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BCPM

Implementation details

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See the notes pages for an explanation of the slides

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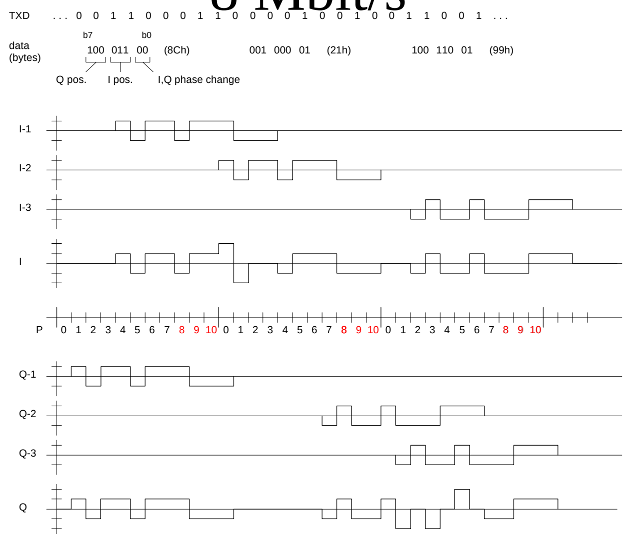
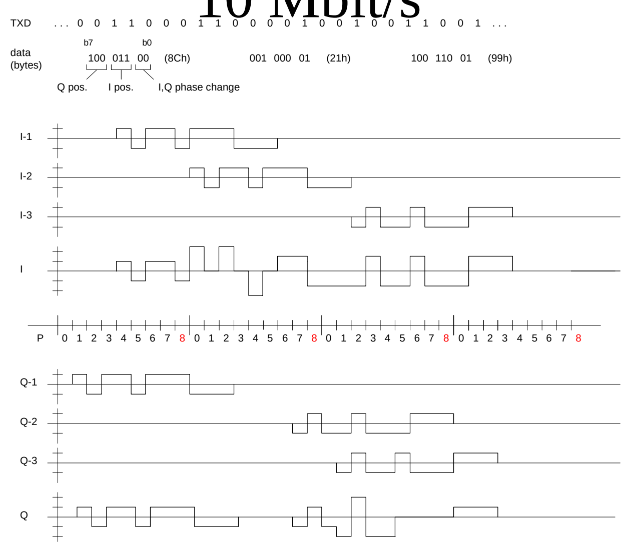
Contents

- Transmitter
  - 10 Mbit/s modulation scheme
- Receiver structure / complexity
- Implementation / performance trade-off
- Preamble / training
  - interoperability / coexistence

8 Mbit/s



10 Mbit/s



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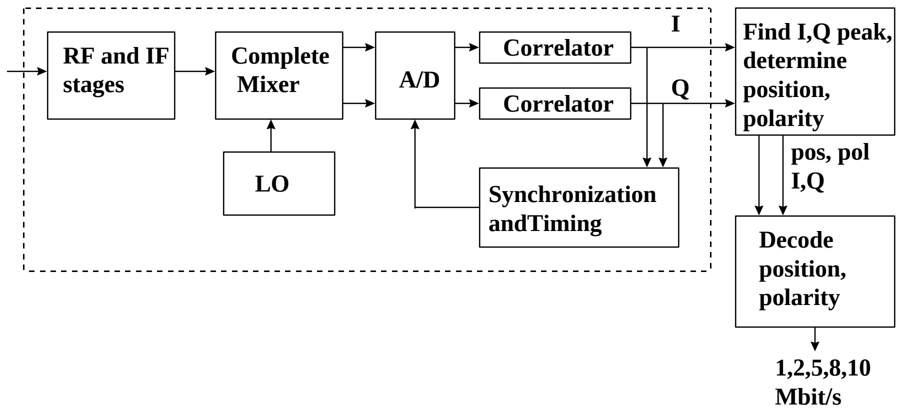
Basic receiver structure



