RICE

Center for Multimedia Communication

WARP WIRELESS OPEN-ACCESS RESEARCH PLATFORM

Design, Analysis, and Implementation of Full Duplex Wireless Communication Systems

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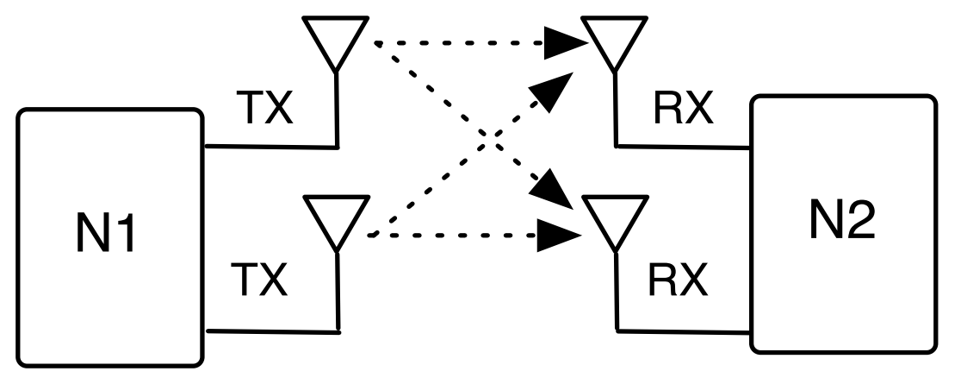
Contributions

- Measurement based characterization of the self interfering channel.
- Experimental comparison of the capacity of half duplex and full duplex systems.

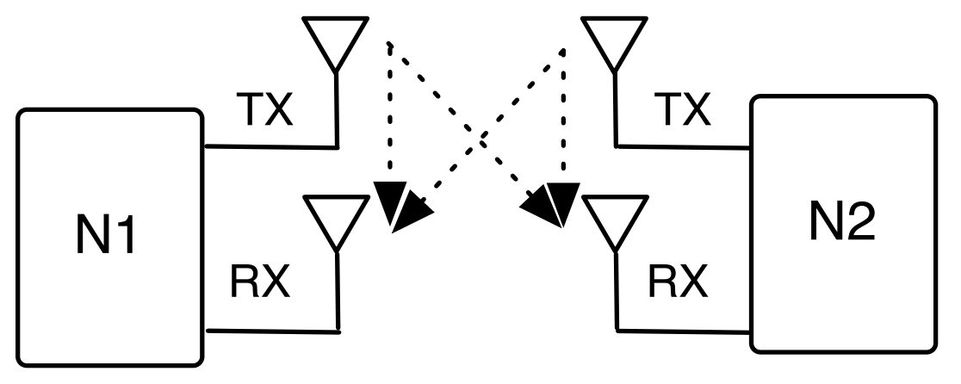
2x2 Bidirectional Communication

- Half Duplex System.



  - Time sharing.
  - Full diversity: Alamouti.
  - Spatial Multiplexing: Channel Inversion

