Efficiency of very small Concentric Array Radial Line Slot Antenna

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1. Introduction

A radial line slot antenna (RLSA) is a high gain and high efficiency planar antenna proposed for DBS subscribes [1]. It is a kind of slotted waveguide array with very small conductor loss, and high efficiency is predicted theoretically. The efficiency of 80~87% has been realized for RLSAs with the antenna diameters of 40~60cm ϕ at 12GHz [2]. The simple structure is suitable for manufacturing, and now they are released on the market. However, smaller ones cannot reach such high efficiency. One reason is termination loss and another is the degradation due to rotational asymmetry of the illumination. Figure 1 shows the theoretical and measured efficiency of spiral array RLSA in 12GHz. To solve these problems concentric array RLSA (CA-RLSA) has been proposed [3].

This paper presents a design of very small CA-RLSA and demonstrates the diameter dependence of antenna gain and efficiency. Remarkable efficiency of more than 80% is measured for 24 cm ϕ and 16 cm ϕ antennas and design is confirmed.

2. Concentric array RLSA

Figure 2 shows the structure of CA-RLSA. All the slot pairs are arranged concentrically and perturbation of slots does not cause rotational asymmetry. The power is fed by the cavity resonator and is transferred into a rotating mode. Matching elements are jointly adopted as the outermost elements at the end of shorted waveguide, which radiate all the residual power and suppress a reflected inward traveling wave. In addition, slots on the common radius have the common parameters. The number of design parameter is so small that complete numerical optimization can be possible.

In CA-RLSA, the number of turns changes discretely as aperture diameter changes, which have much influence on gain. Figure 3 shows aperture-diameter dependence of gain of CA-RLSA, on the assumption that all slots are excited uniformly. Gain varies stepwise when the number of the turns varies; the smaller the diameter becomes, the higher the step size of gain becomes. The maximum efficiency of 7-turn array is 90% and efficiency of 80% is possible, even for only 3-turn array.

3. Slot design

An analysis model of slots is shown in Figure 4 [4]. Cylindrical coordinate system is replaced by Cartesian coordinate system. Assuming that slots are arranged periodically in the x direction, we can reduce the numbers of unknowns and parameters. Radial waveguide is regarded as the rectangular waveguide with periodic walls. The input TEM plane wave comes from -z direction.

All slots are designed, based on an analysis by Galerkin's method of moments, with the following two objectives. The first is to realize small reflection and low axial ratio of each slot by varying slot spacing, so that all the slots radiates circularly polarization in the boresight. The second is to adjust radiation amplitudes and phases of all slots by varying slot length and slot pair spacing, for uniform aperture distribution.

4. Experimental results

To verify this method we fabricate a 5-turn CA-RLSA of 24cm diameter. Antenna parameters are shown in table 1. A feed circuit is a single feed cavity resonator. The measured gain is shown in Figure 6. The peak gain is 28.6dBi (84% efficiency) at 11.75GHz.

As an extremely small antenna, we also fabricate a 16cm diameter antenna with 3 turns. Figure 5 shows the slot pattern. Antenna parameters are also shown in Table 1. The measured gain is shown in Figure 6. The peak gain is 25.1dBi (82% efficiency) at 11.85GHz. The calculated one is also presented, which is in fine agreement with the experiment.

5. Conclusion

Extremely small CA-RLSAs with matching slots are designed and aperture-diameter dependence of gain are estimated. Then we produce CA-RLSAs of 24cm and 16cm diameter by this method. The measured peak efficiency of the 24cm and 16cm antennas are 84% and 82%, respectively, which verifies the usefulness of RLSA originally proposed for high gain antennas. To make clear the minimum diameter for this rectangular coordinate analysis model is left for future study.

