A new receiver for digital mobile radio channels with large multipath delay

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- Sparse channel simplification
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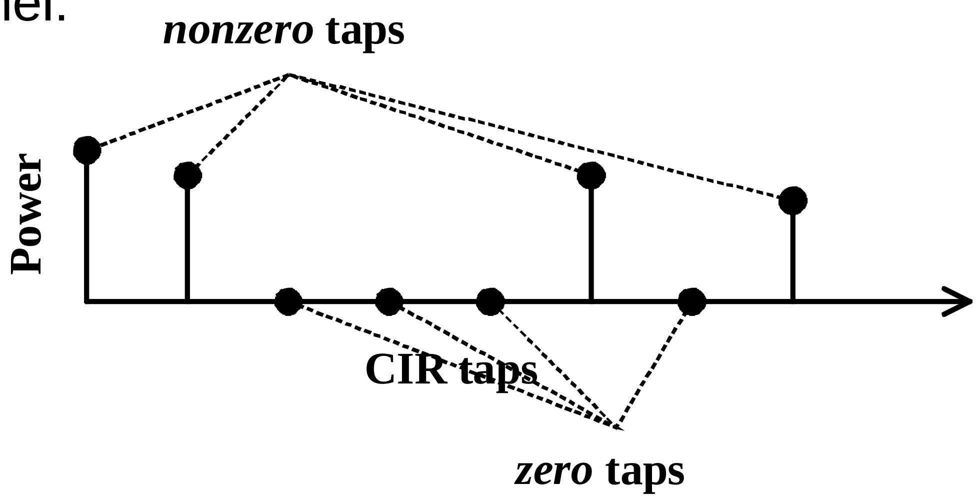
  - calculation of transition probability matrix
- Equalisation strategy
- Numerical results
- Conclusions

Introduction

- “sparse“ channel:



- motivation for sparse channel simplification
  - complexity reduction, handling high symbol rates

⇒ we propose sparse channel algorithm for SBS-MAP equaliser

Known algorithms for SC-equalisation

Using MLSE:

N.C. McGinty, R.A. Kennedy, P. Hoeher, “Parallel Trellis Viterbi Algorithm for Sparse Channels”, IEEE Communications Letters, May **1998**.

N. Benvenuto, R. Marchesani, “The Viterbi Algorithm for Sparse channels”, IEEE Transactions on Communications, March **1996**.

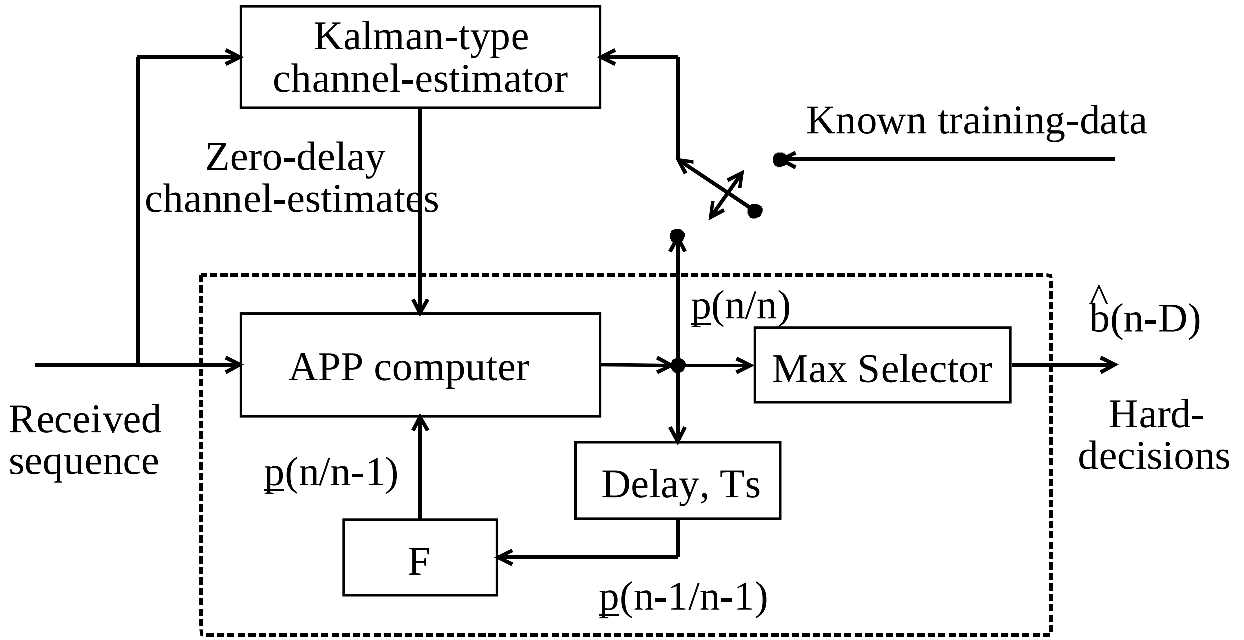
N. Ishii, R. Kohno, “Tap selectable Viterbi Equalisation Combined with Diversity Antennas”, IEICE Transactions on Communications, Nov. **1995**.

