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Full-Model Analysis of a Radial Line Slot Antenna including the Feeder and Estimation of the Distance between Slot Pairs in the Circular Direction

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1 Introduction

A radial line slot antenna (RLSA) is a high-gain, high-efficiency and low-cost planar antenna, which was originally proposed for satellite TV reception at 12 GHz band [1]. The slot design for realizing uniform aperture illumination and maximizing antenna efficiency is the key feature of RLSAs. A rotating mode which is uniform in amplitude and linearly tapered in phase in the circumferential (ϕ-) direction in a radial waveguide together with concentric arrangement of the slot pairs is required to get a pencil-beam in the boresight in a concentrical-array RLSA (CA-RLSA) [2]. The antenna characteristics of CA-RLSA have been estimated by using a linear array model of slot pairs in a rectangular waveguide with periodic-boundary walls [3]. Since an actual feeder to excite the rotating mode for CA-RLSA is not symmetrical in the ϕ-direction, the measured efficiency of CA-RLSA is lower than the calculated one[2, 4, 5]. The degradation of the aperture efficiency can not be estimated in the above-mentioned linear array model.

In this paper, a structure of CA-RLSA including the feeder is analyzed numerically by the method of moments (MoM). We call hereafter this analysis as "full-model analysis". Figure 1 shows the structure of the antenna with the feeder. The broad wall of a rectangular waveguide is connected to the center of the lower plate of a radial waveguide. The radial waveguide is excited through a crossed slot. A RLSA with this feeder was designed and fabricated at 5.8 GHz. The gain of an antenna with the diameter of 300 mm was 22.7 dBi with efficiency of 56 % [5]. In this paper, the calculated results by the full-model analysis are compared to the measurement results. The distance between slot pairs in ϕ-direction is estimated by using the full-model analysis in ϕ-direction. The directivity is peak in a=0.61λ in the 10 GHz band.

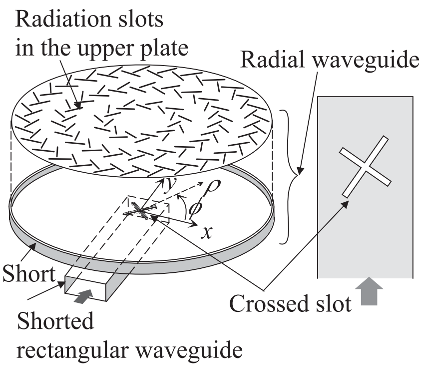

Figure 1: Structure of the crossed-slot transformer with a CA-RLSA.

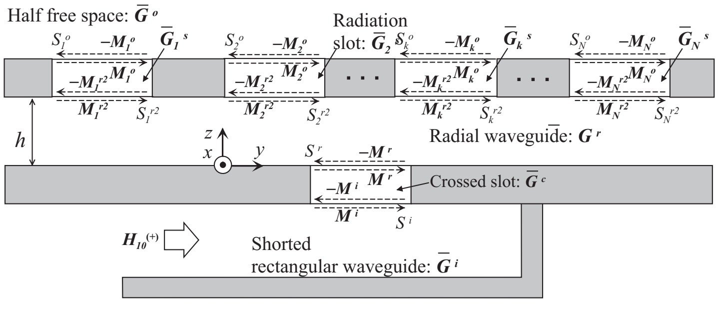

Figure 2: Analysis model of the RLSA including feeder.

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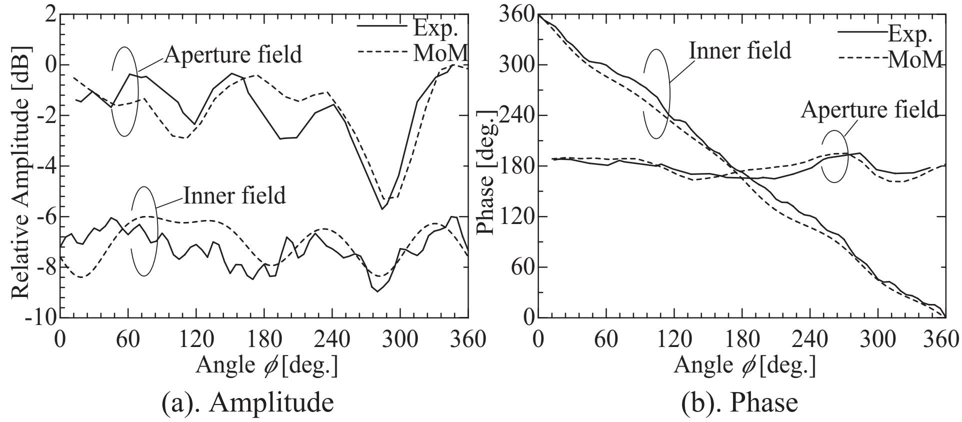

Figure 3: Aperture and inner field distribution in radial waveguide (5.8 GHz).

