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Analysis of In-band Full-Duplex OFDM Signals Affected by Phase Noise and I/Q Imbalance

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The idea of the simultaneous transmission and reception of data using the same frequency is a potential candidate to be deployed in the next generation wireless communications standard 5G. The In-Band Full-Duplex (IBFD) concept permits to theoretically double the spectral efficiency as well as to reduce the medium access control (MAC) signaling which will improve the overall throughput of a wireless network. However, IBFD radios suffer from loopback self-interference (LSI) that is a major drawback that hinders the full exploitation of the potential benefits that this system is capable of offering. Recently, there has been an increased interest in modeling and analyzing the effect of LSI on the performance of an IBFD communication system, as well as in developing novel LSI mitigation techniques at the radio-frequency (RF) front-end and/or at the baseband stage.

LSI mitigation is approached by three different ways: The first approach is a propagation domain approach, where the transmitter and receiver antennas of the full-duplex node are designed in a manner that results in minimizing the interference between them. Although this method seems promising, the risk of nulling the received signal of interest is always present. Motivated by this risk, researchers have resorted to the use of analog circuitry to regenerate the LSI effect by adjusting the gain, phase and delay of the known transmitted data to mimic the effect of the channel of the received LSI signal on the transmitted data, and finally subtracting the estimated signal from the received signal. However, this turns out to be a formidable task since the surrounding environment of the full-duplex node is always varying and the LSI channel variations are difficult to track using analog circuit components. Both of the discussed approaches are classified as passive LSI mitigation approaches, given that they lack the ability to adapt to the constantly varying LSI channel. To overcome this drawback, a third technique of LSI cancellation is implemented, where the complex implementation of an adaptive LSI mitigation technique is moved to the digital domain, and the receiver actively updates the estimation of the LSI channel depending on the performance of the communication system to finally combine it with the known transmit data and subtract it from the received signal. Given that the

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LSI mitigation process can be easily performed in the digital domain using digital signal processing (DSP) algorithms, one might ask: why isn't the whole LSI mitigation process performed in the digital domain? The answer is that the signal entering the analog-to-digital converter (ADC) is limited by the ADC's dynamic range. Consequently, a combination of the three aforementioned LSI mitigation techniques must be deployed towards the implementation of an efficient and reliable IBFD communication node.

Orthogonal frequency division multiplexing (OFDM) is the preferred modulation scheme that is adopted by many wireless communication standards. Its implementation using direct conversion receiver architecture, which is favored over its super-heterodyne counterpart, suffer from inter-carrier interference (ICI) introduced by RF impairments such as oscillator phase noise (PHN) and in-phase/quadrature-phase imbalance (IQI). PHN's effect is manifested in the spread of the energy of an OFDM subcarrier over its neighboring subcarriers, and IQI introduces ICI between image subcarriers. In this work, we analyze the joint effect of PHN and IQI on the process of LSI mitigation in an IBFD communication scenario. The analyses is performed to yield the average per-subcarrier residual LSI signal power after the final stage of the digital LSI cancellation. The analysis shows that, even with the perfect knowledge of the LSI channel-state information, the residual LSI power is still considerably high, and more sophisticated LSI mitigation algorithms must be designed to achieve a better performing IBFD communication scheme.

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