Design and Measurement of a Parallel Plate Slot Array Antenna Fed by a Rectangular Coaxial Line

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***Abstract*- We propose a parallel plate slot array antenna fed by a rectangular coaxial line, which can simplify the electrical contact between the bottom plate of the parallel plate and the rectangular coaxial line. We adopt hard walls at the both side walls of the parallel plate in order to excite a quasi-transverse electromagnetic (TEM) wave. We analyze the overall structure of the antenna, and measure its prototype. The measured bandwidth for VSWR less than 1.5 is 2.1%, and the antenna efficiency is 50.5% at 4.859 GHz where the reflection is minimized.**

I. INTRODUCTION

Wireless access system in the 5 GHz band has expected to have a potential for high speed and long distant wireless transmission because it can use high power in outside. This system is needed to register and the number of the stations is small, so that wireless communication system which has less interference and enables to communicate stably can be created. Wireless LAN can be suitable for disasters, places difficult to construct wired networks and temporary usages. We propose a parallel plate slot array antenna which has a very simple structure and low loss as one of the antennas for this system.

We proposed a parallel plate slot array antenna fed by a rectangular waveguide [1]. The feed slot pairs on the rectangular waveguide for the reflection suppression needed to be spaced by not a half of the guide wavelength but one guide wavelength. The relative permittivity of the dielectric in the feed waveguide should have a range in comparison with that in the parallel plate waveguide. Since a current of the dominant TE10 mode in the feed waveguide flows between the bottom plate of the parallel plate and the side walls of the feed waveguide, the electrical contact between them needed firmly. In this paper, we propose a rectangular coaxial line as the feed waveguide. The transverse electromagnetic (TEM) wave is dominant in the parallel plate waveguide and a current flows in parallel to the axis of the rectangular coaxial line, which can simplify the electrical contact between the between the bottom plate of the parallel plate and the rectangular coaxial line [2].

We demonstrated the feasibility of this antenna which used the feed slot pairs on the rectangular coaxial line for the reflection suppression. However, when the coupling got larger, the distance between the slots in a pair got smaller due to the mutual coupling, which could not be realized. We propose one feed slot and the step structure in the inner conductor of the rectangular coaxial line for the reflection suppression. In order to excite a quasi-TEM wave, we adopt hard walls, which is filled with the dielectric which has a large relative permittivity at the both side walls of the parallel plates [3][4]. In this paper, we design the feed slots and the radiating slot pairs, and present the analysis result of the overall antenna structure and measurement of its prototype.

II. ANTENNA STRUCTURE AND OPERATION

Figure 1 shows the antenna structure of a parallel plate slot array antenna fed by a rectangular coaxial line. A radiating waveguide consists of two square conductor plates. An x-directed rectangular coaxial line is mounted on the back of the parallel plates in the center. Both the parallel plate waveguide and the rectangular coaxial line are filled with the dielectric of the permittivity ε_r and ε_f, respectively. Radiating slot pairs are arrayed on the top plate of the parallel plates. The two slots in each pair are spaced by about a quarter of a guide wavelength. Reflections from the two slots in a pair are canceled. The two slots in a pair are shifted from each other in the x direction in order to decrease the mutual coupling.

Feed elements are arrayed between the parallel plate and the rectangular waveguides. The feed element consists of one slot and a step structure in the inner conductor of the rectangular coaxial line. The reflection from the slot is canceled by that from the step structure.

A TEM mode, excited by a probe at the center of the feed waveguide, propagates in the $\pm x$ direction in the feed waveguide. It couples to the parallel plate waveguide through the feed slots which are spaced by the guide wavelength λ_f to excite in equal amplitude and phase. A quasi-TEM wave excited in the parallel plate waveguide propagates in the $\pm y$ direction. The quasi-TEM wave couples to the radiating slot pairs, spaced by a_r and λ_r in the x and the y directions, respectively. The slot pairs radiate a linearly polarized wave in equal amplitude and phase [1].

