6.2 ML-MUD With Signatures – Classic Results

- With signatures, each antenna output expands to an inner product per user – in fact, KL correlations per symbol time for synchronous, or NKL correlations per packet if asynch. This is our familiar

$$\underline{y}_m = R\,C_m A\,\underline{b} + \underline{\nu}_m$$

- The problem is still to find which of the candidate sequences has the highest likelihood.

- [Verd 86], a densely-written paper, is the base of much of what we know of ML-MUD with signatures. System: AWGN, asynchronous, flat, single antenna.

  Contributions:

  - decomposition of the metric into a cyclically causal format, limiting the state set explosion
  - upper and lower bounds on error performance
  - tightening the union (upper) bound through definition of "decomposable" error sequences and discard of unnecessary terms

– definition of asymptotic multiuser efficiency

· Examples

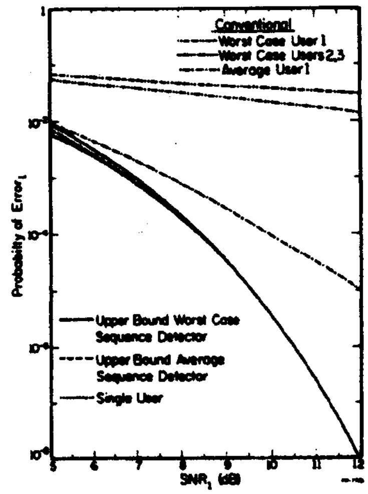
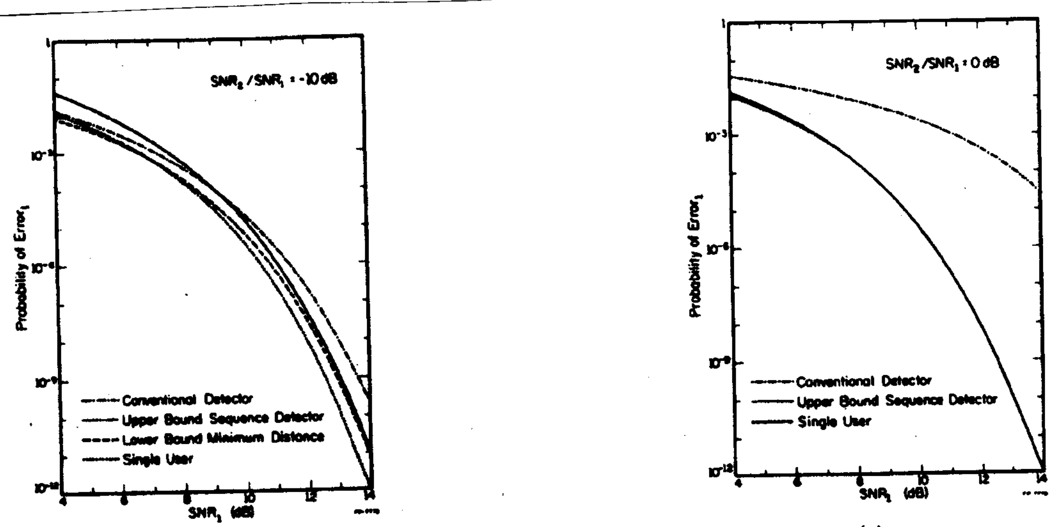


Fig. 5. Worst-case and average error probabilities achieved by conventional and optimum multiuser detectors with three active users employing m-sequences of length 31.

$N_c = 31$
$K = 3$
BER dep. on value of rel. delays

Worst-case relative delay is infrequent, but devastating for the conventional detector. MLSD doesn't even notice it

– Down to K = 2, examine near far. This is Pe for stronger user when interferer is −10 dB, 0 dB



(a)

(c)

Fig. 6. Bounds on minimum error probability of user 1. Worst-case delays and two active users. (a) $w_2/w_1 = -10$ dB. (b) −5 dB. (c) 0 dB.

As interferer becomes stronger, conventional detector has seriously compromised performance, but strong user moves to the single user bound!