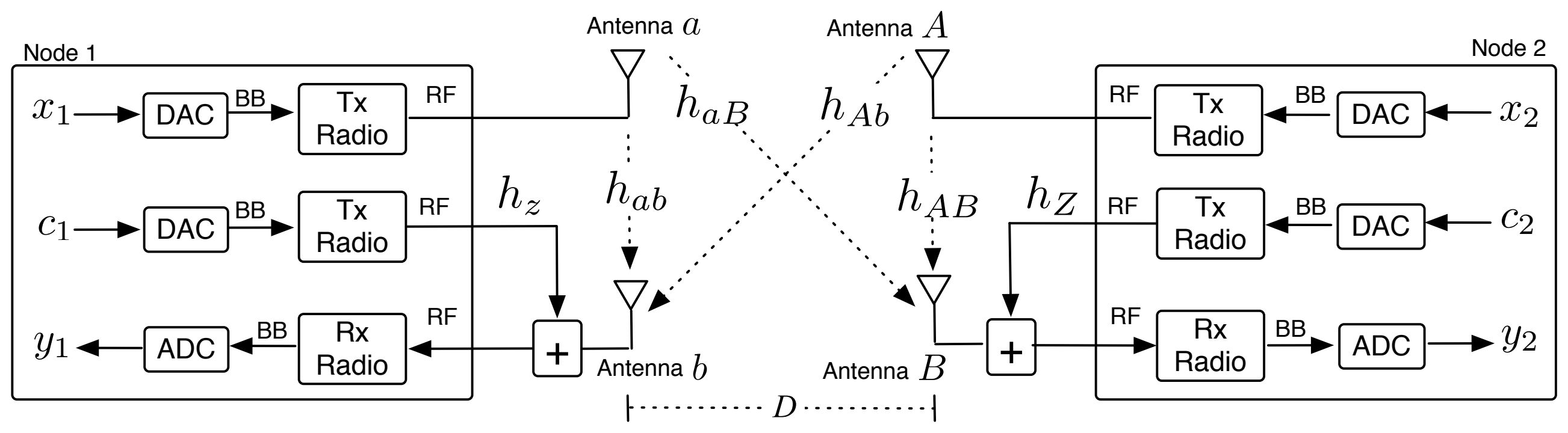
- Full Duplex System



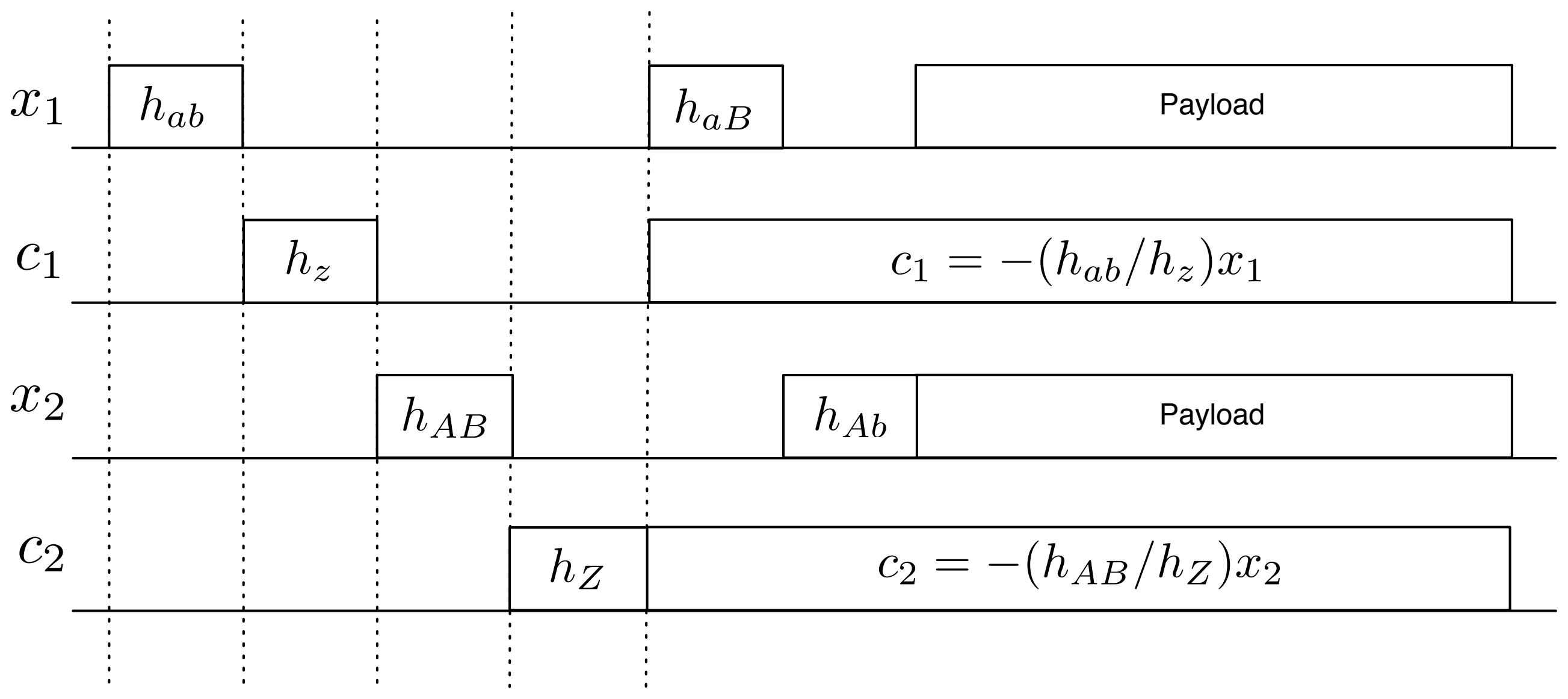
  - Simultaneous bidirectional communication
  - 1x1 SISO system with self interference cancellation

