Improved scheme of Open loop Transmit Diversity (STTD) in the DS-CDMA case

S. MAYRARGUE, *CEA-LETI*

T. CLESSIENNE, *France Telecom R&D*

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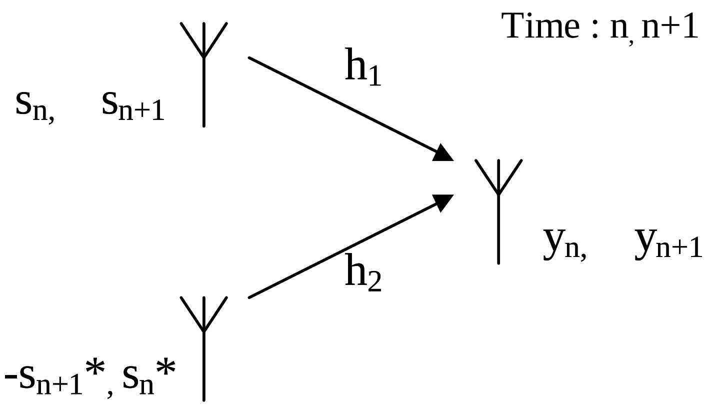
Outline

- STTD (Spatio-temporal transmit diversity or « Alamouti scheme ») in the flat fading case
- STTD: extension to frequency selective channels in UMTS
- Problems with UMTS approach in terms of intra-cell interference
- Conditions that spreading codes should fulfill in order to obtain full benefit of STTD for frequency selective channels in a CDMA system
- Simulation results
- Conclusion

STTD- flat fading case

- Spatio-temporal Transmit diversity original scheme



- $y_n = h_1 s_n - h_2 s_{n+1}^* + b_n$
- $y_{n+1} = h_1 s_{n+1} + h_2 s_n^* + b_{n+1}$

$\Leftrightarrow$

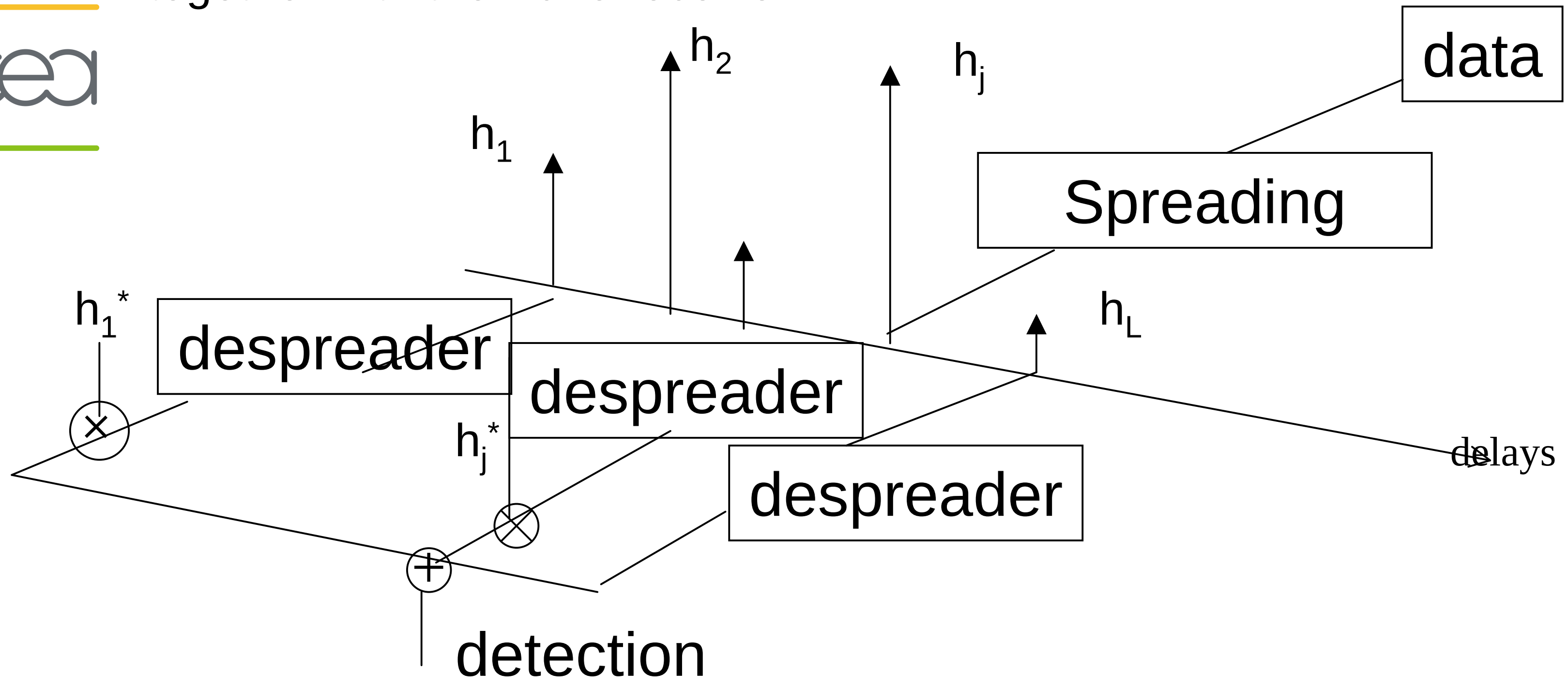
$$\begin{bmatrix} y_n \\ y_{n+1}^* \end{bmatrix} = \begin{bmatrix} h_1 & -h_2 \\ h_2^* & h_1^* \end{bmatrix} \begin{bmatrix} s_n \\ s_{n+1}^* \end{bmatrix} + \begin{bmatrix} b_n \\ b_{n+1}^* \end{bmatrix}$$

