RADIAL LINE SLOT ANTENNAS FED BY A RECTANGULAR WAVEGUIDE THROUGH A CROSSED SLOT

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1 Introduction

A radial line slot antenna (RLSA) was a high gain, high efficiency and low-cost planar antenna, which was conventionally proposed for DBS reception at 12 GHz band [1]. In the conventional RLSA, a radial waveguide was fed by a coaxial feeder. In millimeter wave band, however, manufacturing of this coaxial feeder is difficult due to its small physical size [2, 3]. A concentric array RLSA was proposed for smaller RLSA [4]. A rotating mode is required in a radial waveguide for getting a pencil beam in the broadside in a concentric array RLSA (CA-RLSA) [5]. We proposed a rectangular-to-radial waveguide transformer through a ring slot for excitation of the rotating mode. A RLSA fed by this transformer was designed and fabricated at 38 GHz. The gain of an antenna with the diameter of 46 mm was 22.5 dBi with efficiency of 53 % [6].

In this paper, an analysis for excitation of a rotating mode in a radial waveguide by a crossed slot-coupled rectangular waveguide is proposed by adopting numerical eigenmode basis functions in the method of moments [7]. An excellent transformer with the ripple of amplitude in ϕ-direction of no is 2.3 dB is designed by this analysis.

2 Structure

Figure 1 shows the structure of the feed circuit. 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. To obtain a rotating mode ($e^{-j\phi}$: uniform in amplitude and linearly tapered in phase in the ϕ-direction), the crossed slot is composed by two straight slots of different lengths so that the excited amplitudes are equal and the phase difference are 90 degrees. In this feed circuit, the shorting position and the waveguide height are the parameters for matching.

3 Analysis

Numerical eigenmode basis functions are applied in the method of moments (MoM) [7]. Figure 2 shows the model of MoM. The basis functions of the magnetic current in MoM are eigenmode functions of an X-shaped waveguide with a cross section of the crossed slot. They are derived numerically by edge-based FEM. The reactions in the wall thickness (region II) are simply expressed in terms of the slot thickness and the propagating constant without taking mode summations due to the orthogonality of the eigenmode functions. The region of radial waveguide (region III) can be replaced with an equivalent model, which is the original magnetic currents and their images due to the parallel plates all in a free space [8]. In this model with the images, fast convergence of the sum is obtained by using Poisson's formula.

4 Design and experimental results

Rectangular-to-radial waveguide transformers through a crossed slot in 5.8 GHz band and 28 GHz band are designed by this analysis. Figure 3 and Table 1 show the parameters of the transformer. The step of the design procedure is

Step 1: A shorting plate is determined for matching in designed frequency.

Step 2: The width of narrow wall is decided for suppression of the reflection.

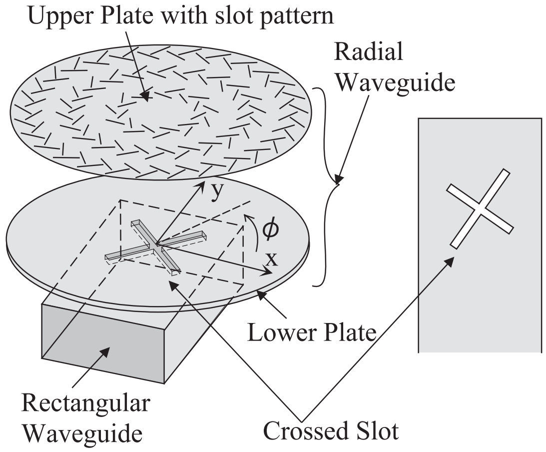

Figure 1: Rectangular-to-radial waveguide transformer through a crossed slot.

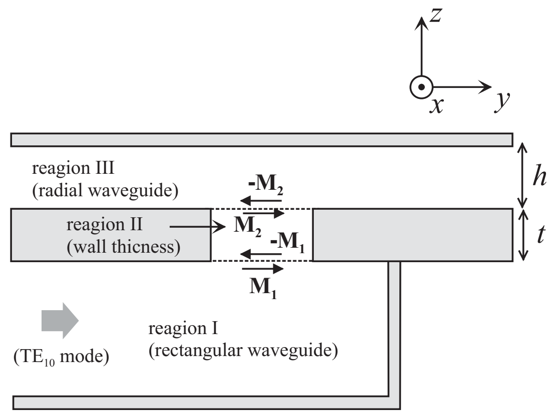

Figure 2: Model of the MoM.