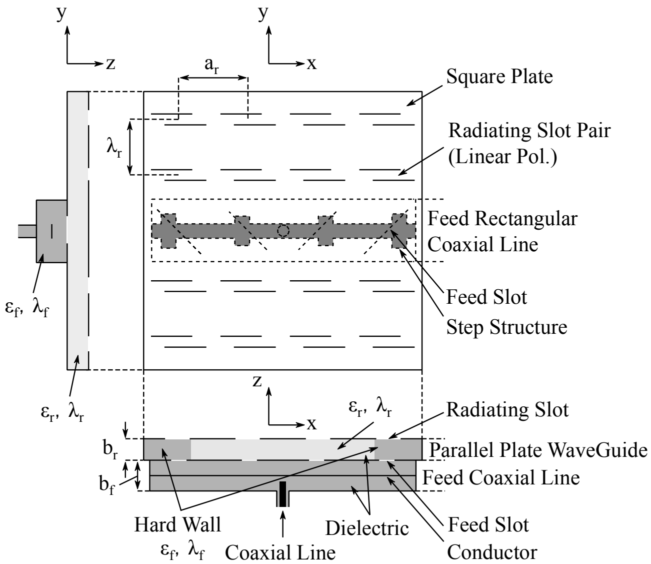

Figure 1: Antenna structure

III. Design of the Feed Element

Figure 2 shows the design model of the feed element. The parallel plate waveguide is a rectangular waveguide whose narrow walls satisfy the periodic boundary condition. A feed slot is inclined 45° to the axis of the rectangular coaxial line and provides coupling both the rectangular coaxial line and the parallel plate waveguide. Because of the symmetry structure, the power at the ports 3 and 4 are of equal amplitude but of opposite phase.

This antenna is designed at 4.85 GHz. The width of the feed slot is 3.0 mm and the plate thickness is 1.5 mm. The width and the thickness of the rectangular coaxial line are 24.0 mm and 10.0 mm. The thickness of the parallel plate waveguide is 7.0 mm. The relative permittivity ε_f, ε_r of the dielectric in the rectangular coaxial line and the parallel plate waveguide are 1.16 and 1.09, respectively. Hard walls at the both side walls of the parallel plate are filled with the dielectric of the relative permittivity of 1.16.

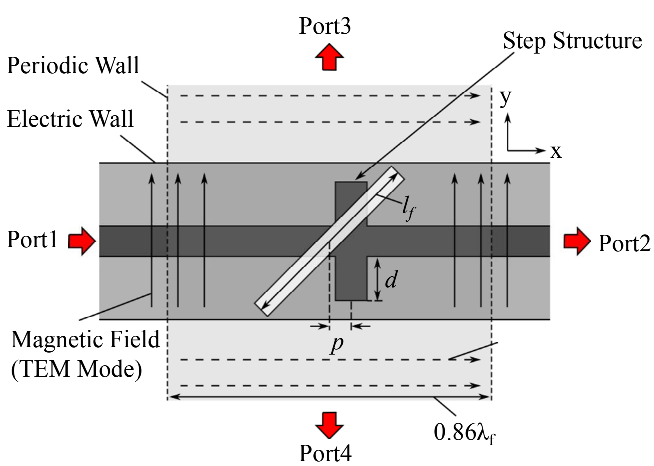

Figure 2: Design model of the feed slot

The design parameters are the slot length l_f, the length d and the position p of the step structure. Firstly, the slot length l_f is given and the length d and the position p of the step structure are determined to minimize the reflection to port 1.

Figure 3 shows the design parameter of the feed element for the desired coupling when the width of the parallel plate waveguide is 0.86 λ_f. The slot length l_f gets longer as the required coupling gets larger and the length d of the step structure gets longer because the reflection gets larger as the slot length l_f gets longer.

IV. Experimental Results

11×10 radiating slot pairs placed in the top plate are designed according to [1]. The number of the feed element is 10. These slots are designed for uniform excitation. We analyze the overall structure of the antenna by HFSS, and measured its prototype.

