Preface

From the birth of mobile communication systems to the present, mobile traffic has rapidly increased. The 5th generation mobile communication (5G) system was launched in 2020 to accommodate it. However, with the evolution and emergence of various applications, the amount of communication capacity consumed by individuals will continue to increase. In addition, Internet of Things (IoT) systems are beginning to play a central role in various fields, such as agriculture, medicine, and disaster prevention. Thus, mobile communication systems are the fundamental platform supporting social infrastructure, and the increase in mobile traffic will explode in the future. Simply using higher and vacant frequencies, such as millimeter and terahertz waves, will eventually exhaust the available frequency bands and have various technical challenges in implementation. Therefore, developing a technology to improve spectral efficiency toward the 5G-Advanecd evolution and the 6th generation mobile communication (6G) system is essential.

This thesis aimed to realize the in-band full-duplex (IBFD) in the 5G system, assuming that the 6G will evolve based on the 5G. The IBFD is one of the candidate technologies to increase spectral efficiency toward the 6G. The IBFD is a duplex scheme in which transmission and reception are performed simultaneously using the same frequency resources. In theory, it can double the spectral efficiency of a conventional half-duplex (HD) system. The IBFD is expected to be introduced into the cellular system called a full-duplex cellular (FDC). Still, various interferences, such as self-interference (SI) at a base station (BS) and inter-user interference (IUI) at a user equipment (UE), have a crucial impact on the demodulation quality and user scheduling operation. To realize the FDC in the 5G system (5G-FDC), the suppression or cancellation scheme of these interferences using the 5G signal format must be developed. However, studies have yet to establish them in the 5G system.

To achieve this goal, this thesis first proposes a 5G-based digital SI cancellation (D-SIC). This scheme considers a 5G signal configuration and a low-density parity-check code adopted in 5G to apply the IBFD to the current 5G system directly. Furthermore, to prove the feasibility of the 5G-FDC, a 5G-FDC physical layer prototype is developed using the software-defined radio (SDR). This prototype implements the proposed 5G-based D-SIC. Because the 5G-FDC prototype consists of the BS, UE for transmitting the uplink (UL) signal (UL-UE), and UE for receiving the downlink (DL) signal (DL-UE), it can demonstrate the 5G-FDC. The computer simulation and experimental results showed that the UL transmission affected by the SI can succeed in a block error ratio of 10% even in the IBFD operation. Therefore, one of the problems in realizing the 5G-FDC is conquered.

Second, this thesis develops a 5G-based IUI cancellation (IUIC) based on successive interference cancellation (successive IC) techniques. This thesis reveals the effectiveness of the IUIC by computer simulation using a simple model in terms of IBFD-applicable area and IBFD application ratio. After that, this thesis proposes the 5G-based IUIC, considering a 5G signal format to coexist with the 5G-based D-SIC and channel coding to improve performance. Moreover, user scheduling and adaptive modulation algorithms are also proposed to establish one of the operations of the whole 5G-FDC system with the IUIC. The computer simulation results showed that the IUIC can significantly increase the UL throughput with a slight degradation of DL throughput in dynamic full-duplex cellular system.

The above-mentioned proposed schemes directly solve the problems for realizing the IBFD. However, they were evaluated only by computer simulation or laboratory experiments. In addition, the measurements of communication performance and channel state information are necessary to introduce the new technologies into practical systems and validate them because the radio wave propagation characteristic is environment-specific. Thus, this thesis develops a 5G measurement platform using SDR, which can implement any signal processing scheme related to 5G. As an example of using this platform, this thesis proposes signal processing methods that can receive signals at speeds of 500 km/h or higher and be used for the experiment regarding the IBFD in a highly mobile environment. Those methods are evaluated by the experiment.

Finally, to achieve the goal of this thesis, the feasibility and effectiveness of the IBFD in the 5G system are discussed in real fields. Using the developed 5G measurement platform, radio wave propagation data is acquired in the outdoor and indoor factory environments. The experimental evaluation results based on the measured data showed that introducing the IBFD is feasible, and the proposed IUIC effectively improves the UL throughput. These results can contribute to designing the mobile communication system used for the platform in various fields.

The chapters of this thesis are listed as follows. Chapter 1 discusses the background of mobile communication systems and the overview of this thesis. Chapter 2 introduces the physical layer of the 5G system, which is the basis of the following chapters. In Chapter 3, a 5G-based D-SIC is proposed, and a 5G-FDC physical layer prototype is developed. Chapter 4 presents a 5G-based IUIC, including user scheduling and adaptive modulation algorithms. Chapter 5 develops a 5G measurement platform and proposes signal processing for highly mobile environments. In Chapter 6, the feasibility and effectiveness of the IBFD in the real field are confirmed based on the experimental data. Finally, Chapter 7 concludes this thesis.