Spatial Multiplexing

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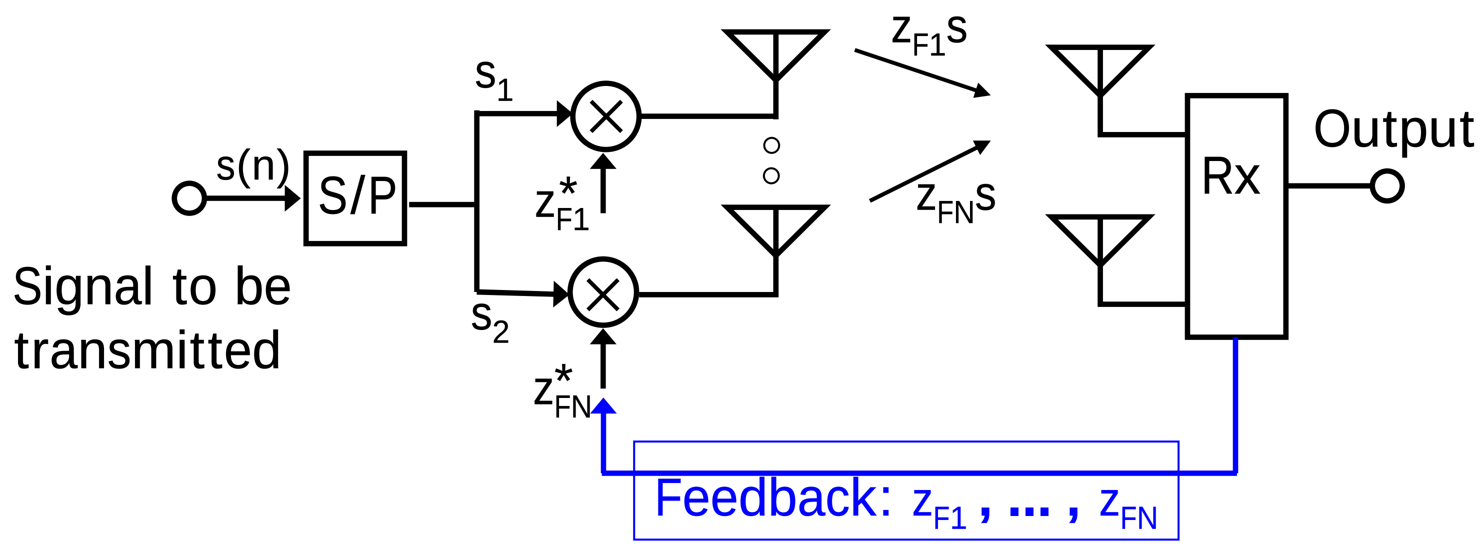
Contents

1. Introduction to Spatial Multiplexing

- The basic concept of multiplexing: divide (multiplex) transmit a data stream several branches and transmit via several (independent) channels in
  - time ⇨ time–division multiplexing (TDM)
  - frequency ⇨ frequency–division multiplexing (FDM)
    - typical example: orthogonal FDM (OFDM)
  - space ⇨ space–division multiplexing (SDM) or *spatial multiplexing*
    - different bits from different antennae
    - requires independent channels
  - code ⇨ code–division multiplexing (CDM)
    - applied in 3G systems.

Spatial Multiplexing Idea

- Several different data bits are transmitted via several independent (spatial) channels.



Characteristics

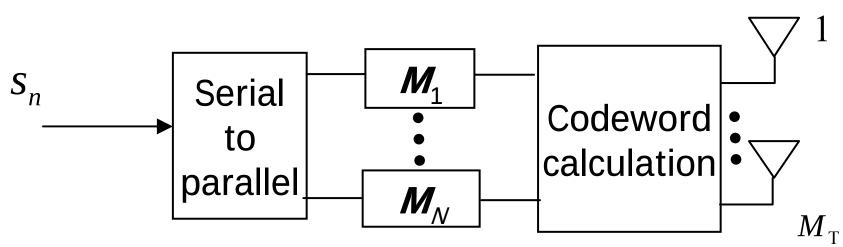
- No bandwidth expansion.
- Space–time equalization needed in the receiver.
  - **Conventionally**: no. Rx antennae ≥ no. Tx antennae.
- The data streams can be separated by the equalizer, if fading processes of the spatial channels are (nearly) independent.