After matched filtering :

$$\begin{bmatrix} R_n \\ R_{n+1} \end{bmatrix} = \begin{bmatrix} h_1^* & h_2 \\ -h_2^* & h_1 \end{bmatrix} \begin{bmatrix} y_n \\ y_{n+1}^* \end{bmatrix} = \begin{bmatrix} |h_1|^2 + |h_2|^2 & 0 \\ 0 & |h_1|^2 + |h_2|^2 \end{bmatrix} \begin{bmatrix} s_n \\ s_{n+1}^* \end{bmatrix} + \begin{bmatrix} h_1^* & h_2 \\ -h_2^* & h_1 \end{bmatrix} \begin{bmatrix} b_n \\ b_{n+1}^* \end{bmatrix}$$

STTD: extension to frequency selective case, CDMA

- STTD introduced in UMTS standard « open loop- diversity » downlink together with the Rake receiver



- each branch of the Rake receiver corresponds to a flat fading case
- STTD flat fading is applied on each branch

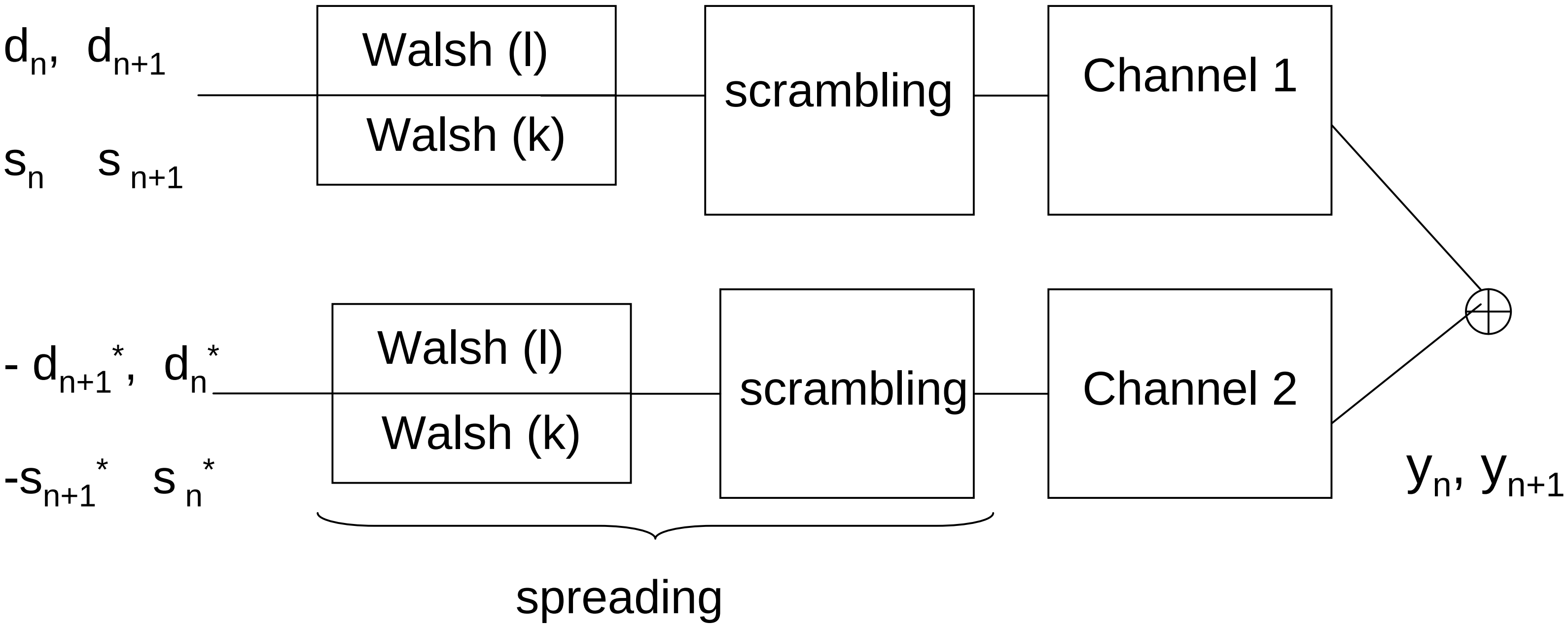
Problem with the previous approach

- CDMA is a MULTI CODE transmission system
- Simultaneously transmitted codes are orthogonal
- Multipath propagation induces orthogonality loss

⇨ Rake receiver is impaired by MAI (Multiple Access Interference)

STTD implemented as above creates additional MAI caused between codes transmitted during different time instants of the STTD symbol pair.

