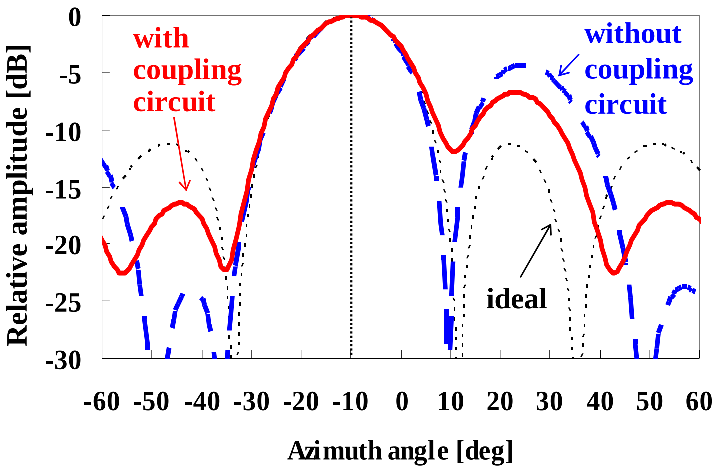


Fig.5 Calculated array factor (xy-plane).

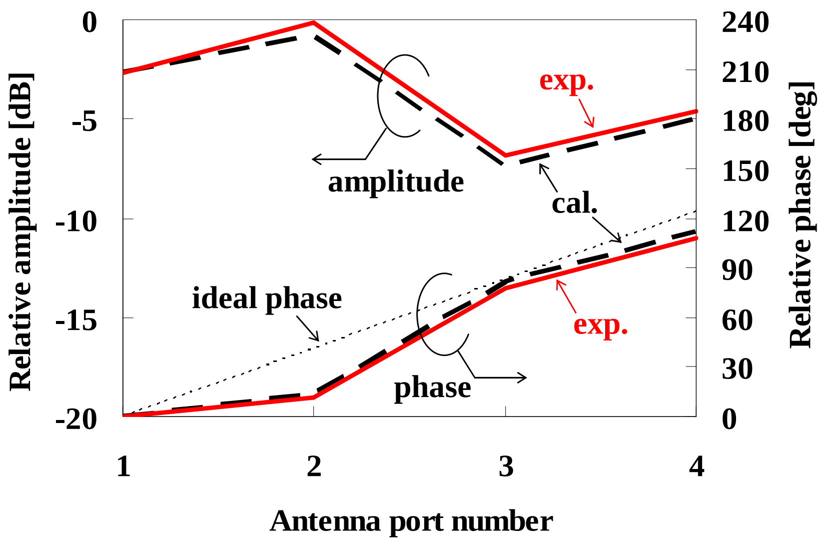


Fig.6 Output amplitude and phase of the antenna ports.

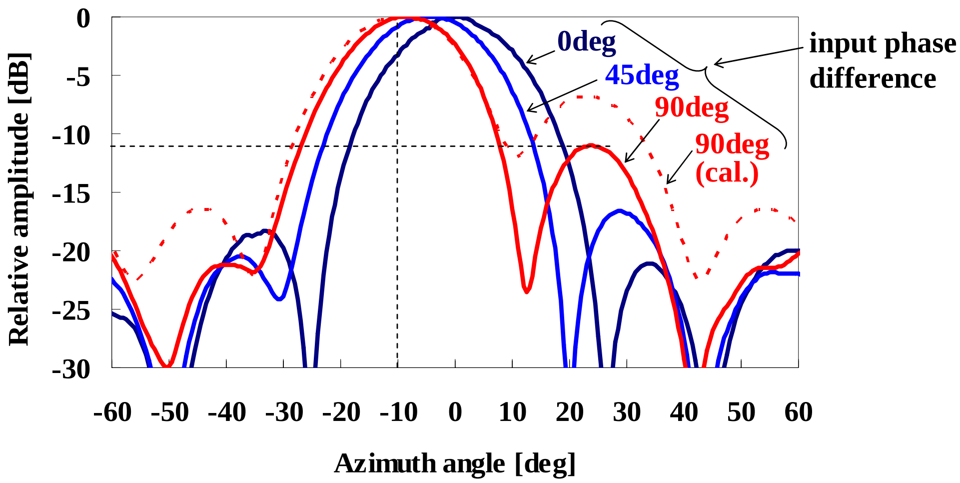


Fig.7 Radiation patterns of slotted waveguide phased array antenna (xy-plane).

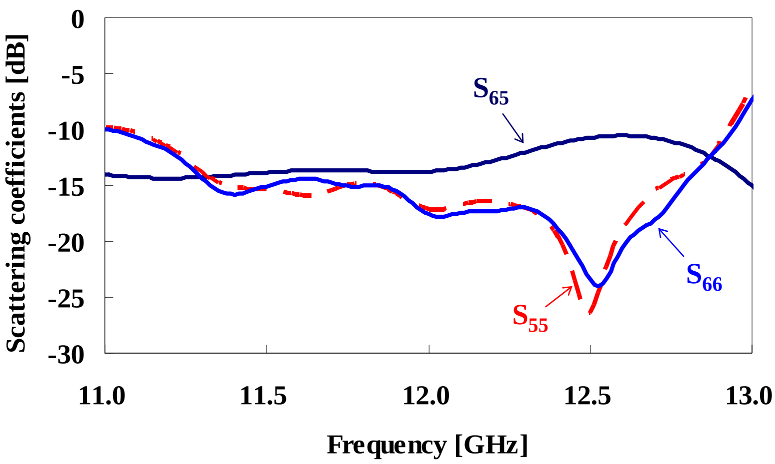


Fig.8 Reflection (S_{55}, S_{66}) and isolation (S_{65}) coefficients at the two input ports.