⇨ Actual multiple–input multiple–output channel with capacity linearly increasing the number of antennae or more precisely independent spatial channels.

- Alternative to spatial diversity: *multiplexing–diversity trade–off* is under intensive study.

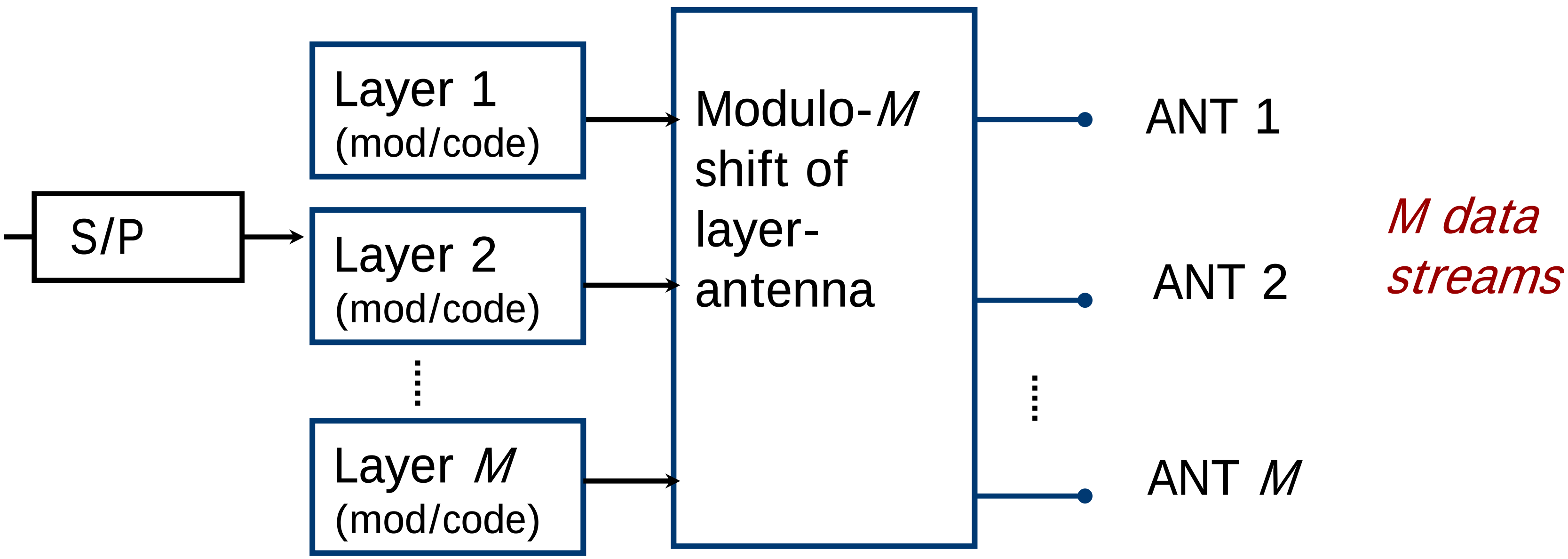
Linear Dispersion Coding

- Linear dispersion coding (LDC) offers a framework to combine spatial multiplexing and transmit diversity.
- Code design consists of finding optimum dispersion matrices.