Example with 2 codes

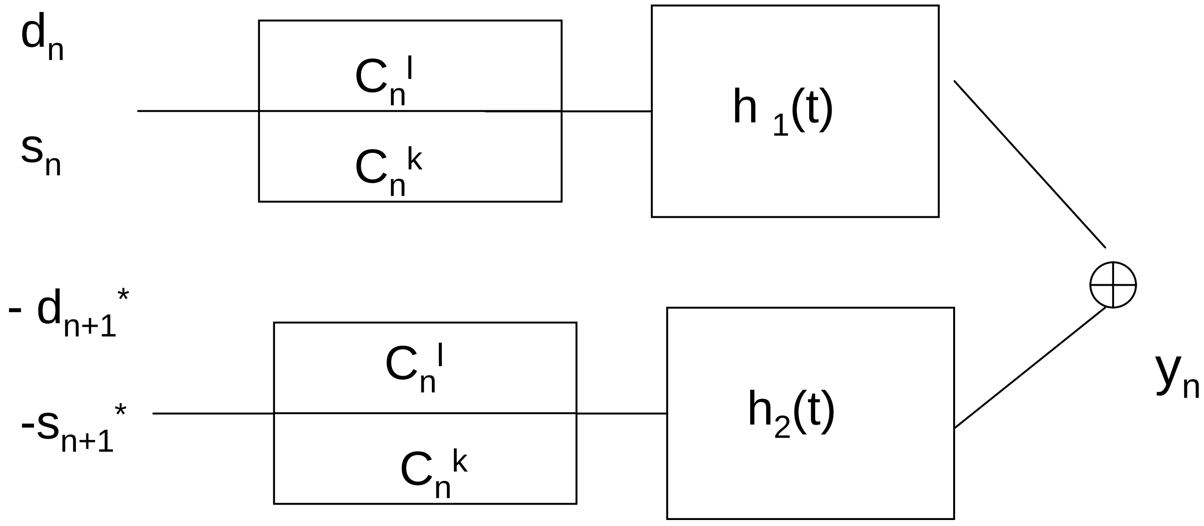


Spreading codes are time dependent after scrambling

C_n^k = diag (spreading seq. (n))* Walsh (k)

C_n^l = diag (spreading seq. (n))* Walsh (l)

Example with 2 codes- Time domain



$$Y_n(\tau) = (s_n h_1(t) - s_{n+1}^* h_2(t)) * C_n^k(t) + (d_n h_1(t) - d_{n+1}^* h_2(t)) * C_n^l(t)$$

$$Y_{n+1}(\tau) = (s_{n+1} h_1(t) + s_n^* h_2(t)) * C_{n+1}^k(t) + (d_{n+1} h_1(t) - d_n^* h_2(t)) * C_{n+1}^l(t)$$

- For notational simplicity, equations are considered in the frequency domain, which is equivalent to assuming a cyclic prefix, and to assimilate the Rake receiver to a matched filtering.

- Y_n (f) = (H_1(f) s_n – s_{n+1}* H_2(f)) $C_{n,}{}^k$ (f)+ (H_1 (f) d_n – d_{n+1}*H_2 (f)) C $_n{}^l$ (f)

- Y_{n+1} (f) = (H_1(f) s_{n+1} + s_n* H_2(f)) C $_{n+1}{}^k$ (f) + (H_1 (f) d_{n+1} - d_n*H_2(f)) $C_{n+1}{}^l$ (f)

$$\begin{bmatrix} Y_n(f) \\ Y^*_{n+1}(f) \end{bmatrix} = \begin{bmatrix} H_1(f)C^k_n(f) & -H_2(f)C^k_n(f) \\ H^*_2(f)C^{k\,*}_{n+1}(f) & H^*_1(f)C^{k\,*}_{n+1}(f) \end{bmatrix} \begin{bmatrix} s_n \\ s^*_{n+1} \end{bmatrix} +$$

$$\begin{bmatrix} H_1(f)C^l_n(f) & -H_2(f)C^l_n(f) \\ H^*_2(f)C^{l*}_{n+1}(f) & H^*_1(f)C^{l\,*}_{n+1}(f) \end{bmatrix} \begin{bmatrix} d_n \\ d^*_{n+1} \end{bmatrix}$$

$$= H(f) \begin{bmatrix} s_n \\ s^*_{n+1} \end{bmatrix} + H_{int}(f) \begin{bmatrix} d_n \\ d^*_{n+1} \end{bmatrix}$$

Example with 2 codes Matched filtering

- Matched filtering the previous equation gives

$$\begin{bmatrix} R_n \\ R_{n+1} \end{bmatrix} = \int_B H^*(f) \begin{bmatrix} Y_n(f) \\ Y^*_{n+1}(f) \end{bmatrix} df = \int_B H^*(f) H(f) \begin{bmatrix} s_n \\ s^*_{n+1} \end{bmatrix} df + \int_B H^*(f) \left(H_{int}(f) \begin{bmatrix} d_n \\ d^*_{n+1} \end{bmatrix} \right) df$$

