Reuse Within a Cell -
Interference Rejection or Multiuser Detection?

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- 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.

Multiuser detection and interference rejection?

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

Is there a difference?

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Yes and no!

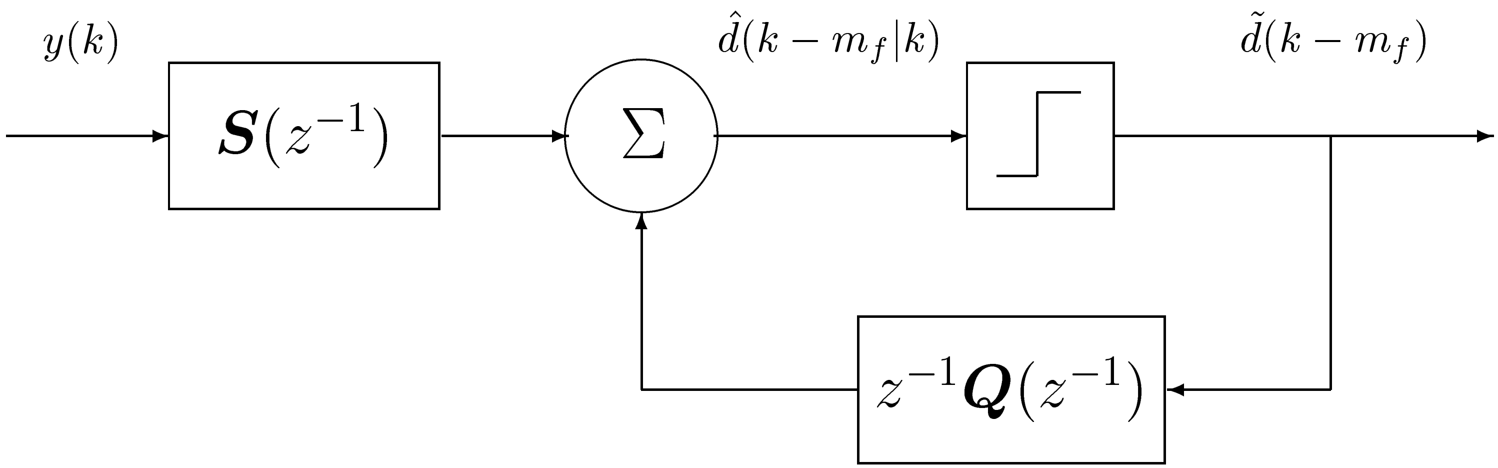
- For linear detectors:
  - a set of linear receivers, each detecting one signal and rejecting the remaining as interference is *exactly the same* as a single linear receiver which detects all signals simultaneously.

- 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

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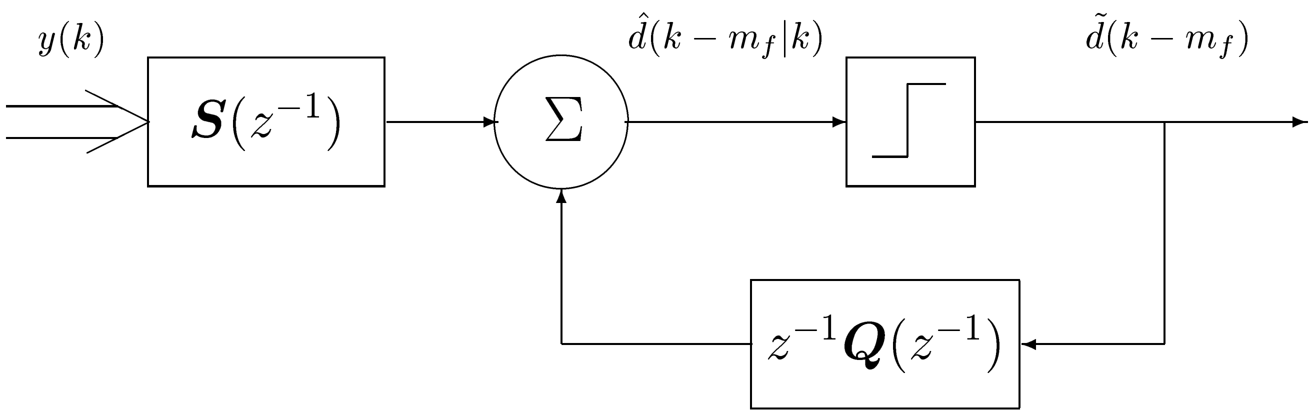
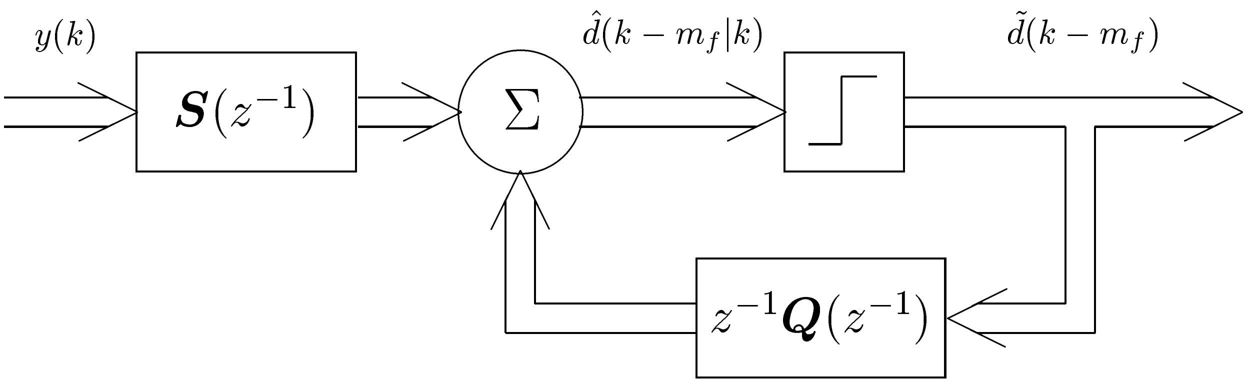
An interference rejecting DFE



