# Prototype System Evaluation and Field Trial of 40 GHz-band Directional Division Duplex (DDD) Radio System

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***Abstract*** **–For the purpose of the realization of radio communication with high speed and high frequency utilization efficiency, we propose a 40 GHz-band full duplex radio system (called the Directional Division Duplex (DDD) system). The system realizes transmission and reception at the same time by using the same radio frequency and same polarization. We have developed the DDD radio system and performed field trial with the prototype equipments. This paper describes the overview of the prototype system and explains the characteristics of DDD system and the result of field trial.**

***Index Terms*** **— Full duplex, Radio communication, Millimeter wave, Broadband communication.**

## 1. Introduction

In 5G mobile networks, it is aimed to achieve more than multi-Gbps transmission speed. In order to realize it, it has been studied to deploy base stations with mixed macro cell and small cell. It is indispensable to develop more compact and more high-speed Fixed Wireless Access (FWA) system to connect flexibly between mobile base station and core network as a backhaul system.

Therefore, we have developed 40 GHz-band Directional Division Duplex (DDD) radio system that achieves twice frequency utilization efficiency as that of the traditional duplex system of TDD or FDD. DDD is a duplex system that transmits and receives at the same time by using the same radio frequency and same polarization. Conventionally, it has been studied high-order modulation to develop high-speed FWA system. However, the higher the modulation order $2^m$ (m means information bit number included in 1 modulation symbol), brings less performance against the rain fade. On the other hands, the DDD system has the feature to able to achieve equal transmission speed in the modulation order of $2^m/2$, compared with TDD or FDD, and that can be realized high-speeding without shortening the communication distance.

This paper introduces overview of our 40 GHz-band DDD radio system and explains performances of Bit Error Rate (BER) and of effective throughput. Then, this paper reports the results of field trial.

## 2. Prototype System Overview

DDD radio system suffers from the self-interference from transmitted signal to its own reception circuit, because the system utilizes the same radio frequency channel and same polarization for transmission and reception at the same time. The self-interference is added to the desired signal and is received at antenna. In order to suppress the self-interference, we have applied the dual waveguide slot array antenna with high spatial isolation in excess of 80 dB and the interference canceller realized by adaptive digital filter [1].

We have prototyped the DDD radio system and have achieved the performance that effective throughput is of 2 Gbps max. as a total rate of uplink and down-link by using radio frequency of 40 GHz-band, radio clock frequency of 200 MHz and modulation scheme of 64QAM. Table I lists the system specifications of this prototype system, and Fig. 1 is photogragh of the prototype radio equipment.

TABLE I. System specifications.

| | |
|---|---|
| Radio frequency | 40 GHz band |
| Communication scheme | Point-to-Point,<br>Single-carrier / DDD |
| Modulation scheme | QPSK, 16QAM, and 64QAM |
| Tx power | +23 dBm max. |
| Communication distance | 10 m to 1000 m |
| Radio clock frequency | 200 MHz |
| Effective throughput | 2 Gbps max. at full duplex |
| Network interface | 1000 base-T (RJ-45) |

Fig. 1. Prototype radio equipment.

## 3. System Performance

We have evaluated the performance of the prototype system using coaxial cables in the laboratory environment prior to the outdoor field trial. The propagation path for the evaluation was modeled in the self-interference signals of one short-delayed and two long-delayed self-interference signals [2].

Fig. 2 shows the BER performance of the DDD system. The horizontal axis indicates the desired signal power input to the reception circuit, the vertical axis indicates the BER before channel decoding. Degradation from the theoretical value at BER = $10^{-6}$ is within 2 dB. We have judged that this degradation has little influence for the field trial.

