THz Transport Technologies and Strategists Beyond 5G/6G Systems

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Abstract: Utilization of THz wave is being considered to achieve the target expected for 6th Generation Mobile Communication System (6G). The research topics and considerations how to use the bands in 6G era is addressed.

1. Introduction

5th Generation Mobile Communication System (5G) has been launched around 2020. 5G is the first generation to use millimeter wave bands for commercial mobile communications. While mobile communication services before 4th Generation Mobile Communication System (4G) were mainly communication services related to people, 5G also features a role as social infrastructure such as services that connect things to things. Therefore, in 5G, in addition to the scales such as data rate and capacity, (eMBB, enhanced Mobile Broadband), which are the main elements of wireless communication system, the performance to be satisfied is specified for some other scales such as URLLC (Ultra-Reliable and Low Latency Communications) and mMTC (massive Machine Type Communication) [1-4]. Around the time of commercialization of 5G, research and development on beyond 5G, that is, 5G Evolution and 6G, has been attracting attention and becomes an emerging topic. Figure 1 shows a diagram showing the performance expansion targets toward 6G [2].

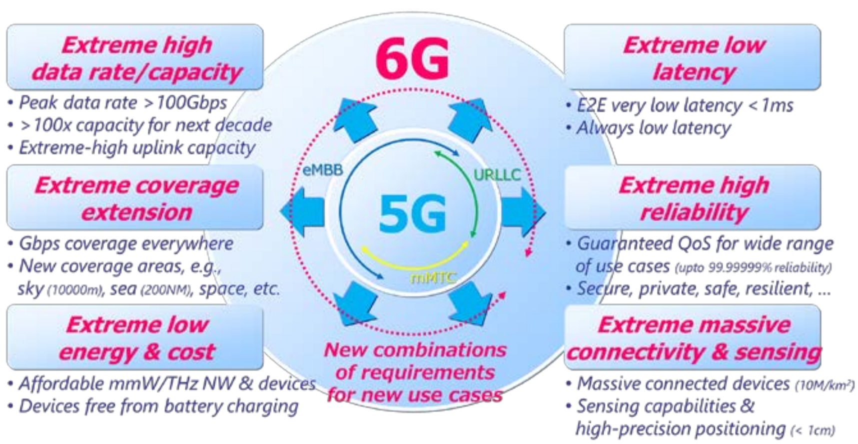

Fig. 1. Extreme Targets toward Beyond 5G [2]

As a research and development topic of 5G Evolution and 6G, improvements on data rate and capacity are still universal issues. Achieving data rates exceeding 100 Gbps and communication capacity 100 times higher than before, as shown in Fig. 1, are extremely challenging targets, and it is considered difficult to achieve that only in the frequency bands assigned to mobile phone services up to now.

In mobile communication so far, we have been studying from the viewpoint of how to improve the spectrum efficiency and increase the high data rates and capacity in a relatively narrow bandwidth of a relatively low frequency band below the microwave band. With technologies and/or schemes such as multi-level modulation, code-division multiple access (CDMA) and orthogonal frequency-division multiplexing (OFDM), spectrum efficiency has increased and reached to almost the limit. In order to achieve the challenging targets on data rate and capacity shown above, there is no choice but to expand the bandwidth and also increase the multiplicity in space. In the higher frequency spectrum from the millimeter-wave band to terahertz (THz) wave band, it is possible to use a drastically wider bandwidth compared to 5G. Therefore, the technologies for millimeter-wave and THz wave utilization have become a hot topic [4-7].

2. Issues on utilization of millimeter-wave and THz wave bands

2.1. Issues on antenna and propagation

As shown in Fig. 2, 5G supports the frequency bands up to 52.6 GHz, and the possibility of extending its support to about 90 GHz is being studied. In addition, the Federal Communications Commission (FCC) recommends that higher frequency bands than those used in 5G, such as 95 GHz to 3 THz, be studied for 6G [8]. At present, radio waves up to about 300 GHz are considered to be within the scope of 6G.