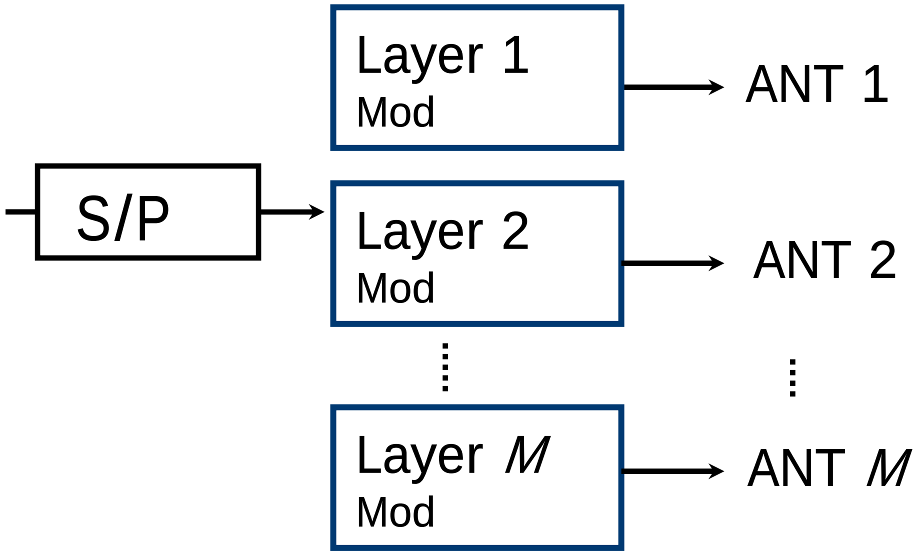
2. Layered Space–Time Architectures

- Bell Labs Layered Space–Time (BLAST) architecture was one of the first spatial multiplexing systems.
  - Called also layered space–time (LST).
- Detection originally based on linear and decision–feedback equalization, i.e., nulling and cancellation.



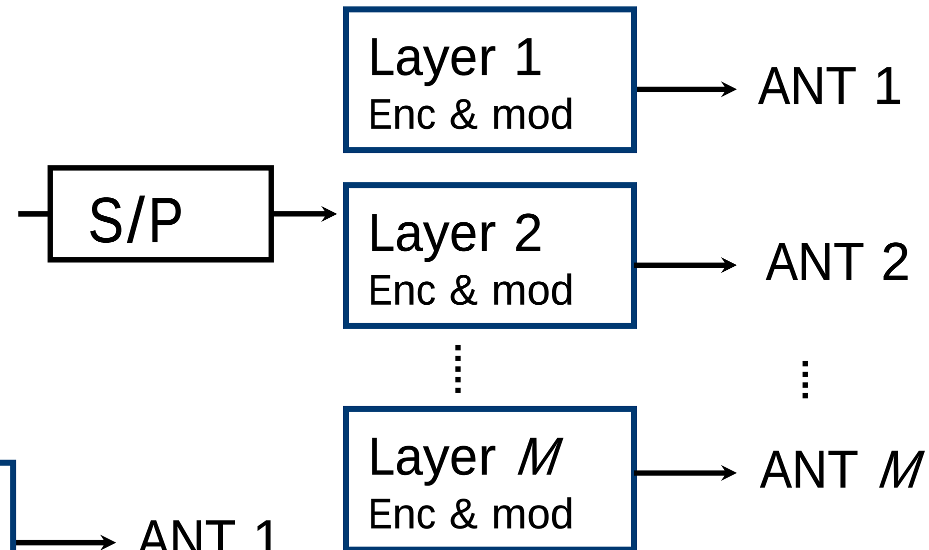
Vertical LST (V–LST)

