Low Complexity Self Interference Cancellation for Multi Channel Full Duplex Systems

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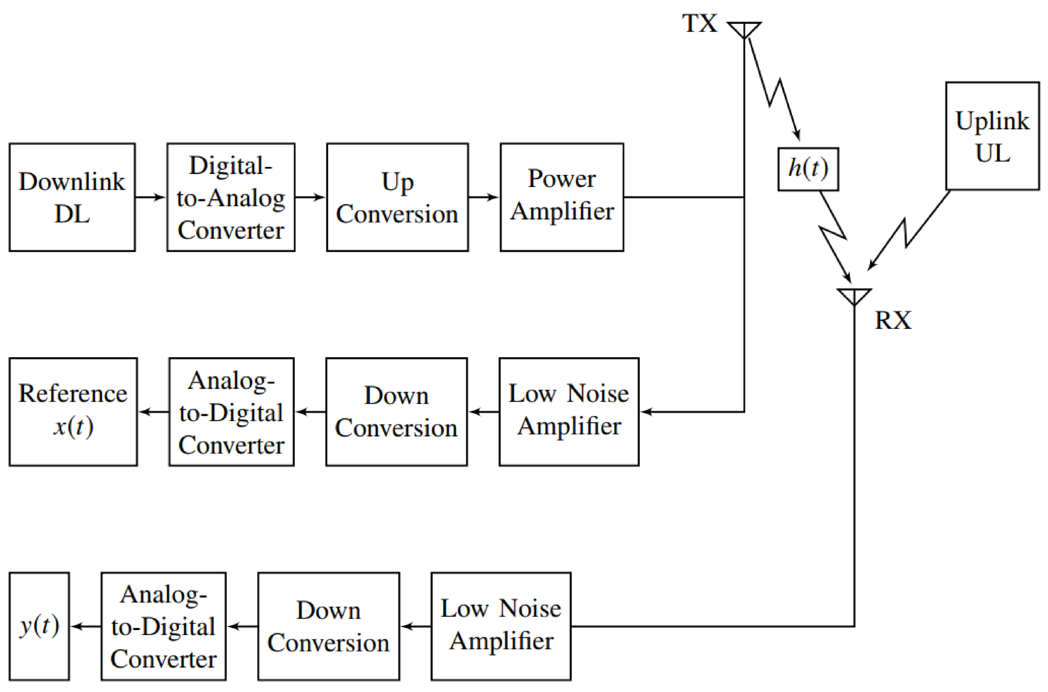
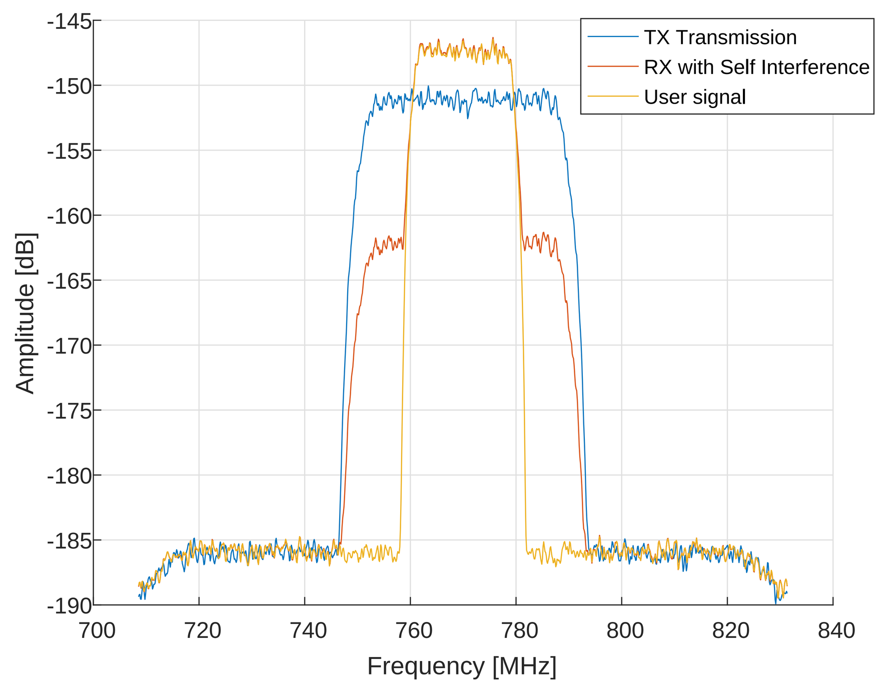
1. Transmitter Self Interference in Multi Channel Full Duplex

- Self interference in a communications system occurs when there is electromagnetic coupling between the transmission (TX) and reception (RX) radio frequency (RF) chains or antennas.
- This coupling degrades the system's RX sensitivity to incoming signals.
- In multi channel full duplex communication, multiple carriers at overlapping arbitrary bandwidths and powers are simultaneously received (uplink - UL) and transmitted (downlink - DL) by the system.
- In multi channel full duplex, current algorithms for self-interference mitigation based on Recursive Least Squares (RLS) and Least Mean Squares (LMS), fail to provide sufficient interference rejection since the incoming signal is not spectrally white, which is critical for their performance.





2. System Model

The DL is denoted as $x[n]$ and the received signal at the ADC's output,

$$\underline{y} = X\underline{h} + \underline{s}$$

- $\underline{s}$ is the UL signal.
- $\underline{h}$ is the self-interference filter of length M
- X is an NXM tall Toeplitz matrix ($N \gg M$) with $X_{ij} = x[i+j]$ for $0 \leq i < N$ and $0 \leq j < M$.

