Reuse Within a Cell -
Interference Rejection or Multiuser Detection?

Claes Tidestav, Mikael Sternad and Anders Ahlen
Signals and Systems Group
• With array receivers in FDMA/TDMA systems, several users could share one channel in each cell.

• Simplest receiver: spatial beamforming

• More advanced space-time processing:
  - Interference rejection
  - Multiuser detection.
Interference rejection of multiuser detection?

Multiuser detection and interference rejection?

- Multiuser detection: Detect *all* signals simultaneously.
- Interference rejection: Detect *one* signal at the time and consider the remaining as interference.

*Is there a difference?*
Yes and no!

• For linear detectors:
  – a set of linear receivers, each detecting one signal and rejecting the remaining as interference is *exactly the same* as a single linear receiver which detects all signals simultaneously.

• For non-linear detectors:
  – a set of non-linear receivers, each detecting one signal and rejecting the remaining as interference is *different* from a single non-linear receiver which detects all signals simultaneously.
Example scenario:

- several antennas at the receiver
- several users to detect, all
  - in the same cell
  - at the same frequency
  - in the same time-slot
- intersymbol interference
- different “flavours” of decision feedback equalizers employed
The decision feedback equalizer: an old idea

- Suppress intersymbol interference and noise using the two filters
- The effect of symbols already detected is removed by the feedback filter
- The coefficients of the filters are adjusted to minimize some criterion
An interference rejecting DFE

- Several inputs, one for each antenna
- One output for the single user we are trying to detect
- The feedforward filter suppresses
  - intersymbol interference
  - interference from other users (co-channel interference)
  - noise
- The feedback filter can only reject intersymbol interference
A DFE performing multiuser detection

- Several inputs, one for each antenna
- Several outputs, one for each user
- The feedforward filter suppresses
  - intersymbol interference
  - co-channel interference
  - noise
- The feedback filter suppresses
  - intersymbol interference
  - *co-channel interference*
Interference rejection of multiuser detection?

Performance example (simulations)

- BPSK
- Four antennas
- Three Rayleigh fading taps
- Channel estimated from 26 training symbols
- 1,2,3 and 4 users
- DFE:s performing multiuser detection (MU) and interference rejection (SU)
Why such large differences in performance?

For the MU DFE, some of the co-channel interference can be rejected by the feedback filter.

Additional users can be accommodated.

Exactly how many users can be handled for the two types of detectors? When can we expect a detector to “work properly”? 

Interference rejection of multiuser detection?
Minimum mean-square error designs

- Design criterion of equalizers: almost always MMSE
- Minimizes the expected value of the squared estimation error
- Pros:
  - provides balance between interference rejection and noise suppression
  - simple adaptive implementation
  - always exists
- Con:
  - always exists (!)
- We cannot use the existence of an MMSE equalizer as an indication of a “well-posed” detection problem!
The zero-forcing design and near-far resistance

- A zero-forcing (ZF) equalizer is designed to completely remove both the intersymbol and co-channel interference.
- Disadvantages:
  - Noise enhancement
  - Worse performance than the corresponding MMSE design
- If the intersymbol or co-channel interference cannot be completely rejected, no ZF equalizer will exist!
- Performance will deteriorate with increasing co-channel interference, for the corresponding MMSE equalizer.

We can use the existence of a ZF equalizer as an indicator of a “well-posed” detection problem (or of near-far resistance).
The example scenario

- Factors which affect the existence of ZF equalizers:
  - system properties:
    - number of users
    - number of antennas
  - channel properties:
    - delay spread
    - bulk delay
    - common factors
  - detector properties:
    - decision delay
    - filter degrees

- An MU DFE requires (much) shorter filters than an IR DFE!
Interference rejection of multiuser detection?

Experiments:

- The DFE:s have been applied to uplink measurements from an antenna array testbed
- DCS-1800
- Antenna properties:
  - One 8-element array antenna
  - One conventional sector antenna with two-branch diversity
- Two mobiles, travelling the same route in Kista
- ~20000 GSM-bursts collected and detected
Results

Array antenna

Sector antenna

Estimated BER vs. Average C/N (dB) for different antenna types and user configurations.
Results (continued)

- **Array antenna:**
  - in agreement with simulations: the more antennas, the smaller the difference

- **Sector antenna:**
  - not in agreement with simulations!
  - possible to design a zero-forcing IR DFE since
    - there is negligible dispersion in the channel
    - “All” intersymbol interference due to partial response modulation
    - The channel from one user to all antenna elements will have a common factor

⇒ Spatial suppression of the interferer is sufficient
Conclusions

- There is a difference between non-linear multiuser detectors and non-linear interference cancellers.
- In general, a system using multiuser detection can handle more simultaneous users than a system using interference rejection.
- However, the difference is small when
  - The number of users is small compared to the number of antennas.
  - The delay spread is small.