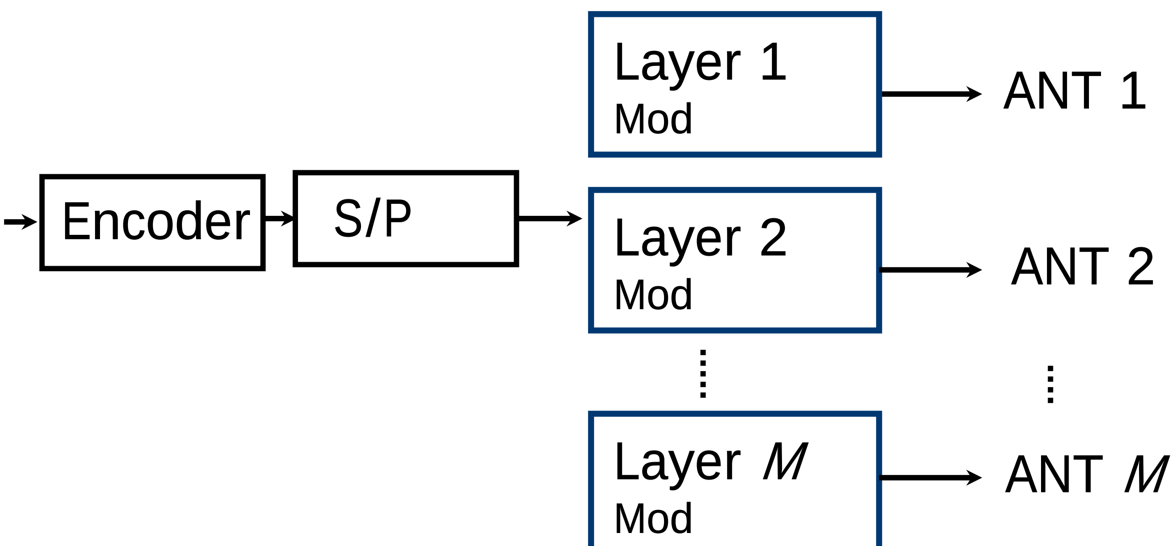
- Basic scheme with no coding involved.



Horizontal LST (H–LST)

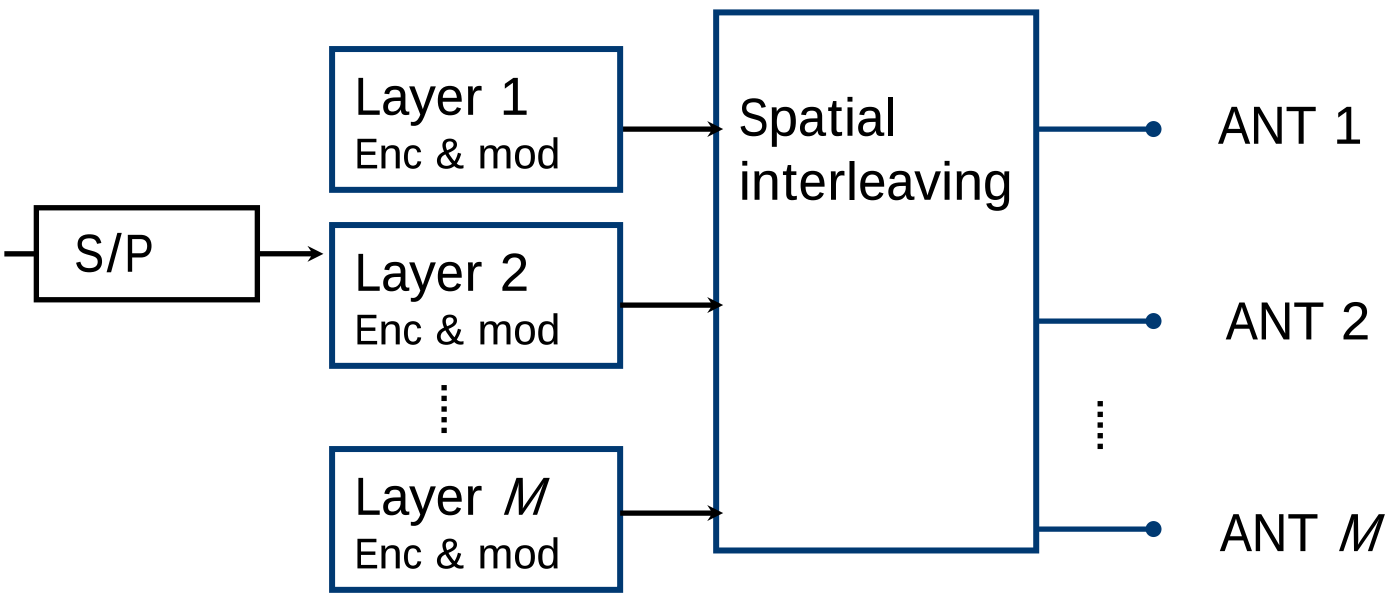
- Coding included.



