Measurement of Far Field Radiation Pattern of 300GHz-band Cassegrain Antenna

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***Abstract* - We measured far field pattern of a 300-GHz Cassegrain antenna. The far-field measurement of the high-gain antenna requires a transmission distance of several tens of meters or more, and the receiver system requires a dynamic range of more than 70 dB and high sensitivity. In this paper, we obtained a 300-GHz-band experimental radio station license in Japan and measured the far field pattern of a Cassegrain antenna with a gain of 45 dBi. We also measured the near field pattern of the antenna, and calculated the far field pattern from the near field pattern. The measured far field pattern and the calculated far field pattern from the near field pattern are in good agreement. The far field pattern agrees with the antenna pattern models described in Recommendation ITU-R that covers below 86 GHz.**

***Keywords* — 6G, Terahertz wireless system, Far field measurement, Near-field to Far-field Conversion**

I. INTRODUCTION

The next generation mobile communication standard, 6G, is expected to employ terahertz (THz) wireless system to achieve >100-Gbps data rates. For the design of fixed wireless link and interference evaluation, antenna model is necessary. However, the antenna radiation pattern models described in the Recommendations ITU-R covers only up to 86 GHz. In addition, few experimental results have been reported on the far-field radiation pattern of high-gain antenna at 300 GHz, because the far-field measurement of a high-gain antenna even at 300 GHz requires a transmission distance of several tens of meters, and a radio station license is required to conduct outdoor experiments. Furthermore, for the evaluation of the side lobes of a high-gain antenna, the measurement system requires a large dynamic range and high sensitivity for the receiver. In this paper, far field radiation pattern of a 300-GHz-band Cassegrain antenna with a gain of 45 dBi are measured. In order to conduct the outdoor far-field measurements, we prototyped a 300-GHz-band transmitter (Tx) and receiver (Rx) and obtained an experimental radio station license in Japan. The calculation of far field radiation pattern from the measured near field pattern enables the indoor measurement of antenna radiation pattern and allows low receiver sensitivity, however it had not been investigated by experiment that the near-field to far-field conversion can be applied at 300 GHz. We measured the near field pattern and calculated the far field radiation pattern from the measured near field pattern, and the calculated radiation pattern was compared with the measured far field pattern.

II. FAR-FIELD MEASUREMENT

In order to measure the far-field pattern of the 45-dBi Cassegrain antenna, we prototyped a 300-GHz-band Tx and Rx and obtained an experimental radio station license from the Kanto Telecommunications Bureau in Japan in November 2020. The configuration of Tx and Rx is shown in Fig.1. In Tx, 16.3-GHz LO signal was multiplied by 18 to 293.4 GHz. The output power is 1.2 mW. In Rx, a sub-harmonic mixer down-converts the RF signal to a 24 MHz IF signal, and the received power can be evaluatied by measuring the IF signal magnitude by a spectrum analyzer.

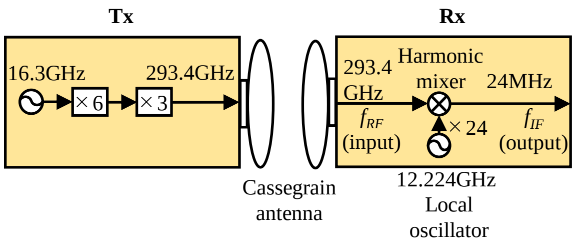

Fig.1. Schematic diagram of 300-GHz-band Tx/Rx

Tx and Rx were set up at 50m apart, and the radiation pattern of the Cassegrain antenna attached to Rx was measured by rotating Rx. Figure 2(a) shows a photograph of the measurement setup of far field radiation pattern. The height of the transmitter and the receiver is 1.2 m, which is sufficiently higher than the first Fresnel zone (0.3 m), so it is considered that the effect of reflection at the ground is negligible. Figure 3 shows the measured far field radiation pattern of the Cassegrain antenna in the E-plane. The half-power beamwidth (HPBW) of the beam is about 0.4 degrees. The side lobes at an offset angle of 60° are 60 dB lower than the main lobes.

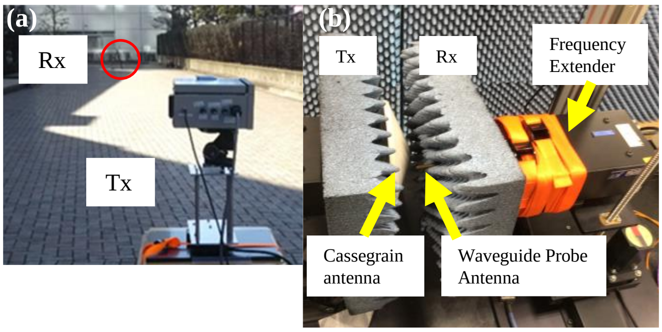

Fig.2. Photographs of experimental setup for (a) far-field and (b) near-field antenna radiation pattern

