Multiuser Detection Algorithms: Techniques for Improving Computing Power of Multiuser Receivers

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Motivation

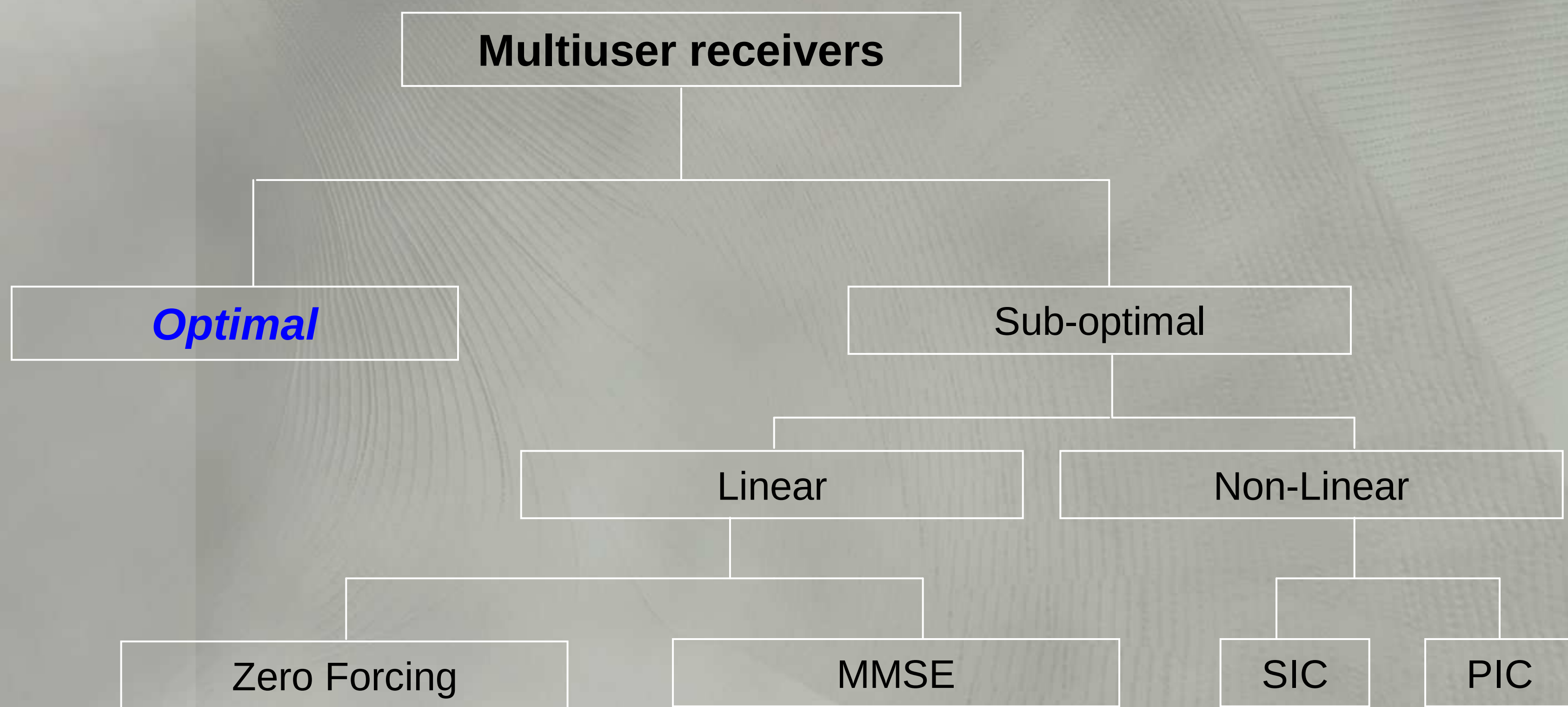
- **Reduce the computational complexity of optimum receivers.**
- **Maintain an acceptable BER for voice communication networks.**

Outline

- **Background and Related Work**
- **Multiuser detection algorithms**
  - **Maximum likelihood (ML)**
    - ***Problem Statement***
  - **Transformation Matrix (TM)**
- **Performance Analysis**
  - **Bit Error Rate (BER)**
  - **Signal to Noise Ratio (SNR)**
- **Conclusion & Future Work**

Background & Related Work

Multiuser Optimal and Suboptimal Receivers



Sub-Optimal Multi-user Receiver

- **Features**
  - In order to reduce the complexity, Sub optimal multiuser receivers have been proposed.
  - Few of them achieve close to optimal performance with reasonable computational complexity.
  - Detect simultaneously all user signals
  - For signal detection, they perform linear transformation.