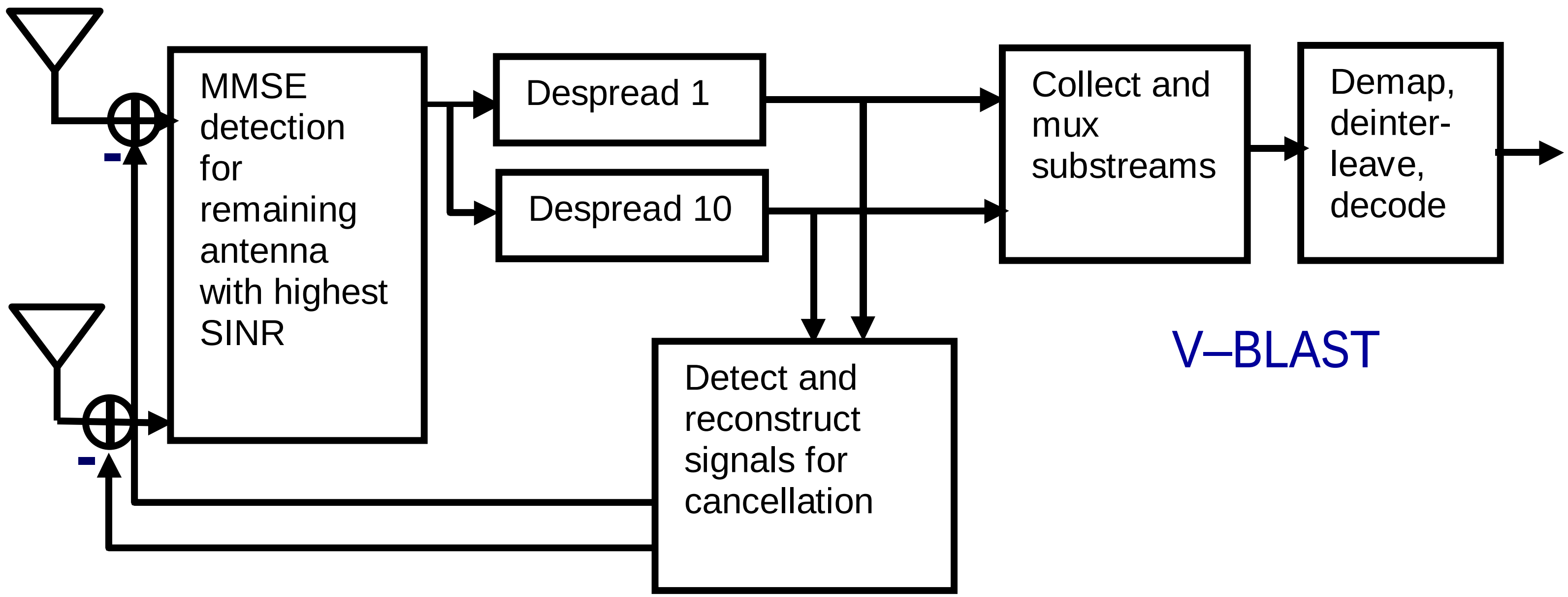


Diagonal LST (D–LST)

