Characterisation of Terahertz Antenna for beyond 5G Systems

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Abstract – It is important to build the antenna and propagation models of THz wireless communications in order to evaluate the interference between other services, and to estimate communication quality of THz wireless communications. ThoR (TeraHertz end-to-end wireless systems supporting ultra-high data Rate applications) project is a joint EU-Japan project to provide technical solutions for the data networks beyond 5G based on 300 GHz RF wireless links. This paper presents the measurement results of 300-GHz-band antenna and propagation characteristics in ThoR project.

Keywords – terahertz; antenna; propagation; beyond 5G;

1. Introduction

Terahertz (THz) wireless systems are a very promising solution for beyond 5G system [1]. World Radiocommunication Conference (WRC) 2019 will be held in Oct-Nov 2019, and its agenda item 1.15 relates to consideration of identification of frequency bands for the land-mobile and fixed services applications operating at 275-450 GH [2].

It is important to evaluate the antenna pattern in order to evaluate the communication quality of THz wireless system, or in order to avoid the interference between backhauls and fronthauls or with these passive services. There are passive services, such as earth exploration-satellite service (EESS), operating in this frequency range, and sharing between THz wireless links and EESS will be discussed at WRC 2019.

One of the important parameters for evaluation of the interference between different systems is the radiation pattern of antennas. International Telecommunication Union Radiocommunication Sector (ITU-R) defines the antenna pattern models in Recommendation ITU-R F.699 and F.1245 [3]. However, these Recommendations cover at a frequency range of up to 87 GHz, and there are no recommendations that defines the radiation pattern of antennas at a frequency range of over 100 GHz. It is difficult to measure accurate radiation patterns at THz frequency range, because the output power of THz transmitter and the sensitivity of THz receiver is not so high, which makes the measurement system dynamic range small.

ThoR (TeraHertz end-to-end wireless systems supporting ultra-high data Rate applications) project is a joint EU-Japan project to provide technical solutions for the data networks beyond 5G based on 300 GHz RF wireless links [4]. One of the objective of this project is the experimental characterization of 300 GHz antennas and to build antenna model at THz range. This paper presents the overview of ThoR project and the measurement results of THz antenna and propagation characteristics.

2. Overview of ThoR project

The ever-increasing demand for higher data transfer rates in up- and down-link for each device in a mobile network leads to huge aggregated data rates, especially in cities [5]. To service a fully mobile and connected society networks beyond 5G system must undergo tremendous growth in connectivity, data traffic density and volume as well as the required multi-level ultra-densification. The ThoR project is a joint EU-Japan project and started July 2018. Figure 1 shows an overview of ThoR project [4]. ThoR will apply state-of-the-art photonic and electronic technologies to

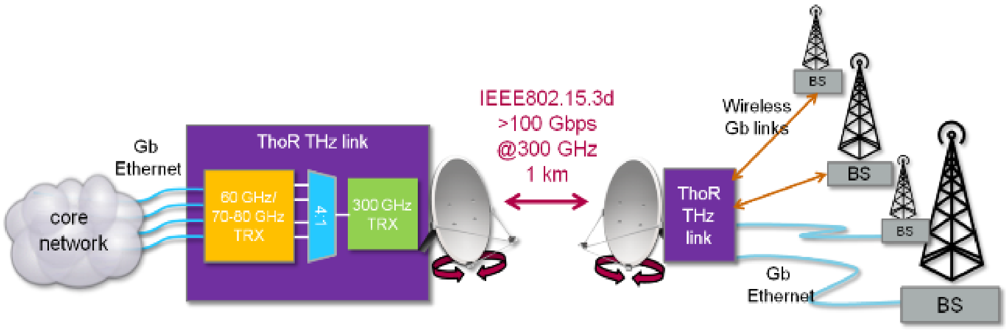


Figure 1. Overview of ThoR project [4].

build an ultra-high bandwidth, high dynamic range transceiver operating at 300 GHz combined with state-of-the-art digital signal processing units, and final objective is >100 Gbps P2P link at 300 GHz.

One of the objective is the characterization of the antenna and propagation environment and produce advisory documents, which will be fed into international standardization conferences. Figure 2 shows the antenna and propagation studies in ThoR project. The objectives of this activities are (a) to make an antenna model in the 275-325 GHz region, (b) to derive THz propagation models, (c) interference studies with passive services, and (d) to make the base station deployment scenario for space division multiplexing of backhaul/fronthaul links.