Full Duplex with Self Interference Cancellation

- Self interference cancellation mechanisms:
  - Antenna Separation (AS).
    - d = 20 cm.
    - 40 dB attenuation.
  - Radio Frequency Cancellation (RFC).
    - Avoid receiver front end saturation.
    - Use ADC dynamic range for desired signal.
    - 26 dB attenuation.
  - Baseband cancellation (BBC).
    - Remove interference after imperfect RF cancellation
    - 10 dB attenuation.
  - Total self interference cancellation = 76 dB.
- Block diagram:

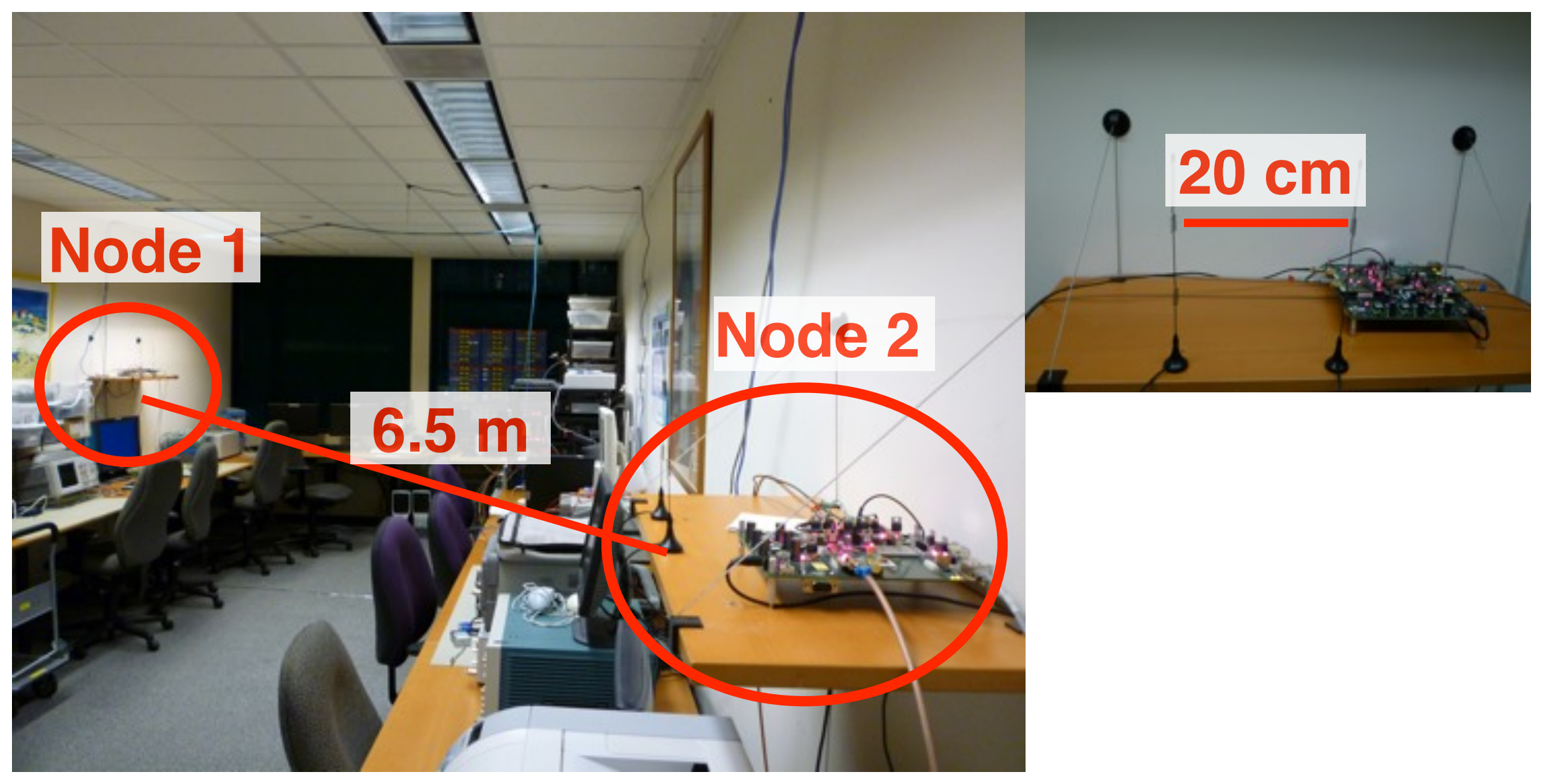


- Time diagram:



Experiment Setup

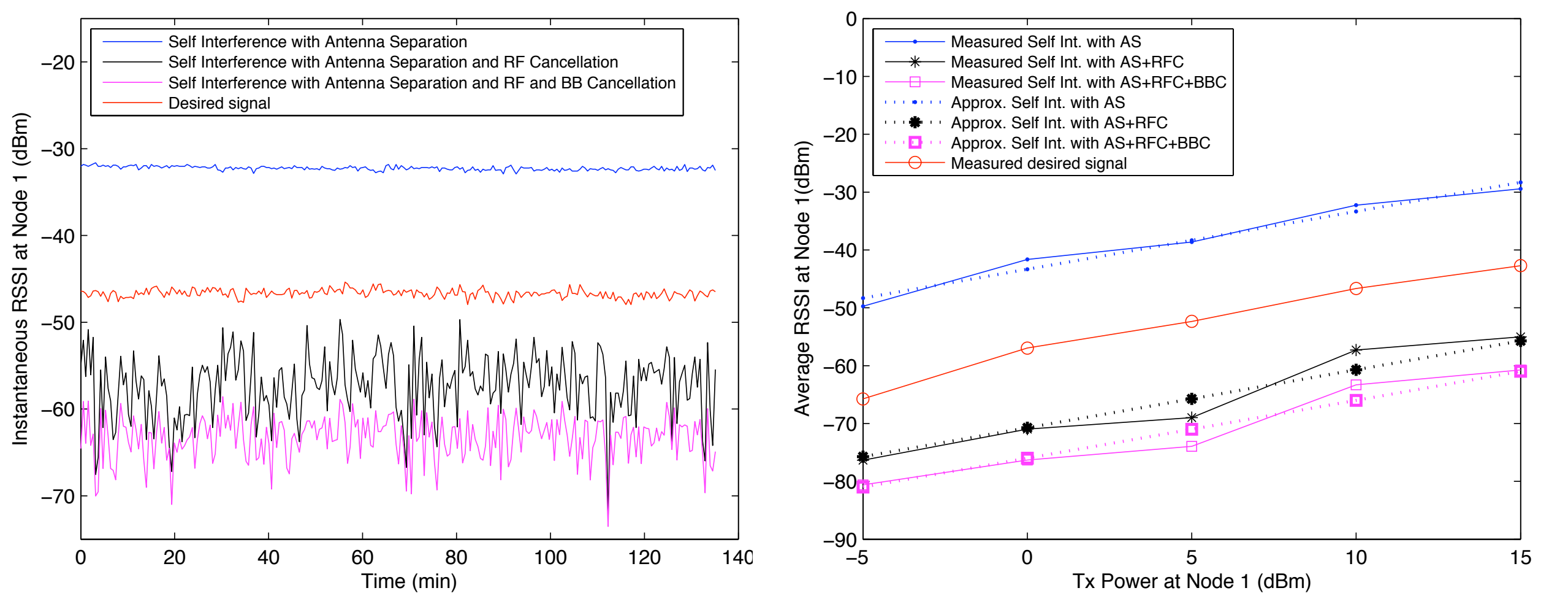
- Used Rice University's WAPRLab framework
  - One PC controls two WARP nodes
  - MATLAB for signal processing, non real time processing.
  - WARP for wireless interface, real time channel use.