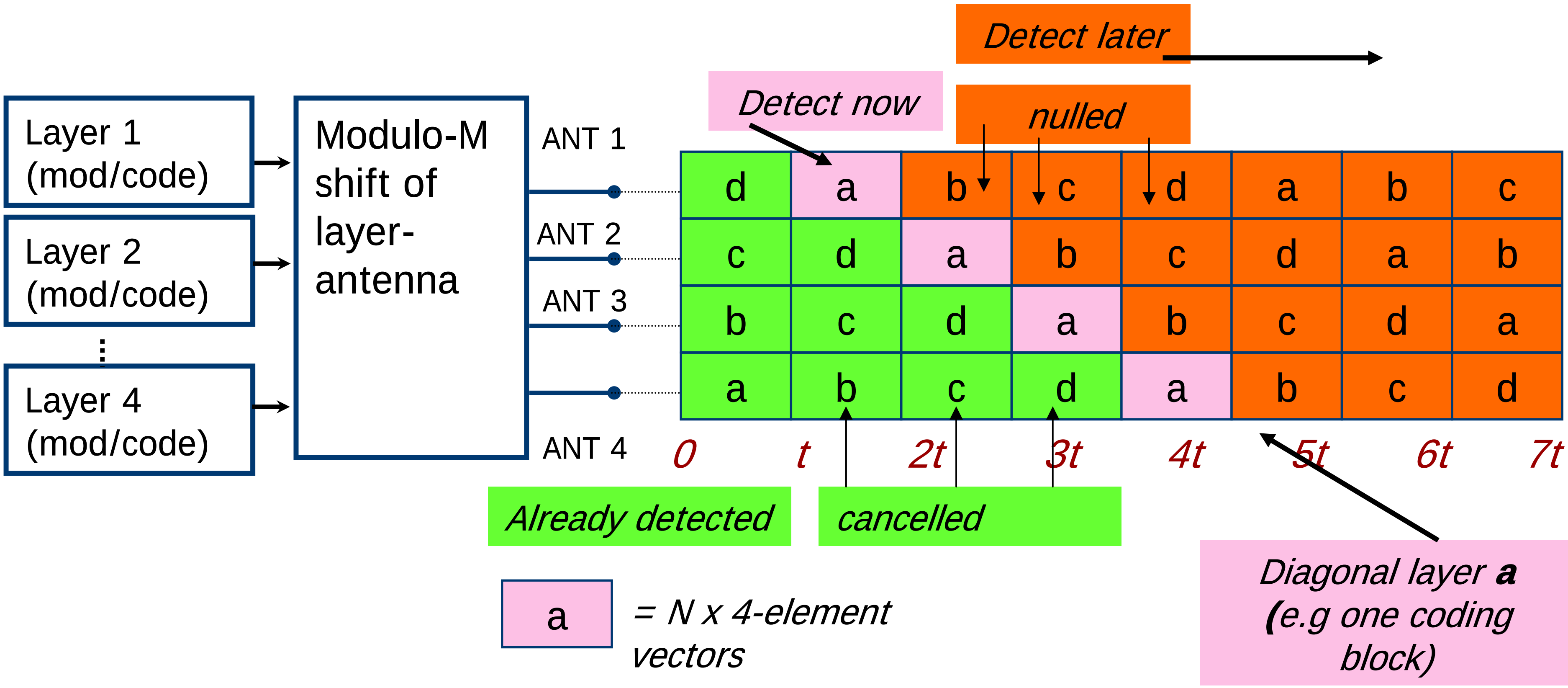
- Coding and spatial interleaving included.
- Spatial interleaving to improve performance via spatial diversity.



Nulling and Cancellation



Nulling and Cancellation Order in D–LST



Space–Time Equalization

- The optimum receiver for LST transmissions is maximum a posteriori (MAP) equalizer similarly to the intersymbol interference (ISI) or multiple–access interference (MAI) channels.
- Suboptimal receivers include:
  - linear equalizers
  - interference cancellation (IC)
  - iterative (turbo) receivers
  - sphere detectors.
- Space–time equalization is under intensive study.

