Full-Duplex Communications for Future Wireless Networks

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Editors

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Preface

This book is the capstone to a biannual series of workshops titled *Full-Duplex Communications for Future Wireless Networks*. Since 2017, the editors were part of the organizing committee of a series of workshops at the flagship conferences in communications engineering, namely *IEEE International Conference on Communications* and *IEEE Global Communications Conference*, with the objective of showcasing the most recent advances in full-duplex technologies. Throughout these years, the workshops have gathered leading-edge contributions evincing Full-Duplex research's maturity, novelty in overcoming key challenges, and a wide range of applications, besides practical demonstrations and field trials.

This book captures the essence of the state-of-the-art research, where we aim to provide a critical overview of the research challenges in full-duplex communications and solutions thereof—that enabled its feasibility—as well as novel applications that demonstrate the flexibility and potential of full-duplex for future wireless systems and networks. Therefore, we have split the book into two parts; notably

Part I: Self-interference Cancellation delves deep into self-interference characterization and cancellation in the complete transceiver chain from antennas and electronics up to digital-domain processing.

Part II: Applications and Future Trends scrutinizes established and trending full-duplex applications from radio resource management to energy harvesting systems and from security to test beds and trials.

Part I is composed of four chapters out of which Chaps. 1 and 2 review radio-frequency transceiver architectures for in-band full-duplex encompassing antenna design and radio-frequency cancellation of the self-interference produced by its own transmitter. Distinct isolation mechanisms and the use of multiple antennas for transmission and reception are discussed. Moreover, the authors overview single-antenna duplexing architectures, which are preferred due to their small form factors despite hardware additions that are needed for signal cancellation. Therefore, the authors then discuss passive—in which radio-frequency components mitigate the self-interference—and active cancellation techniques with respect to performance and complexity since channel estimation of residual self-interference is required

and performed by adding transmit chains. Despite the advances in antenna design and analog domain, where self-interference is attenuated, it still prevails, which brings us to Chap. 3, where the authors delve into digital-domain solutions for efficient self-interference cancellation in low-cost full-duplex radios that are able to mitigate impairments caused by nonlinear distortion. The combined achievements in the antenna design and analog and digital domains suppress the self-interference, in some cases, by more than 100 dB, which is close to—and in some cases even below—the noise floor of some architectures. Further, Chap. 4 discusses the use of time-domain rather than frequency-domain digital filtering, thus allowing to relax constraints on waveforms and synchronization between transmitted and received signals, which once combined with spatial filters are able to suppress nonlinearities caused by circuitry impairments. Altogether, due to all the recent advancements in antenna design, analog and digital domain brought residual self-interference to tolerable levels, thus enabling several applications, which are the focus on *Part II: Future Trends and Applications*.

Part II encompasses seven chapters that describe the prospects, challenges, and solutions that are enabled by full-duplex technology, which has the potential of doubling the spectral efficiency of point-to-point transmissions. Nonetheless, since more nodes are potentially active due to simultaneous uplink and downlink transmissions, a full-duplex network perceives higher interference profile than its half-duplex counterparts, thus bringing challenges to radio resource management. In this context, Chap. 5 overviews the challenges of full-duplex operation under cellular networks and the solutions that unlock its potential. Then, Chap. 6 discusses novel solutions for enhanced mobile broadband and ultra-reliable low latency communication service classes introduced by the fifth generation of cellular networks. The authors discuss also the impact of network traffic asymmetry, which can hamper gains in throughput. The inherent characteristics of simultaneous transmission and reception renders full-duplex operation a suitable solution for latency-constrained applications. Likewise, in the recent years, non-orthogonal multiple access solutions have emerged as an alternative to increase spectral efficiency by allowing multiplexing signals on power or code domain. The envisaged spectral efficiency gains are magnified when non-orthogonal solutions are combined with full-duplex operation, especially through the use of techniques such as optimal relay and beamforming antenna selection in multiple antenna, relaying and cognitive systems as surveyed in Chap. 7. One more technology that has emerged in the recent years, whose potential gains are amplified in full-duplex setting, is wireless energy transfer in communication networks. Chapter 8 overviews energy harvesting conversion process and its relation to key full-duplex transceiver architectures and discusses the idea of self-energy recycling transceivers hinting the idea of a sustainable wireless network. The authors evaluate key scenarios that showcase the potential gains and performance of full-duplex wireless-powered systems. Next, we move from non-orthogonal and wireless-powered full-duplex systems to defense and security. In fact, full-duplex systems first historically emerged in continuous-wave radars already around mid-twentieth century. Conversely to cellular systems that focus predominantly on spectral efficiency enhancements, in the context of defense and

security the full-duplex transceiver returns to its original function as a sensor as well as a key component in electronic warfare systems. Therefore, the authors in Chap. 9 overview the integration of tactical communications with full-duplex electronic warfare and explore concepts of securing critical applications in the form of a radio shield. Moving further, from a practical applied perspective to more theoretical security, in Chap. 10, the authors discuss the use of artificial noise jamming to secure uplink transmissions in cellular networks by proposing a multi-objective optimization framework securing transmissions while minimizing power consumption against potential eavesdroppers. Finally, we conclude this journey through the realm of full-duplex transceivers and applications with Chap. 11 that reviews recent research on integrated full-duplex radio systems, discusses design aspects related to the semiconductor technology, and revisits key ideas discussed throughout Parts I and II of this book. Therefore, Chap. 11 presents the reader a walk-through relevant concepts and a wide picture of integrated full-duplex radio through an experimental setup.

All in all, we hope that the readers enjoy the contributions and the compilation proposed by this book. We would like to point out that we have not attempted to provide a comprehensive survey on all full-duplex concepts and ideas, but rather a discerning compilation of carefully selected contributions that evince challenges, solutions, and the potential of full-duplex technologies in a wide range of applications. In addition, we would like to thank audience, authors, technical committee members, and reviewers that have been participating in the workshop series, and especially to the authors and the reviewers that have contributed to this book. Finally, we sincerely hope that this book will inspire students, practitioners, and researchers to contribute, perhaps even more, to future developments of full-duplex communications.

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