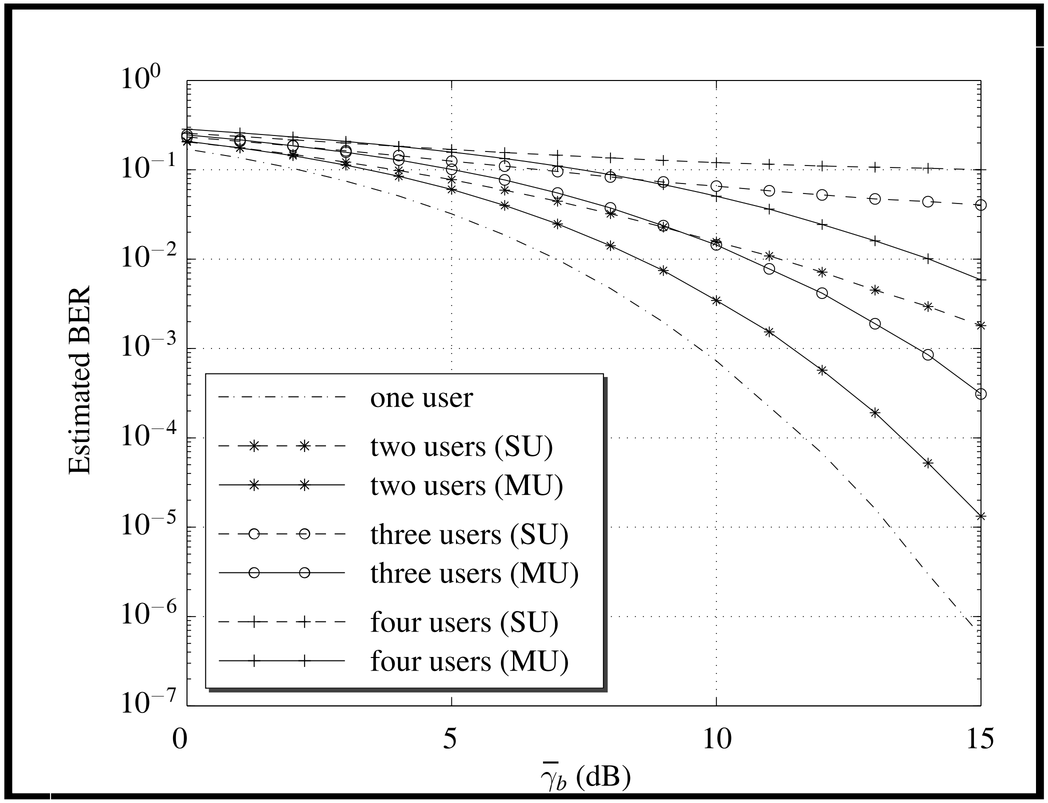
- Several inputs, one for each antenna
- One output for the single user we are trying to detect
- The feedforward filter suppresses
  - intersymbol interference
  - interference from other users (co-channel interference)
  - noise
- The feedback filter can *only* reject intersymbol interference

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*

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"?

