TAMPERE UNIVERSITY OF TECHNOLOGY

Implementation Challenges in Full-duplex Radio Transceivers

Dani Korpi, Mikko Valkama, Taneli Riihonen, and Risto Wichman

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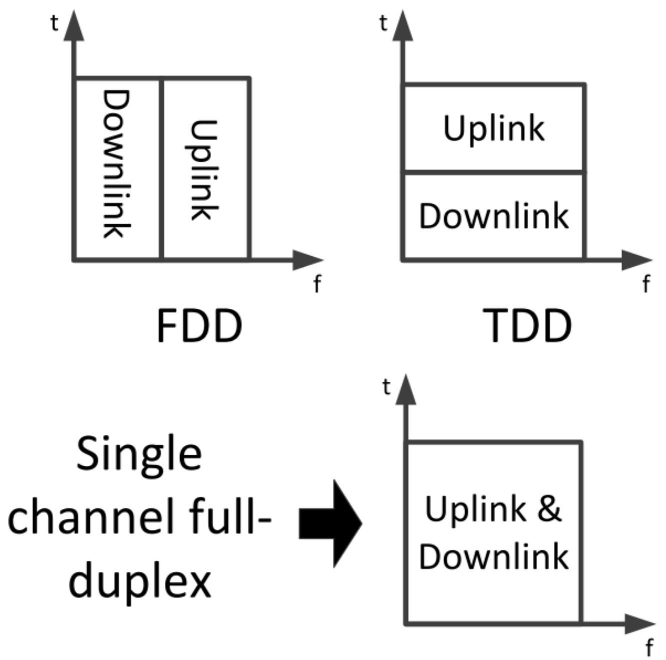
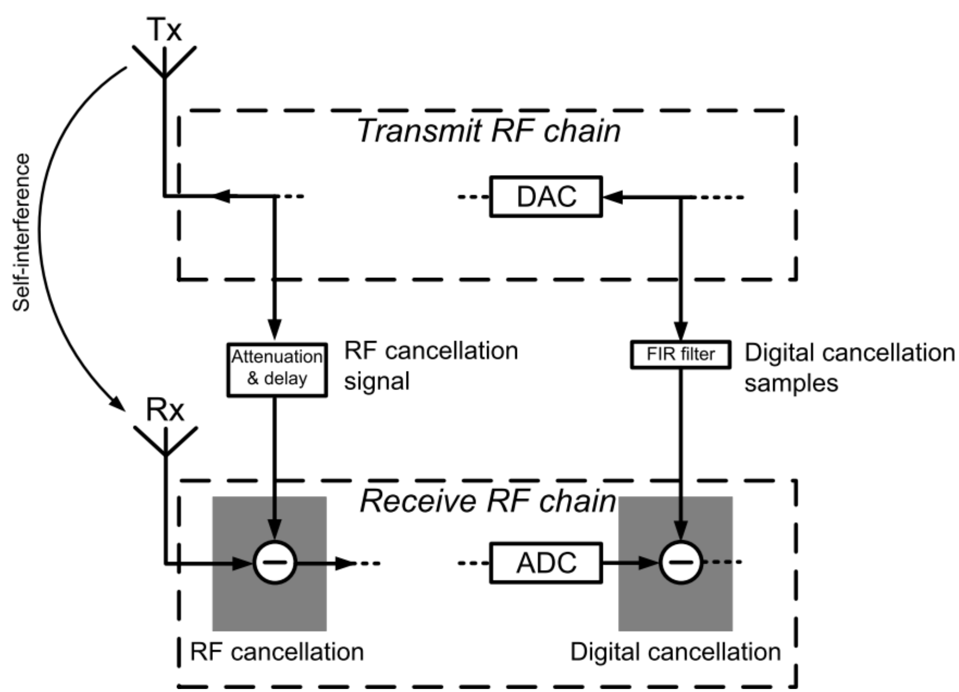
Wireless single channel full-duplex communications