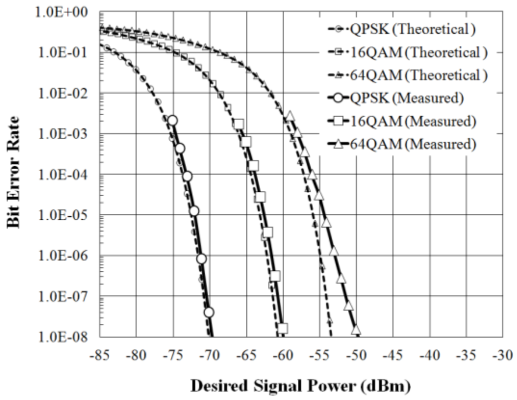


Fig. 2. BER performance.

Fig. 3 shows the throughput characteristics of the prototype system with the adaptive modulation. The horizontal axis indicates the desired signal power input to the reception circuit, the vertical axis indicates the effective throughput measured at MAC (Media Access Control) interface. The throughput characteristics was measured when the length of the MAC frame is set between 64 and 9600 octets at random. The prototype system provided optimal throughput performance for each modulation scheme, and behaved at optimal modulation scheme according to variation of the desired signal power. From the results, it was obtained that the system has sufficient performance for the field trial.

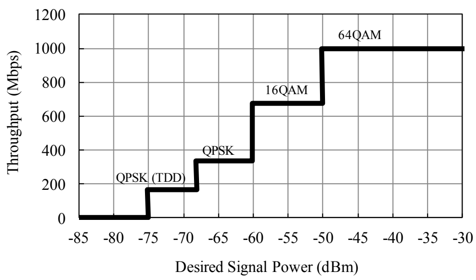


Fig. 3. Effective throughput performance.

## 4. Field Trial

We built a network of three radio links by using the prototype equipments in Tokyo Institute of Technology, and carried out field trial. Fig. 4 illustrates the network of field trial. Fig. 5 shows the canceller's behavior in the case of rainy weather, and indicates the time versus the fluctuations of the interference signal power, the desired signal power and the cancelling performance. In the rainy weather, an interference signal power greatly fluctuates, but the canceller is tracking the grate fluctuations and consequently the appropriate radio link quality is kept. It was demonstrated that the canceller is operating effectively in the field environment to confirm the effectiveness of DDD radio system.

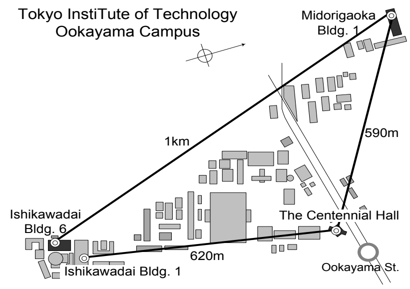


Fig. 4. Radio link network of the field trial.

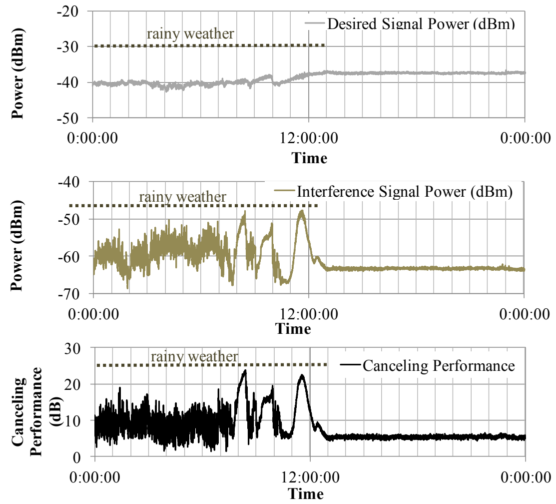


Fig. 5. Time v.s. Signal Power / Cancelling Performance.

## 5. Conclusion

We have proposed a 40 GHz-band DDD system for attaining twice frequency utilization efficiency of the TDD or FDD. The DDD system has a problem of the degradation of performance due to the self-interference, however this problem is solved by using dual antenna and an interference canceller for suppressing self-interference contained in the received signal. In this paper, we have stated that the prototype system overview and the performance, and the result of field trial. We are collecting data of various situations continuously to analyze these to confirm the effectiveness of this system.

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## References


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