Step 3: By optimizing the parameters of the crossed slot, the ripple of the amplitude in ϕ-direction is suppressed.

The step of procedure is gone over. As the result of optimizing, the rectangular waveguide is thin (a:b=5:1) in comparison with a standard one and shoring position is about $\lambda_g/4$. The diameter of the upper plate is 300 mm at 5.8 GHz and 32.3 mm at 28 GHz band. The aperture has 3-round of slot pairs at 5.8 GHz band and 2-round at 28 GHz band.

Figure 4 shows a measured near-field distribution over the antenna aperture at 5.8 GHz. The ripple of the amplitude in the ϕ-direction is about 6 dB and the degradation in the antenna efficiency by this ripple is estimated to be about 10 % [9]. Spin-linear radiation patterns of the antenna at 5.8 GHz are shown in Fig. 6. Figure 6(a) shows the radiation pattern in a deg. cut plane along $\phi = 45$, and (b) shows another one along$\phi = 135$ deg. The half-power beam widths of (a) and (b) are 10.0 deg. and the main beam is almost symmetrical. The sidelobe level is -11.2 dB in (a) and -14.9 dB in (b). This difference in side lobe level is smaller than that in a case using a ring slot for the feed at 38 GHz [6]. Figure 5 shows the gain of the antenna at 28 GHz band. The measured gain at the designed frequency is 16.2 dBi and the efficiency is 47 %. In antenna efficiency, the efficiency degradation in the measurements from the calculated one is about 30 %.

5 Conclusion

A rectangular-to-radial waveguide transformer through a crossed slot has been analyzed by using the MoM. Radial line slot antennas fed by this transformer are designed and fabricated at 5.8 GHz band and 28 GHz band. The antennas have rotational symmetry both in the near-field distribution and the radiation pattern. The gain of the antenna with the diameter of 32.3 mm is 16.2 dBi with the efficiency of 47 %.

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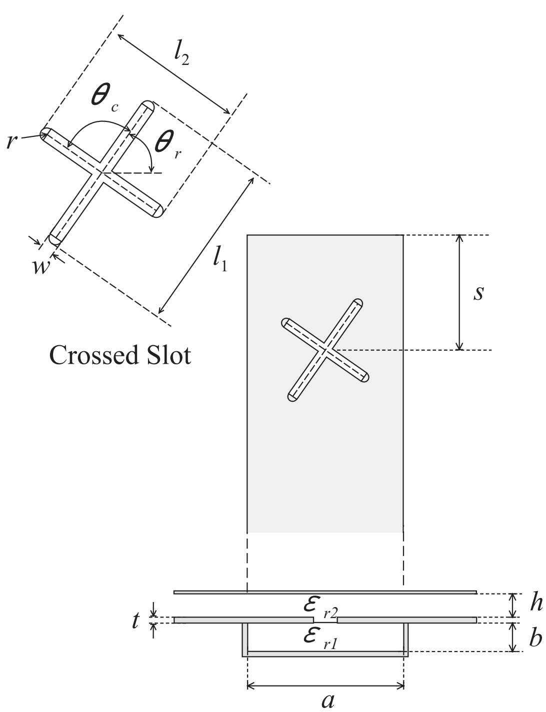
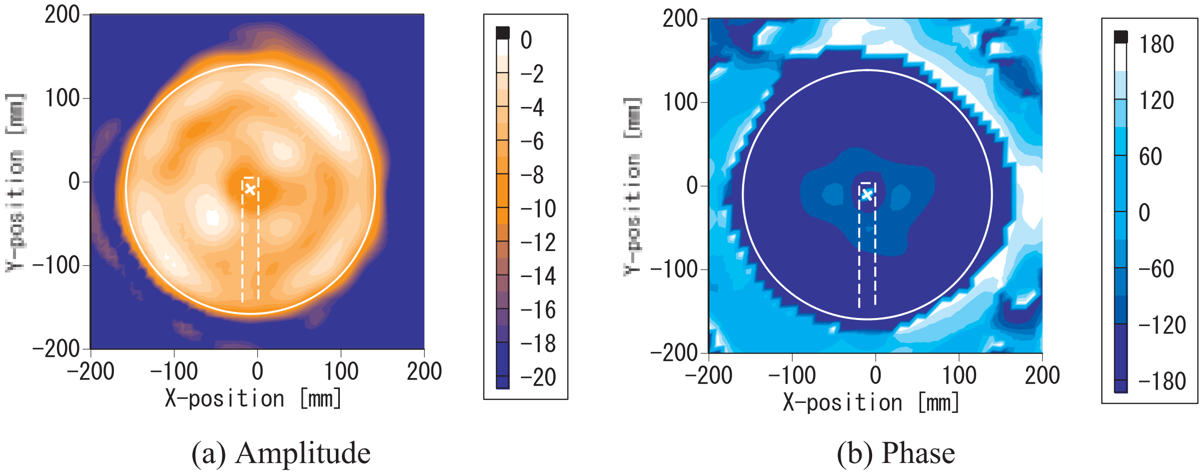