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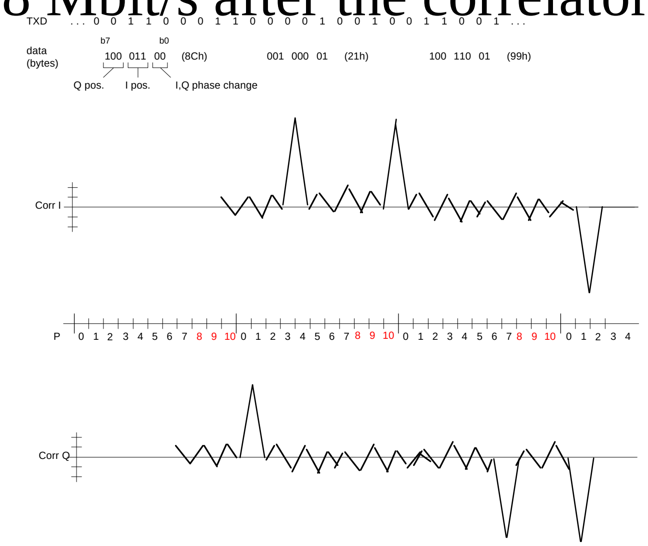
8 Mbit/s after the correlator



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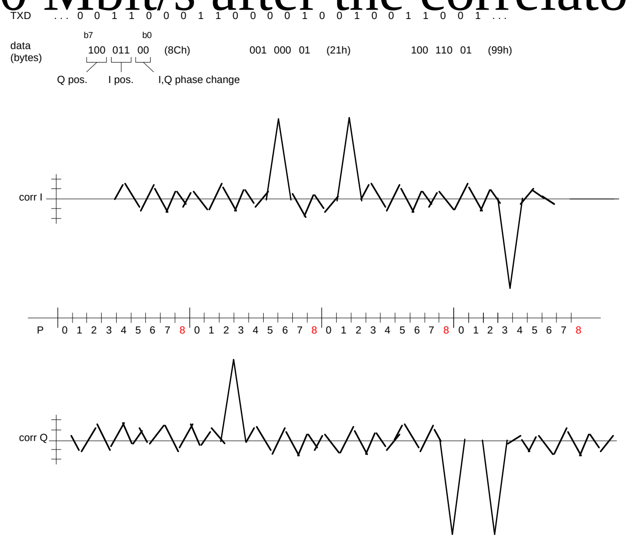
10 Mbit/s after the correlator



8 and 10 Mbit/s compared

- Eb/N0
  - detection problem is the same (QPSK and 1 out of 8 positions)
    - Eb/N0 = 6dB for both 8 and 10 Mbit/s
- SNR
  - At 10 Mbit/s 11/9 more (0.87dB) than 8 Mbit/s
  - Effect on link budget minimal, because also 11/9 more energy is send at the transmitter (Barker sequences shifted into each other)

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Performance at multipath channel

- Delayspread in combination with Barker sidelobs reduce the performance
- With basic receiver delayspread up to 30-40 ns can be handled
- Dramatic improvement by treating sidelobs and the channel with MLSE techniques
- MLSE receiver structure is not complex due to Barker correlation properties

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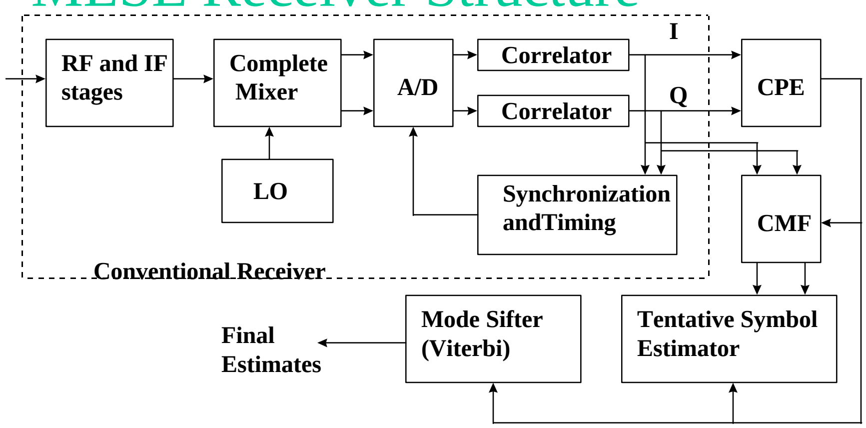
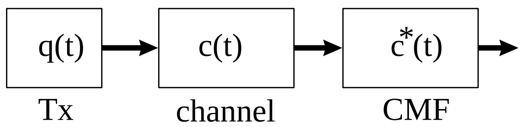
MLSE Receiver Structure