- Transmitting and receiving data simultaneously, using only one channel

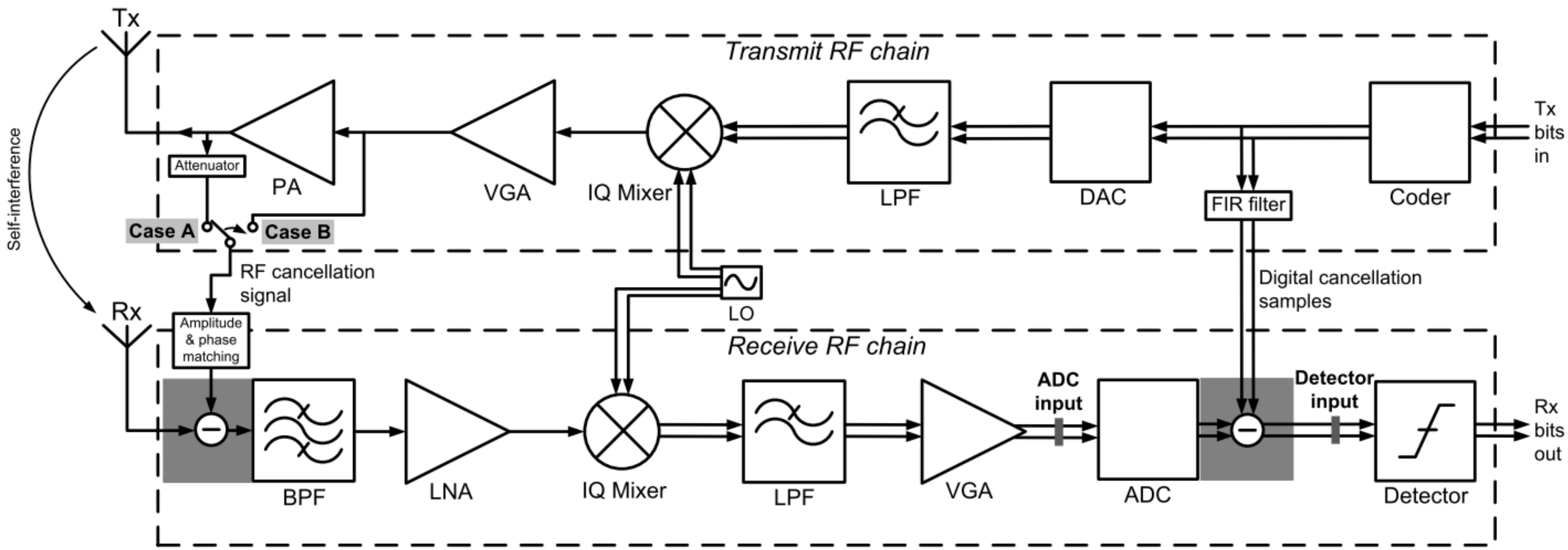




Implementational challenges

- Achieving a sufficient amount of self-interference cancellation
- Nonlinear distortion caused by the strong self-interference signal
- Dynamic range of the analog-to-digital converter

Analyzed transceiver model



Parameters

- Typical parameters for the components were chosen from previous literature

- Two cases for the RF cancellation reference signal path were considered

Parameter	Value
SNR requirement	5 dB
Bandwidth	3 MHz
Sensitivity level	-100.1 dBm
Received signal power	-95.1 dBm
Antenna separation	30 dB
RF cancellation	40 dB
Digital cancellation	35 dB
ADC bits	10

Component	Gain	IIP2	IIP3	NF
PA (Tx)	27 dB	-	15 dBm	5 dBm
LNA (Rx)	25 dB	43 dBm	-15 dBm	4.1 dBm
IQ Mixer (Rx)	6 dB	42 dBm	15 dBm	4 dBm
VGA (Rx)	0-69 dB	43 dBm	10 dBm	4 dBm

