MIMO RX Design, ISI Mitigation Techniques, Multicarrier Modulation and OFDM

Lecture Outline

- **MIMO RX Design**
- **ISI Mitigation Techniques**
- **Multicarrier Modulation**
- **Overlapping Subcarriers and OFDM**

1. **MIMO Receiver Design (see supplemental notes)**
   - Optimal MIMO receiver is maximum-likelihood (ML) receiver. Finds input vector $\mathbf{x}$ that minimizes $||\mathbf{y} - \mathbf{Hx}||^2$ for $||\cdot||$ the vector norm.
   - This receiver is exponentially complex in the constellation size and number of transmitted data streams.
   - Can reduce complexity through linear processing of input vector $\mathbf{Ax}$.
   - Zero-forcing receiver forces all interference from other symbols to zero. This can result in significant noise enhancement.
   - MMSE receiver: trades off cancellation of interference from other symbols for noise enhancement. Reduces to zero forcing in the absence of noise.
   - Sphere decoder: uses upper triangular decomposition of H to reduce complexity. Finds constellation point within a sphere of a given radius. Provides near-ML performance with near-linear complexity.

2. **ISI Countermeasures:**
   - Equalization: signal processing at receiver to remove ISI. Too complex for high-speed systems with large delay spread.
   - Multicarrier modulation: send data over independent subcarriers at slow enough rate such that they experience flat-fading.
   - Spread spectrum modulation: Use properties of spreading codes to remove or coherently combine ISI at receiver.
   - Use directional antennas to reduce delay spread and ISI.

3. **Multicarrier Modulation (MCM):**
    - Mitigates ISI by dividing the transmit bit stream into N substreams.
    - Each substream modulated by a separate subcarrier with signal bandwidth B/N.
    - N is made sufficiently large so that $B/N < B_c$, so substreams experience flat-fading.
    - MCM can be implemented using frequency division multiplexing.

4. **Overlapping Subcarriers**
    - More bandwidth-efficient implementation (OFDM)than MCM overlaps the transmitted substreams such that they can be separated at the receiver.
    - For rectangular pulses, minimum required separation is B/N. Can be less if phases of subcarriers are aligned.

Main Points

- MIMO RX design trades complexity for performance. ML detector is optimal but exponentially complex. Linear decoders enhance noise. Sphere decoders allow performance vs. complexity tradeoff via radius; most common technique in practice.
- ISI typically mitigated by equalization, multicarrier modulation, spread spectrum, or antenna techniques. Equalization not used in current wireless standards due to complexity.
- Multicarrier modulation splits data into narrowband (flat-fading) substreams.
- Multicarrier modulation made more bandwidth efficient by overlapping subchannels.