References

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Table 1 Antenna parameters

Antenna diameter	24cm	16cm
Dielectric constant	1.215	1.215
Waveguide height	3.0mm	3.0mm
Design frequency	11.85GHz	11.85GHz
Number of slots	342	146

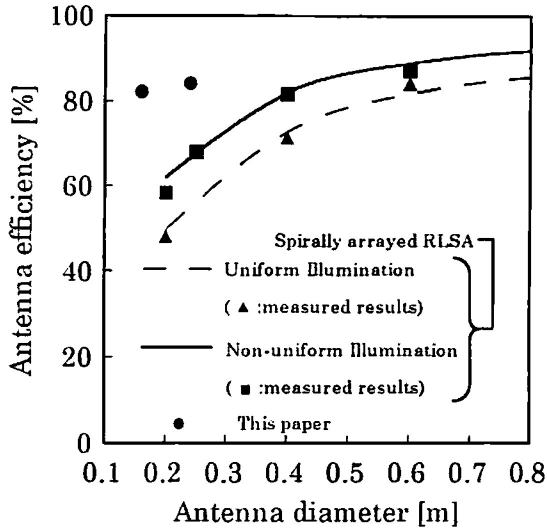

Figure 1 Antenna efficiency and diameter of RLSA

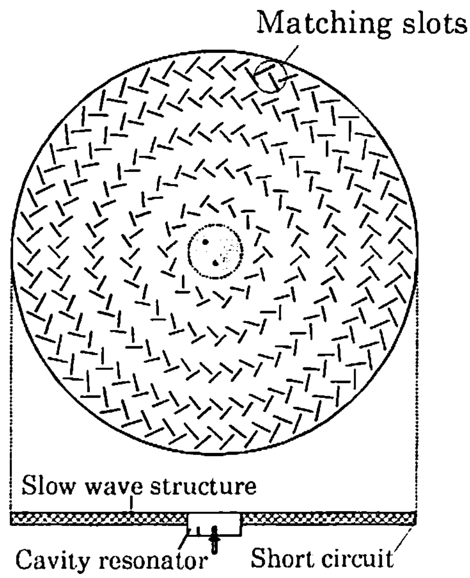

Figure 2 Structure of CA-RLSA (5-turn)