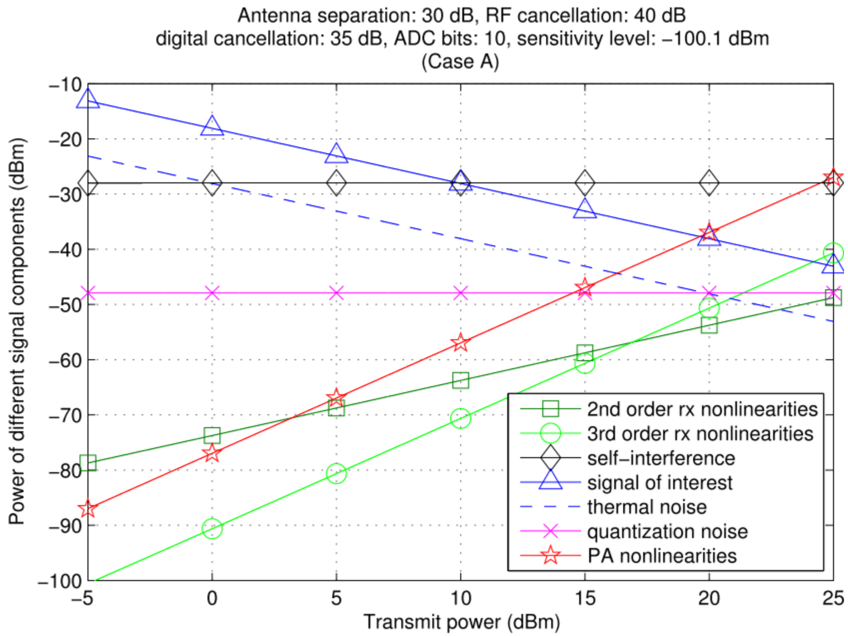
Analytical system calculations

- Based on determining the power levels of the different signal components at certain points in the receiver chain
  - Signal of interest
  - Thermal noise
  - Self-interference
  - Nonlinear distortion
  - Quantization noise
  - etc.

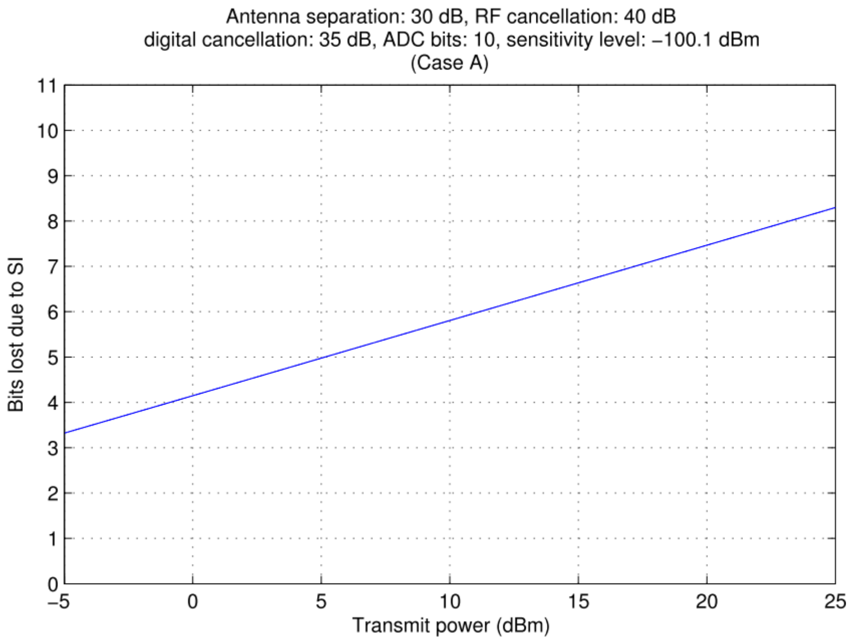
Analytical system calculations

- Nonlinear distortion:
  - Calculations are based on intercept points (IIP2 and IIP3)
    - ”The point at which the power of the *n*th order nonlinearity is as powerful as the fundamental signal”
- Dynamic range of the ADC
  - It is calculated based on the well-known equation for the SNR of an ADC
    - $SNR_{ADC} = 6.02b + 4.76 - PAPR$

Example result (Case A)