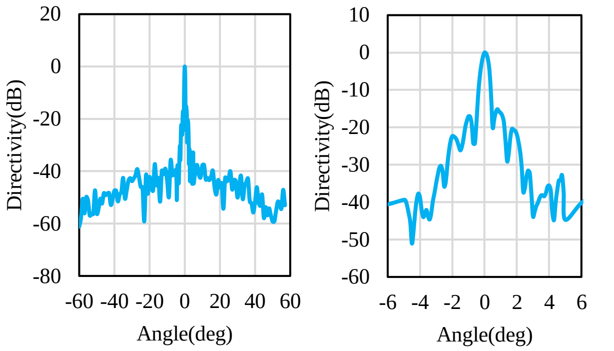

Fig.3.Measured far-field pattern of Cassegrain antenna

III. NEAR-FIELD TO FAR-FIELD CONVERSION

Figure 2(b) is a photograph of the antenna near-field measurement system. We used the same Cassegrain antenna as in Chapter II for Tx and a waveguide probe antenna for Rx. The probe antenna was set at a distance of 5mm from the Cassegrain antenna surface. The probe antenna was moved to map the near-field distribution. The map area was 150 mm × 150 mm. The amplitude and phase of 293.4 GHz signal were measured with a vector network analyzer. The pitch width of the scan of the waveguide probe antenna is 0.5 mm. Figure 4 shows the measurement results of the intensity of the near field. The effect of shadowing by the hyperbolic sub-reflector was observed at the center of the near field pattern. Since the transmitting and receiving planes were not perfectly parallel, a phase shift in the antenna plane was observed.

Figure 5 is a calculated far-field pattern from the near field measurement results shown in Fig.4. The near-field-to-far-field conversion was performed based on the following references [1-2]. The measured far field pattern (Fig. 3) the antenna model described in the ITU-R Recommendation was also shown in Fig. 5. The measured far field pattern and the calculated far field pattern are in good agreement. These results indicate that the near-field-to-far-field transformation is a valid method to evaluate the far field pattern of high-gain antenna at 300 GHz. The measurement results for this antenna were also found to agree with the ITU-R model applied below 86 GHz.

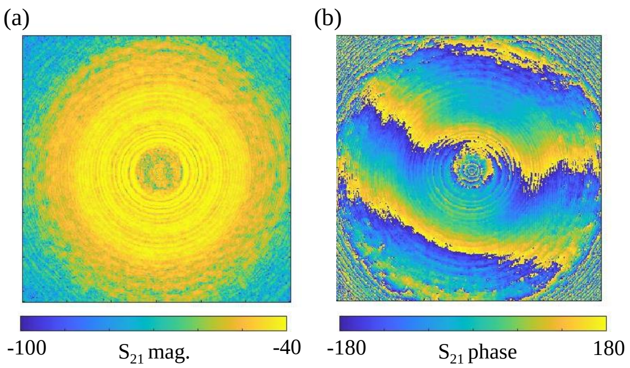

Fig. 4 Measured near-field pattern of Cassegrain antenna. (a) S_{21} magnitude, (b) S_{21} phase.

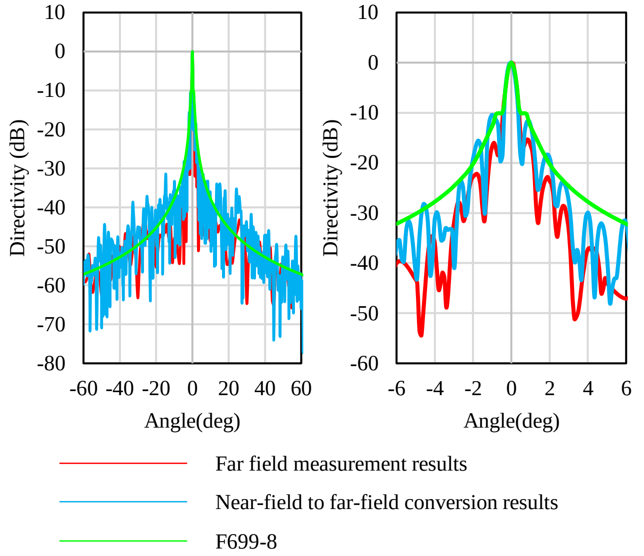

Fig. 5 Measured far-field pattern and calculated far-field pattern of Cassegrain antenna. Antenna pattern described in Recommendation ITU-R F699-8 is also shown.

IV. CONCLUSION

The far field radiation pattern of the 300 GHz band Cassegrain antenna with 45 dBi gain was measured. In order to conduct the far-field measurements, a prototype of 300 GHz band radio station that can be used for outdoor transmission experiments was fabricated and we obtained an experimental radio station license in Japan. We also measured the near field pattern of the same Cassegrain antenna, and calculated the far field pattern from the measured near field pattern. The results of the measured far field pattern and the calculated far field pattern are in good agreement. These results show that the near-field-to-far-field conversion is an effective method to evaluate the far field pattern of high-gain antenna at 300 GHz. The measurement results for this antenna were also found to be in good agreement with the ITU-R model applied below 86 GHz.

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