Experiment Results: RSSI Characterization

Instantaneous RSSI @ PTx = 10 dBm

Average RSSI

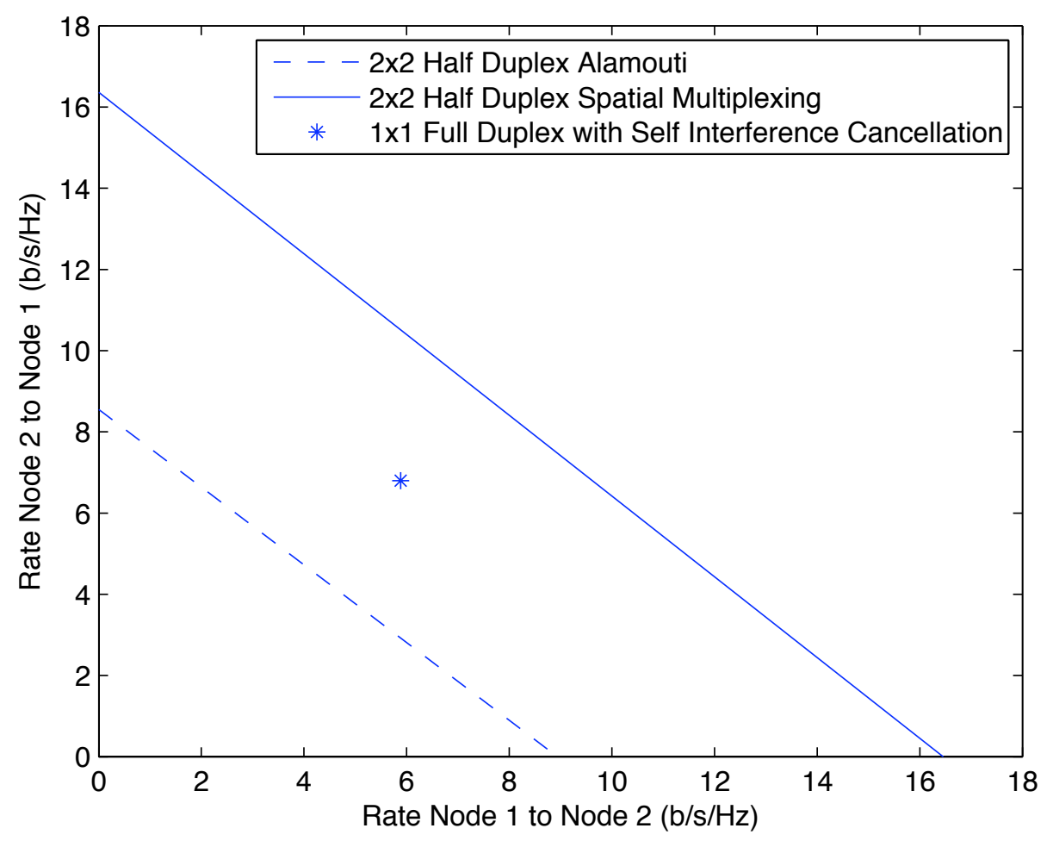


- Using self interference cancellation reduces the self interference power below the power of the desired signal.
- Average power of self interference increases linearly with average power of interfering transmitter.
  - Verified experimentally and analytically.

Experiment Results: Comparison Between Full Duplex and Half Duplex

- Compute rate from node 1 to node 2 and from node 2 to node 1 for the three following schemes:
  - 2x2 half duplex Alamouti.
  - 2x2 half duplex spatial multiplexing.
  - 1x1 full duplex with self interference cancellation.
- Average transmitted power per antenna is equal to 10 dBm.
- Measure SINR per frame, SINR[f], for each data stream. Transmit F frames. For each data stream compute the achievable rate as