J.C.S. Cheung, R. Steele, “Modified Viterbi equaliser for mobile radio channels having large multipath delays”, Electronics Letters, Sept. **1989**.

Using DFE:

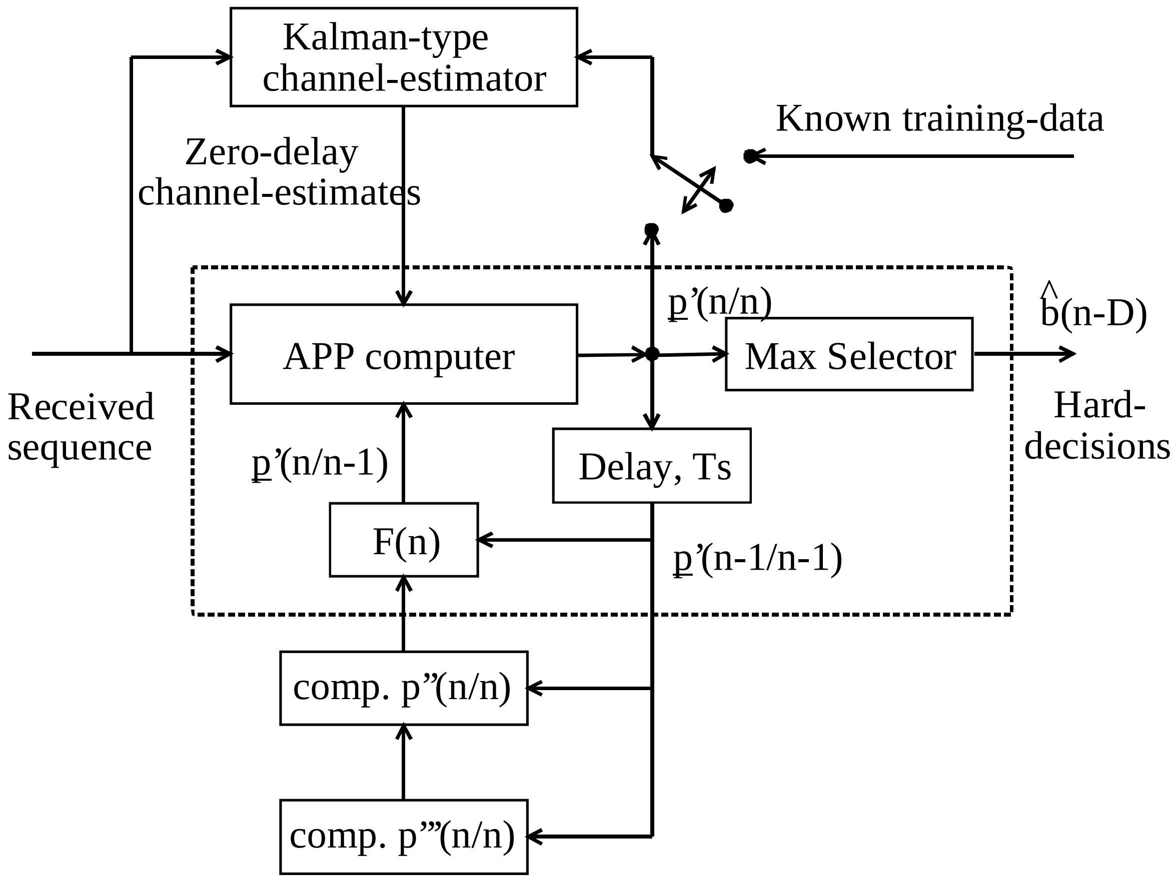
S. Ariyavisitakul, N.R. Sollenberger, L.J. Greenstein, “Tap-Selectable Decision-Feedback Equalization”, IEEE Transactions on Communications, Dec. **1997**.