3. Our UL Model

In multi channel communications, the UL is clearly not white, but can be viewed as a WSS process, we propose to approximate it by an AR process

$$s[n] = \sum_{k=1}^{p} g_k s[n-k] + u[n]$$

- $\underline{g}$ is an unknown vector of size p,
- $u[n]$ is a complex circularly symmetric white Gaussian process with $u[n] \sim \mathcal{CN}(0, \sigma_u^2)$

4. Challenge: ML with Unknown Covariance

Our approach: We propose the following estimator for the UL signal,

$$\hat{\underline{s}} = \underline{y} - X\hat{\underline{h}}$$

where $\hat{\underline{h}}$ is an estimator of the self interference filter, which would ideally be the ML estimation.

Challenge: The UL's covariance, Σ_g is unknown a-priori and thus ML is not feasible.

Our Solution: We propose to use GLRT,

$$\hat{\underline{h}}, \hat{\underline{g}} = \arg\max_{\underline{h},\underline{g}} p(\underline{y}|\underline{h}; \Sigma_{\underline{g}})$$

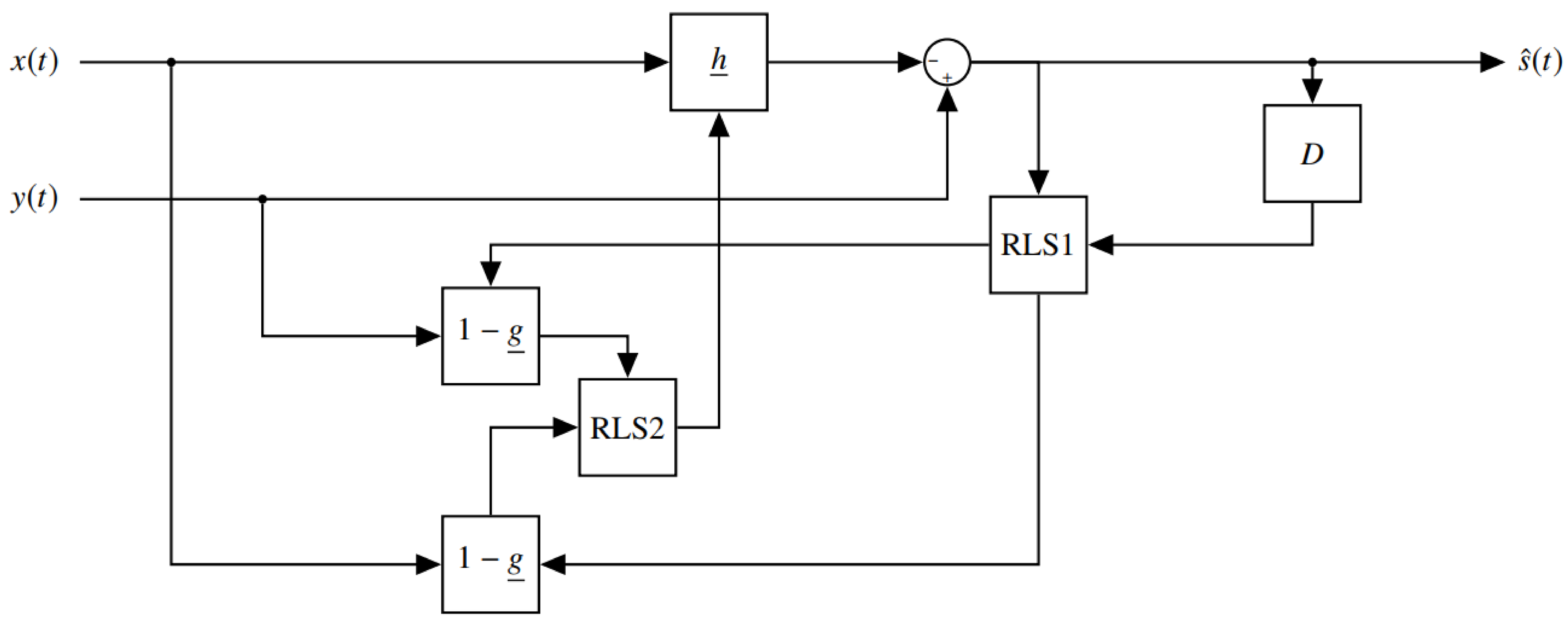
Since the UL is modelled as an AR process, then $\Sigma_{\underline{g}}^{-1} \propto W_{\underline{g}}^{\star} W_{\underline{g}}$ where $W_{\underline{g}}$ is the convolution matrix of the whitening filter. Thus the GLRT becomes,

$$\hat{\underline{h}}, \hat{\underline{g}} = \arg\min_{\underline{h},\underline{g}} (\underline{y} - X\underline{h})^{\star} W_{\underline{g}}^{\star} W_{\underline{g}} (\underline{y} - X\underline{h})$$

Challenge: The optimization is done jointly on the covariance matrix and filter $\underline{h}$ and this problem does not have a simple closed form solution!

5. Our Solution: Joint Whitening RLS (JWRLS-DCD)

- **We propose an approximate solution using a novel alternating minimization algorithm.**
- The algorithm is comprised of two RLS modules working jointly: one RLS estimates the AR parameters (whitening filter) and another the self interference filter using whitened $x[n]$ and $y[n]$ signals.
- RLS modules are implemented using a low complexity (number of multipliers linear with the filter order) approximation of RLS (RLS-DCD).



6. Simulation Results

We have examined the self interference rejection performance of the algorithm in two full duplex scenarios and compared it to RLS,LS and LMS.

- Two narrow band UL signals with equal power and a wide band DL signal.
- Near-far scenario, where there are two UL signals, one with higher power and another with lower power, simulating a close proximity user and a distant user.

JWRLS-DCD produces an output with better rejection of the interference than all the other algorithms, some areas are even 10dB better!