PLANAR FEED CIRCUITS WITH A RING SLOT FOR A ROTATING MODE RADIAL LINE SLOT ANTENNA

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1. Introduction

The radial line slot antenna (RLSA) is a slotted waveguide planar antenna, which is originally proposed for DBS reception in 12GHz band [1]. Its simple structure is suitable for low cost mass production. The excellent efficiency of more than 80% is realized over a wide range of gain. High efficiency is also expected even in millimeter wave band, since the transmission loss is sufficiently small in principle. We have proposed millimeter wave RLSA's and reasonable performance is observed [2].

In conventional RLSA's, the power is fed by feeders with three-dimensional structure, that is, a coaxial feeder for a rotationally symmetric mode feeding [3], or a cavity resonator for a rotating mode feeding [4]. However, it would be difficult to maintain the accuracy in manufacturing in millimeter wave band. In addition, planar structures, such as a microstrip or a co-planar line, are more attractive than conventional three-dimensional structures with the view of integrating with RF planar active circuits. Planar feed circuits for RLSA have been proposed, where a microstrip or a co-planar line is adopted to excite a ring slot on the lower plate [5] [6].

In this paper, new planar feed circuits are proposed. The ring slot is placed on the upper plate of the radial waveguide, for the purpose of reducing backward radiation from the feed circuit. Two types of feed circuits are designed for a rotating mode excitation. Measured results in 4GHz band shows the reasonable characteristics. The simulated results in 12GHz band are also shown.

2. Planar feed circuits with a ring slot on the lower plate

Figure 1 shows the structure of a concentric array RLSA (CA-RLSA) fed by a planar feeder, which have a ring slot on the lower plate of the radial waveguide [5]. The ring slot is excited by a microstrip line on the lower plate. To obtain a rotating mode ($e^{j\varphi}$: uniform amplitude and linearly tapered phase in ϕ-direction), the I-slot is placed as a perturbation element at the center of the ring.

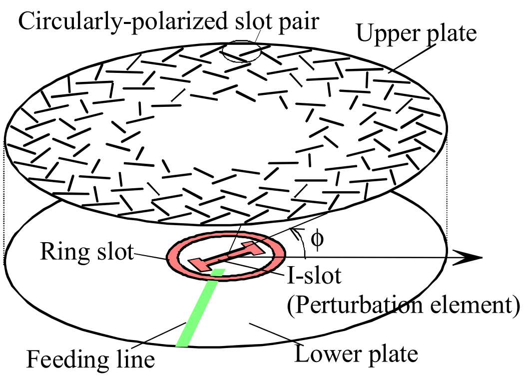


Figure 1 : Planar feed circuit with the ring slot on the lower plate.

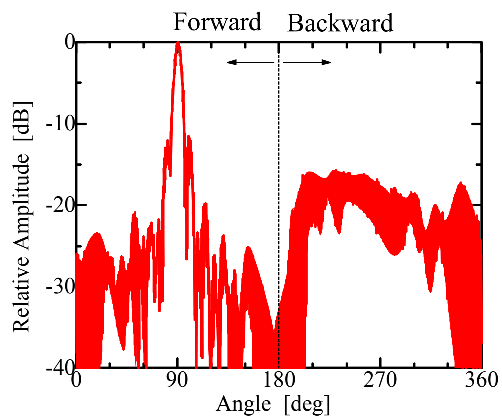


Figure 2 : Radiation of the CA-RLSA fed by a conventional planar feeder.

The circuit was fabricated for 12GHz band and a reasonable rotating mode excitation was confirmed. However, it can not be ignored that the backward radiation from the resonating ring slot instead of propagating to the radial waveguide. Figure 2 shows the measured radiation pattern of the CA-RLSA fed by this circuit. Although reasonable circular polarization is radiated to the boresight, the undesired radiation is observed in the backward, which mainly comes from the ring slot. The efficiency is considerably reduced to less than 30% by the backward radiation loss.

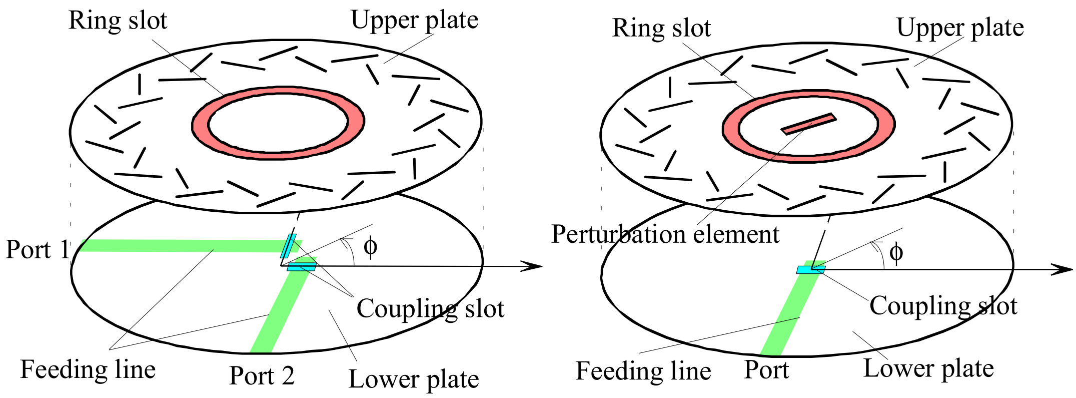
To solve this problem, cavity-covered planar feed circuit fed by a co-planar waveguide is proposed [6]. Densely arrayed metal pins compose an equivalent circular cavity wall. The antenna efficiency is expected to be improved. However, the structure is more complicated and cost consuming.