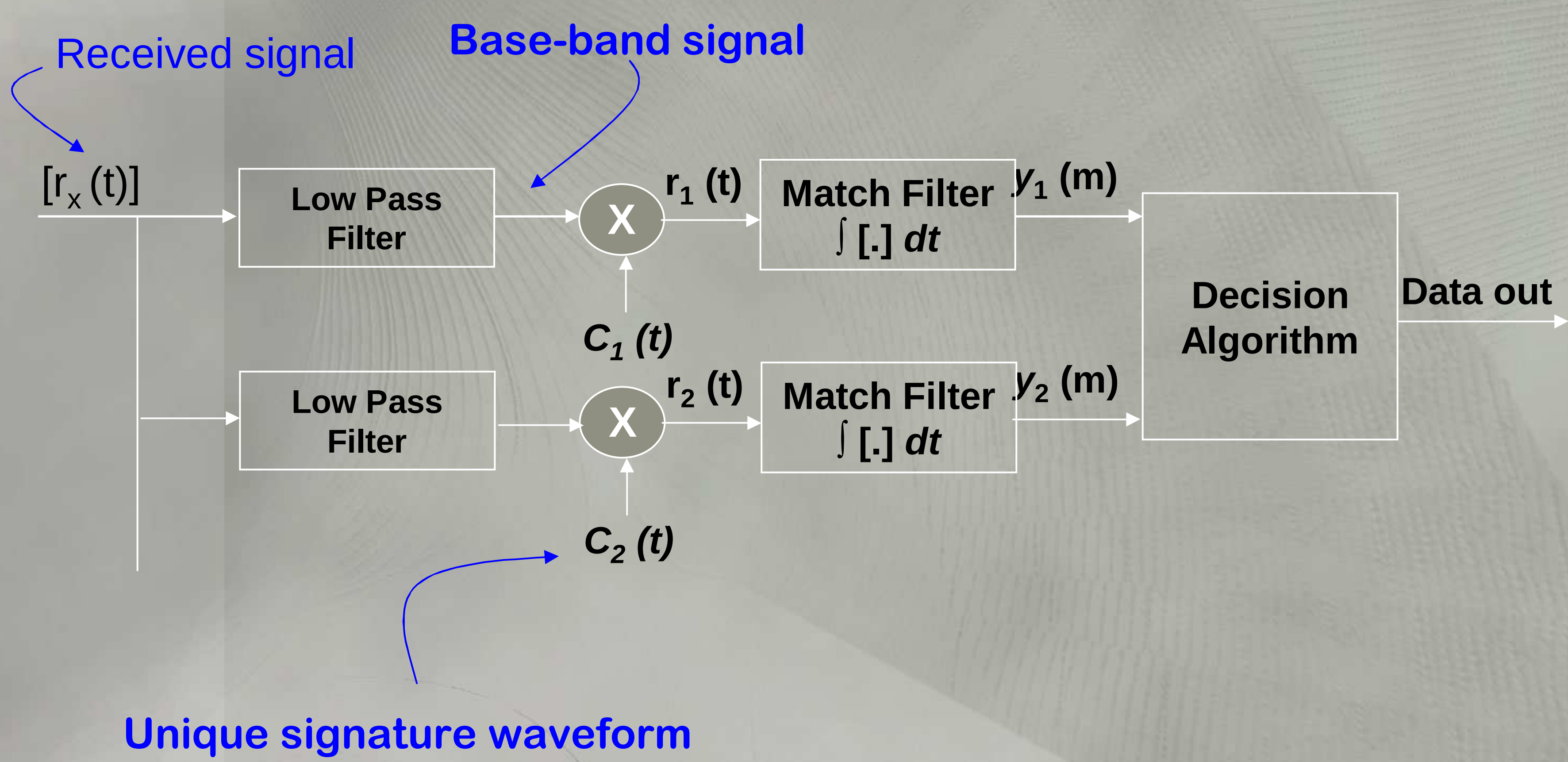
- **Problems**
  - Enhance the noise component significantly.
  - Degrades the BER performance.

Optimal Multi-user Receiver

- First proposed by Verdu’s in 1985.
- Consists of a match filter with maximum likelihood (ML) detector
- Use a maximum likelihood (ML) detection instead of linear transformation.
- Improve both data rate and the user capacity.
- Give optimal performance.
- Computational complexity is $O(2)^k$.

Problem Statement

Optimal Multi-user Receiver



Block diagram of an optimum receiver

Problems with the existing Verdu's Optimum Receiver

- **High computational complexity at the receiving end**
  - Complexity grows exponentially with respect to number of users.
  - Asymptotic computational complexity is approximately $O(2)^k$.