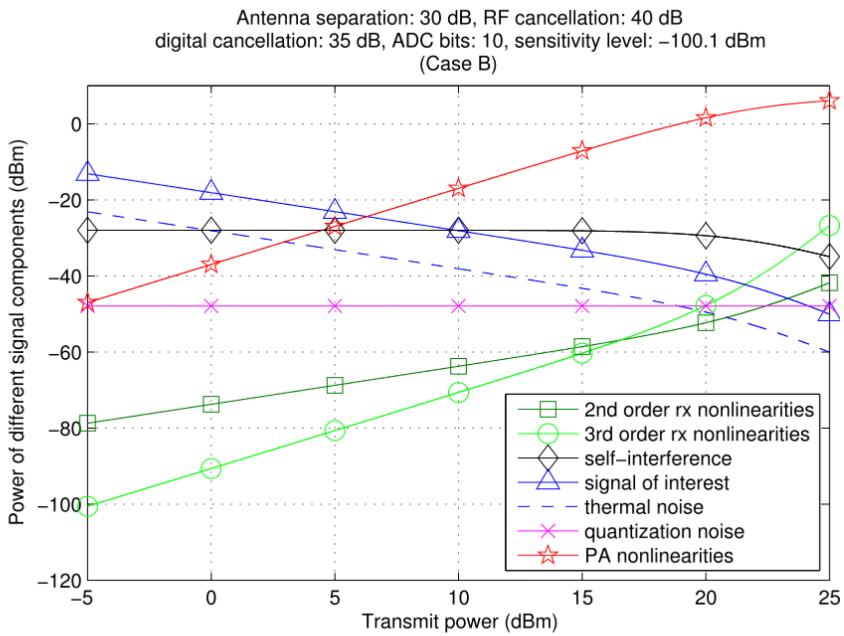


Power levels of the different signal components after digital cancellation

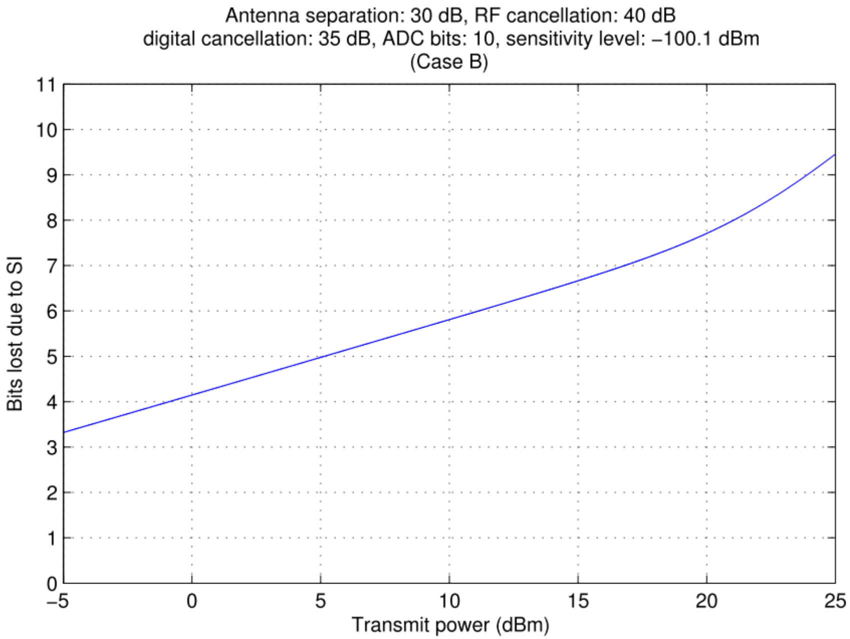


Amount of bits lost at the ADC due to self-interference

Example result (Case B)