- [Lupa 90] focuses power disparities, near-far issues.

  Model: asynch CDMA, AWGN, flat

  Contributions:

  - introduced definition of near-far resistance
  - demonstrated near-far resistance of ML and decorrelator

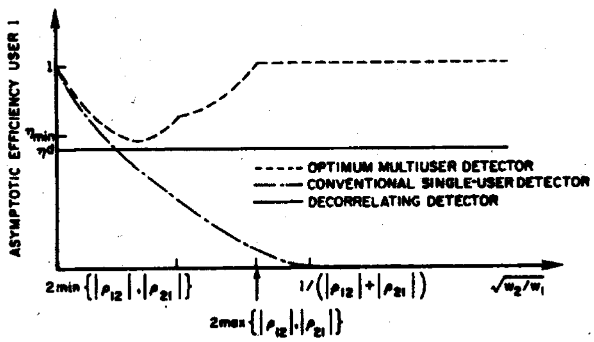


Fig. 7. Asymptotic efficiencies in the two-user case for infinite transmitted sequence length, when the user energies are constant over time (here we chose $|\rho_{12}|, |\rho_{21}| = 0.3, 0.5$ which yields $\eta_{min} = 0.68$, $\eta^d = 0.59$).

  - noted that imperfect decorrelation (due, e.g., to model error) remove the NFR defined in a strict sense.

- [Zvon 94] took it to fading channels.

Model: asynchronous, flat fading, single antenna, perfect CSI

- New results:
  - upper and lower bounds using quadratic forms
  - tightened the union bound by extending decomposability to fading channels
  - asymptotic multiuser efficiency definition and calculation for fading channels.
- Numerical presentation

$N_c = 127 \quad K = 2$

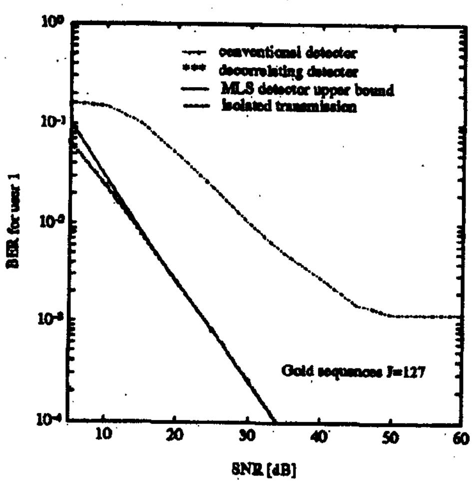


Fig.2. Bit error rate of user 1 for the two-user case with Rayleigh faded paths (same average path strength) and Gold sequences of period J=127.

- Low correlation between users, but fading produces error floor in conventional (easily derived). ML is indistinguishable from single user bound.
- Lightly loaded

$N_c = 3 \quad K = 2$

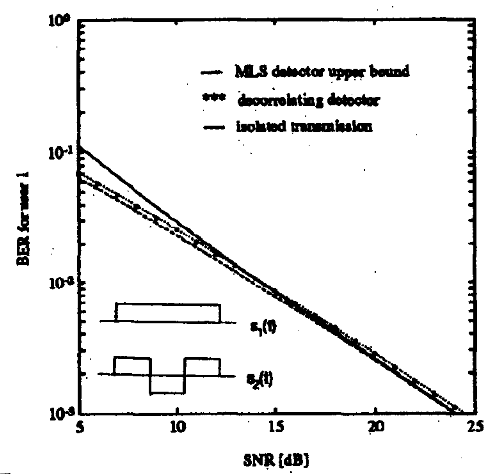


Fig.3. Bit error rate of user 1 for the two-user case with Rayleigh faded paths (same average path strength) , spreading ratio J=3.

- High correlation. MLSD is virtually identical to single user, supporting speculation (Sect. 6.1) that spreading reduces the SNR penalty. Note decorrelator does well – it could handle at most one more user.
- Heavily loaded