- **Decision Algorithm performs MAI cancellation for all K-1 users**
  - Detection of a desire signal depends on the cross-correlation.
  - Searches all received demodulated bits to find out all possible decision regions.
  - Provide Slower detection rate (***i.e., reduce the computing power of a receiver***).

Transformation Matrix (TM) Algorithm

TM Algorithm

Main Idea

- Transformation Matrix approach
- Perform MAI cancellation only on selected users.
- Eliminate unnecessary MAI cancellation.
- Reduce the computational complexity at the receiving end.
- Computational complexity is $O(5/4)^K$

Implementation Issue

- *How to determine most correlated users? ….*

TM Algorithm

- ***Transformation matrix stores pattern of occurrences of the demodulated bits.***
- ***Demodulated bits correspond to a range of users.***
- ***Transformation matrix helps to determine the decision region.***
- ***Decision algorithm can determine the strongest signals coming from K-1 users.***
- ***Transformation matrix processes only those bits that most likely lead to an incorrect decision.***

Mathematical Model for TM Algorithm

- The output of the match filter can be transformed:

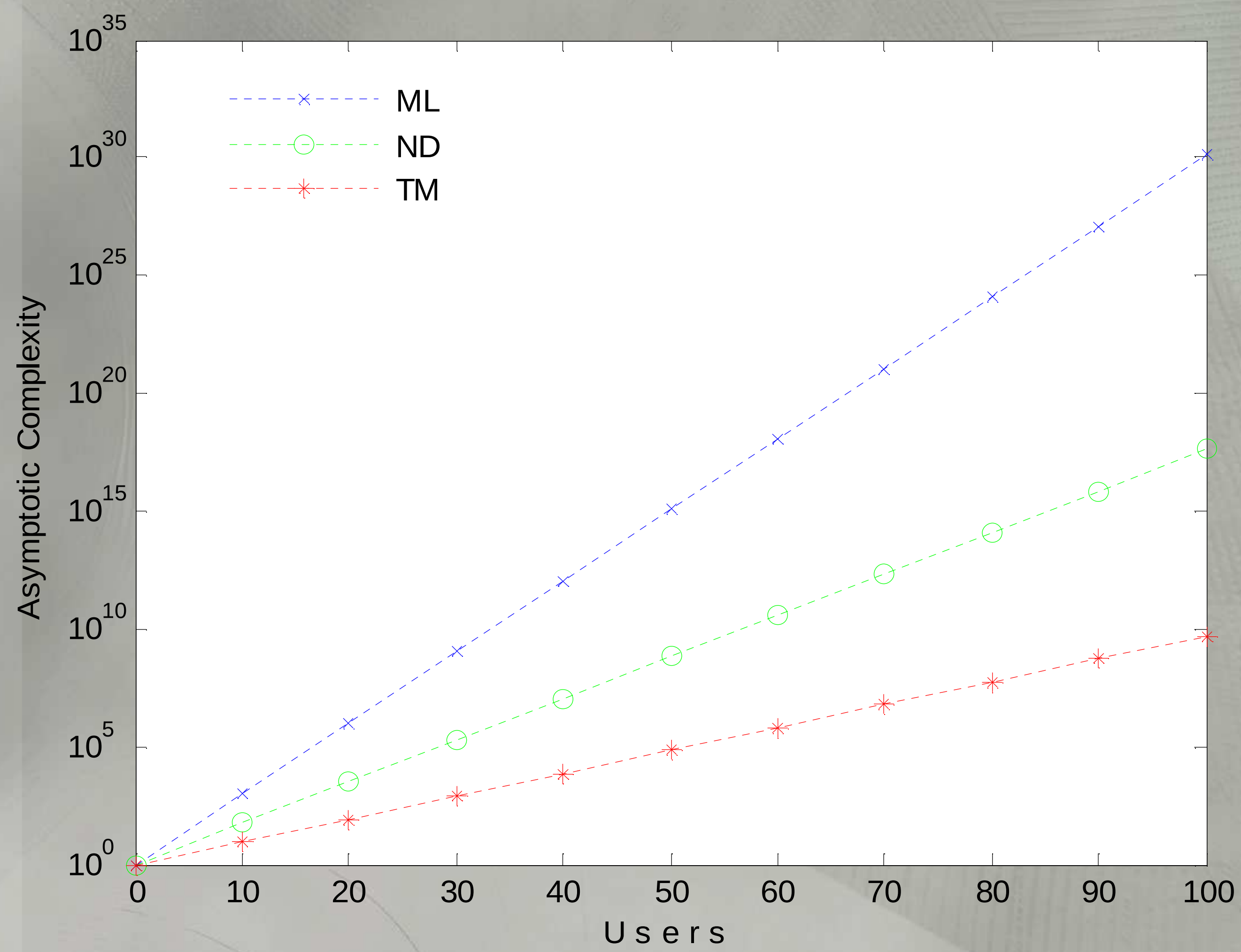
$$y(m) = \mathrm{T}\,\mathrm{b} + \eta$$