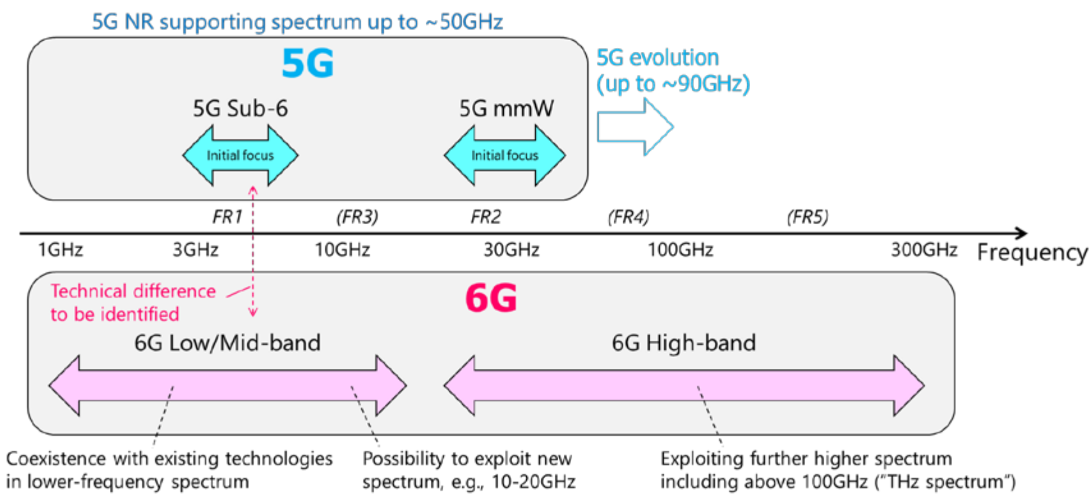

Fig. 2. 6G Spectrum Extension [2].

It is generally known that the higher the frequency, the larger the path loss. The free space path loss (FSPL), L, in radio propagation derived from Friis transmission formula [9], is represented as follows;

$$L\ (\mathrm{dB}) = 92.44 + 20\log f + 20\log d \qquad (1)$$

, where f is the frequency in GHz, and d is the path length in km. In order to compensate for the increase in FSPL due to the high frequency and to establish high-speed communication on that frequency, it is necessary to use high-gain antennas on the transmitting side (TX) and the receiving side (RX). Generally, as the gain of the antenna is increased, its directivity becomes sharper, and when a gain of several tens of dB is obtained, it looks like a laser beam, so it is necessary to determine the direction of each other, TX and RX, and control the directivity. When the communication partner moves, it becomes necessary to control the directivity of the antenna following the movement of the other party. In mobile communication in the form of a base station (BS) and a user equipment (UE), it is considered difficult for the UE to use such a high gain antenna. Therefore, the antenna of BS will require higher gain and more precise directivity control than that of UE.

Radio waves in millimeter-wave or THz band have a strong tendency to travel through a straight path and to be highly attenuated by shields, which are metals, structures such as buildings, human body, etc. Thus, the challenge is how to establish and secure the line-of-sight (LOS) environment between TX and RX in mobile communication. It is also necessary to carry out technical examination to clarify their radio propagation characteristics and establish their propagation model and high-precision propagation simulation technique.

2.2. Issues on RF devices

For millimeter-wave and THz wave band utilization, RF (Radio Frequency) circuits, such as high power amplifier, low noise amplifier, frequency converter, frequency oscillator, filter, etc. and their implementation to communication equipment are big challenges [5-7]. They should be achieve low power consumption and high heat dissipation for providing small-size devices. In addition, optical technologies may be important especially for frequency generation, conversion and control in the THz waves. Semiconductor devices, or chips, must be manufactured with a level of precision and cost applicable to actual commercial services. As the wiring loss will be larger in those high frequency bands, the composition of chips and circuits, and implementation method for connecting antennas are also major challenges. Regarding wiring for the high frequency bands, attention is being paid to dielectric waveguides, which have the same principle as optical fibers. The chips need to be highly integrated and some chips must have calibration capabilities to correct manufacturing variations and other error factors. A research theme would be how to achieve optimization of both the pursuit of performance of the device itself and the improvement of performance of the device by digital signal processing, factoring in the evolution of future semiconductor manufacturing technology. We have just begun studying technologies for predicting and complementing deviations from ideal values for RF devices used in such high frequency bands.

3. Summary

The target expected for 5G Evolution and 6G is briefly addressed, and issues on utilization of millimeter-wave and THz wave bands are also described. In the presentation at the OFC, we will outline the research topics regarding the use of millimeter-wave and THz wave bands and considerations how to use those frequency bands in 6G era.

Acknowledgment

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