CPE channel parameter estimator
CMF channel matched filter

Channel Matched Filter

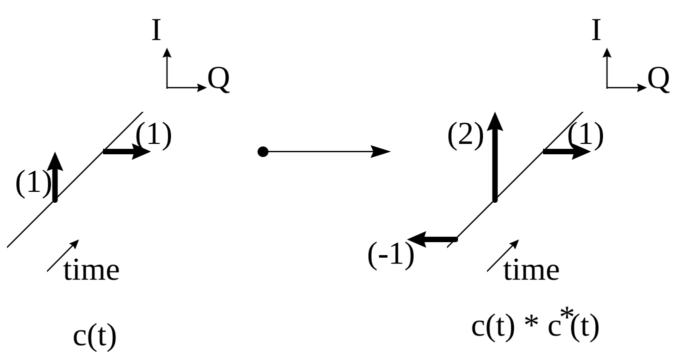
- CMF is the complex conjugate of the channel impulse response c(t)



Output of CMF is the impulse response of the transmitted signal by the convolution of the channel and the CMF
[c(t) * c*(t)]

Simple example

– Two ray channel impulse response



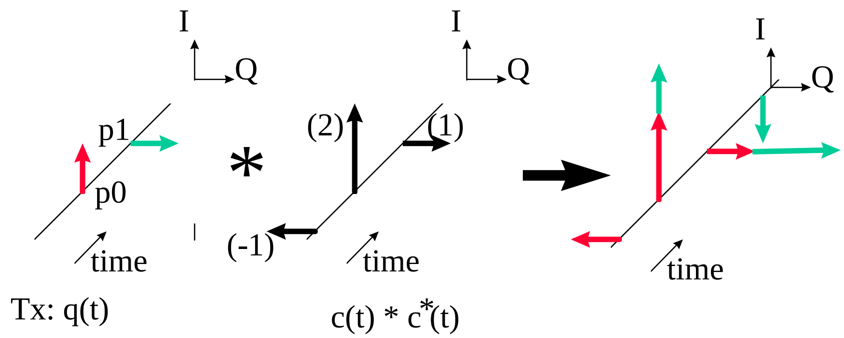
Benefits of the application of the CMF

- Concentrates energy, improving SNR
- Gives (anti-)symmetric impulse response
- Gives optimal sample timing

Tentative Symbol Estimator

- With knowledge of channel the TSE removes cross rail interference i.e. crosstalk of I component on the Q component and vice versa and estimates the 4 most likely positions combinations for I and Q
- Crossrail interference is caused by the channel (echoes) and the CMF (convolution of the two)
- Interference is known
- Interference of I on Q and Q on I is symmetrical because of the antisymmetrical impulse response of the channel and the CMF and is defined by the imaginary part of $c(t) * c^{*}(t)$

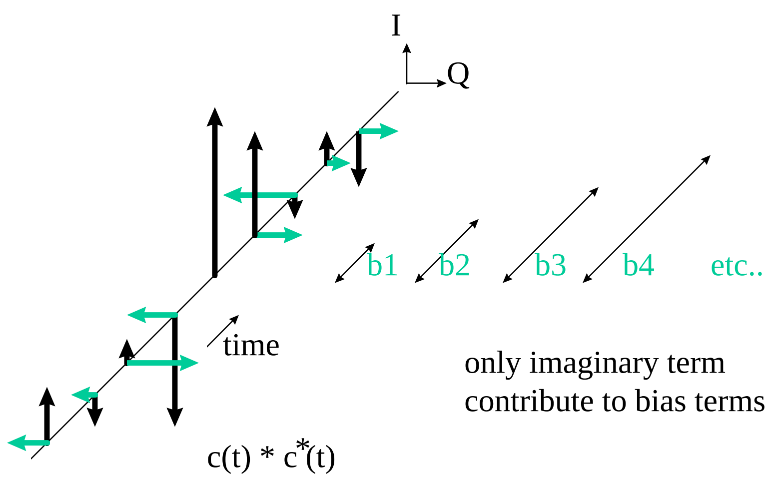
Crossrail example



Because of knowledge of the channel crossrail terms (imag. part of c(t) * c (t)) are known (bias terms)

Bias terms are calculated during training (8 values for 8 positions)