  - *T* represents the *transformation matrix*
  - b represents the *demodulated bits*
  - *η* represents the *noise components*

- **Use transformation matrix only on selected region.**
- **Decision region indicates MAI cancellation.**
- **Should not process correct decision.**

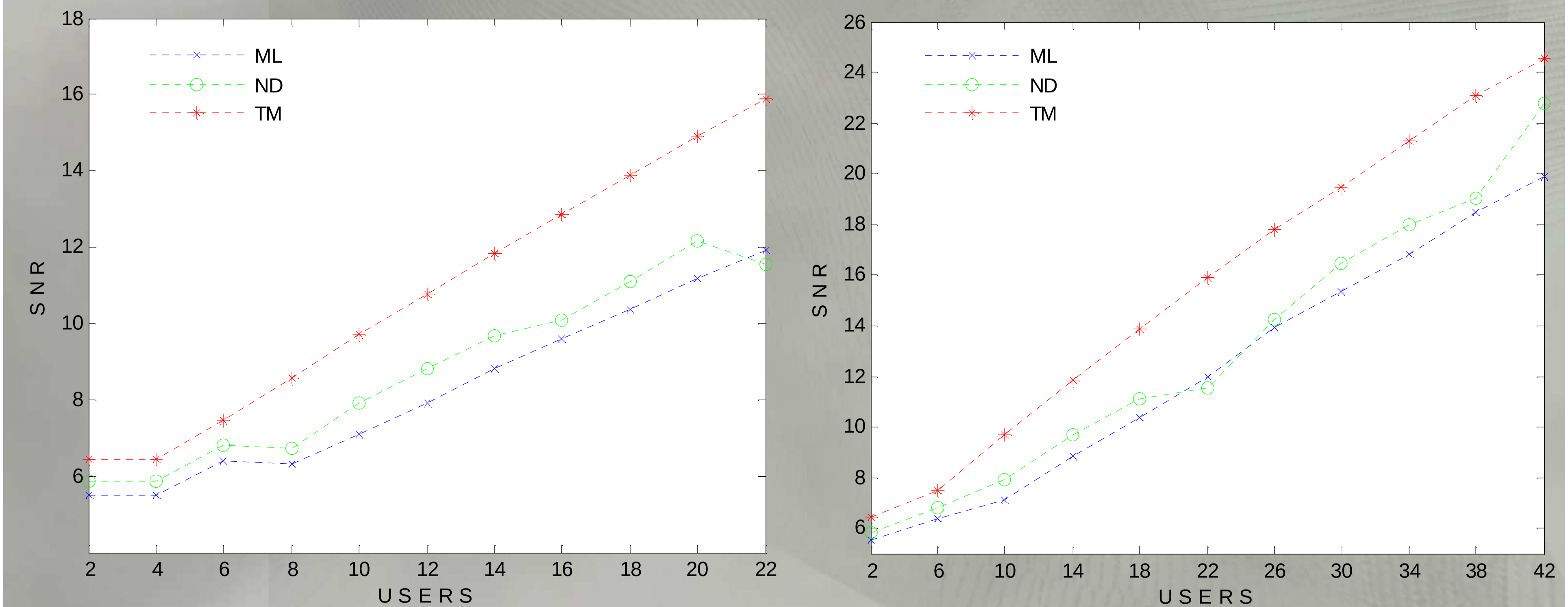
Performance Analysis

Comparison of Computational Complexities for 100 Users



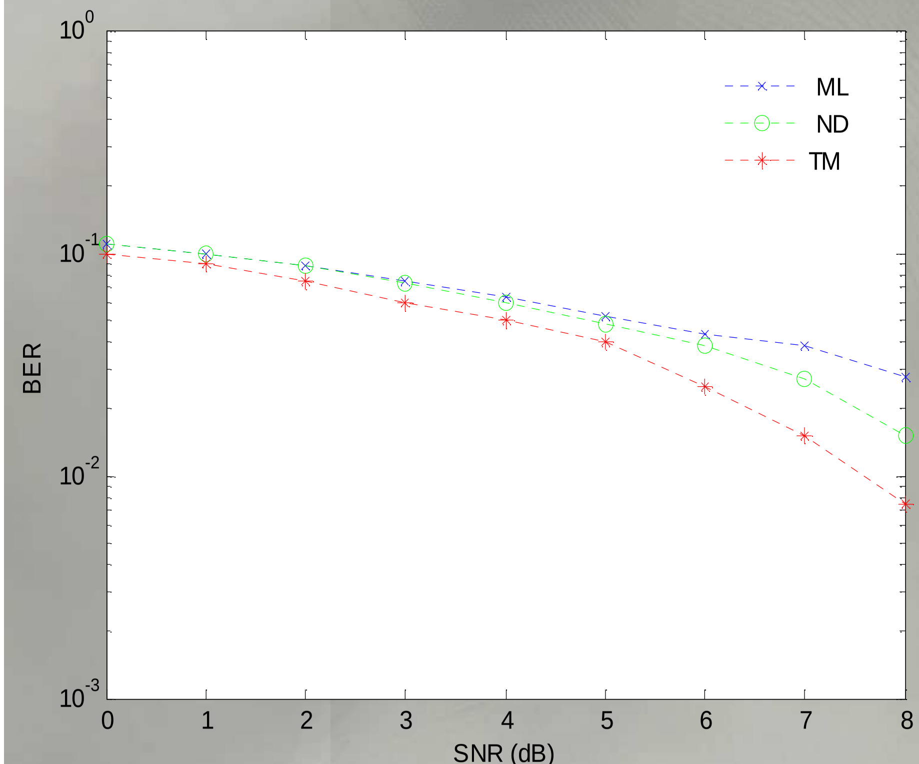
The Computational Complexities Versus Number of Users

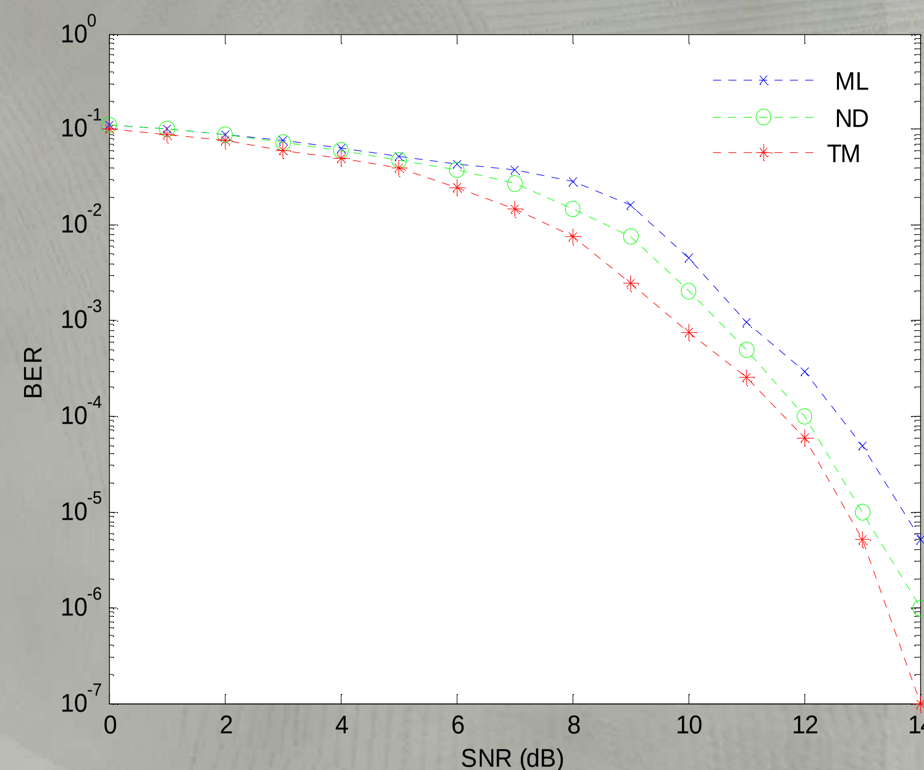
Performance Analysis of SNR



Approximate value of SNR (dB) versus number of users (K=22 and 42) with a random amount of variance for a synchronous DS-CDMA system in a Gaussian channel.

Performance Analysis of BER





Comparison of BER versus SNR (dB) curves for a synchronous BPSK/DS CDMA system in a Gaussian channel for a small value of K (i.e., 0<K<50).

Conclusion & Future Work

- We described Optimal ML algorithm and the associated problem.
- Too complex for practical implementation.
- TM algorithm can be used to reduce computational complexity.
- Useful for better processing gain.
- Algorithms should implement for asynchronous system and they should consider imperfect power control.

Questions?