EFFICIENCY ENHANCEMENT OF RADIAL LINE SLOT ANTENNAS BY APERTURE ILLUMINATION CONTROL

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1.INTRODUCTION

A radial line slot antenna (RLSA) is a slotted waveguide planar array proposed for DBS subscriber antennas [1]. It is free of conductor loss and the high efficiency of more than 75%(36.3dB) was realized for the double-layered RLSA with uniform slots and uniform aperture illumination [2][3]. A single-layered RLSA (SL-RLSA) is structurally simpler than a double-layered one. It utilizes non-uniform slots which cancel the tapered aperture illumination associated with a radially outward traveling wave excitation [4][5]. The efficiency of 70~84% has been realized for SL-RLSAs with the diameters of 0.3m~0.6m. Some of these antennas are now released for commercial use [6].

Uniform illumination is the design object in these antennas. Major reduction of efficiency is due to termination loss. This loss becomes notable for smaller antennas and is no less than 20% for a 0.3mϕ antenna. Recent study suggests the efficiency enhancement by adopting non-uniform aperture illumination, which reduces the termination loss.

This paper presents the measured performances of the SL-RLSAs designed in this concept [7]. The efficiency enhancement of about 10% is observed; the measured gain of 36.7dBi(87%) and 32.9dBi(81%), the axial ratio around 1dB for a 0.6mϕ and 0.4mϕ antennas respectively verify this technique.

2. A SINGLE-LAYERED RLSA

Figure 1 shows the structure of a single-layered RLSA. The power is fed at the center and transferred into rotationally symmetrical outward travelling wave. While propagating outward, part of the power is radiated from slots. Slots on the top plate consisting of many pairs, each one of which is a unit radiator of circular polarization, are arrayed along a design spiral. To suppress the grating lobes from the array, the waveguide is filled with dielectric material.

In the design of a SL-RLSA, slot coupling control for uniform aperture illumination is the most important technology. The basic concept is to adopt non-uniform slots. The required slot coupling factor is presented in Fig.2. The slot coupling is maximized at outer position to compensate the unperturbed amplitude taper of $1/\sqrt{\rho}$. Authors have already conducted the full-wave analysis of slot coupling to a parallel-plate waveguide [8]. Slot lengths and spacings are varied over the aperture according to this analysis.

3. NON-UNIFORM APERTURE ILLUMINATION

The termination loss is about 15~30% in the design of uniform aperture illumination since slot coupling is limited. For further enhancement of efficiency, the reduction of this loss is necessary. We have proposed non-uniform aperture illumination minimizing the termination loss power [9]. Figure 2 shows coupling factor and aperture amplitude distribution. In non-uniform aperture illumination, the location of maximum coupling is shifted inward from outermost part. The illumination is uniform inside and tapered outside of this point. Though the aperture uniformity is a little bit degraded, the radiation increases almost every where. As a result, overall aperture efficiency is enhanced. Figure 3 shows the aperture efficiency and the termination loss of this type of illumination as a function of antenna diameter. The efficiency enhancement becomes large as the diameter becomes small.

The model antenna parameters are listed in Table 1. Its efficiency is compared with the conventional ones with uniform illumination. The measured gain of the model antennas (D=0.4mϕ, 0.6mϕ) is shown in Fig.4. The calculated one is also presented, which is in fine agreement with the experiment. The axial ratio is around 1dB. Measured results for the SL-RLSAs are also plotted in figure 3 by ○ and × for the non-uniform and uniform illumination, respectively. Aperture efficiency increases as the diameter becomes larger since the termination loss becomes smaller. The value of efficiency enhancement is 11%(0.2mϕ), 9%(0.4mϕ), 6%(0.6mϕ). The experiments agree well with theoretical values. The efficiency of 87%(0.6mϕ) and 81%(0.4mϕ) are observed for model antennas.

4. CONCLUSION

The efficiency enhancement by the non-uniform aperture illumination is realized. The efficiency of 81%(0.4mϕ), 87%(0.6mϕ) are observed for model SL-RLSAs. The high potential of SL-RLSA as well as the validity of the non-uniform aperture illumination design is demonstrated. For smaller antenna, this new design is indispensable. The matching spiral [10] has also been proposed to reuse the termination loss power and reduce the noise temperature. This will be used jointly in future design.