Conventional MAP equaliser



- F is the channel state transition probability matrix
- p(n/n) is the A Posteriori Probability vector of the actual channel state
- p(n/n-1) is the A Posteriori Probability vector of the predicted channel state

Sparse channel simplification

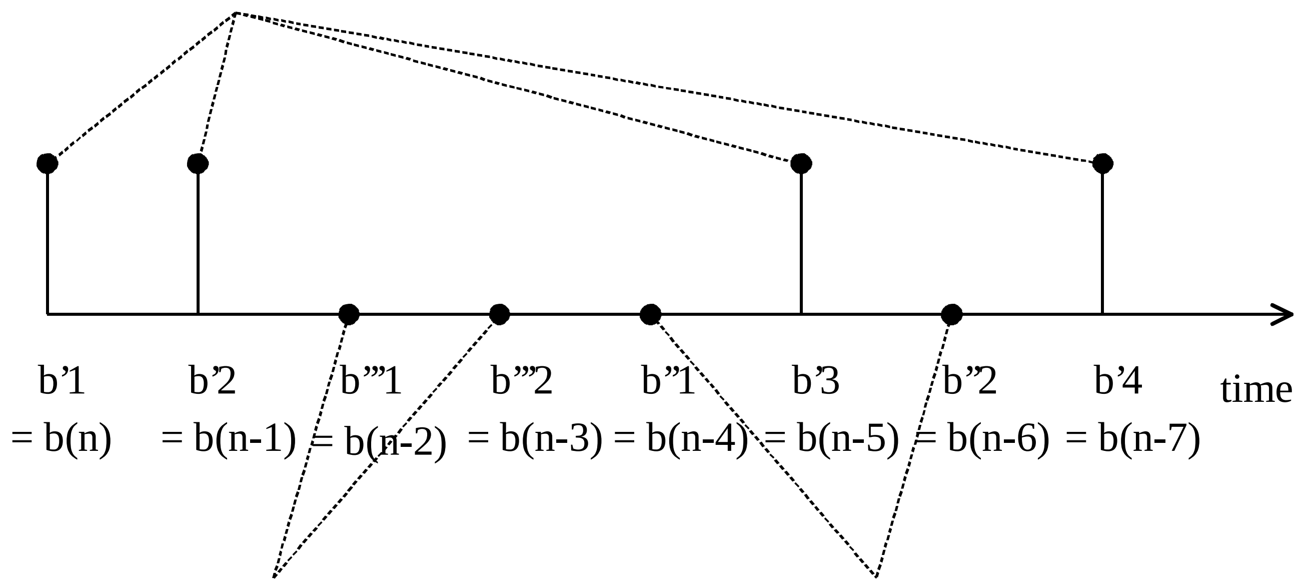


- equalisation using *nonzero* taps only
- based on substates: p'(n/n) p''(n/n) p'''(n/n)
- F is now time dependent

Dividing states into substates

Visible Channel State => p’(n/n)

b’(n) = { b’1 b’2 b’3 b’4 }



Far Hidden Channel State

b’’’(n) = { b’’’1 b’’’2 }

=> p’’(n/n)

Near Hidden Channel State

b’’(n) = { b’’1 b’’2 }

=> p’’’(n/n)

Calculation of channel state transition probability matrix, F(n)

- needed in the calculation of the one-step prediction of $\underline{p}(n/n)$

  $\underline{p}(n/n\text{-}1) = F \cdot \underline{p}(n\text{-}1/n\text{-}1)$

For SC-MAP:

- one-step prediction over the *visible channel states* only

  $\underline{p}'(n/n\text{-}1) = F(n) \cdot \underline{p}'(n\text{-}1/n\text{-}1)$

- however, each prediction over the *visible channel states* is affected by the symbols that become visible at the next step, i.e., *near hidden states*

  $\rightarrow$ each *near hidden channel state* requires a different realisation of the transition probability matrix

- F(n) is calculated by averaging the different transition probability matrix realisations weighted by their probabilities at step n