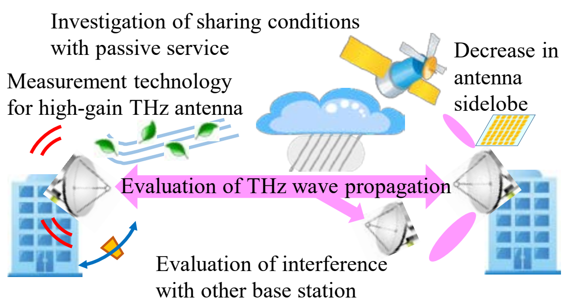


Figure 2. Antenna and propagation studies in ThoR project [4].

3. Antenna pattern measurement

WRC 2019 will be held in Oct-Nov 2019, and identification of frequency bands for the land-mobile and fixed services applications operating at 275-450 GH will be discussed. One of the main issues in the conference is frequency sharing between THz wireless service and EESS. In order to evaluate the interference from THz wireless service to EESS, the accurate antenna model is necessary. However, there is no ITU-R model of radiation pattern that covers up to 300 GHz. Therefore, the sharing studies on Agenda Item 1.15 employs the existing Recommendation ITU-R F.699 and F.1245 that covers up to 87 GHz. Moreover, the experimental characterization data of high-gain antenna at THz range is few [6]. It is difficult to measure accurate antenna patterns at THz frequency range. The output power of THz transmitter and the sensitivity of THz receiver is not so high because of the limitation of semiconductor devices at these frequency range. Therefore, the dynamic range of radiation pattern measurement system at THz range is smaller than that at microwave range and millimeter-wave range. The narrow dynamic range of measurement system makes it difficult to obtain accurate sidelobe pattern of high gain antenna, because the power ratio of sidelobe is much smaller than that of main lobe. The antenna pattern should be measured at far field. In case the antenna gain is 45 dBi (antenna diameter: 0.15 m) and the frequency is 300 GHz, the boundary of far field is 45 m. In this case, the free-space propagation loss (FSPL) is about 115 dB, and the received power is quite small, especially in case of the measurement of side lobe pattern.

Figure 3 shows the measurement results of a low-gain antenna (WR-3.4 standard horn antenna). In order to achieve accurate radiation pattern measurement of this antenna, we employed a vector network analyser (VNA) and the measurement was conducted in a small anechoic chambers at

NICT. Two horn antennas were opposed to each other at a distance of 0.5 m. The measured radiation pattern agreed well with the simulation results.

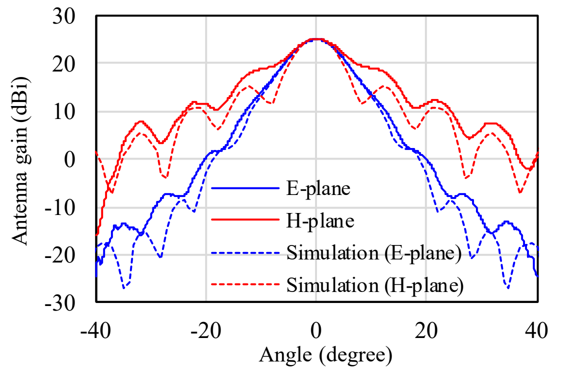


Figure 3. Radiation patterns of WR-3.4 standard horn antenna at 300 GHz.

We also measured the radiation pattern of a high-gain Cassegrain antenna with a diameter of 150 mm (45 dBi). The experimental results are shown in Figs. 4. The antenna pattern models described in Recommendation ITU-R F.699-8 and F1245-3 are also shown. A small dip was observed at the top of the main lobe. In this experiment, the transmission distance was 20 m. This distance is smaller than the boundary of far field (45 m). Therefore, the shadowing effect of the secondary reflector are observed. The sidelobes of measured radiation patterns are larger than that of ITU-R antenna pattern models. These results indicate that new antenna pattern models at 300-GHz band are necessary. In order to measure the accurate radiation pattern of the Cassegrain antenna, we have to increase the transmission distance. It is difficult to set the transmission distance over 45 m in an anechoic chamber. We are going to make a transmitter and to obtain an experimental radio station license. By using this transmitter, we are going to conduct outdoor transmission experiments. Another way to obtain an accurate radiation pattern of the high-gain antenna is the conversion of measured near-field pattern to far-field pattern. Near field measurement of high-gain antenna by EO probe is one of the promising solution [7].