3. Spatial Multiplexing in 3G Systems: PARC

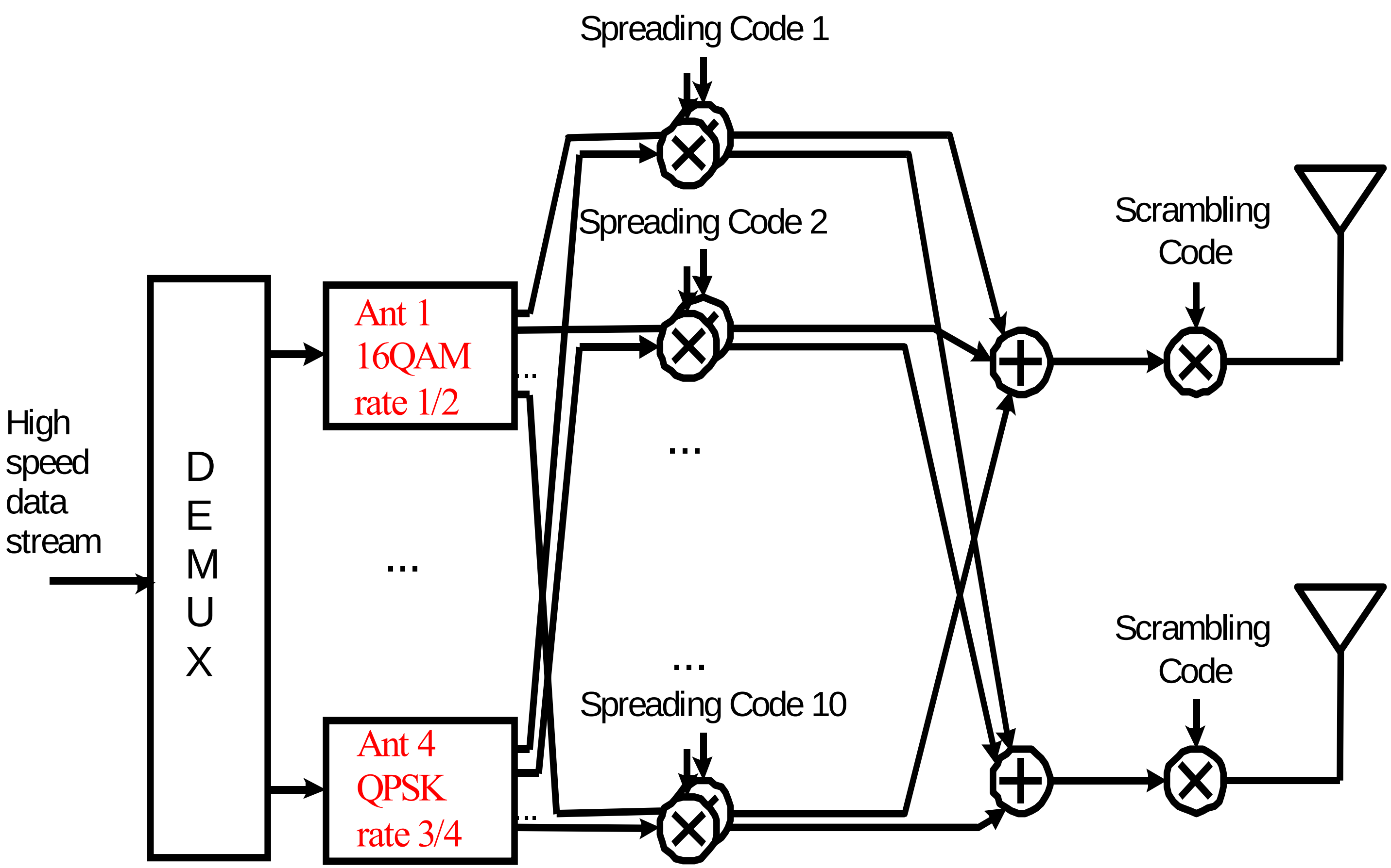
- Current MIMO proposals (e.g., code reuse, code reuse with STTD (DSTTD)):
  - Node B transmits with ***the same rate on each antenna*** (or antenna pair) depending on UE feedback and spatial channel realization

If the transmitter can adjust the antenna rates independently, a layered receiver architecture (MMSE with successive cancellation) can approach Shannon capacity. [Varanasi, Guess 1998] [Chung, Huang, Lozano 2001]

- **Per-antenna rate control (PARC)** for HSDPA MIMO:
  - Node B adjusts antenna rates independently depending on UE feedback and spatial channel realization.
  - Receiver consists of MMSE linear transformation followed by interference cancellation based on decoded bits.