Equalisation strategy

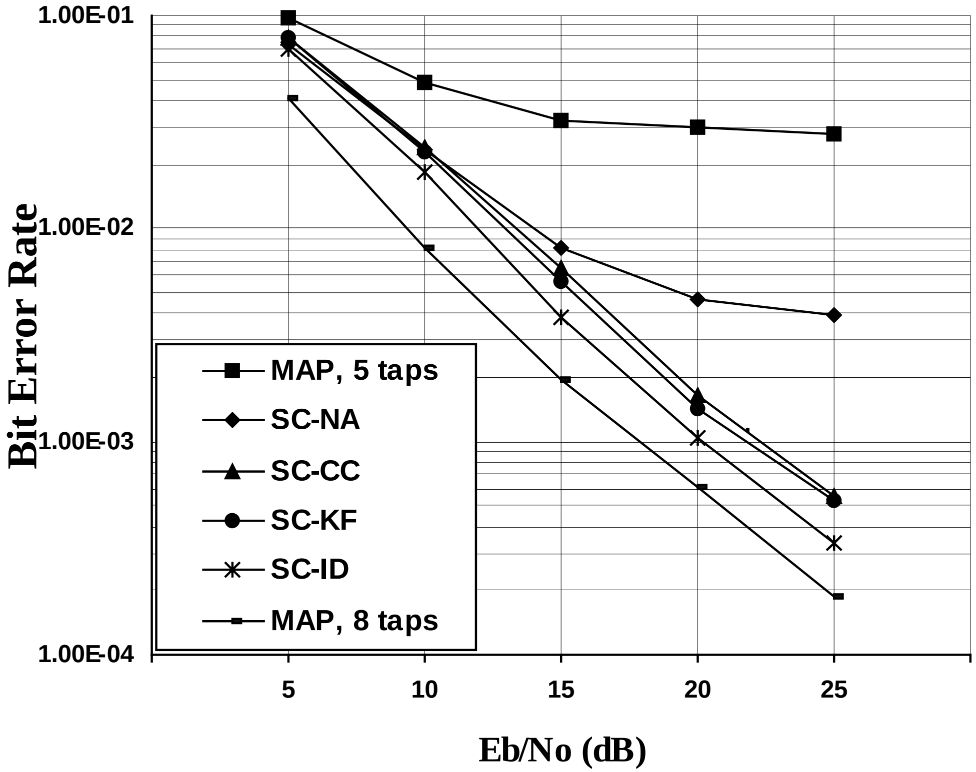
- equalisation strategy:
  1. identify the *nonzero* taps from the training sequence
  2. re-estimate the selected *nonzero* CIR taps from the training sequence via the data-aided ANKL channel estimator
  3. apply SC-MAP equaliser (with the ANKL channel estimator) to process and decode the received data symbols

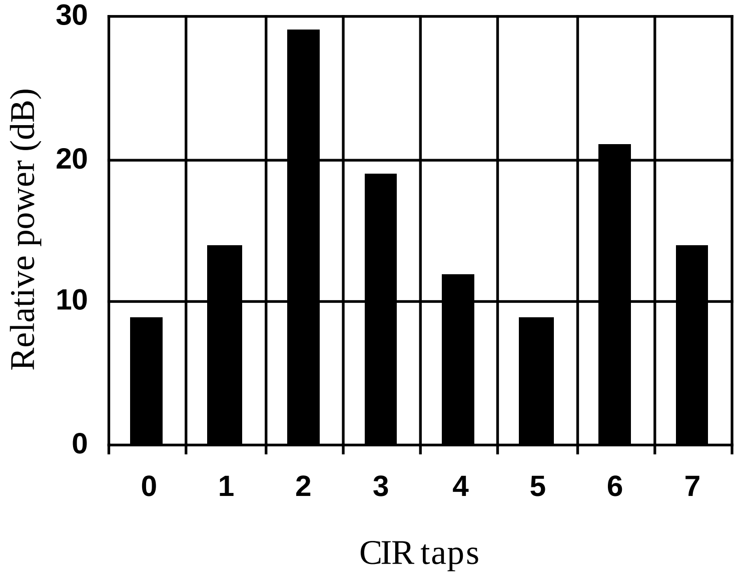
- locations of the *nonzero* taps are identified via
  - SC-CC: cross-correlation method
  - SC-KF: data-aided Kalman-like filter
  - SC-ID: true CIR taps at the end of the preamble
  - SC-NA: channel power-delay profile a priori

Numerical results

- modulation BPSK with 270.8Kbps or 500Kbps
- independent timeslots each with
  - 26 preamble bits + 58 data bits for 270.8Kbps
  - 52 preamble bits + 116 data bits for 500 Kbps
- Hilly Terrain (HT) GSM test channel
- Land Mobile fading spectrum with $B_d T_s = 10^{-4}$