2 Analysis model

Figure 2 shows the analysis model of CA-RLSA including the feeder. We use the eigenmode functions of the electric field determined by the cross section of the crossed slot as the basis functions of the equivalent magnetic currents [6]. The region of the radial waveguide can be replaced with an equivalent model where the original magnetic currents and their images spacings due to the parallel plates exist in free space [7].

3 Calculated results

We calculate the model of CA-RLSA fed by a rectangular waveguide in the 5.8 GHz band and compare to the measurement results. Figure 3 shows the calculated and measured aperture distribution over the radial waveguide at 5.8 GHz. The calculated aperture-field distribution is the excitation of each slot pairs on the outermost round by the full model analysis. The calculated ripple of the amplitude and the deviation of the phase in the ϕ-direction are about 5.3 dB and 33 degrees (peak to peak) in the aperture field. The calculated results show reasonable agreement with the experimental ones. To see the detail of the slot perturbation, the inner-field distribution in the radial waveguide without any radiation slots is also measured, calculated and included in Fig. 3. The ripple of the amplitude in the inner-field without slot perturbation is suppressed to 3.0 dB[5] both in measured and calculation. Then, the ripple of the aperture field is considerably larger than that of the inner-field distribution because of the perturbation of the slot array on the upper plate. The full model analysis accurately predicts the effects of this perturbation.

Figure 4 shows the calculated directivity of the antenna in the 5.8 GHz band. In the full-model analysis, the directivity at the design frequency is 22.7 dBi and the efficiency is 55.5%. The efficiency of the full model is only 0.4% lower than the conventional model using the linear array with rotational symmetry. The degradation of the efficiency by the amplitude ripple of 3.0 dB is estimated to be small.

4 Estimation of the distance between slot pairs in ϕ direction

We estimate effect of distance between slot pairs in ϕ-direction by using the full-model analysis. Figure 5 shows the three models changed the distance a. Conventionally, this distance a is determined about 0.5 wavelength (λ), because this a can not be designed correctly by using the linear-array model.

Figure 6 shows calculated aperture distributions of these models. These aperture distributions are on third slot pair round. These amplitude ripples of a=0.49λ, 0.61λ, and 0.83λ are 5.7 dB, 7.4 dB, and 16.4 dB. Figure 7 shows the directivity at changing the parameter a. Since the ripple in ϕ-direction is large in Fig. 6, the directivity with wide a is low. When the a is over about 0.7λ, the directivity is almost same. The peak of calculated directivity is 20.7 dBi in a=0.61λ.

5 Conclusion

A full model structure of CA-RLSA with feeder has been analyzed by using the MoM. The results of the calculated aperture-field show reasonable agreement with the experimental ones on the outermost round of slot pairs by the full-model analysis. We estimate effect of distance between slot pairs in ϕ-direction. As a result of design, enhance of the aperture efficiency is 2%. We propose a design method by using this full-model analysis. The ρ-positions of the slot pairs are adjusted respectively to suppress the deviation of the phase in the ϕ-direction. As a result of calculation in the 10 GHz band, the directivity is peak in a=0.61λ.

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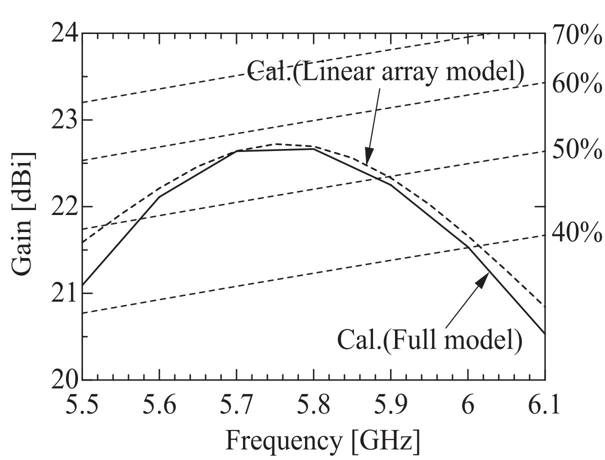

Figure 4: Analysis results of the antenna gain in the 5.8 GHz.

