Parallel plate slot array antenna fabrication by a nano-imprinting technology in the millimeter-wave band

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1. Introduction

This paper presents a 60GHz radial line slot antenna (RLSA)[1] by using nano-imprinting technology. Conventionally, slot array antennas on substrates are fabricated by etching. However, the etched slots have fabrication error around 25μm in the slot dimensions. Such error causes the operating frequency shift of about 500MHz. On the other hand, the nano-imprinting technology gives more accurate fabrication with nanometer order and is used for making optical disks [2-4] at low cost. This technology is expected to improve the deviation of the operating frequency to less than 25MHz.

2. Nano-imprinting technology for fabrication of RLSA

Nano-imprinting is a kind of nano-scale molding processes. This process is applied for fabrication of a parallel plate slot array antenna. The fabrication flow is shown in Fig.1.

Step 1: A plastic sheet is put between stampers. The stampers have dents for slot antennas as shown in Fig. 1 (a). Both the stampers are heated up to the glass transition temperature of the plastic sheet and pressed each other. Relief patterns are stamped on a plastic sheet by the stampers.

Step 2: The plastic sheet is cooling down, removed from the stampers and metalized on the whole surface as shown in Fig. 1 (b).

Step 3: The metal plates on the ledges are removed by polishing to make slot apertures as shown in Fig. 1 (c). The thickness of the metal plate becomes 5μm by polishing. Thus, we can get radiating slot apertures on the upper plate and a feed slot on the lower plate, respectively. The slot patterns are shown in Fig. 2.

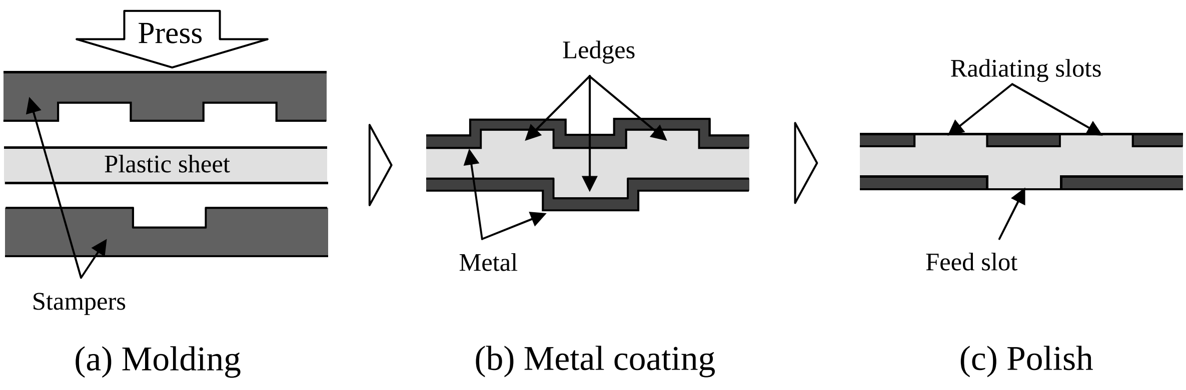
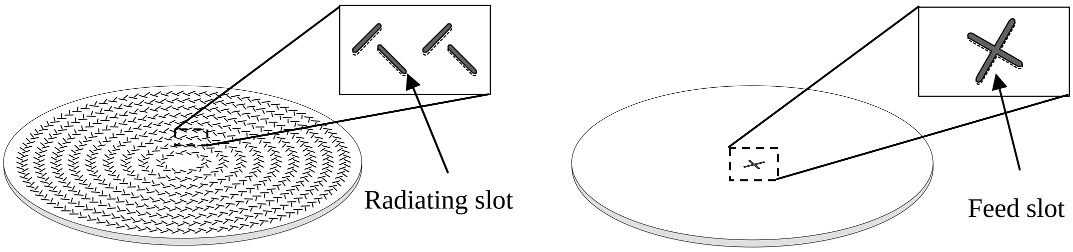