- In order to avoid s_{n+1} (resp. s_n) interfere with estimate of s_n (resp. s_{n+1}), we have to have

$$\int_B H^*(f)\, H(f)\, df \quad // \text{identity matrix}$$

- « usual » MAI is created by dn (resp d_{n+1}) interfering on s_n (resp. s_{n+1}). « extra » MAI would be created by d_{n+1} (resp. d_n) interfering on s_n (resp. s_{n+1}). Avoiding this « extra » MAI, we should have

$$\int_B H^*(f) H_{int}(f)\, df = \text{diagonal matrix}$$

Dependencies on codes

$$\int_B H^*(f)H(f)\,df = \int \begin{bmatrix} |H_1|^2|C_n^k|^2 + |H_2|^2|C_{n+1}^k|^2 & H_1^* H_2\,(|C_{n+1}^k|^2 - |C_n^k|^2) \\ H_1^* H_2\,(|C_{n+1}^k|^2 - |C_n^k|^2) & |H_1|^2|C_{n+1}^k|^2 + |H_2|^2|C_n^k|^2 \end{bmatrix} df$$

Clearly, this matrix is proportional to Identity iff $|C_n^k|^2 = |C_{n+1}^k|^2$

$$\int_B H^*(f)H_{int}(f)\,df = \int \begin{bmatrix} |H_1|^2 C_n^{k*} C_n^l(f) + |H_2|^2 C_{n+1}^{k*} C_{n+1}^{l*}(f) & H_1^* H_2\,(C_{n+1}^k C_{n+1}^{l\,*} - C_n^{k*} C_n^l) \\ H_1 H_2^*\,(C_{n+1}^k C_{n+1}^{l*} - C_n^{k*} C_n^l) & |H_1|^2 C_{n+1}^{k*} C_{n+1}^l(f) + |H_2|^2 C_n^{k*} C_n^{l*}(f) \end{bmatrix} df$$

This matrix is diagonal if $C_{n+1}^k(f) = C_n^{k*}(f)$ for all codes

NB This second condition implies the first one

What does it mean?

- C_{n+1}^{k} (f) = $C_{n}^{k\,*}$ (f) in the frequency domain means

  C_{n+1}^{k} (t) = $C_{n}^{k\,*}$ (T-t) in the time domain

Codes on each symbol of the STTD pair should be time reversed and conjugate from each other.