3. Planar feed circuits with a ring slot on the upper plate

The structures of the new feeders are shown in Fig. 3. The ring slot is placed on the upper plate of the waveguide, while the microstrip line is still on the bottom of the antenna. The ring slot is coupled with the microstrip line via non-resonating apertures on the lower plate, which will not radiate the power strongly to the backward. The backward radiation is expected to be reduced and the structure is still simple. While it is similar to the feed circuit using circular patch antenna [7], this structure does not only excite the radial waveguide but also radiate the power to the boresight.

A dual-feed type and a single-feed type are designed for rotating mode excitation. In the dual-feed type, two orthogonal feed lines in both space and phase are placed, as shown in Fig. 3 (a). In the single-feed type, a rectangular slot is placed at the center of the ring slot (Fig. 3 (b)), or two notches are cut at opposite periphery, as a perturbation element.

The feed circuits are simulated by using the software "Ensemble". The thickness of the waveguide is relatively thin in order to realize certain coupling between the feedline and the ring slot. The radius of the ring slot is decided to resonate at the design frequency and is almost one wavelength. The perturbation element is optimized to reduce the deviation of the field distribution.



(a) dual-feed type. (b) single-feed type.

Figure 3: Planar feed circuit with the ring slot on the upper plate.

4. Experimental results

(a) Dual-feed type

A dual-feed type model is designed and fabricated for 4GHz band to confirm the basic operation. The parameters are shown in Table 1. Figure 4 shows the reflection. Because of the manufacturing error of the position of the coupling aperture, the optimum frequency is shifted to lower frequency. The coupling between each port is reasonably suppressed at the design frequency. Figure 5 shows the measured and the predicted inner field variation in ϕ-direction in the radial waveguide. The measured ripple of the amplitude is about 10dB, while the predicted ripple is 4dB. The deviation will be mainly caused by misalignment of the coupling aperture. Figure 6 shows the predicted ripple of the amplitude as a function of the frequency. The relation between the deviation of the rotating mode and the antenna efficiency reduction is roughly estimated in [4]. The ripple of –6dB in amplitude corresponds to about 10% reduction of the efficiency, which is practically reasonable. The bandwidth of the reasonable rotating mode excitation is about 10% for this circuit. Figure 7 shows the predicted radiation from the ring slot. It is roughly estimated that the radiation power to the boresight is ten times larger than that to the backward.

These results indicate that the new structure is effective as a rotating mode feeder. The measured deviation of the rotating mode will be improved by accurate manufacturing.

Table 1: Parameters of the dual-feed structure.

Design frequency	4.1GHz
Radius of the ring	13.5mm
Width of the ring	2.0mm
Height of the waveguide	3.2mm
Dielectric constant of the waveguide	2.2
Coupling aperture	9.6x2.6mm
Impedance of the microstrip line	50Ω

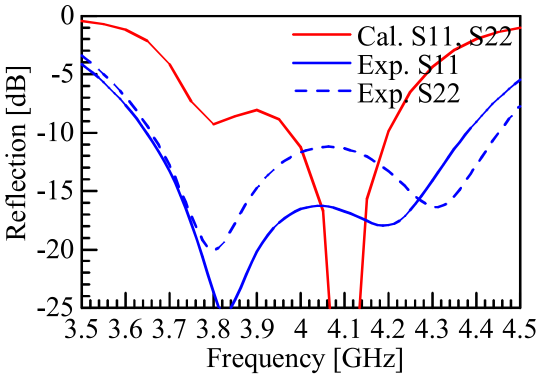


Figure 4 : Reflection of the dual-feed type.