Biasterms



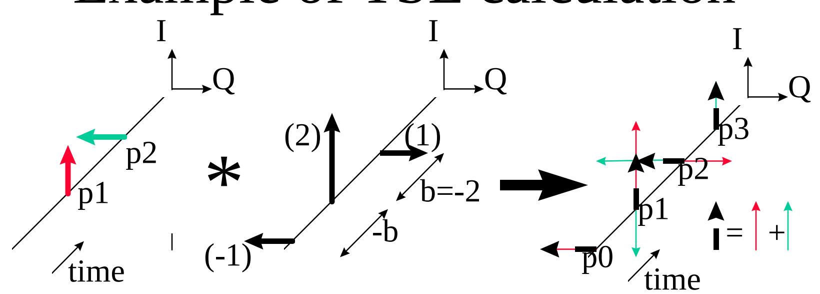
TSE procedure

- For all possible positions of I (from 0 to 7) and Q (also from 0 to 7) calculate:

	maximum determines polarity of I and Q	
	I	Q
b+(I+Q)	+	+
b-(I+Q)	-	-
-b+(I-Q)	+	-
-b-(I-Q)	-	+

- Select 4 maxima out of 64 (to be evaluated in the Mode Sifter (trellis))

Example of TSE calculation



Tx: q(t)

c(t) * c*(t)

Position evaluation

I position	Qposition	b	b+(I+Q)	b+(I-Q)	-b+(I-Q)	-b-(I-Q)
1	2	-2	-2	-2	4	0
1	0	2	2	2	0	-4
3	2	2	2	2	0	-4

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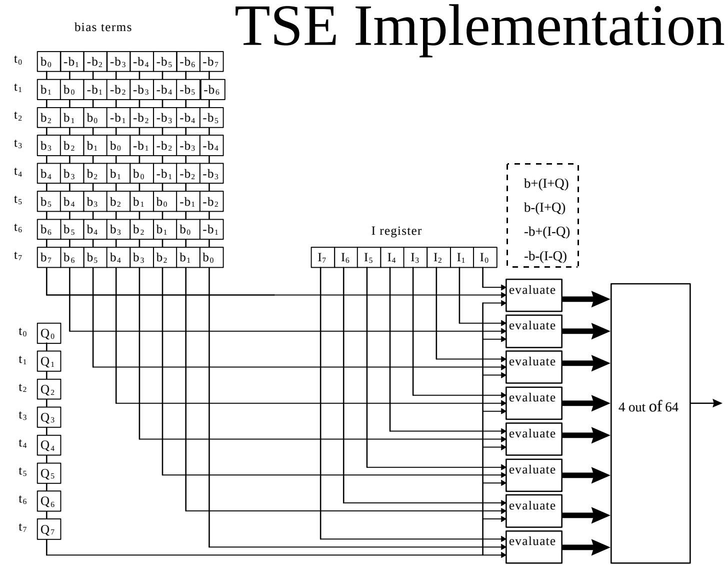
TSE Implementation



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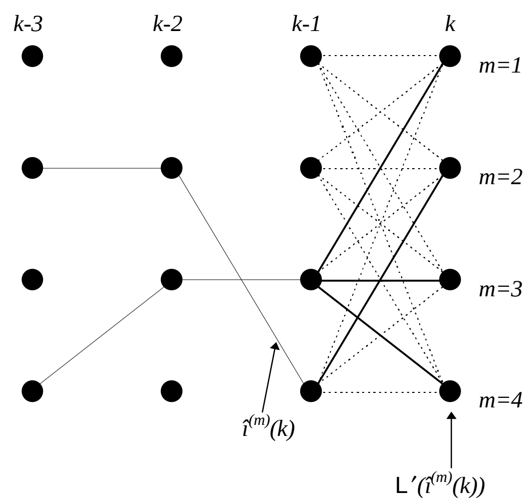
TSE implementation

- Low complexity:
  - in evaluation block 64 *4*2 additions during a symbol period (1 microsecond)
    - optimal implementation choices can reduce this number
  - selection of 4 maximum values out of 64

The Mode Sifter

- Reduced state trellis structure sifting the tentatively retained modes (maxima of TSE)
- Calculates path metric taking ISI and sidelobs into account
- Trellis path determines final estimate
  - path depth of 4 is sufficient