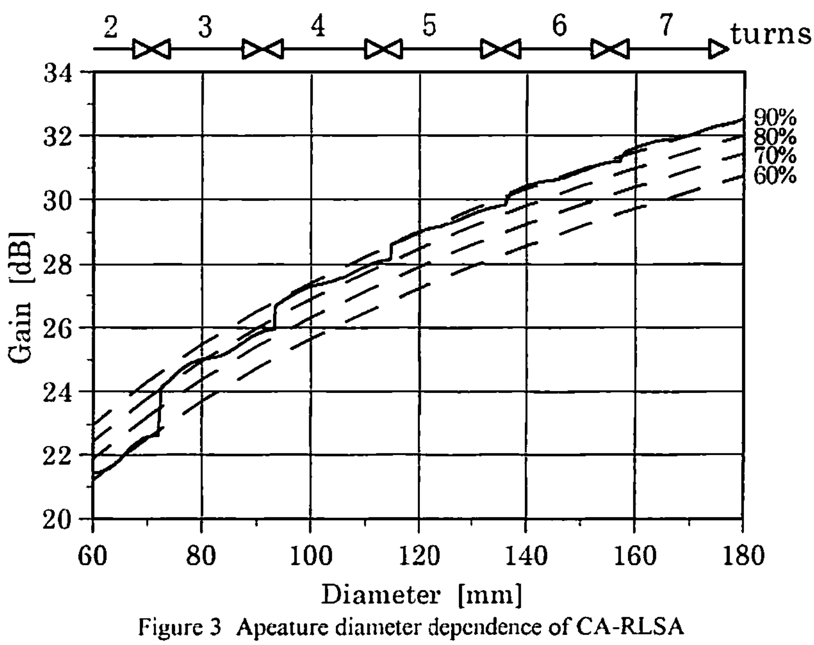

Figure 3 Apeature diameter dependence of CA-RLSA

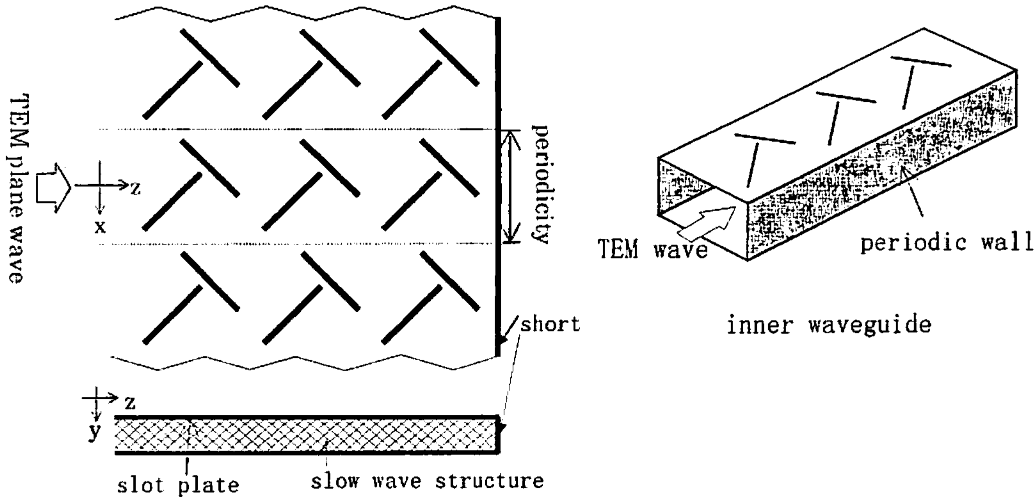

Figure 4 Analysis model of slots

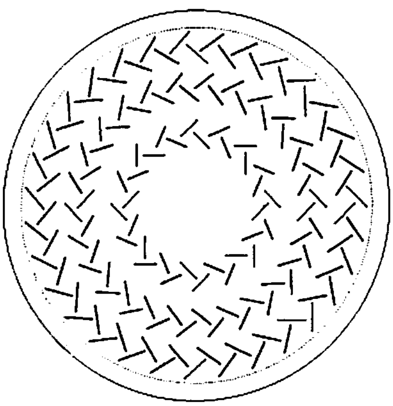

Figure 5
Slot pattern of 16cm antenna

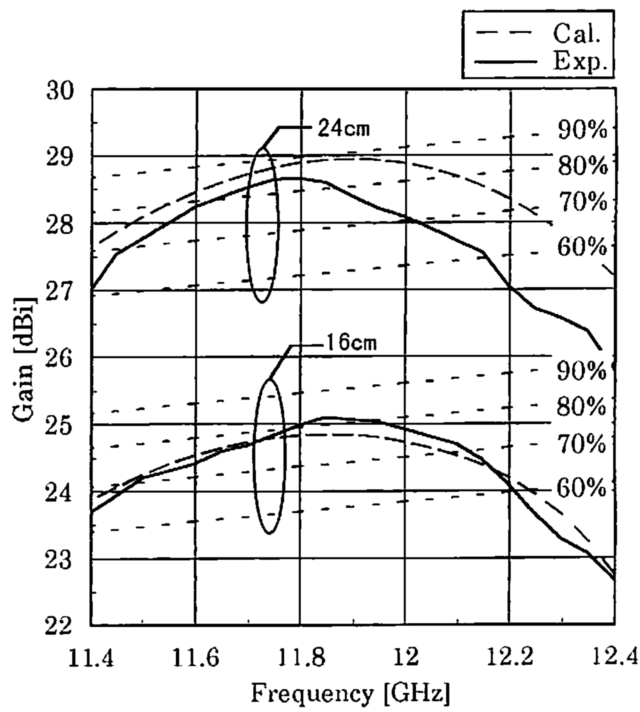

Figure 6 Measured gain of 24cm and 16cm antenna