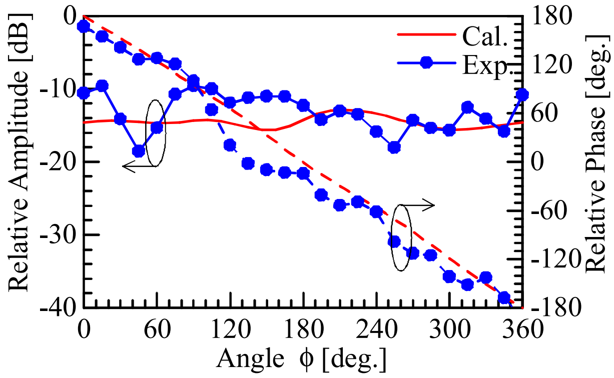


Figure 5 : Field distribution in ϕ-direction.

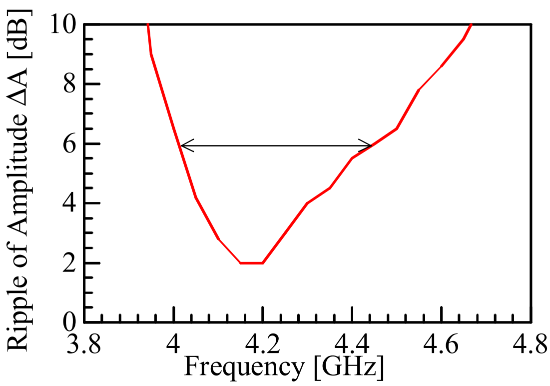


Figure 6 : Ripple of the amplitude.

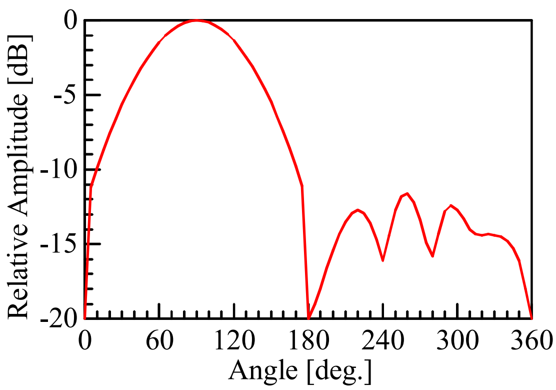


Figure 7 : Radiation from the feeder.

(b) Single-feed type

A single-feed type model is designed for 12GHz band. The parameters are shown in Table 2. The reflection is sufficiently suppressed at the design frequency. Figure 8 shows the predicted inner field variation in ϕ-direction at 12.0GHz. The ripple of the amplitude is about 2dB, which is better than that of the dual-feed type. Figure 9 shows the predicted ripple of the amplitude as a function of the frequency. The bandwidth of the reasonable rotating mode excitation is about 1.3% and is much smaller than the dual-fed type. The measured results will be shown in the presentation.

Table 2: Parameters of the single-feed structure.

Design frequency	12.0GHz
Radius of the ring	4.7mm
Width of the ring	0.6mm
Height of the waveguide	0.8mm
Dielectric constant of the waveguide	2.2
Coupling aperture	3.4x0.6mm
Perturbation element	3.0x0.8mm
Impedance of the microstrip line	50Ω

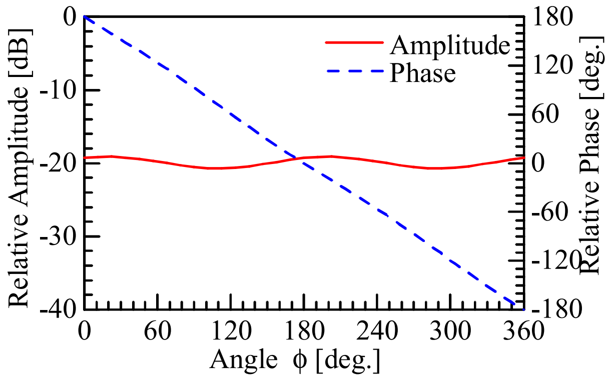


Figure 8 : Field distribution in ϕ-direction.

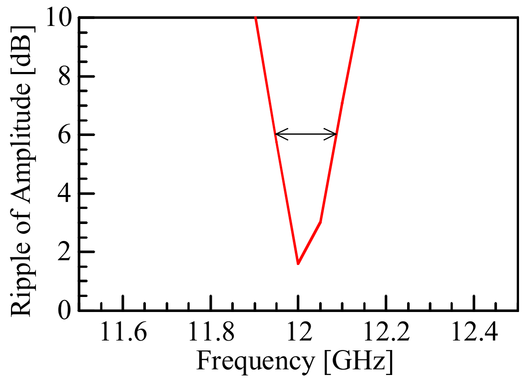


Figure 9 : Ripple of the amplitude.

5. Conclusion

Two types of planar feed circuits for a radial line slot antenna are designed, which excites a rotating mode. The ring slot is placed on the upper plate of the radial waveguide. The ring slot is excited by a microstrip line via an aperture. The validity of this structure is confirmed by measurements in 4GHz band. To estimate the power ratio of the outward radiation to inward propagation in the waveguide is also future study.

References

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