Massive MIMO Transmitter Design
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Motivation
- Massive MIMO provides significant advantages
  1. High spectral efficiency
  2. Relaxed Scheduling
  3. Spatial Multiplexing - Diversity - Beamforming
- Until now only small MIMO (8x8) supported in LTE

Why no massive MIMO implementation?
- Cost
- Each antenna requires own RF chain
- Size
- \( \frac{1}{2} \) distance between antennas
- Power Consumption
- Increases with number of RF chains

Possible Solutions
- Hybrid Beamforming
  - Using a combination of digital and analog beamforming
- Spatial Modulation
  - Using the antenna index for modulation
- Parasitic Antennas
  - Only one active antenna element
  - UE RF Chain
    - Using the cost optimized RF chains of mobile phones

Hybrid Beamforming [1]

Basic Idea
- Use a combination of digital and analog beamforming to reduce the number of RF chains

Spatial Modulation [3]

Basic Idea
- Instead of transmitting with all antennas only use one or a subset

Spatial Modulation uses \( \log(N_t) \times m \) bits
- Generalized Spatial Modulation uses a subset of antennas

\[
d_k = \sum_{k=1}^{N_t} \phi_k(x) \phi_k(x) d_k
\]

Disadvantages
- Analog Network
- Insertion loss
- Reproducibility
- Many phase shifters necessary

Spatial Modulation Performance

Hybrid Beamforming Performance [2]

- Transmit Antennas (M)
- Transmit RF Chains (\( Q_k \))
- Users (\( P_k \))
- Receive Antennas (\( W_k \))
- Receive RF Chains (\( P_{in} \))

Advantages
- Near full digital beamforming performance with less than 50 % RF chains depending on the SNR

Disadvantages
- Fast antenna switching
- Channel estimation
- Suboptimal spectral efficiency

Parasitic Antenna Implementation

- Implementation with only one parasitic element
- Vector \( \omega \) emerging from \( \chi \) QAM constellation is multiplexed over the air
- Signal \( \omega \) is directly driven to the sole RF chain

Parasitic Antennas [4]

Basic Idea
- Emulate the beam pattern of a conventional MIMO system with only one active antenna element and one or more parasitic antenna elements

- The transmit symbols \( \{\phi_k(x)\}_{k=1}^{N_t} \) are mapped on orthonormal modes \( \{\phi_k(x)\}_{k=1}^{N_t} \)

\[
\phi_k(x) \sim \frac{1}{\sqrt{N_t}}
\]

Advantages
- Single RF chain
- Energy efficient

Disadvantages
- Spectral Efficiency Example
  - 8x8 16 QAM V-BLAST \( \Rightarrow 32 \text{ b/s/Hz} \)
  - SM 16 QAM needs \( 2^8 \) antennas for the same spectral efficiency \( \Rightarrow \) Infeasible

Parasitic Antenna Performance

- With ideal loads conventional MIMO performance can be achieved in this \( 2 \times 2 \) 16 QAM scenario

Possible Solutions
- Analog network

Current Challenges
- Can we emulate patterns for a large number of antennas and high modulation?

References