Trellis structure



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Metric calculation

- Iteration process

$$\Lambda'(\boldsymbol{\hat{\imath}}^{(m)}(0)) = V(\hat{\imath}^{(m)}(0))$$
$$\Lambda'(\boldsymbol{\hat{\imath}}^{(m)}(k+1)) = \Lambda'(\boldsymbol{\hat{\imath}}^{(m)}(k)) + V(\hat{\imath}^{(m)}(k+1)) - G(\hat{\imath}^{(m)}(k+1), \hat{\imath}^{(m)}(k))$$

where V is the metric as calculated in the TSE
G is the ISI term

- At each step (symbol) the addition of the two terms have to be performed for 16 possible paths

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The ISI term

$$\begin{aligned} G(\hat{\imath}(k+1), \hat{\imath}(k)) = \; & \hat{a}(k)\hat{a}(k+1)L_r(11 + \hat{l}_a(k+1) - \hat{l}_a(k)) + \hat{b}(k)\hat{b}(k+1)L_r(11 + \hat{l}_b(k+1) - \hat{l}_b(k)) \\ & + \hat{a}(k)\hat{b}(k+1)L_i(11 + \hat{l}_b(k+1) - \hat{l}_a(k)) - \hat{b}(k)\hat{a}(k+1)L_i(11 + \hat{l}_a(k+1) - \hat{l}_b(k)) \end{aligned}$$

where: $\hat{a}(k)$ = sign of the real part of symbol *î(k)*: {1,-1}
$\hat{b}(k)$ = sign of the imaginary part of symbol *î(k)*: {1,-1}
$\hat{l}_a(k)$ = position of the real part of symbol *î(k)*: {1,2,3,4,5,6,7,8}
$\hat{l}_b(k)$ = position of the imaginary part of symbol *î(k)*: {1,2,3,4,5,6,7,8}
î(k) = $(\hat{a}(k), \hat{b}(k), \hat{l}_a(k), \hat{l}_b(k))$
$L_r(k)$ = real part of autocorrelation function of basic received signal (Barker-code + channel)
$L_i(k)$ = imaginary part of autocorrelation function of basic received signal (Barker-code + channel)

Complexity of Modesifter

- Metric calculation
  - 16 * 5 additions per symbol
- Path maintenance
  - basic digital techniques can be applied
- Because the reduced trellis structure (4X4) the Modesifter has, compared to other blocks, a rather low complexity in terms of gates

Performance/complexity trade-off

- Basic receiver
  - no CMF, TSE or MS
  - gate count 20-30 Kgates
  - will work in a (simple) office environment
    - up to 30-40 ns delayspread for 8 and 10Mbit/s
    - fall back to 1,2 or 5 Mbit/s

Performance/complexity trade-off

- Basic receiver with CMF
  - gatecount 35-45 Kgates
  - works in office environments and most other environments at 5 Mbit/s fallback
  - delayspread
    - 5 Mbit/s 275-350 nsec
    - 8 Mbit/s 55-90 nsec
    - 10 Mbit/s 50-80 nsec

Performance/complexity trade-off

- receiver with CMF, TSE and MS
  - gatecount about 60 Kgates
  - works in office, retail and industrial environments
  - delayspread
    - 5 Mbit/s 355-400 nsec
    - 8 Mbit/s 235-265 nsec
    - 10 Mbit/s 130-220 nsec

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Preamble and training

- Training (above standard 1 Mbit/s)
  - 8 or 16 symbols for CMF
  - calculation for Bias and ISI terms
    - during processing of 1Mbit/s SFD (16 symbols)
- Optional short preamble is proposed
  - draft text doc 98-10r
  - March presentation 98-99

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Interoperability / Coexistence

conclusion

- Interoperabilty
  - short preamble Tx - short preamble Rx
  - long preamble Tx - long preamble Rx
  - long preamble Tx - short preamble Rx
- Coexistence
  - all Proposed DS Phy’s
- BUT..

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Coexistence with FH

- Symbol Technologies showed that coexistence with Frequency hoppers can be achieved by adding a FH signal preceding the preamble.
- Lucent proposes to incorporate the optional extension into the BCPM proposal.

Conclusions

- BCPM is not complex
- Implementation of a MLSE structure is not complex for BCPM
  - CMF, TSE and MS described
  - Doubles gate count compared to 2 Mbit/s DS
- Implementation (gate count) / performance trade-off
- Coexistence/interoperability with current DS and FH standard