Recent Progress on Terahertz Communications at 300 GHz for Practical Short-Range Applications

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1. Introduction

Ever since various multimedia services based on the Internet were introduced in 1990s, traffic related to such services has been steadily increasing worldwide, usually via wired networks. However, with the introduction of new mobile devices and new multimedia services working in wireless environments, we are seeing changes in how people consume multimedia services. Users are consuming many more digital information with handheld mobile devices such as smart phones or tablet PCs. Moreover, the popularity of personal multimedia devices, such as digital cameras and camcorders, and inexpensive large-capacity personal storage media enable every single individual to perform a more active role in the circulation or distribution of multimedia information. Recent users are generating digital contents and distributing them by themselves using their smart phones via the Internet. In these days, each single user is one single source of digital information and those users are demanding new ways to manage and share their data on PCs and mobile devices more easily and quickly.

To satisfy the needs of users, the data capacity of wireless communications has been improved over the last a couple of decades, with progress in speed that has been much faster than for wired systems, and this trend will continue for a while [1]. In order to accommodate the trend and need, it is obvious that more spectral resources are necessary. In the race toward ultra-fast wireless communications systems, in spite of several drawbacks of terahertz (THz) waves such as the poor output power and sensitivity of THz emitters and detectors, respectively, THz wave signal is attracting great interest, especially for short-distance applications [1], because of its inherent large bandwidth. Recently, several attempts of wireless data transmission at above 275 GHz, where is not allocated for specific use yet, have been reported.

In this report, we will present our recent progress for practical THz communications.

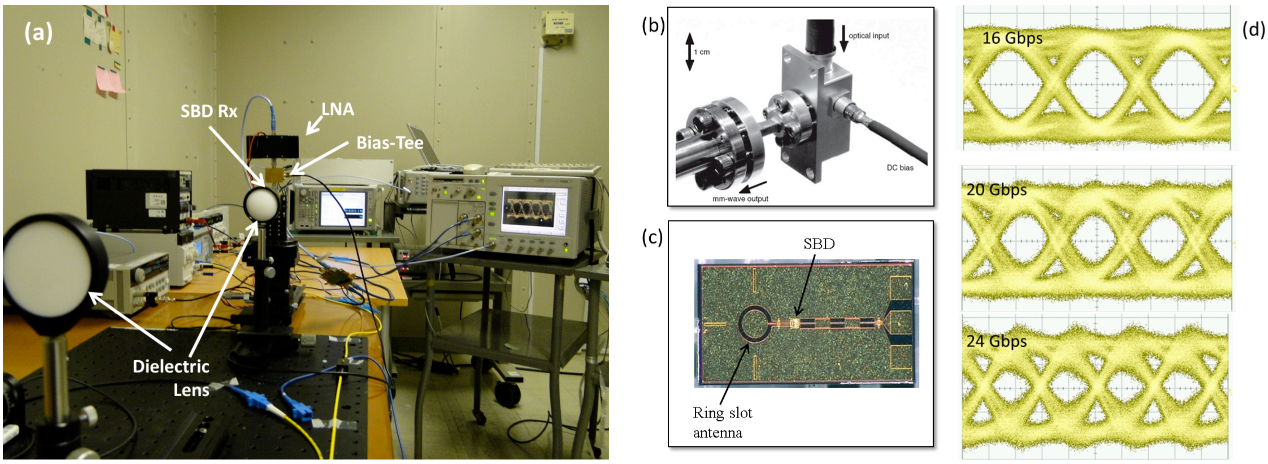


Figure 1. Experiment setup (a) of feasibility test using UTC-PD (b) as transmitter and Schottky barrier diode detector (c). Measured eye diagram at several bit rates at up to 24 Gbps

2. Recent Progress on Transceiver ICs and Packaging

In the early phase of the research on the terahertz communications, we have conducted the feasibility tests with photonic technologies originally developed for the fiber-optic communications at the 1550-nm wavelength band. Optical heterodyning scheme with an ultra-fast photomixer provides great freedom in generating terahertz wave signals. Frequency and intensity of the terahertz-wave can be tuned simply by adjusting those of laser sources [2]. In addition, intensity, frequency and phase modulation of the terahertz wave can be also easily implemented with commercially available optical modulators at up to 40 Gbps. Recent advanced devices for the optical coherent communications allowed us to produce even higher-order modulated terahertz signals such as QPSK or QAM [3]. In fact, there is the other importance of the photonic technologies in the terahertz communications; terahertz communications system can be incorporated with the optical network as wireless access points to the fiber optic using the photonic technologies for the transmitters.