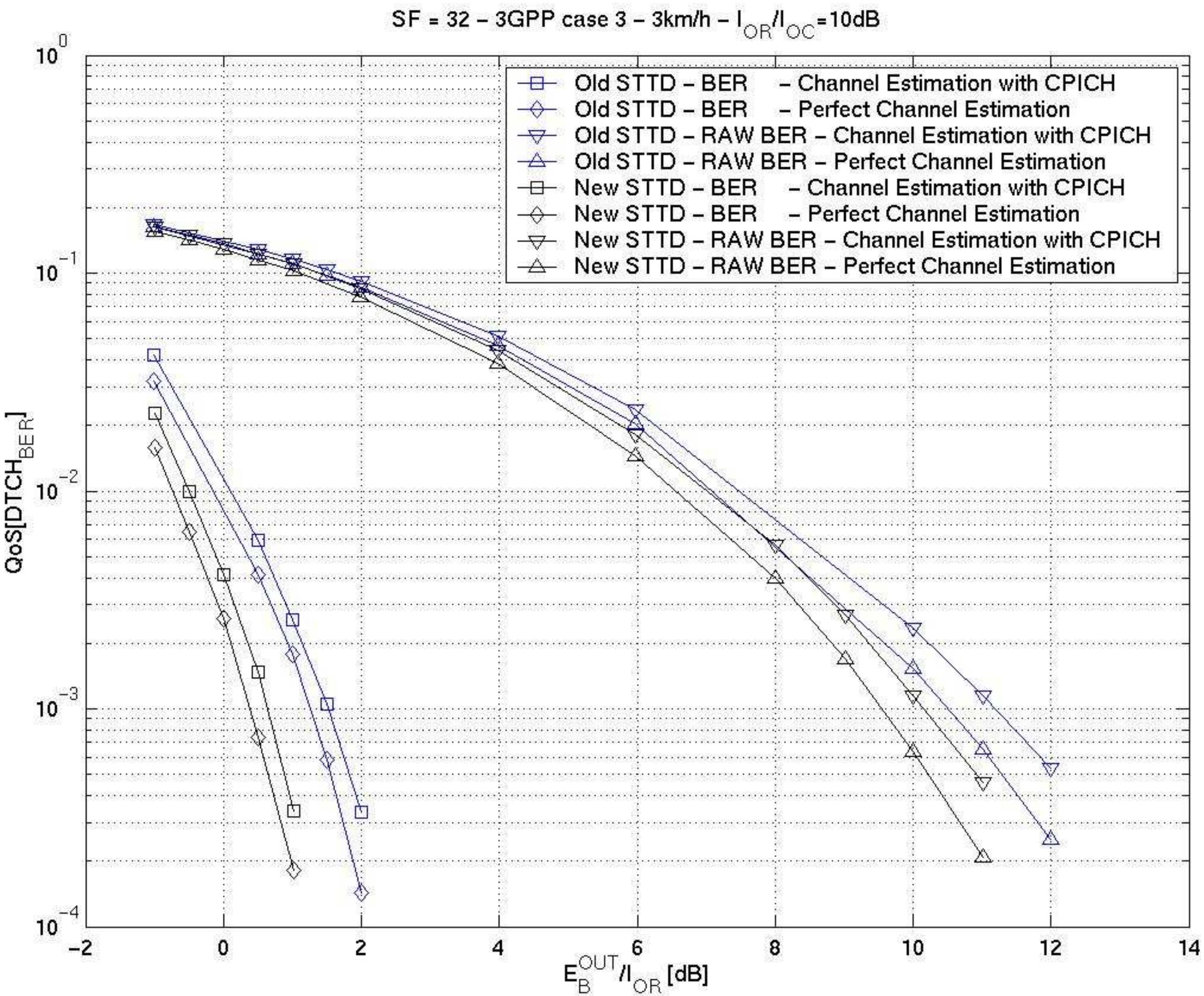
Both orthogonal codes and scrambling sequence should have this property.

Otherwise, additional MAI arises.

