Compatible Improvement of the GSM/GPRS System by Means of Space-Time Block Codes

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1. Introduction

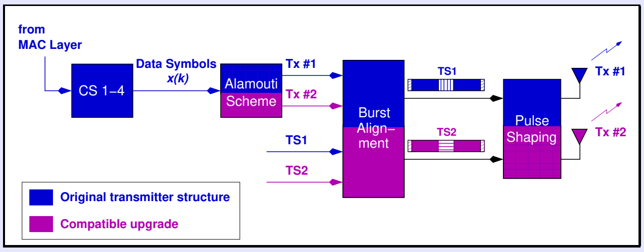
- In many current cellular systems two (or more) transmit (Tx) antennas are used at the **base station (BS)**, where the Tx signal is simultaneously transmitted over each antenna.
- **Enhancement:** Space-time codes; multiple antennas at the mobile station (MS) **not** required.
  - → Lower bit error rates/higher data rates due to **spatial diversity**.
  - → **Well suited** to enhance the crucial downlink (DL) ('bottleneck').
- **Example:** Alamouti scheme (S. M. Alamouti, 1998), simplest special case of a Space-Time Block Code (STBC) for two Tx antennas.
- **Goal:** Compatible improvement of the GSM/GPRS downlink by means of the Alamouti scheme.

2. Compatible Transmitter Structure

- **Alamouti scheme:**
  Pairs $[x(k), x(k+1)]$ of M-ary data symbols are transmitted over two antennas at two time instants k and $k+1$:

	k	$k+1$
Tx antenna #1:	$x(k)$	$x(k+1)$
Tx antenna #2:	$-x^*(k+1)$	$x^*(k)$

  ($(.)^*$ denotes complex conjugation.)
- **GPRS** ('General Packet Radio Service'):
  - Part of the GSM specifications ('Phase 2+').
  - Used for the transfer of packet-switched data.
- **Compatible upgrade** of the GSM/GPRS transmitter structure:
  - Retaining the adaptive **channel coding** schemes 'CS 1-4'.
  - **Space-time processing** of the binary data symbols $x(k)$ according to Alamouti scheme.
  - Mapping on GSM/GPRS bursts and Gaussian pulse shaping.
  - **Two different** training sequences TS1 and TS2 required.



3. Training Sequence Pairs

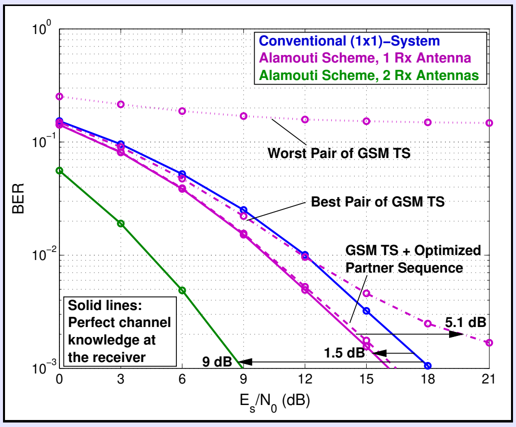
- For training sequence TS1, one of the **8 GSM training sequences** shall be used. However, the **GSM specifications** do not comprise any partner sequences w.r.t. the GSM sequences at all. Pairs of GSM sequences are characterized by comparably **poor cross-correlation** properties.
- Adequate partner sequences w.r.t. the 8 GSM training sequences:
  - Same **length** as the original GSM sequences (26 symbols).
  - Same **perfect** cyclic **autocorrelation** for shifts $|\xi| \leq 5$.
  - Pairs have **perfect cross-correlation** for shifts $|\xi| \leq 2$.
  - **Minimum** estimation error in case of a typical urban (TU) channel model (memory length $L = 3$).

4. Equalization

- **Trellis-based** maximum-likelihood sequence estimator (MLSE) for the Alamouti scheme:
  - Algorithms available for the conventional (1x1)-system have to be modified such that the received symbols are processed as **pairs** – corresponding to the Alamouti transmitter structure.
  - → A trellis segment spans **two** time indices k and $k+1$.
  - → As in case of the (1x1)-system, the **number** of possible **states** is M^L (L even).
  - → Same complexity compared to the MLSE for the conventional (1x1)-system.
- Due to Gaussian pulse shaping, equalization is required even in case of **frequency-flat fading**.

5. Simulation results

- **Simulation parameters:**
  - GSM 05.05 TU channel model, block fading channel.
  - Uncoded transmission.
  - Overall Tx power normalized w.r.t. the number of Tx antennas.
  - Root-raised-cosine Rx filter (roll-off $r = 0.5$).
  - MLSE.



⟹ **Significant** performance **improvements** w.r.t. the conventional (1x1)-system (especially for two Rx antennas).

⟹ Choice of **adequate** training sequence pairs is **crucial**.

6. Conclusions

- The Alamouti scheme is an **attractive technique** for a compatible extension of the current GSM/GPRS specifications with regard to **high data rate** wireless services.
- Adequate **training sequences pairs** are crucial for the overall system performance.
- An **MLSE** for the Alamouti scheme has been derived.

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