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

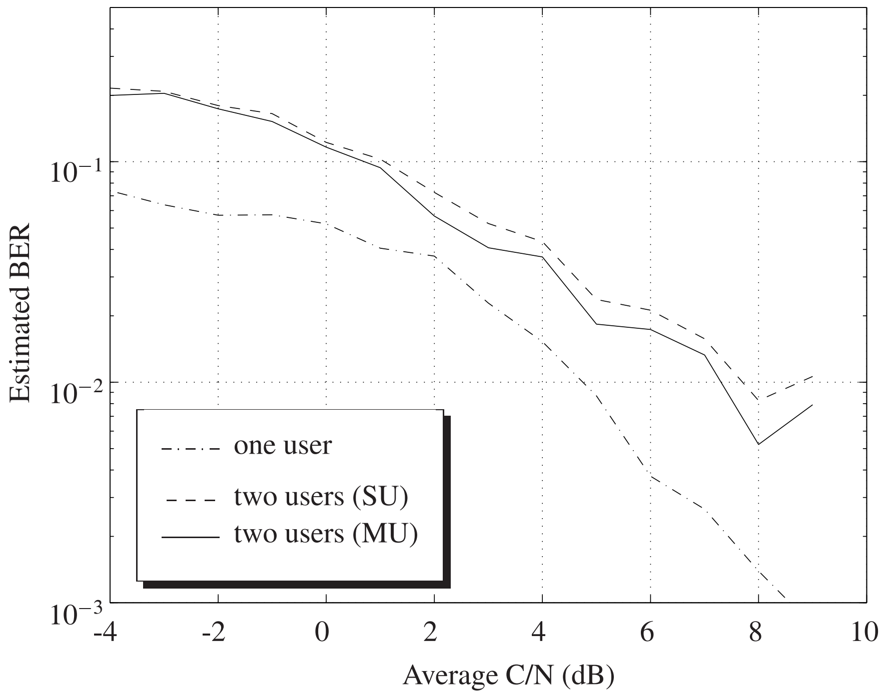
- Factors which affect the existence of ZF equalizers:
  - system properties:
    - number of users
    - number of antennas
  - channel properties:
    - delay spread
    - bulk delay
    - common factors
  - detector properties:
    - decision delay
    - filter degrees
- An MU DFE requires (much) shorter filters than an IR DFE !

Experiments:

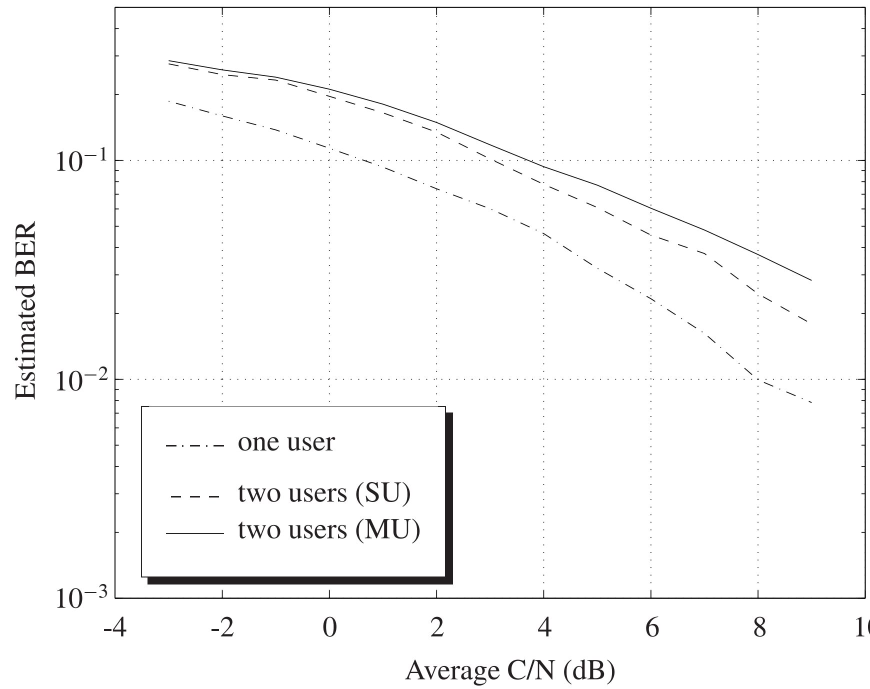
- The DFE:s have been applied to uplink measurements from an antenna array testbed
- DCS-1800
- Antenna properties:
  - One 8-element array antenna
  - One conventional sector antenna with two-branch diversity
- Two mobiles, travelling the same route in Kista
- ~20000 GSM-bursts collected and detected

Results

Array antenna



Sector antenna



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