Self-Interference Mitigation in Full-Duplex Beamformed Antenna Arrays

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Summary

In-band full-duplex (IBFD) is a type of network architecture that allows for simultaneous transmission and reception of signals at the same frequency band and offers the potential to increase the spectrum efficiency and data rate of wireless communication systems as well as improved sensitivity in e.g., radar and Electronic Warfare (EW) applications [1]. However, implementing IBFD systems presents a significant challenge due to self-interference (SI) - the transmission of the signal from the transmitter (TX) leaking into the receiver (RX), which needs to be properly mitigated in order to receive the desired signal with maximum spurious free dynamic range (SFDR). SI can be mitigated consecutively over three domains, namely, the analog domain (AD), and the digital domain (DD), the propagation domain (PD). The survey in [2] offers a comprehensive collection to date of these techniques and discusses how all of them can be implemented within the different domains of a typical transceiver. Figure 1 demonstrates the anatomy of a full-duplex system with three stages of SI cancellation. The AD approaches intend to generate a copy of the transmit signal in order to cancel the SI at the receiver input. The DD cancellation exploits the known transmitted data symbols and the estimated SI channel to cancel the residual SI in the digital baseband. The PD methods aim to isolate the transmitter and receiver to reduce the SI arriving at the receiver. PD techniques can be categorized into passive and active self-interference cancellation (SIC). Passive SIC techniques are used to electromagnetically isolate the transmitter and receiver. Active SIC techniques are usually applied in the digital and analog domains to exploit the knowledge of its own transmitted signal to cancel the self-interference, i.e., to generate a cancellation signal in the receive signal path to null the self-interference [2].

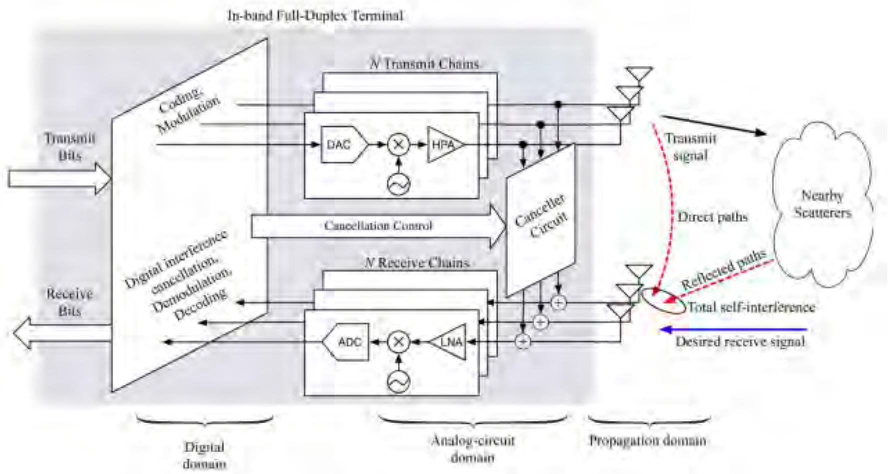

Figure 1. Block diagram of a typical full-duplex system with three stages of self-interference cancellation [1].

In MIMO systems, beamforming-based approaches can be used to mitigate the SI at the RX [3]. With enough isolation between separate and closely positioned TX and RX antenna arrays, a full-duplex (FD) transceiver could simultaneously transmit and receive in-band. This is the background of our methodology; we propose a joint TX and RX beamforming method that: (i) seeks to prevent non-linear gain compression of the low-noise amplifiers at the RX side; (ii) retains a sufficient degree of freedom for TX and RX beamforming without requiring larger array sizes or complex hardware self-interference cancellation. This approach involves finding the TX subspace of excitation vectors that keeps a total coupled TX-to-RX power that is below a certain threshold. Then, these vectors can be used to perform TX beamforming while maximizing the realized array antenna gain. Once the coupling matrix and the TX and RX propagation channels have been estimated, the optimal excitation and beamformer weight vectors can be determined in a systematic, iterative-free manner with minimal impact on system latency.
The proposed approach for TX beamforming requires a priori information of the S-parameters between the TX and RX. The

approach follows a systematic process to first identify a subspace of excitation vectors for TX beamforming that will keep the power coupled to the RX below a certain threshold to avoid the non-linear region of the low-noise amplifiers. Then, regular TX beamforming can be performed using these vectors and the channel matrix for the propagation channel. The self-interference vector at the RX side is then known, and the optimal RX beamformer can be determined (e.g., to maximize the signal-to-(noise-to)-interference ratio). The TX beamforming already ensures that self-interference is below a certain threshold, and the RX beamforming further minimizes this self-interference at the RX output. Finally, the optimal TX and RX beamformers are typically selected as those that perform best over a certain frequency range in order to minimize their sensitivity to parameter errors.

References

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