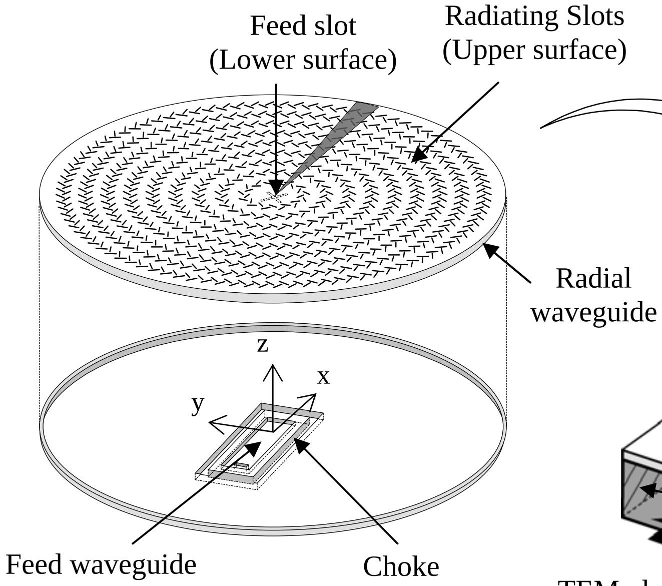
Figure 1: Antenna fabrication flow



(a) Upper surface (b) Lower surface

Figure 2: Antenna slot pattern

3. Analysis and Design



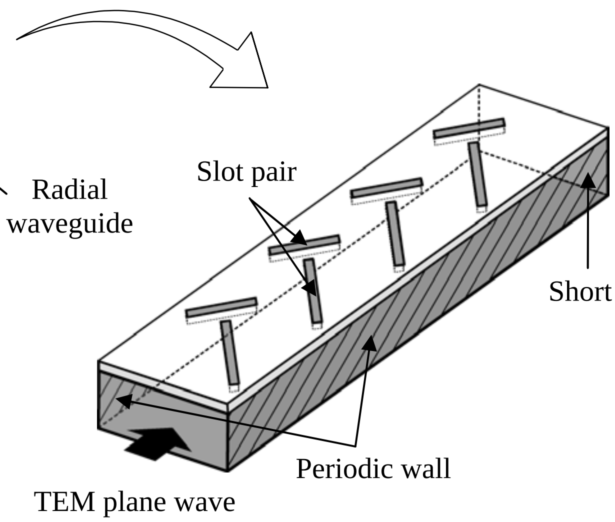


Figure 3: Structure Figure 4: Analysis model

Figure 3 shows the structure of the fabricated RLSA. The radiating slot pairs are arranged concentrically on the upper plate of a radial waveguide (CA-RLSA) [5]. Electromagnetic power is fed from a rectangular feed waveguide to the radial waveguide through the feed slot on the lower plate to obtain a rotating mode ($e^{-j\phi}$: uniform in amplitude and linearly tapered in phase in the ϕ-direction). A choke is used around the feed waveguide to suppress the leakage at the junction of the radial waveguide and the rectangular feed waveguide. The antenna is analyzed by using the method of moments (MoM). Fig. 4 shows the analysis model. The analysis model is a one-dimensional slot pair array on a shorted rectangular waveguide with periodic boundary walls to simulate the mutual couplings in the transverse direction. An infinite ground plane is introduced for an external region. The excitation of magnetic current on each slot is calculated by considering the slot region as a rectangular cavity and the external region as a half free space. All the slot pairs are designed to obtain uniform excitation, to suppress reflection and to realize circular polarization. The parameters are the slot lengths, the pair spacings and the position of the shorted wall. The feed crossed-slot is also analyzed by MoM [6]. The crossed-slot composed by two slots with different lengths in order to excite same amplitude and 90-degree phase difference. The parameters are the slot lengths, the rotating angle and the position from the shorted plate of the rectangular feed waveguide. They are determined to suppress the reflection and to realize the rotating mode in the radial waveguide.

4. Measured Results

Figure 5 shows the aperture distribution at 59.5GHz where the maximum directivity is obtained. In the ϕ–direction, the deviations of the amplitude and the phase are 3.2dB and 27.5 degrees. In the ρ-direction, the deviations of the amplitude and the phase are 7.6dB and 29.4 degrees. Figure 6 shows the radiation pattern of the right-hand circular polarization at 59.5GHz. A sharp main beam is obtained in boresight. The 3dB beamwidth is 4.9 degrees at y-z plane and 5.3 degrees at x-z plane. The side lobe level is suppressed below -15dB. Figure 7 shows the gain and the directivity. The directivity is calculated by measured near-field distribution while the gain is measured at an anechoic chamber. The maximum directivity is 30.7dB at 59.5GHz. The maximum gain is 28.7dBi at 59.3GHz with efficiency of 53.4%. It is lower than the directivity by about 2dB in the frequency range from 58GHz to 61GHz. This gain reduction could be caused by the leakage from the junction of the radial waveguide and the feed rectangular waveguide. The bandwidth for the gain of more than 28dBi is 1.8GHz. The measured peak frequency shifts lower than the designed one by 500MHz. The reflection is shown in Fig. 8. The bandwidth of the reflection below -15dB is 2.7GHz.

5. Conclusion

We have developed a RLSA at 60GHz by using the nano-imprinting fabrication technique where the accuracy is nanometer order. The antenna gain is 28.7dBi with efficiency of 53.4% at 59.3GHz in spite of the design frequency of 60GHz. The antenna gain is less than the directivity by about 2dB due to the leakage between the radial waveguide and the feed waveguide. As future study, the gain should be improved by reducing the leakage loss. The operating frequency also should be tuned.

