Grating Lobe Suppression of Narrow-wall Slotted Waveguide Array Antenna using Thin Narrow-wall Waveguides in Millimeter-wave Band

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***Abstract* - Slotted waveguide array antenna is popular for use in millimeter-wave applications. The waveguide is assembled from two parts divided at the center of the broad-wall to reduce leakage from the gap. However, as the slot spacing is one guided wavelength and is larger than a wavelength in free space, grating lobes appear. It is possible to shorten the spacing between the radiation slots in the tube axis direction of the waveguide when the slots on two waveguides are triangularly arranged. But slot spacing is still large in the diagonal direction. We designed a slot array antenna on thin narrow-walls to suppress the grating lobes. The simulated characteristics are presented in this paper.**

***Index Terms* — Waveguide, Slot, Array, Grating lobe, Millimeter-wave.**

I. Introduction

Slotted waveguide antennas are one of the most attractive planar antennas for millimeter-wave systems because of its low loss and high efficiency capability in high frequency band. The waveguide is assembled from two parts divided at the center of the broad wall to reduce leakage from the gap. Radiation slots are arranged on the narrow-wall. Since a guided wavelength (λ_g) is longer than a wavelength in free space (λ_0), grating lobes are a serious problem in the design of a slotted waveguide broadside array with slot spacing of one guided wavelength for traveling-wave excitation. To solve this problem, narrow-wall slotted two-waveguide array antenna with interleave arrangement has been developed [1]. In this antenna, the slot spacing in the tube axis direction becomes $1/2\lambda_g$ due to triangular arrangement of slots on two waveguides. However, slot spacing is still large in the diagonal direction, grating lobes appear. To reduce the slot spacing in the diagonal direction, we designed an antenna that have a small spacing between the adjacent slotted waveguides using a small narrow-wall width. The simulated characteristics are presented in this paper.

II. Antenna Configuration

We designed a narrow-wall slotted waveguide array antenna using two thin narrow-wall waveguides for grating lobe suppression. Antenna configuration is shown in Fig. 1. This antenna consists of two waveguides with slots on the narrow-walls. Slot arrangement shifts by $1/2\lambda_g$ in x-direction on adjacent waveguides to reduce the slot spacing. To excite all slots in phase, adjacent two waveguides are fed with 180 degrees phase difference out of phase. The feeding circuit is shown in Fig. 2. The feeding waveguide (WR-10) is connected perpendicularly at the end of two radiating waveguides. The input power is equally divided to the Port 2 and 3 with 180 degrees out of phase. A post and an iris in the feeding circuit are designed for impedance matching. The slot arrangement shifts by $1/2\lambda_g$ in x-direction and two waveguides are fed with 180 degrees phase difference out of phase, therefore, all slots are excited in phase.

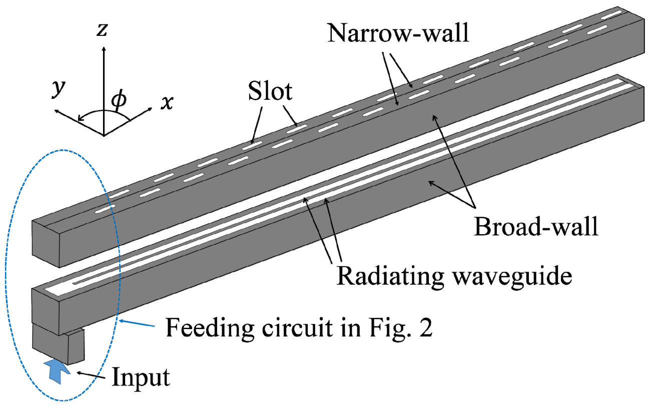

Fig. 1. Configuration of proposed antenna

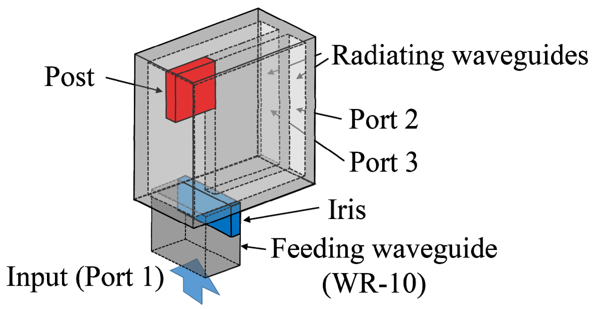

Fig. 2. Feeding circuit

Slot arrangement on the two waveguides is shown in Fig. 3. To reduce the slot spacing in the diagonal direction, the dimensions of the waveguide cross section are 3.6×0.9mm and the wall thickness between the two waveguides is 0.3mm in the proposed structure, whereas in the conventional structure, the dimensions of the waveguide cross section are 3.6×1.6mm and the wall thickness is 0.9mm. Slot spacing in y-direction is $0.31\lambda_0$ which is less than a half of $0.64\lambda_0$ in the conventional structure. Consequently, maximum slot spacing in the diagonal direction becomes $0.55\lambda_0$ which is less than $0.76\lambda_0$ in the conventional structure.