As shown in Fig. 2, it is important to suppress sidelobes of high-gain antennas. We are now investigating a 300-GHz-band THz absorber that employs surface metamaterials. The THz absorber employs slot ring resonator (SRR) absorber [8] that is shown in Fig. 5(a). The SRR patterns are made by a 2-μm-thick gold on a 200-μm-thick quartz substrate. The simulation results of S_{21} is shown in Fig. 5(b). S_{21} at 296.7 GHz is -32.4 dB, and -10-dB bandwidth is about 37.7 GHz. We are planning to use these THz absorber to suppress the sidelobes of THz high-gain antenna.

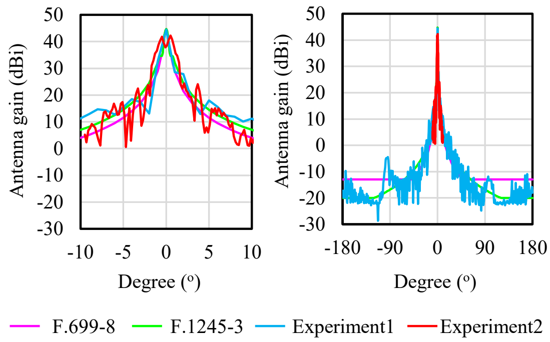
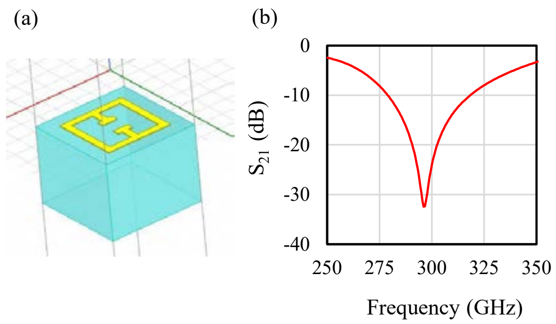


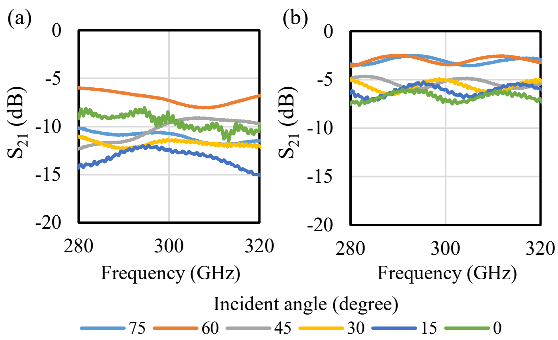
Figure 4. Radiation patterns of Cassegrain antenna at 300 GHz, and that of Recommendation ITU-R.



Figures 5. (a) Unit cell of THz absorber. (b) Simulation result of transmission characteristics of THz absorber.

4. Reflection characteristics of building materials

To increase the accuracy of radio wave propagation simulation, accurate material property model, such as reflection coefficient of building materials, should be used. Material property models described in Recommendations IUT-R P.1238 and P.2040 are usually used for the propagation simulations [9]. However, there is no recommendation of material property models that can be used for the 300-GHz-band THz wave propagations. We measured the reflection characteristics of various building materials on the incident angle. We used two diagonal horn antennas with a gain of 25 dBi, and they are attached with the frequency extenders for the VNA. Figure 6 shows the dependence of reflection characteristics of wood and glass on the incident angle. Periodic fluctuations are observed. These periodic fluctuations come from the superposition of reflection wave at the sample surface and at the sample bottom. As the incident angle increases, S_{21} increases. The period of the fluctuations becomes shorter as the incident angle decreases. We conducted outdoor propagation simulations using these measured reflection characteristics in order to evaluate the interference between fronthaul wireless links that are placed nearby each other. We are going to measure the complex permittivity of building materials by using terahertz time domain spectroscopy (THz-TDS) [10].



Figures 6. Reflection characteristics of (a) wood and (b) glass at 280-320 GHz.

5. Conclusion

We conducted the measurement of 300-GHz-band antenna and propagation characteristics in ThoR project. Radiation pattern measurement of high-gain THz antenna is difficult due to the limitation of measurement equipment dynamic range and that of transmission distance of propagation experiment. The sidelobe pattern of high-gain antenna did not coincide with the antenna model described in Recommendation ITU-R. These results indicate we have to evaluate the accurate radiation pattern of high-gain antenna at 300 GHz, and make new antenna model at this frequency. The conversion of measured near-field pattern by EO probe to far-field pattern is one of the promising solution to obtain an accurate radiation pattern of the high-gain antenna. Measurement of reflection characteristics of building materials is important to evaluate the interference between fronthaul wireless links that are placed nearby each other.

Acknowledgment

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