Demo: Achieving Self-Interference Cancellation Across Different Environments

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Abstract

In order to enable the simultaneous transmission and reception of wireless signals on the same frequency, a full-duplex (FD) radio must be capable of suppressing the powerful self-interference (SI) signal emitted from the transmitter and picked up by the receiver. Critically, a major bottleneck in wideband FD deployments is the need for adaptive SI cancellation (SIC) that would allow the FD wireless system to achieve strong cancellation across different settings with distinct electromagnetic environments. In this work, we evaluate the performance of an adaptive wideband FD radio in three different locations and demonstrate that it achieves strong SIC in every location across different bandwidths.

CCS Concepts

• **Hardware** → **Wireless devices**; *Radio frequency and wireless circuits*; • **Networks** → **Wireless access networks**.

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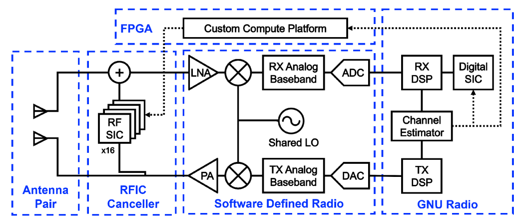
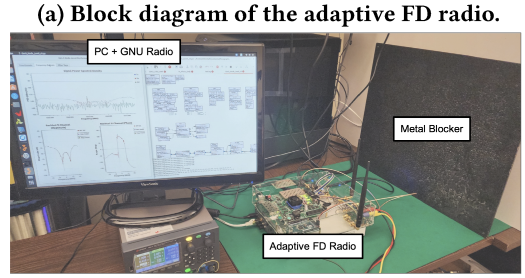
1 Introduction

Full-duplex (FD) wireless — the simultaneous transmission and reception of radio signals on the same frequency — has seen significant attention over the past decade [2, 7, 8, 15], as its adoption would result in enhanced spectrum efficiency, improved data rates, and reduced communication latency compared to existing half-duplex (HD) networks. A main challenge in realizing wideband FD wireless in practical settings is the presence of strong self-interference (SI) at the receiver, preventing the reception of desired signals.



(a) Block diagram of the adaptive FD radio.



(b) The adaptive FD radio near a metal reflector.

Figure 1: The adaptive wideband FD radio.

The SI is typically 70 dB to 110 dB more powerful than the desired signal, requiring very high levels of SI cancellation (SIC) through various means, including passive isolation, active analog cancellation, and digital signal processing algorithms. The SI is especially sensitive to different (potentially time-varying) surrounding electromagnetic environments, requiring intelligent cancellation methods. In particular, an intelligent, adaptive analog RF cancellation stage is required to prevent desensitization in the receiver, which would result in a complete inability to receive any incoming signals.

Although many advances have been made in designing configurable Radio-Frequency ICs (RFICs) [1, 4, 5, 10, 16] that allow for adaptive analog cancellation, an understudied aspect in related works is the performance evaluation of such hardware in a diverse set of locations with distinct electromagnetic environmental effects, including external

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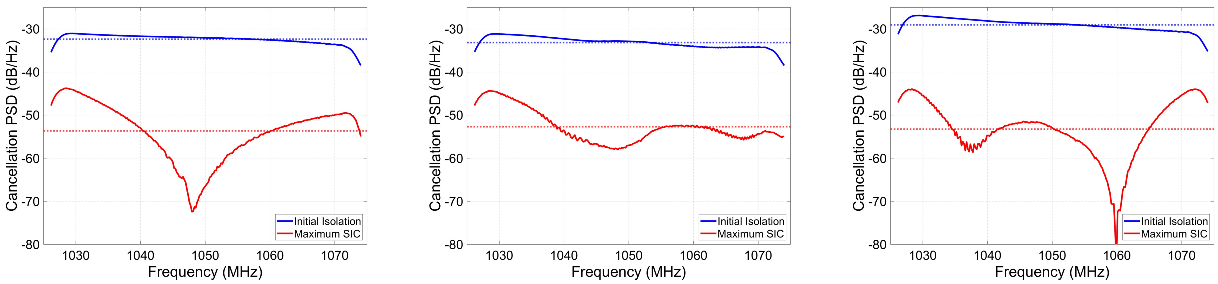

(a) Anechoic Chamber **(b) Lab Bench** **(c) Metal Reflectors**

Figure 2: Initial and maximum SIC obtained by the optimal RFIC configuration at each location.

interference, SI multipath propagation, and others. In this work, we present the SIC performance of the RFIC canceller from [10] as part of a wideband FD radio system [9] in three different locations and across three different bandwidths.

2 Adaptive Wideband FD Radios

In our prior work [9], we presented a wideband FD radio system with a programmable RFIC canceller [10] that achieved high SIC in a particular environment. The canceller utilized switch-capacitor delay lines to implement sixteen RF taps, each with independently configurable gain and delay, resulting in a large configuration space with over 10^{19} possible parameter combinations. This complexity provides the canceller with high flexibility and range, allowing it to (potentially) achieve and maintain strong SIC in different settings with highly varying electromagnetic environments.

The block diagram of the adaptive wideband FD radio used in this demonstration is shown in Figure 1(a). Each FD radio is composed of a dual-antenna interface, an RFIC canceller, an FPGA [17], and a USRP software-defined radio (SDR) [14] controlled from a PC running GNU Radio [13], as shown in Figure 1(b). The custom C++ GNU Radio flowgraph performs all the necessary signal processing and control functions necessary for the FD radio to function.

The FD radio operates at a center frequency of 1050 MHz with a bandwidth of up to 50 MHz. The radio transmits data-carrying packets with an average power of 0 dBm, with each packet consisting of a Wi-Fi-like payload [3] and Zadoff-Chu pilot symbols for SI channel estimation [6, 11], which are communicated to the FPGA for computing — and setting — the RFIC canceller's optimal configuration based on stored characterizations of the RF taps [9].

3 Experimental Procedure

Three test environments were selected to evaluate the performance of the RFIC canceller within the full FD radio system:

(1) an RF anechoic chamber;
(2) a standard laboratory benchtop; and
(3) the same benchtop with two nearby metal sheets.

In each location, the experiment is repeated four times with three bandwidths (10 MHz, 25 MHz, and 50 MHz). The FD radio runs its optimization, in which the RFIC canceller's configuration begins with all RF taps disabled and is iteratively updated as the FPGA attempts to maximize SIC.

Bandwidth	**Environment** *Anechoic Chamber*	*Lab Bench*	*Metal Reflectors*
10 MHz	29.3 dB	30.6 dB	31.2 dB
25 MHz	22.9 dB	23.3 dB	22.3 dB
50 MHz	19.7 dB	18.8 dB	18.3 dB

Table 1: Optimal average RFIC canceller performance.

The average increase in SIC between the initial isolation state and the optimal configuration state for each set of experiments is presented in Table 1. Three sample experiments are presented in Figure 2, showing the SI residues before and after the optimization at each of the three locations when transmitting with a 50 MHz bandwidth.

3.1 Demo: Time-Varying Environment

In this demonstration [12], we showcase the capability of the FD radio to achieve and sustain high RF SIC in a dynamic location. Participants will be able to observe the transmitted and received signals in the time and frequency domains, visualizing the evolution of the SIC over time. As participants move and manipulate items around the radio, the electromagnetic environment changes, simulating a change in location. As a result, the FD radio will restart its optimization process, iteratively improving the RFIC canceller's configuration in order to maintain or restore the formerly high RF SIC. We expect to obtain results similar to the ones in Figure 2, wherein there is a significant decrease in received power between the initial state and the final, optimal state.

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