References

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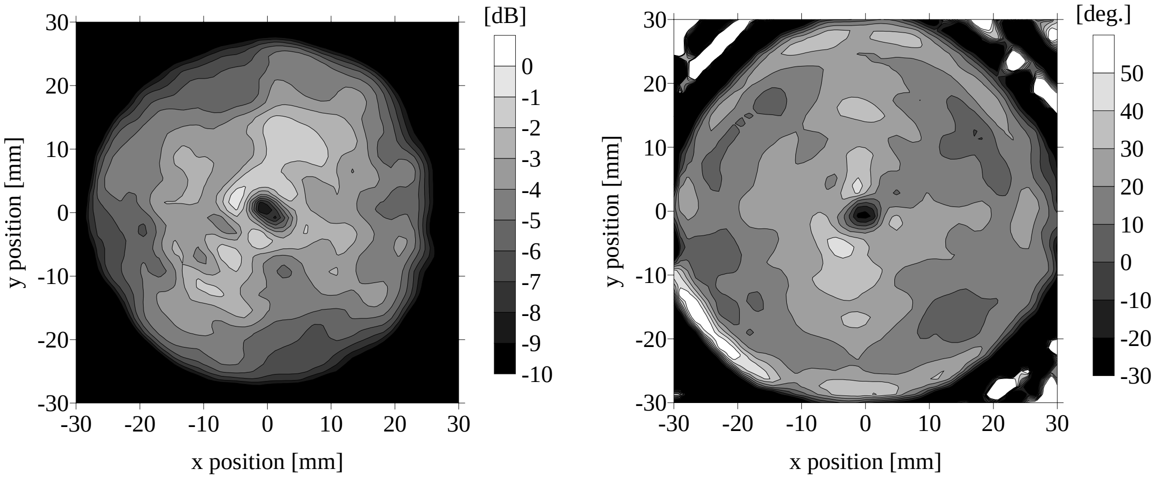
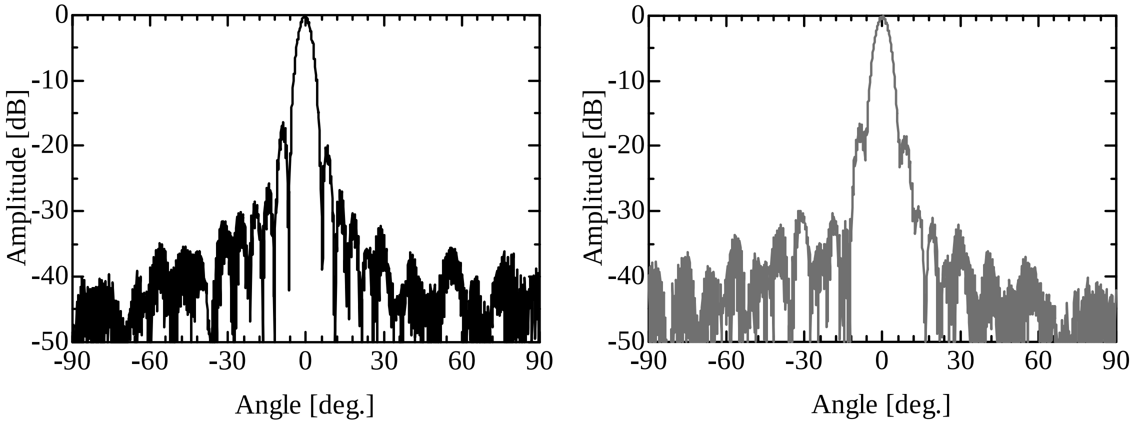


(a) Amplitude (b) Phase

Figure 5: Aperture Distribution of RLSA (59.5GHz)



(a) y-z plane (b) x-z plane

Figure 6: Radiation Pattern (59.5GHz)

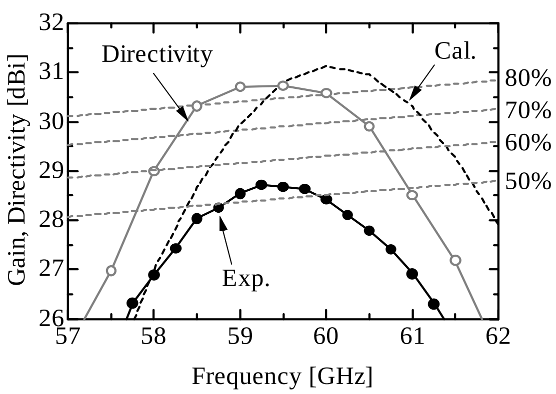


Figure 7: Gain and Directivitiy

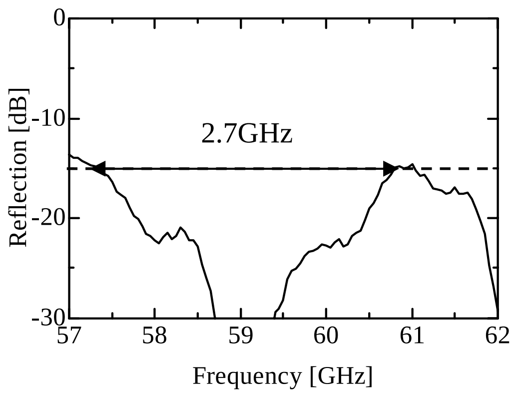


Figure 8: Reflection of RLSA