$$R = \frac{1}{F}\sum_{f=1}^{F}\log(1+\mathrm{SINR}[f])$$



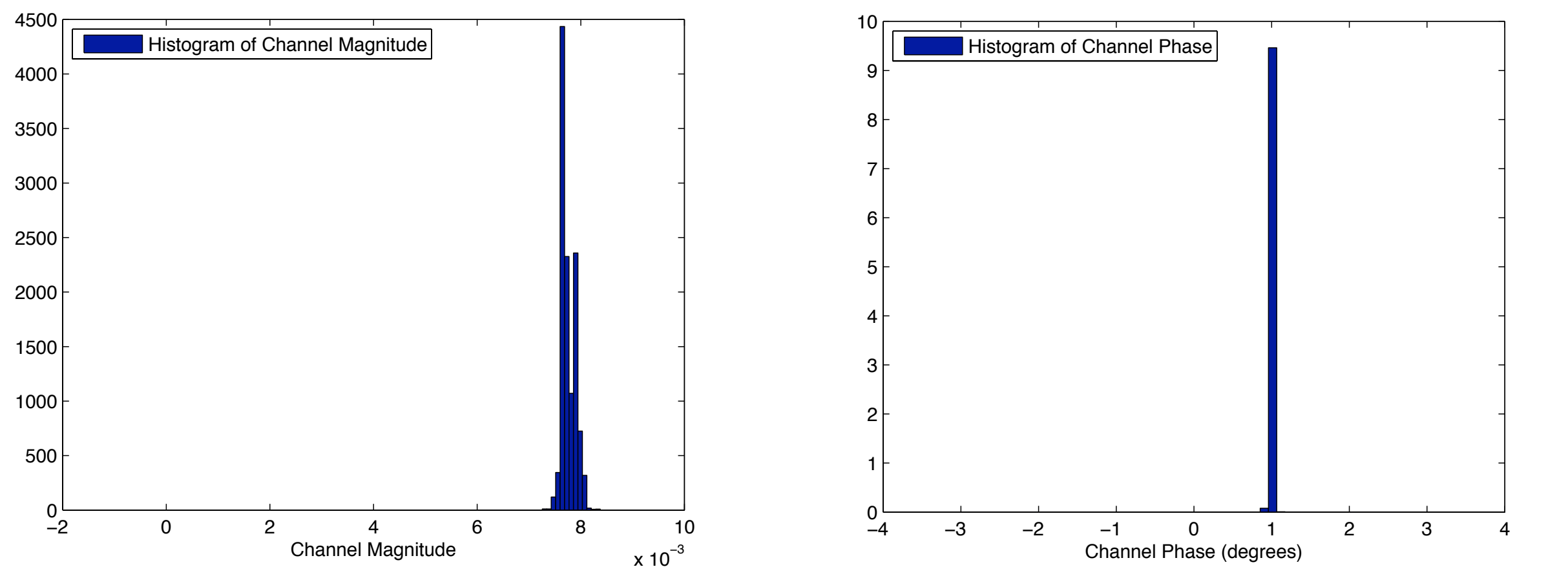
- Full duplex system capacity lies between the capacity of a half duplex Alamouti system and the capacity of a spatial multiplexing system

Experiment Results: Characterization of the Self Interfering Channel

Self Interfering Channel with Antenna Separation

Channel Magnitude

Channel Phase

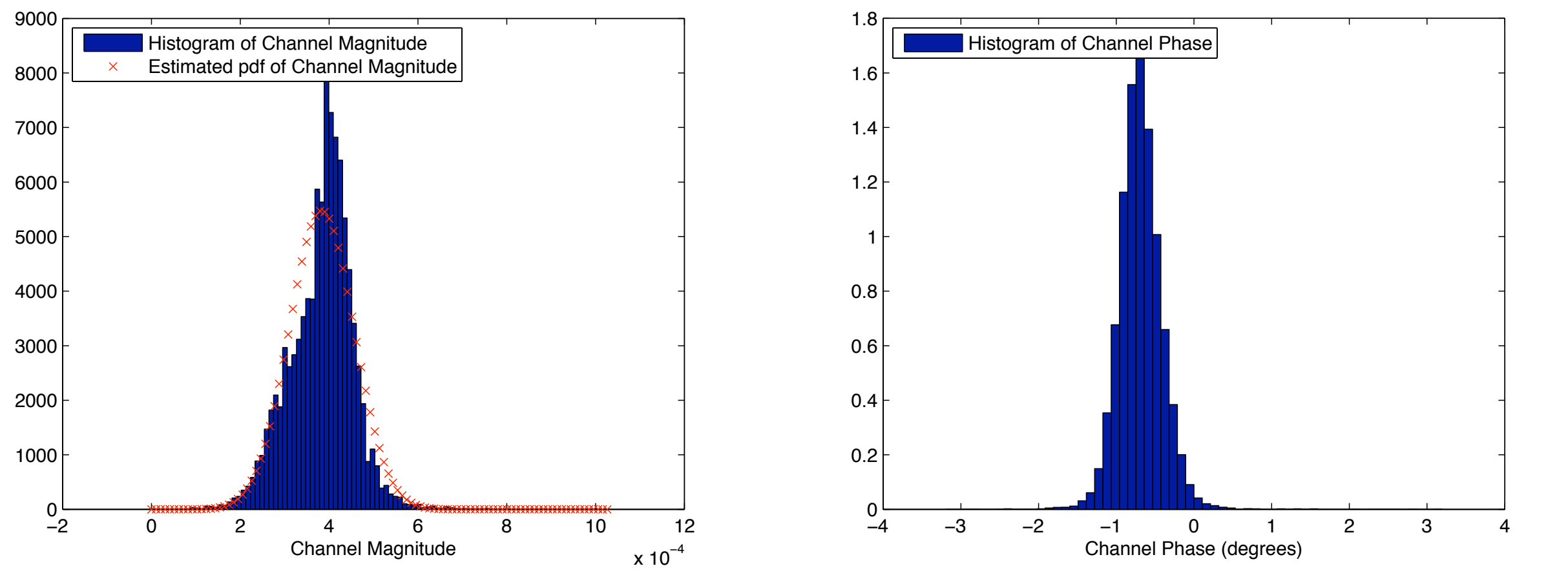


- When Antenna Separation is used for self interference cancellation the self interfering channel is almost deterministic with a strong Line-Of-Sight (LOS) component.
- These channel characteristics are due to the proximity of same node transmitter and receiver antennas (20 cm).