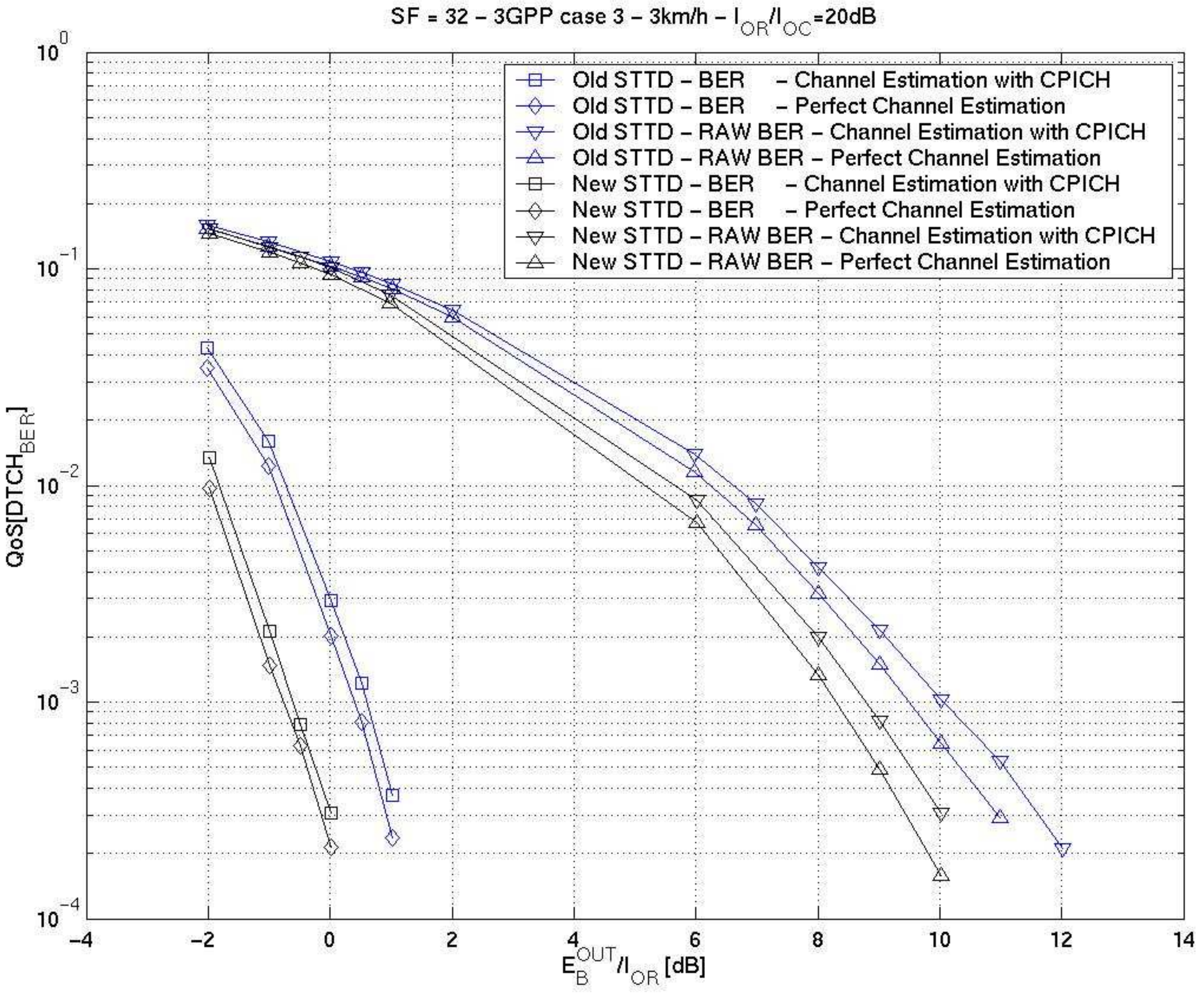
This is the case in UMTS!!