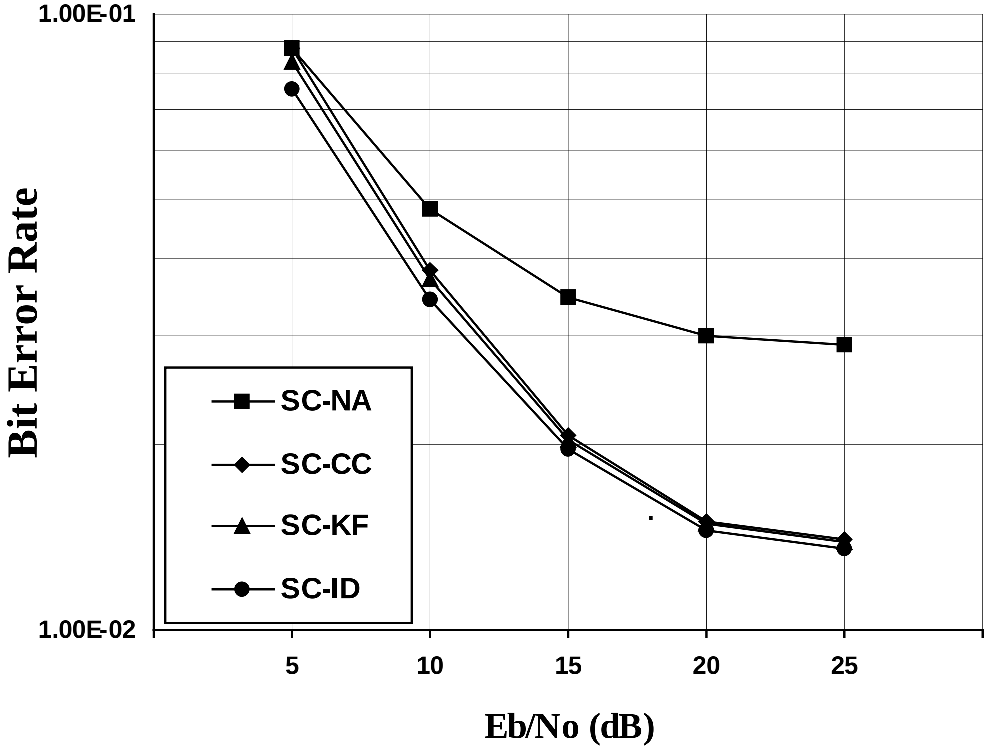
SC-equalisation with 5 nonzero taps

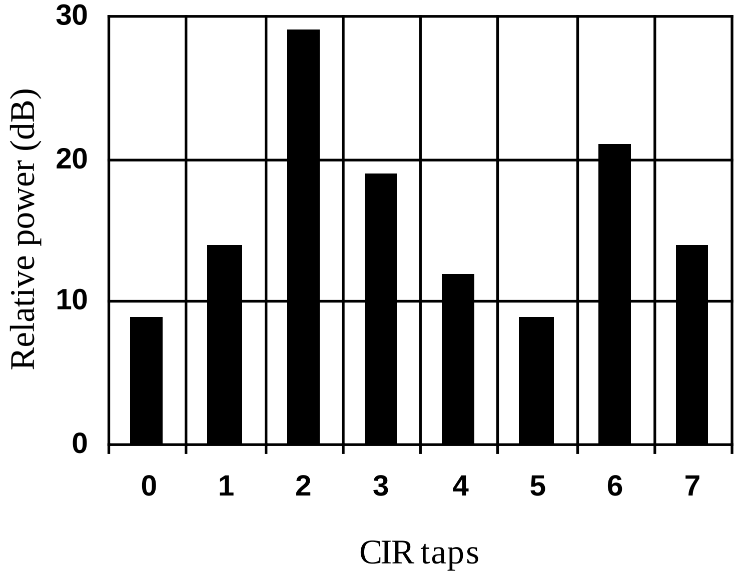




- modulation BPSK @270.8Kbps
- framing (26,58)