Self Interfering Channel with Antenna Separation and RF Cancellation

Channel Magnitude

Channel Phase

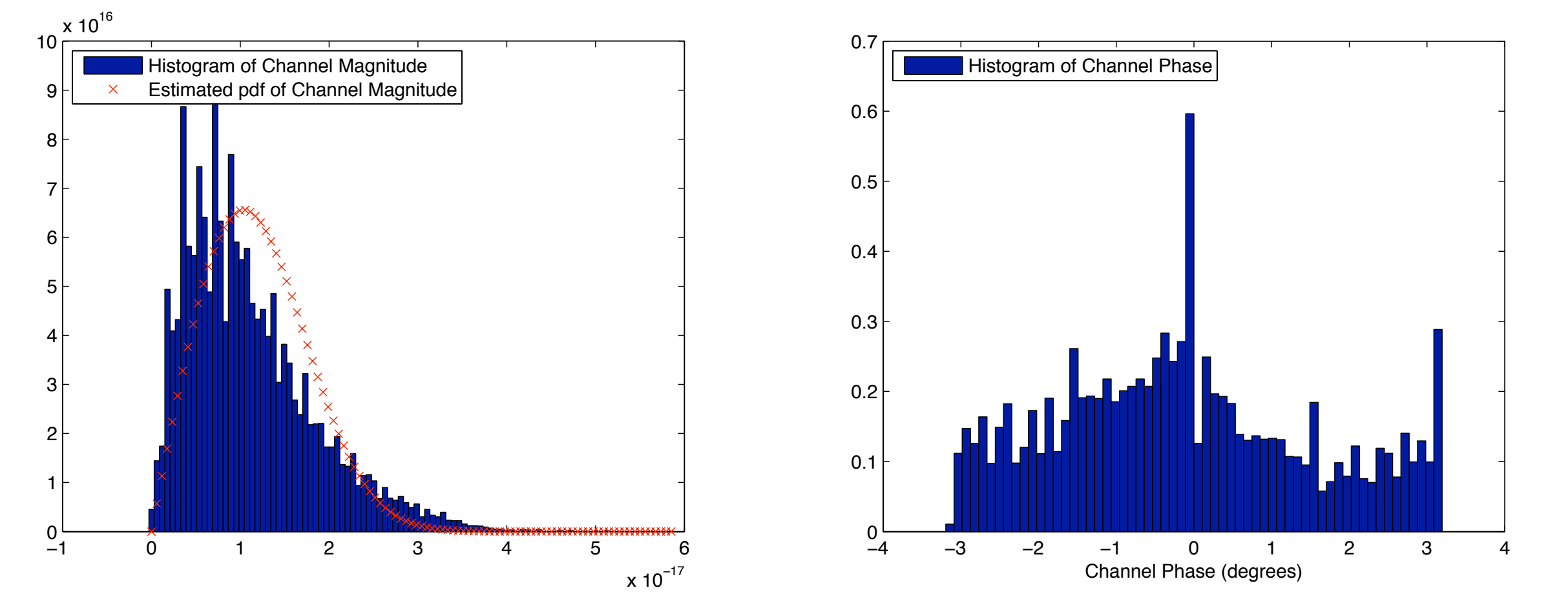


- When Antenna Separation and RF cancellation are used for self interference cancellation the magnitude of self interfering channel is well approximated by a Rician pdf with Rician factor K = 13. Using RF cancellation attenuates the LOS component.

Self Interfering Channel with Antenna Separation and RF and BB Cancellation

Channel Magnitude

Channel Phase



- When Antenna Separation and RF and BB cancellation are used for self interference cancellation the magnitude of the self interfering channel is well approximated by a Rician pdf with Rician factor K = 0.66.
- Using RF and BB cancellation attenuates the power in the LOS component below the total power received from NLOS paths.