Figure 3: Cross section of the transformer.

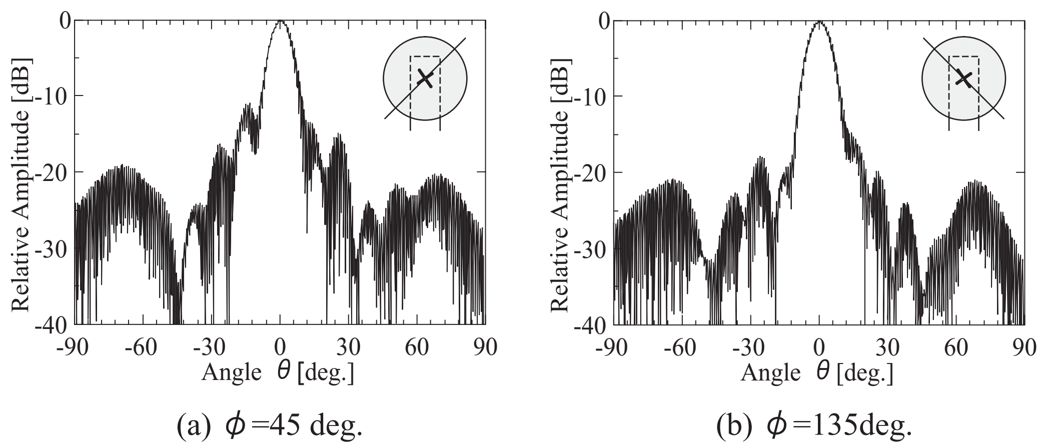
Table 1: Parameters of the transformer.

		5.8 GHz	28 GHz
Crossed Slot	l_1	31.5 mm	5.80 mm
	l_2	25.5 mm	4.86 mm
	w	2.50 mm	0.50 mm
	r	1.25 mm	0.25 mm
	θ_r	55.0 deg.	55.0 deg.
	θ_c	90.0 deg.	90.0 deg.
Radial Waveguide	h	6.00 mm	1.60 mm
	ε_{r2}	1.00	2.20
Rectangular Waveguide	a	40.0 mm	7.112 mm
	b	8.30 mm	1.22 mm
	t	1.50 mm	0.80 mm
	ε_{r1}	1.00	1.00
	s	29.5 mm	7.60 mm



(a) Amplitude (b) Phase

Figure 4: Field Distribution of RLSA at 5.8 GHz.



(a) ϕ=45 deg. (b) ϕ=135deg.

Figure 5: Radiation Pettern of RLSA at 5.8 GHz.

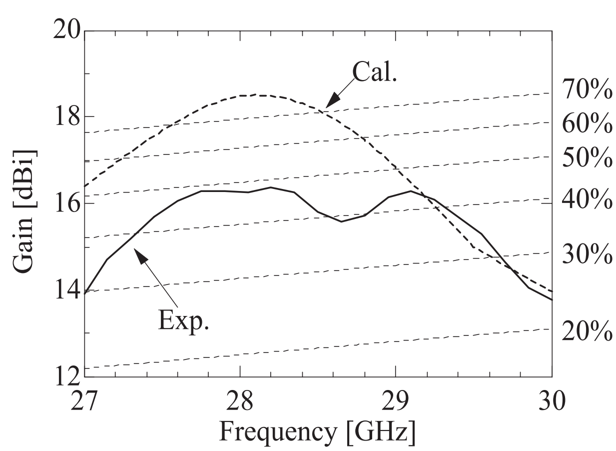


Figure 6: Gain of RLSA in 28 GHz band.