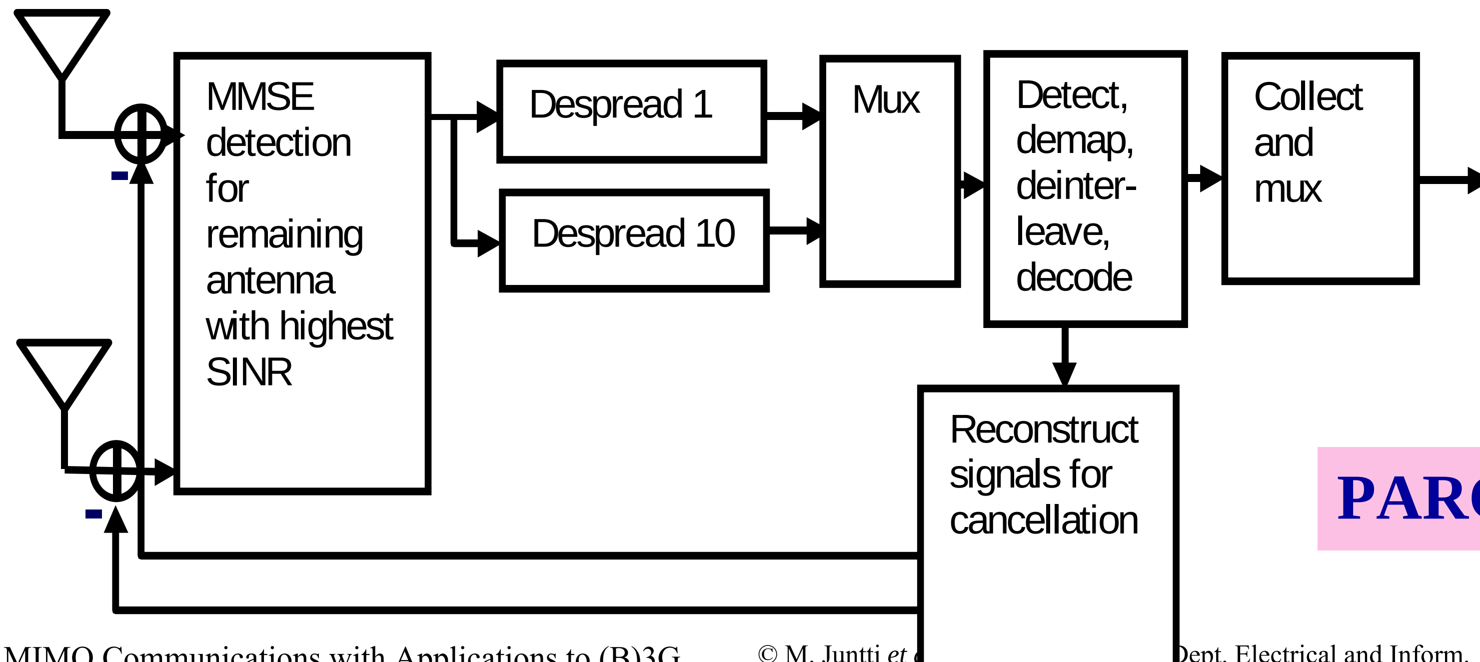
PARC: Transmission technique

- PARC MIMO transmission example:



PARC: Receiver technique

- Proposed MIMO receiver for PARC transmission
  - MMSE linear transformation followed by interference cancellation based on decoded bits.
  - Coding gain results in performance improvement over pre-decoding interference cancellation receiver.
  - This architecture can also be applied to conventional code reuse transmission.



PARC

4. Summary and Conclusions

- MIMO techniques allow high user data rates
- Advanced receivers have to be applied for MIMO systems
- Additional receiver diversity beneficial
- Feedback of CSI may lead to complex systems
- MIMO performance has to be evaluated at system level

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