Power levels of the different signal components after digital cancellation

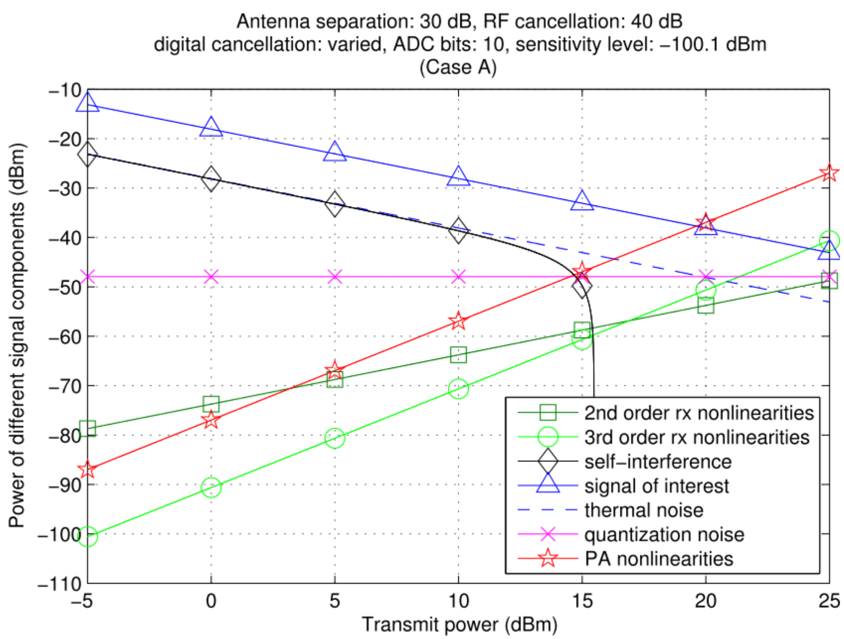


Amount of bits lost at the ADC due to self-interference

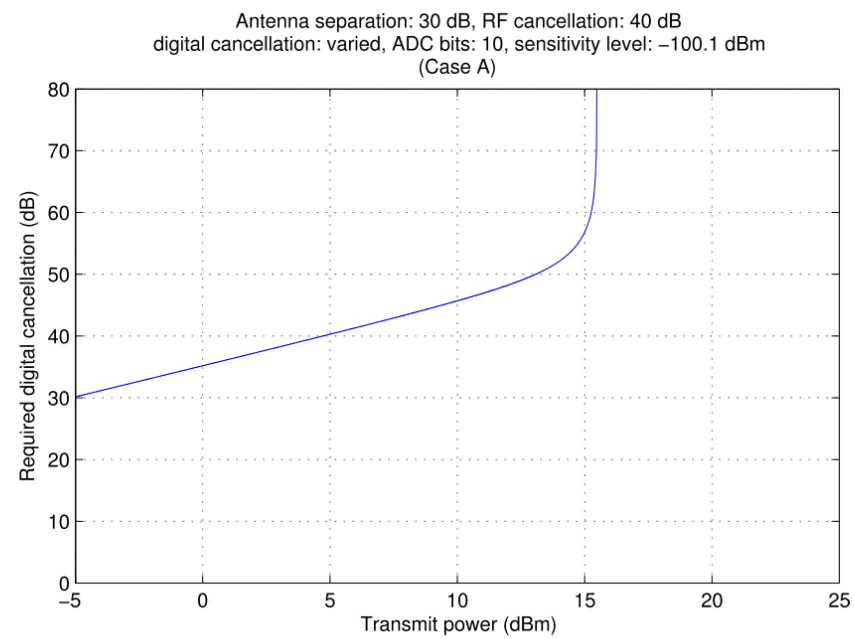
Increasing digital cancellation

- It has been shown that more digital cancellation can be achieved with higher transmit powers
- Thus, it is also analyzed how increasing the amount of digital cancellation to sustain a 3-dB loss of SINR affects the results

Example result, increasing digital cancellation (Case A)



Power levels of the different signal components after digital cancellation. The amount of digital cancellation is increased to sustain a 3-dB loss of SINR.

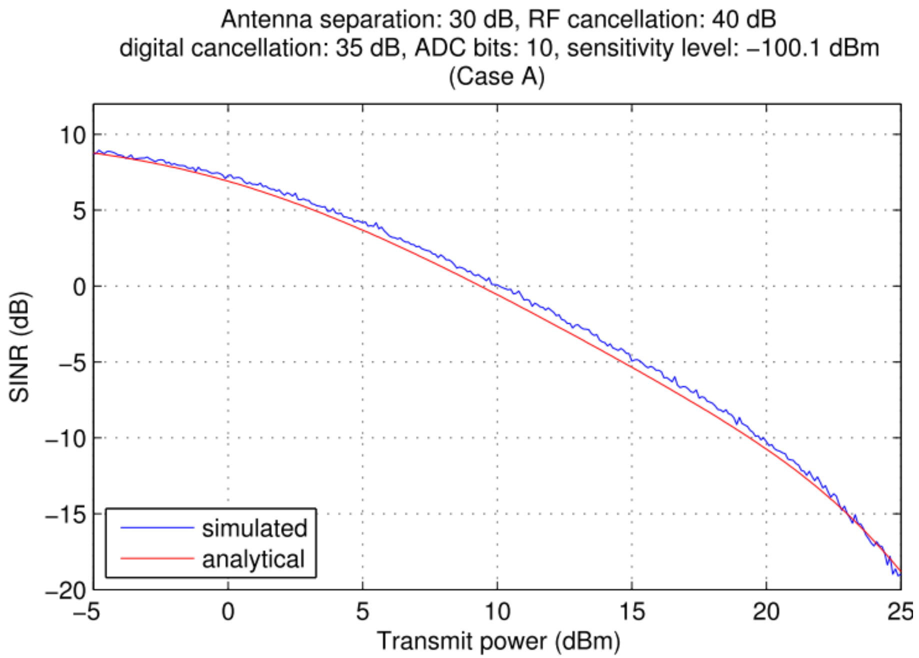


The required amount of digital cancellation for sustaining the specified SINR loss.

Waveform simulations

- To assess the reliability of the results, they were compared to results obtained from complete waveform simulations
- Same transceiver model was used in the simulations as in the analytical calculations
- OFDM signal with 16-QAM constellation was used

Waveform simulation results



The SINR value at the input of the detector.

- The analytically calculated SINR value is slightly lower than the simulated value
  - However, the difference is nevertheless quite small

Conclusions

- The strong SI signal produces nonlinear distortion, which must be considered
  - Especially if the amount of SI cancellation is increased
- With high SI levels, the dynamic range of the ADC might be insufficient
  - The amount of bits should be increased, or higher amounts of SI cancellation should be performed in the analog domain