THz links for future mobile systems

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Abstract – A number of base stations are required to offer global mobile services by use of small cells for high-speed wireless links. The small cells should be connected by networks with various media including optical fibers and fixed wireless links. Required bandwidth for such links would be up to 100 Gb/s. In conventional radio systems, it would be rather difficult to achieve such high-speed transmission. In this paper, we focus on THz links which can offer networks for future mobile networks.

Keywords — THz, propagation, atmospheric attenuation.

I. Introduction

The THz wireless link has attracted great attention from researchers as a transmission medium for high-speed data transmission [1]. Radio spectrum congestion is a problem, especially in the microwave band. Interference mitigation becomes important even in millimeter-wave bands with frequencies below 0.1THz, where broadband wireless links for high-speed rails and high-resolution radar imaging for airport runway monitoring have been developed. Thus, by using a frequency band of less than 0.1THz, it is difficult to achieve wireless transmission with a data rate of more than 100Gb/s. In the THz band (0.1-10THz), a wide spectrum for mobile services is expected to provide more than 100Gb/s of transmission for future mobile services such as 5G. However, because of the large free space propagation loss and atmospheric absorption in the THz band, the expected transmission distance is shorter than a few kilometers, so that a number of base stations (BSs) are required to provide nationwide or global services by the THz band. As an example, we describe THz link design with 0.3 THz and 0.5 THz. Even in such high-frequency bands, interference mitigation would be an issue. We also discuss potential interference between fixe service (FS) and land mobile service (LMS).

II. Link design of short distance THz links

To discuss basic characteristics of THz-links, we investigated link performance of ideal SNR of THz transmission with 300 GHz and 500 GHz. We assumed that noise floor of the link is equal to thermal noise level with 288.15K. Signal-to-noise ratios (SNRs) of links are shown in Figs. 1 and 2. Antenna gain and transmission power are assumed to be 50 dBi and 20 dBm, respectively. Atmospheric attenuation coefficient of 500 GHz is 66.23 dB/km, while that of 300 GHz is 5.24 dB/km [2, 3]. On the other hand, rain attenuation is not so sensitive to carrier frequency in THz region. The attenuation coefficients under

5mm/h rainfall are 4.47 dB/km and 4.27 dB/km for 300 GHz and 500 GHz, respectively [4]. Those under 50 mm/h rainfall are 18.99 dB/km and 17.83 dB/km for 300 GHz and 500 GHz, respectively. The free-space path loss coefficients are 142.0 dB for 300 GHz and 146.4 dB for 500 GHz. That means that the major part of the difference in the SNR is due to the atmospheric attenuation without rain. For short-distance THz-links, the SNR is robust against the rainfall especially in the 500 GHz FS link case.

The transmission capacity depends on the modulation format and the noise figure of the THz link. For quadrature phase shift keying (QPSK), the required SNR is approximately 10dB. By assuming that the noise figure is 15 dB as shown in Ref. [1], the required SNR margin is 25 dB approximately. The modulation speed (baud rate) can be assumed to equal to the signal BW when the THz-wave is modulated by an ideal filtered QPSK waveform. Thus, the transmission capacity of the 100-GHz BW link would be 200 Gb/s. Here, we consider expected link distances for 200-Gb/s transmission under light rain (5 mm/h) and heavy rain (50 mm/h) conditions. As shown in Fig. 1, over 1-km transmission can be achieved by the 300-GHz link under light rain condition, while the expected link distance would be 780 m under heavy rain condition. For the 500-GHz link, the expected link distances are 380 m and 310 m for light rain and heavy rain conditions, respectively. When the transmission power is 0 dBm, the expected link distances are for 130 m and 110 m for light rain and heavy rain conditions, respectively. Due to large atmospheric attenuation, the link distance in the 500-GHz band is much less than in the 300-GHz band. However, the expected distance is still larger than 300 m even in heavy rain condition. Thus, we can use the 500-GHz link to bridge many small cells, without any interference to 300-GHz short-distance links. The antenna size for 500-GHz is much smaller than in conventional bands. For example, the diameter of a 50-dBi parabolic antenna would be 8.5 cm when the aperture efficiency is 50%.

III. Interference study

LMS for short-distance connection between a data kiosk and user terminals would have interference from the FS for a few hundred-meter transmission. The transmission distance of the FS is assumed to be 300 m, while that of the LMS is 1m. The transmission power is 10 dBm for the short-distance LMS, and 20 dBm for the FS. A data kiosk has an antenna of 30-dBi gain for the LMS connecting user terminals. Fig. 6 shows the desired and undesired signal

ratio as a function of the main beam direction difference between the LMS and FS signals, where the antenna pattern offered in Ref. [5] was used to estimate the interfering signal (FS) detected by the antenna for the LMS. Here, we assume that the required signal-to-noise-power ratio (SNR) for 32-QAM is approximately 20 dB. When the direction difference angle is larger than 10 degrees, the interference signal power would be less than the maximum noise level defined by the required SNR. Thus, the angle should be approximately larger than 10 degrees to suppress the interference to the LMS by the FS.

Figure 1. SNR of 300-GHz radio links. Solid lines and dashed lines are for 100-GHz and 2-GHz bandwidth links, respectively.

Figure 2. SNR of 500-GHz radio links. Solid lines and dashed lines are for 100-GHz and 2-GHz bandwidth links, respectively.

IV. CONCLUSION

We investigated THz link performance and interference between FS and LMS, where various radio services have been already proposed. In the 300-GHz band, the interference from a FS link signal to a short-distance LMS link would be an issue. Although attenuation in the air is very large, over 100-Gb/s transmission can be designed by using a small antenna. If we can use the 500-GHz band for such FS links, we can avoid the interference in 300 GHz.

Figure3. Desired and undesired signal ratio.

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