Figure 4 shows the frequency characteristic of the reflection of the overall structure of the antenna. The calculated and the measured bandwidth for VSWR less than 1.5 is 1.5% and 2.1%, respectively. A frequency shift of 45 MHz is observed, since the calculated and the measured reflections are minimized at 4.905 GHz and 4.859 GHz, respectively.

Figure 5 and 6 shows the H plane and the E plane radiating patterns where the calculated and the measured reflections are minimized respectively. The good agreements are obtained not only in the main lobe but also in the side lobes.

Figure 7 shows the frequency behavior of the gain and efficiency. The calculated directivity is 26.3 dBi at 4.905 GHz where the reflection is minimized and the aperture efficiency is 53.8%. The calculated gain is 26.2 dBi and the antenna efficiency is 53.6%, while the measured gain is 25.9 dBi at 4.859 GHz where the reflection is minimized, and the antenna efficiency is 50.5%. The frequency shift of 45 MHz is also observed about the gain, but the bandwidth is almost same.

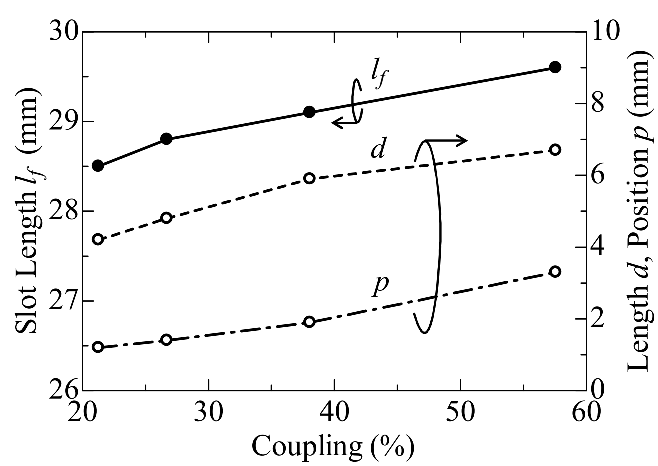

Figure 3: Design parameter of the feed slot for the desired coupling

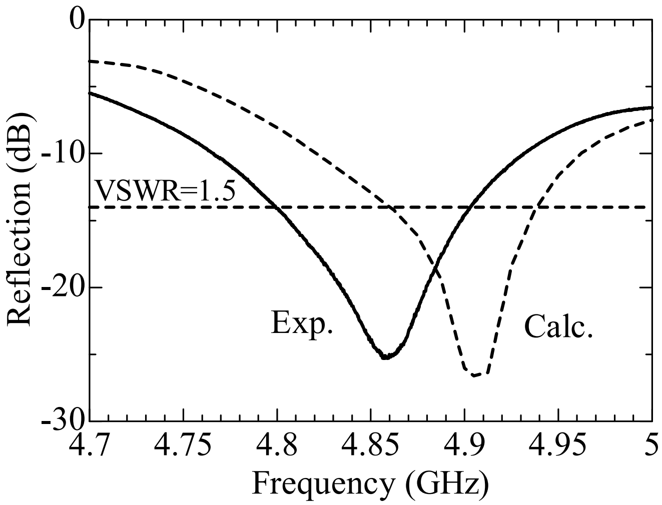