Simulation results for UMTS

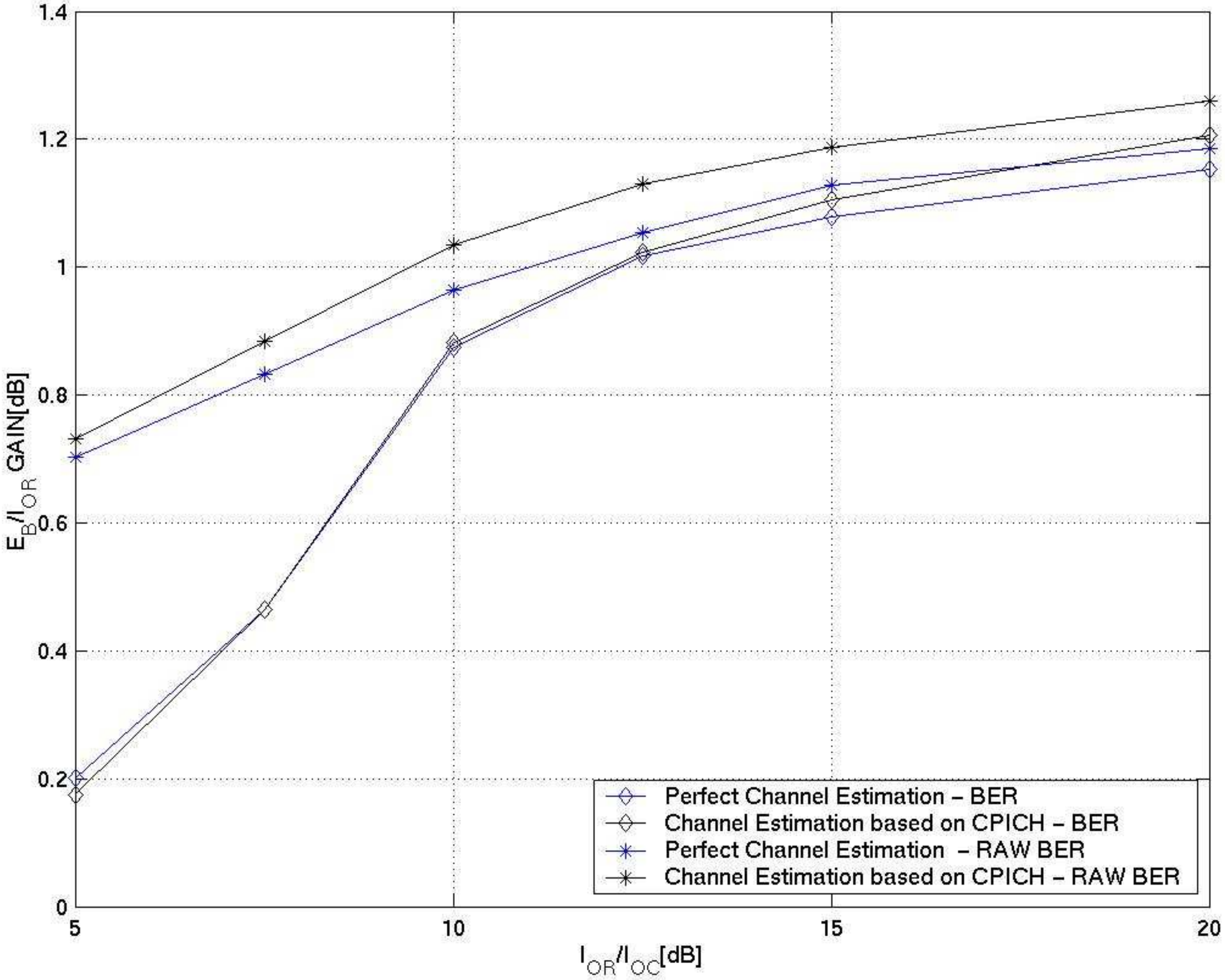
- Comparison of «usual » STTD with STTD with modified codes
- SF =32
- Mobile speed = 3km/h
- Channel 3 of 3GPP
- Ior/Ioc = 10 dB, 20 dB (ratio between intra cell interference caused by other codes, and extra cell interference, modelled by gaussian noise)
- Channel estimation using CPICH
- 2 sets of simulations: with and without coding. Coding is a turbo coding with rate = 1/3



SF = 32 – 3GPP case 3 – 3km/h – I_OR/I_OC=10dB
Old STTD – BER – Channel Estimation with CPICH
Old STTD – BER – Perfect Channel Estimation
Old STTD – RAW BER – Channel Estimation with CPICH
Old STTD – RAW BER – Perfect Channel Estimation
New STTD – BER – Channel Estimation with CPICH
New STTD – BER – Perfect Channel Estimation
New STTD – RAW BER – Channel Estimation with CPICH
New STTD – RAW BER – Perfect Channel Estimation
QoS[DTCH_BER]
E_B^OUT/I_OR [dB]


SF = 32 – 3GPP case 3 – 3km/h – I_OR/I_OC=20dB
Old STTD – BER – Channel Estimation with CPICH
Old STTD – BER – Perfect Channel Estimation
Old STTD – RAW BER – Channel Estimation with CPICH
Old STTD – RAW BER – Perfect Channel Estimation
New STTD – BER – Channel Estimation with CPICH
New STTD – BER – Perfect Channel Estimation
New STTD – RAW BER – Channel Estimation with CPICH
New STTD – RAW BER – Perfect Channel Estimation
QoS[DTCH_BER]
E_B^OUT/I_OR [dB]
10^0
10^-1
10^-2
10^-3
10^-4
–4
–2
0
2
4
6
8
10
12
14

Simulation results 3/3



Conclusion

- A simple modification in the spreading code allows a 1dB improvement on STTD performances, compared to the usual UMTS implementation