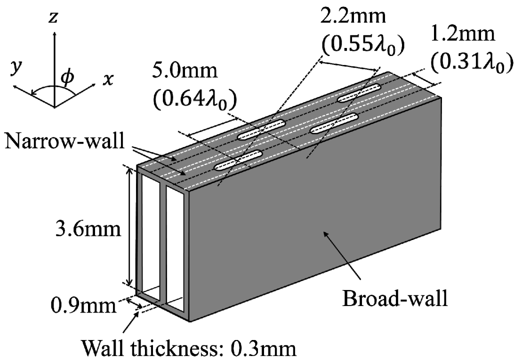

Fig. 3. Slot arrangement on the thin narrow-wall of the radiating waveguides

III. Simulated Performance

Performances of the feeding circuit and the proposed antenna are calculated by electromagnetic simulator of finite element method. The reflection and transmission characteristics of the feeding circuit are shown in Fig. 4. Since the resonant frequency corresponds to the design frequency 76.5GHz, reflection level was lower than -30dB at the frequency by adjusting the dimensions of a post and an iris in the feeding circuit. In addition, the transmission to the two waveguides are equally divided as -3.0dB. Figure 5 shows the transmission phase difference between the two radiating waveguides. Since the transmission phase difference of port 2 and 3 is close to 180 degrees over broad frequency bandwidth, alternating-phase feeding was achieved.

By using this feeding circuit, a thin narrow-wall slotted waveguide array antenna is composed. Although the bandwidth of the reflection is narrow as shown in Fig. 6, the resonant frequency is adjusted at the design frequency. Radiation pattern in the plane with largest element spacing direction (φ = 147° in Fig. 3) is shown in Fig. 7. The sidelobe level due to the part of the grating lobe is −13.5dB.

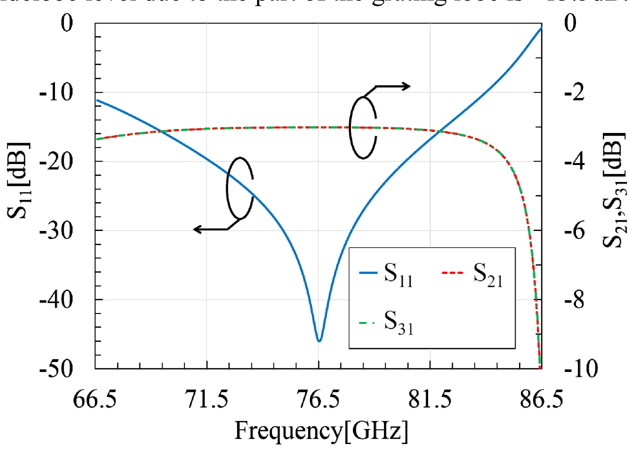

Fig. 4. Reflection and transmission characteristics of the feeding circuit

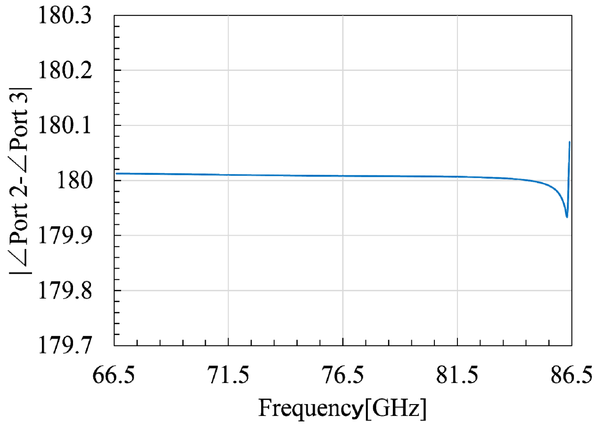

Fig. 5. Transmission phase difference between the two radiating waveguides of the feeding circuit

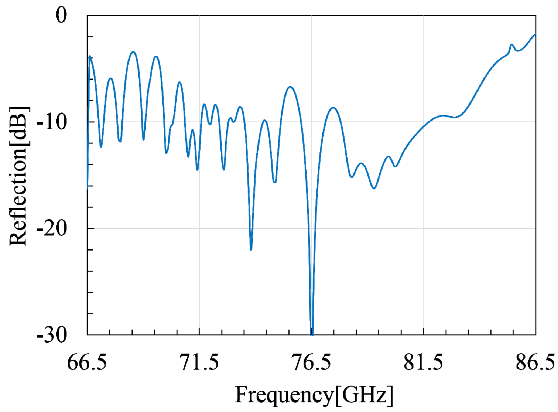

Fig. 6. Reflection characteristics of the overall antenna

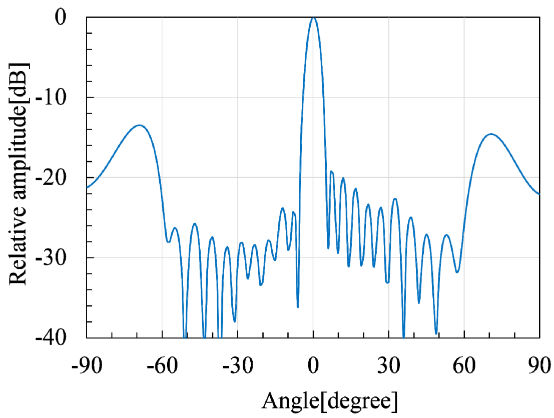

Fig. 7. Radiation pattern in the plane which includes grating lobe peak (φ= 147°)

IV. Conclusion

Narrow-wall slotted waveguide array antenna using thin narrow-wall waveguides is designed for grating lobe suppression. As a result of the analysis, The sidelobe level due to the part of the grating lobe is −13.5dB.

References

[1] A. Kawasaki, K. Sakakibara, K, Seo, N. Kikuma, and H.Hirayama, "Design of Hollow Waveguide Slot Antenna Using Quite Thin Narrow-Wall Waveguide for Grating-Lobe Suppression," in Proc. Int. Symp. Antennas and Propagation, ISAP2007, vol. 3, pp. 354.