Figure 4: Frequency characteristic of the reflection

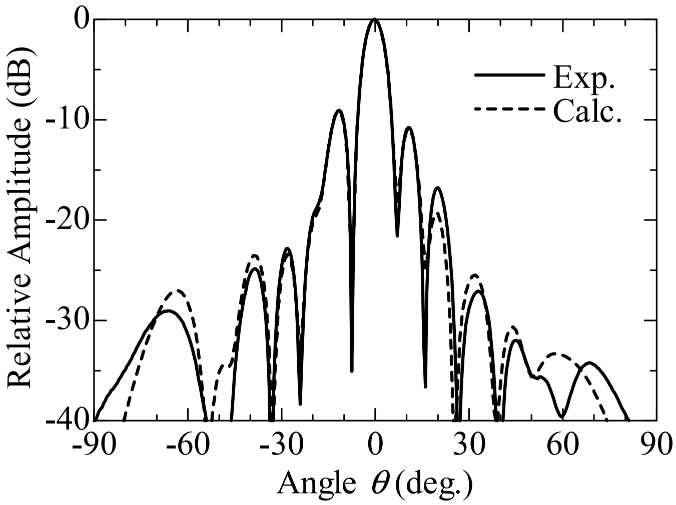

Figure 5: Radiation pattern in the H-plane
(Calc.: 4.905 GHz, Exp.: 4.859 GHz)

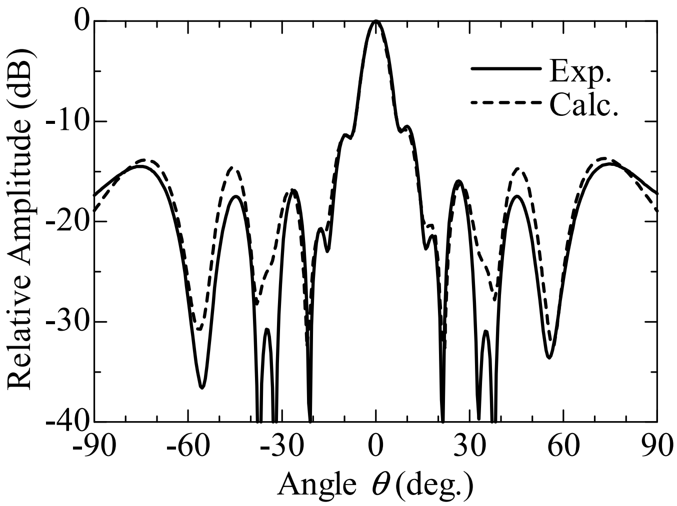

Figure 6: Radiation pattern in the E-plane
(Calc.: 4.905 GHz, Exp.: 4.859 GHz)

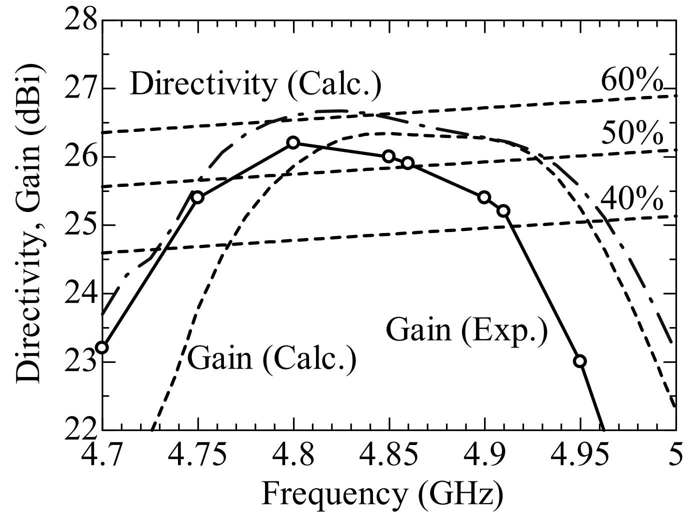

Figure 7: Frequency behavior of the gain and the efficiency

V. CONCLUSION

We have designed the feeding part of a parallel plate slot array antenna fed by a rectangular coaxial line. We have analyzed the overall structure of the antenna, and measured its prototype. The measured bandwidth for VSWR less than 1.5 is 2.1% and the antenna efficiency is 50.5% at 4.859 GHz where the reflection is minimized. The frequency shift of 45 MHz is observed between the measurement and the calculation.

We will consider the bandwidth enhancement of the reflection and the antenna efficiency by changing the relative permittivity of the dielectric in the parallel plate waveguide and the rectangular coaxial line and the angle of the feed slot inclined to the axis of the rectangular coaxial line as the future studies.

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