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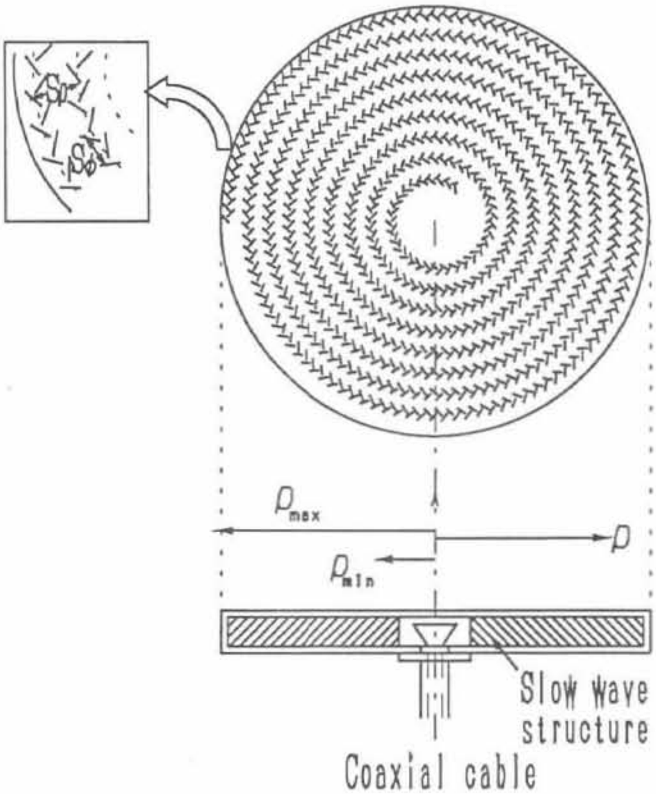

Fig.1 A single-layered RLSA

TABLE 1 Design parameters of model antennas

Model Antenna	Antenna Diameter	Waveguide height	εr	Sρ	Sφ	Inflection point
a	0.20m	3.75mm	1.53	varied	varied	0.100m
b	0.20m	3.75mm	1.53	varied	varied	0.071m
c	0.25m	3.75mm	1.53	varied	varied	0.095m
d	0.40m	3.75mm	1.53	varied	const.	0.200m
e	0.40m	3.75mm	1.53	varied	varied	0.167m
f	0.60m	3.75mm	1.530	varied	const.	0.300m
g	0.60m	3.75mm	1.53	varied	varied	0.266m

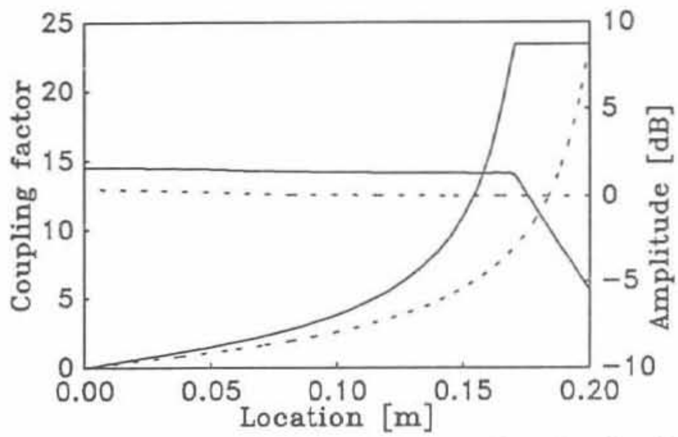

Fig.2 Coupling factor & Aperture amplitude distribution.

—— Non-uniform illumination

----- Uniform illumination

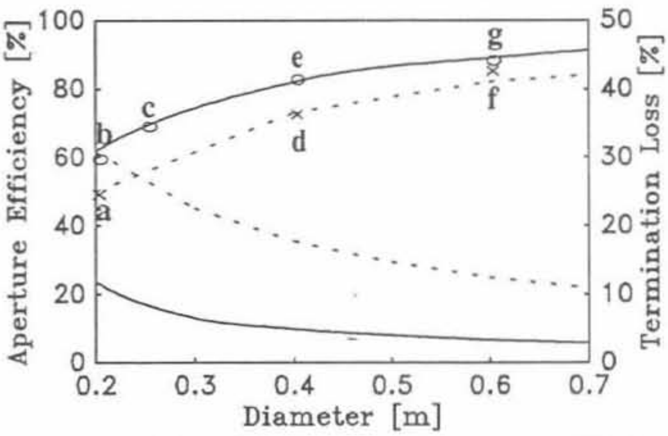

Fig.3 Theoretical & measured aperture efficiency.

—— Non-uniform illumination(○)

----- Uniform illumination (×)

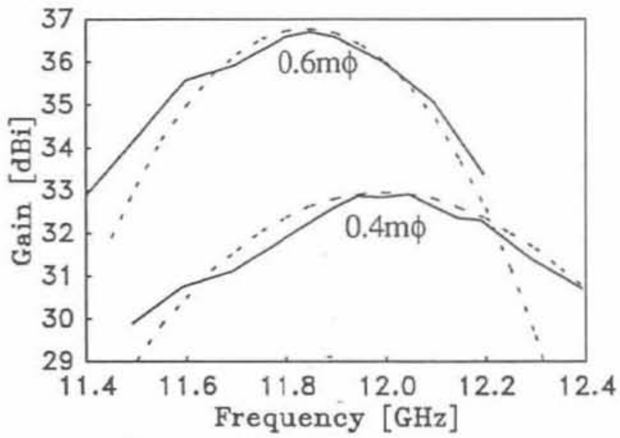

Fig.4 Measured & predicted gain of non-uniform aperture illumination.

—— Measured gain

----- Predict gain