Sequence Optimization-based UWB Receiver

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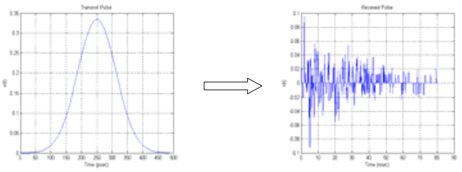
Motivation

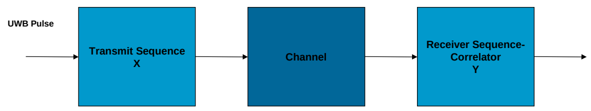
- Large Number of multipath components in indoor UWB channels distort received pulse shape



- Challenge: Maximize energy capture with a simple receiver
- Main receiver topologies:
  - Rake receiver – Large number of Rake fingers required
  - Template-assisted receiver - Noise is augmented
  - Alternative strategies:
    - Pre-Rake receiver: Rake combining at transmitter
    - Modify transmit pulse shape

Proposed Receiver

- Transmit pulse shape controlled by transmit sequence *X*
- Receiver template controlled by sequence *Y*



- Objective: Jointly optimize *X* and *Y*
- Different scenarios:
  - Single User: Maximize SNR
  - Multiple Users: Maximize SINR
  - High-power narrowband interference (NBI): Maximize SINR

Single User Case

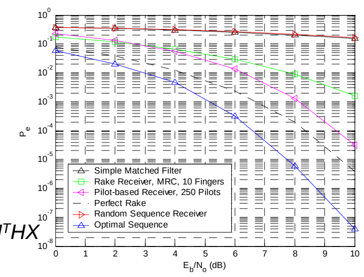
- Objective: Maximize SNR
- Optimal transmit sequence *X* solves:

$$\max_{X\neq 0}\frac{Y^T HX}{X^T X}=\max_{X\neq 0}\frac{X^T H^T HX}{X^T X}$$

H is the channel matrix

- Optimal *X* is the maximum eigenvector of $X^T H^T HX$
- Optimal received sequence *Y* is given by

$$Y = HX$$



- Transmit seq. length = 160
- Results averaged over multiple NLOS channels
- Simple matched filter fails: Captures only first path energy
- Random sequence fails: No coherent combining of paths
- Pilot-based Receiver with 250 pilots: 2 dB away from perfect Rake
- Optimal sequence: 1.5 dB better than perfect Rake
  - Coherent combining of multipath: Boost in received energy level
  - Similar to gains when using transmit beamforming

Multiple Users Case

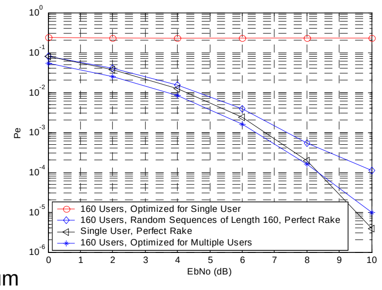
- Objective: Maximize SINR
- *K* users are assumed to exist in the system
- The interference covariance matrix is

$$Z_i=\sum_{j\neq i} p_j H_j X_j X_j^T H_j^T+\sigma^2$$

- Optimal received sequence *Y* is given by

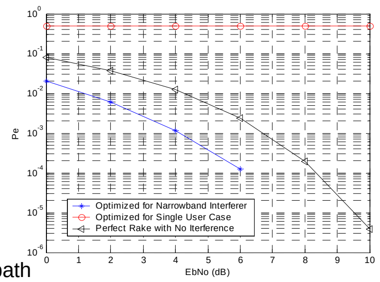
$$Y = Z_i^{-1} H_i X_i$$

- Optimal transmit sequence *X* is the maximum eigenvector of $H_i^T Z_i^{-1} H_i$



- 160 equal-power users
- Sequence optimized for single user fails:
  - Cross-correlations from different users not taken into account
- CDMA-like system with spreading gain 160 is 1 dB away from Rake receiver
- Sequence optimized for multiuser scenario performs almost like perfect Rake in AWGN

High Power NBI Case



- NBI modeled by data-modulated sine wave
- NBI power is 100 dB above signal power
- Sequence length = 160
- Sequence optimized for single user fails:
  - Performance limited by NBI
- Sequence optimized for NBI effectively cancels NBI:
  - 2.5 dB gain over perfect Rake in AWGN

Summary of Results

- Sequence optimization for UWB multipath
- channels:
- Big gains in single user scenarios
- Very good multiuser and NBI cancellation
- Relatively simple receiver
- Requires sequence feedback
- Requires storing real-valued sequence

Relevant Publications

•J. Ibrahim, R. Menon, and R.M. Buehrer, “UWB Signal Detection Based on Sequence Optimization for Dense Multipath Channels,” *IEEE Communications Letters,* April 2006.

•R. Menon, J. Ibrahim, and R.M. Buehrer, “UWB Signal Detection Based on Sequence Optimization”, *WIRELESSCOM 2005*, June 2005.

•J. Ibrahim, R. Menon, and R.M. Buehrer, “UWB Sequence Optimization for Enhanced Energy Capture and Interference Mitigation,” *IEEE Military Communication Conference, MILCOM 2005*, October 2005