In our study, ASK modulation scheme has been used at above 250 GHz with waveguide packaged uni-travelling carrier photodiode (UTC-PD) and Schottky barrier diode (SBD) detector which includes an on-chip planar antenna [4]-[6]. At 300 GHz, error free transmission of 24 Gbps random data has been demonstrated at the link distance of around 50 cm [5]. Though we needed to use dielectric lens to compensate for the low output power from the UTC-PD and the poor receiver sensitivity, we could see how simply that high data rate can be handled using those simple devices and setup at the terahertz frequencies. For the practical system, we have developed an ASK receiver MMIC [7] using state-of-art InP heterojunction bipolar transistors (HBTs) technology. On-chip antenna, RF amplifier, envelop detector and the post data amplifier have been fully integrated in the single chip and the receiver MMIC was packaged with the Silicon lens. Thanks to the 25-dB RF amplifier, we could remove two dielectric lens used in the previous work using the SBD receiver and demonstrate the error free transmission at up to 20 Gbps. In this experiment, the UTC-PD was also used as the transmitter.

Though spectral efficiency is very poor, in general, the ASK scheme with incoherent detection is considered to be more advantageous for THz communications because of the simple structure. However, considering that the operating bandwidth of front-end components, particularly power amplifiers, usually does not exceed 10% of the carrier frequency, and it is not easy to multiplex the system in the frequency domain with incoherent ASK receivers, the ASK modulation scheme is not appropriate for very high throughput, for instance 100 Gbps or more. In this point of view, we are developing multi-level modulation THz transceiver MMICs operating at 300 GHz with state-of-art device technology and have reported a quadrature voltage controlled oscillator and direct quadrature modulator and demodulator [8]-[9].

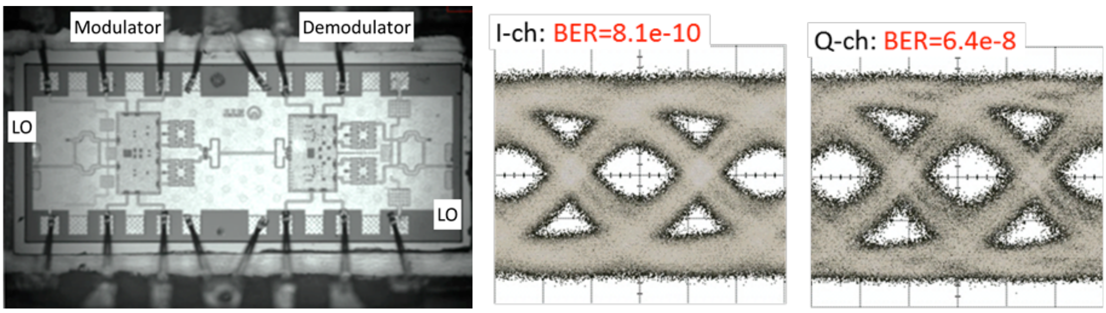
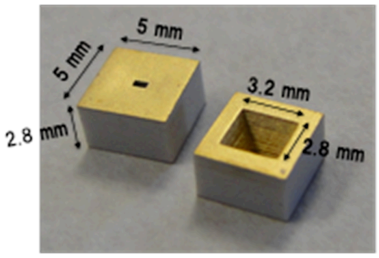
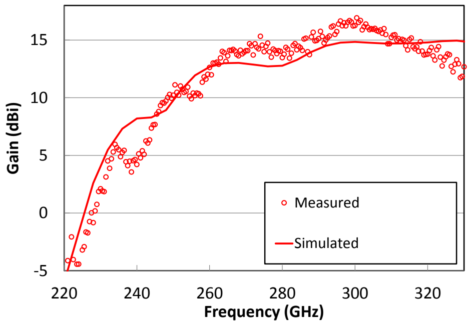


Figure 2. (left) Top view of quadrature modulator and demodulator MMICs of which RF ports are directly tied together for on-chip back-to-back test and (right) the measured eye diagrams at I and Q channels at total bit rate of 50 Gbps (25 Gbps each for I and Q channel)

We are also investigating compact and low cost packaging technologies for a practical system. In general, devices operating at terahertz frequencies are packaged in bulky metallic modules which have rectangular waveguides flanges for terahertz signal in/outputs. It would be no problem for a long distance point-to-point wireless link system or astronomy antenna system. However, those packages are obviously too large and heavy for personal handheld mobile devices. For such practical terahertz communications systems, we are trying to develop compact ceramic packages based on the low-temperature co-fibered ceramic (LTCC) technologies and have recently reported a 300-GHz LTCC horn antenna implemented by stacking multiple cavity structures which is surrounded by via fences. The prototype of the LTCC horn antenna exhibited peak value of 16-dBi gain and 58-GHz bandwidth with return loss better than 10 dB [10]. In addition, very low loss broadband transition between rectangular waveguide and microstrip line in the LTCC package has been demonstrated [11].





(a) (b)

Figure 3. (a) Fabricated LTCC horn antenna and (b) measured antenna gain in H-plane along with the simulated result

3. Acknowledgments

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