FFT Implementation of MCM (OFDM) OFDM Challenges, MIMO-OFDM

Lecture Outline

- OFDM: FFT/IFFT Implementation of MCM
- Implementation Challenges in OFDM
- Fading Across Subcarriers
- MIMO-OFDM

1. **OFDM: IFFT/FFT Implementation of MCM**
   - Complexity of implementing N separate modulators/demodulators is prohibitive.
   - MCM effectively implemented using IFFT at transmitter and FFT at receiver.
   - The IFFT shifts modulated symbols to desired subcarriers.
   - A cyclic prefix is inserted in the data to remove ISI between blocks and make the linear convolution with the channel circular.
   - The received symbol is just a scaled version of the transmitted symbol.

2. **Fading across Subcarriers**
   - Different subcarriers experience different fading (H_i for subcarrier i) and hence different received SNRs.
   - Can invert fading at the transmitter such that received SNR is constant across all subcarriers. This technique, called precoding, is most common in wireline systems. It is wasteful of power when channel has deep nulls since it is effectively inverting the channel.
   - A more common technique to address fading across subcarriers is adaptive loading, which adapts power and rate relative to the fading in each subchannel. This technique is capacity achieving.
   - Can also use coding across subcarriers, so that a subchannel whose symbols are affected by deep fading is compensated by coding across subcarriers with high SNRs.

3. **Implementation Challenges in OFDM**
   - Timing and frequency offsets cause subchannels to interfere with each other.
   - Interference between subchannels mitigated by minimizing the number of subchannels and using pulse shapes robust to timing errors.
   - OFDM/DMT consists of multiple sinusoids summed together, can have a large peak-to-average power ratio (PAPR), which leads to amplifier inefficiencies.
   - PAPR compensated through clipping or coding.

4. **MIMO-OFDM Systems**

   - Most next-generation wireless systems combine OFDM and MIMO, e.g. 4G cellular and Wifi (802.11n/ac/ax) and future generations.
   - These systems use OFDM modulation over each spatial dimension
   - OFDM compensates for ISI, while MIMO is used for its diversity/multiplexing benefits.
   - MIMO-OFDM systems adapt over space, time, and frequency.
   - Receiver complexity depends on both the MIMO parameters and the number of OFDM tones: high data rates lead to more tones to compensate for ISI, hence more complexity.
   - Both OFDM and MIMO systems can be represented by a matrix. MIMO-OFDM represented by a combined matrix.

Main Points

- OFDM efficienctly implemented using FFTs and IFFTs.
- Fading across subcarriers in OFDM compensated by precoding, adaptive modulation, or coding across subcarriers.
- Implementation challenges in OFDM include PAR and timing/frequency offsets.
- 4G Cellular and 802.11n/ac/ax (i.e. Wi-Fi 6) use OFDM+MIMO: OFDM removes ISI, MIMO gives diversity/multiplexing benefits. These systems adapt across space, time, and frequency. Represented/analyzed by a combined OFDM-MIMO matrix.