Wideband Self-Adaptive RF Cancellation Circuit for Full-Duplex Radio: Operating Principle and Measurements

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Outline

• Introduction
• Full-duplex device architecture
• Operating principle of the RF canceler
  – device architecture
• Performance evaluation
• Conclusions
Introduction

• Full duplex radio:
• Capable of transmitting and receiving at the same time at the same frequency
  – Fundamental change in wireless communications with many appealing benefits
• The drawback is self-interference i.e. the own transmit signal leaking to the receiver and masking all the desired RX signals
Introduction (cont’d)

• TX and RX needs to be separated
  – Can be achieved by using separate TX and RX antennas, circulator or electrical balance network

• The separation provided by aforementioned methods are not enough

• Full duplex radio requires additional RF and digital self-interference cancellation
Full-duplex device architecture

Transmitter chain
- PA
- VGA
- IQ Mixer
- LPF
- DAC

Receiver chain
- BPF
- LNA
- IQ Mixer
- LPF
- VGA
- ADC

Wideband RF cancellation circuit
- Vector Modulator
- CONTROL

Digital cancellation
- To detector

RF-cancellation circuit
RF-cancellation circuit

Operating principle

• Part of the TX-signal is coupled to the cancellation network
  – Signal is divided and delayed
  – Individual adjustment of phase and amplitude for each branch or tap
• Replicas are combined and then subtracted from the RX-signal
• The delay of the self-interference needs to be between the delays of the branches
RF-cancellation circuit
Operating principle (cont’d)

• Self-interference channel is seldom static
  – The amplitude and phase adjustments need to be self-adaptive

• Analog domain processing is limited
  – An LMS-type algorithm can be implemented

\[ w_n \leftarrow w_n + \mu \int x_{IQ}^{\ast}(t - \tau_n) z_{IQ}^{\ast}(t) \, dt \]

• Canceler is able to cancel TX noise as well

Block diagram of the canceler

[Diagram showing the block diagram of the canceler with various components and flow of signals.]
Implementation

[Image of a circuit board with dimensions 10 cm x 12 cm]

Photo credits: Janis Werner / TUT
Performance evaluation

• Measurement setup for 100Mhz case

- NI PXIe-5645r
- Step-up amplifier
- IQ control voltage monitoring
- RX antenna
- TX antenna
- PA

\[ \approx 15 \text{ cm} \]
Circulator setup results

- Used circulator: MESL SG 10522
Antenna setup results

- 20 MHz case measurements were conducted using revision I canceler board and the antenna separation was longer.
Adaptivity

PSD after circulator and antenna ($\approx -6$ dBm)

PSD after canceler

Power
Conclusions

• RF cancellation is crucial for full-duplex radios
• The proposed architecture can cancel order of 30 dB actively self-interference in self-adaptive mode (20 MHz signals)
  – Total analog domain cancellation is then 50 to 60 dB
• There are still room for improvements and optimizations