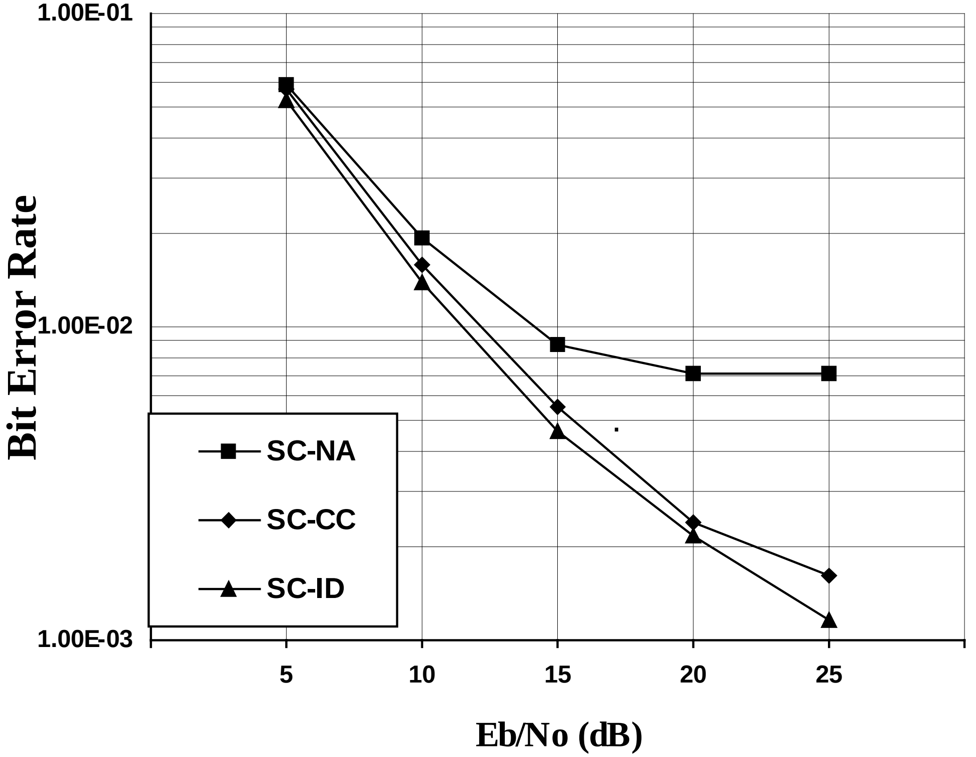
SC-equalisation with 2 nonzero taps

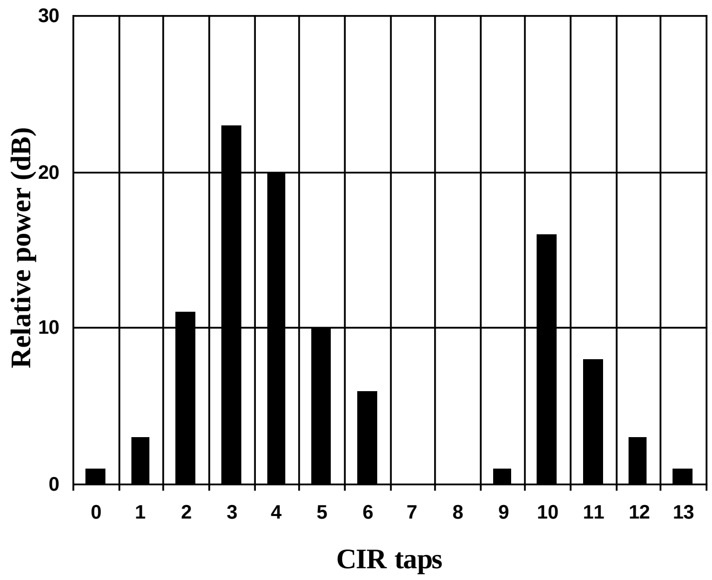




- modulation BPSK @270.8Kbps
- framing (26,58)

SC-equalisation with 4 nonzero taps





- modulation BPSK @500Kbps
- framing (52,116)

Example of computing times

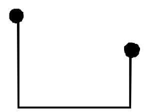
CIR power/delay profile	MAP equaliser	SC-MAP equaliser (NNZ=2)
L=2: [1/2 1/2]	1.0	1.0
L=3: [1/2 0 1/2]	2.6	1.1
L=4: [1/2 0 0 1/2]	10.6	1.4
L=5: [1/2 0 0 0 1/2]	44.2	1.7
L=6: [1/2 0 0 0 0 1/2]	198.2	1.8
L=7: [1/2 0 0 0 0 0 1/2]	1018.0	1.8

- complexity of MAP grows exponentially with L
- complexity of SC-MAP with L=7 is less than twice that with L=2

Conclusions

- SC-MAP equaliser + Kalman-like channel estimator with
  - complexity proportional to the number of *nonzero* CIR taps
  - performance very close to the “full“ MAP when the *nonzero* taps carry most of the energy
- methods for locating the *nonzero* CIR taps

$\Rightarrow$ practical solutions for digital radio-mobile receivers!



b(n)	b(n-1)	p(n/n)
-1	-1	0.95
-1	1	0.01
1	-1	0.02
1	1	0.01