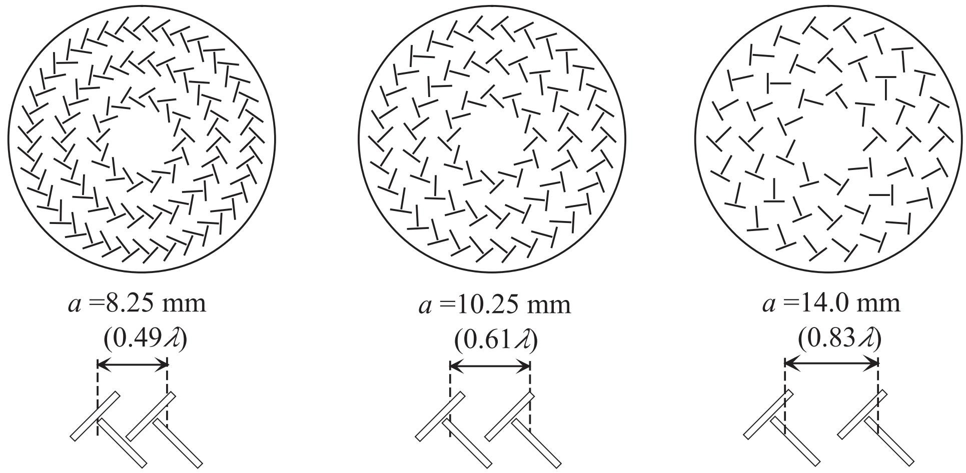

Figure 5: Aperture distribution on each slot pair round in the 10 GHz band.

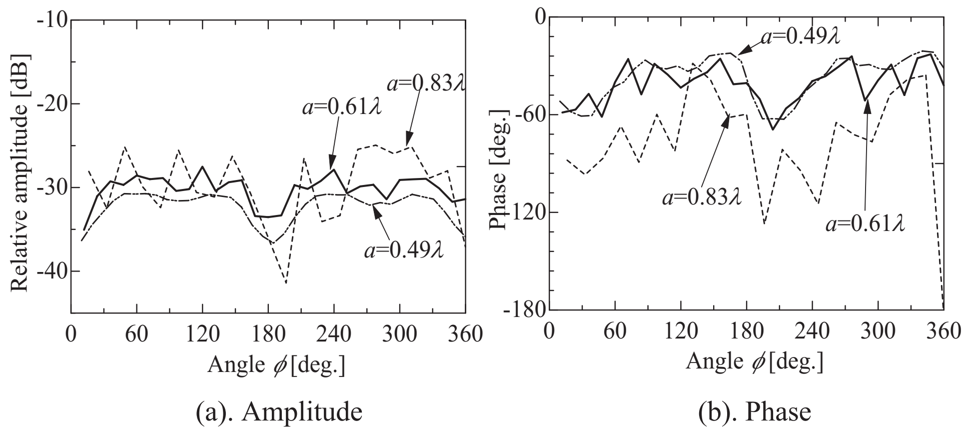

Figure 6: Aperture distribution on slot pair round in the 10 GHz band.

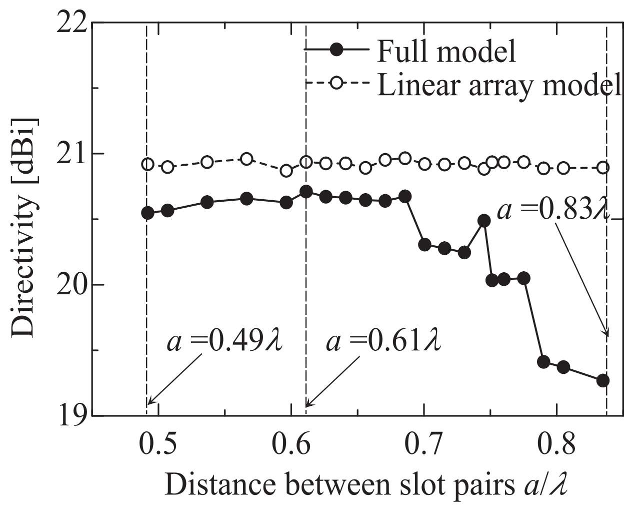

Figure 7: Analysis results of the antenna gain in the 10 GHz.