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Quantum-Inspired Computing for Large-Scale NOMA-MIMO Wireless Networks

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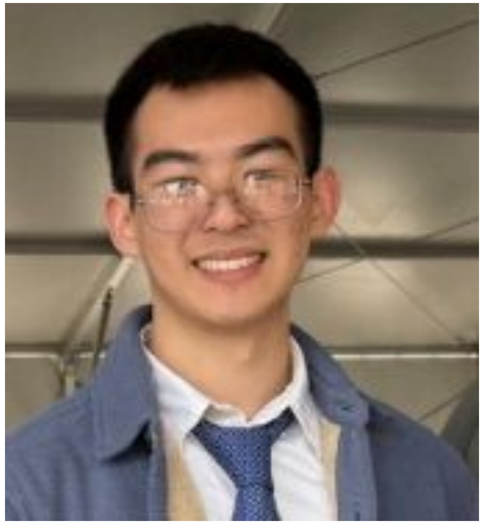
Advisors: Minsung Kim, Byungjun Kim

Project Team



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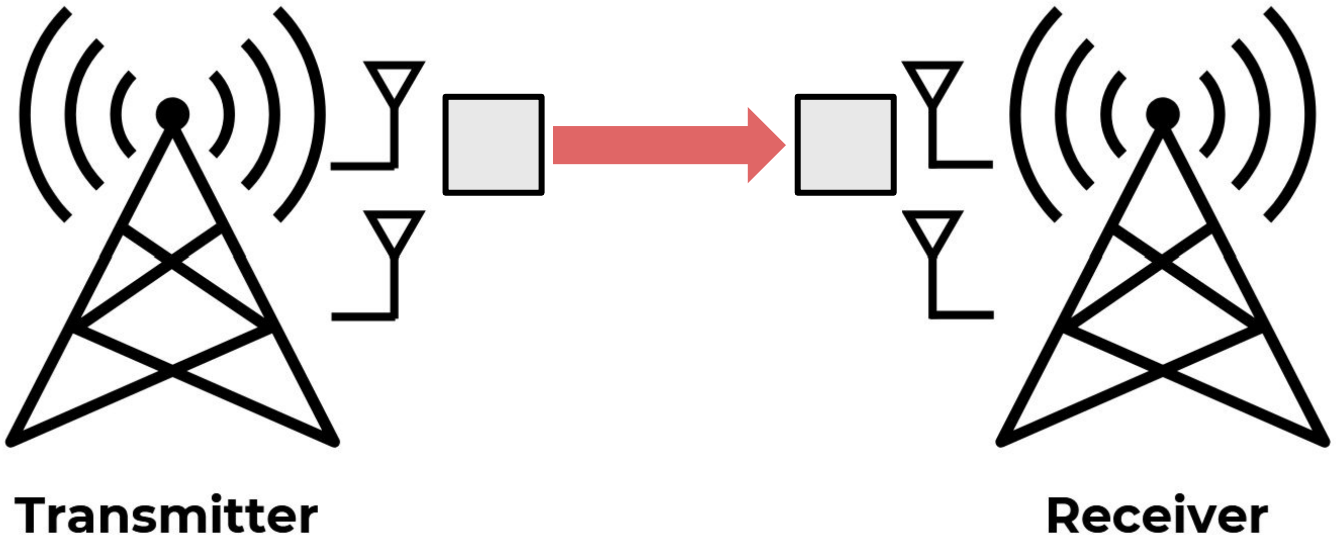
Set Up

For wireless communication, we send data using radio waves.

The path over the air is called a “channel”.



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Problem 1: Low Performance

Solution 1: MIMO

Problem 2: Noise

Solution 2: MIMO Detection

Problem 3: MIMO Detection is slow

Solution 3: ParaMax!

Problem 1: Low Performance

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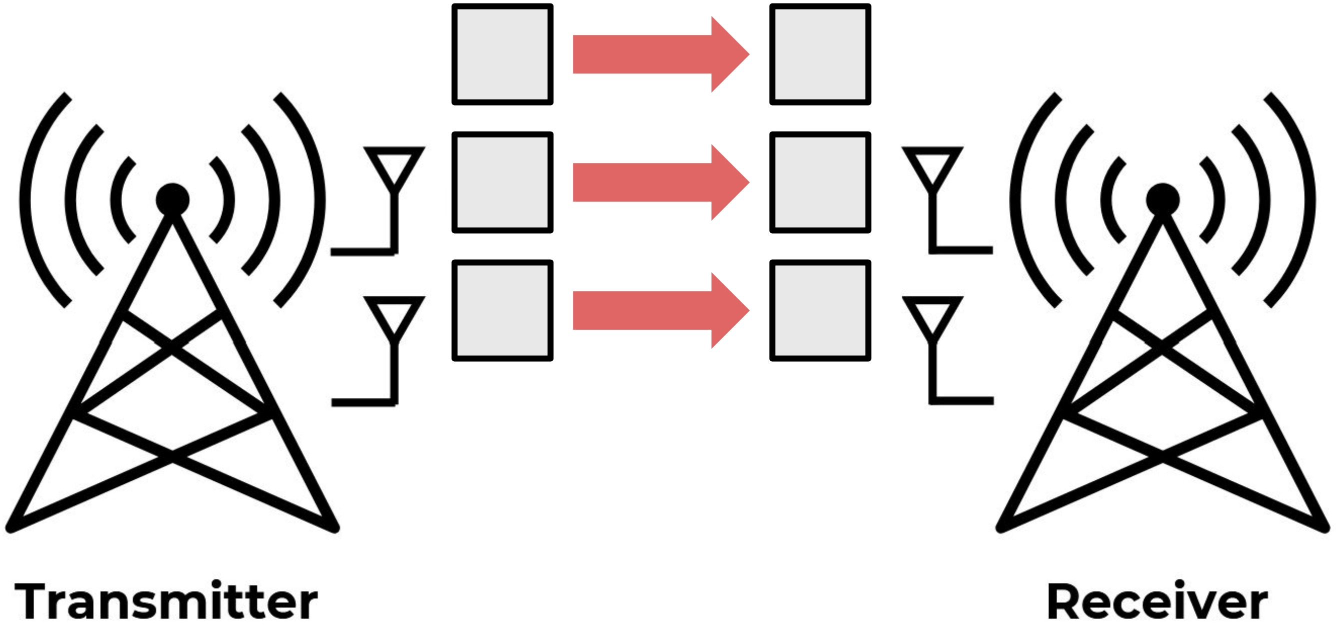
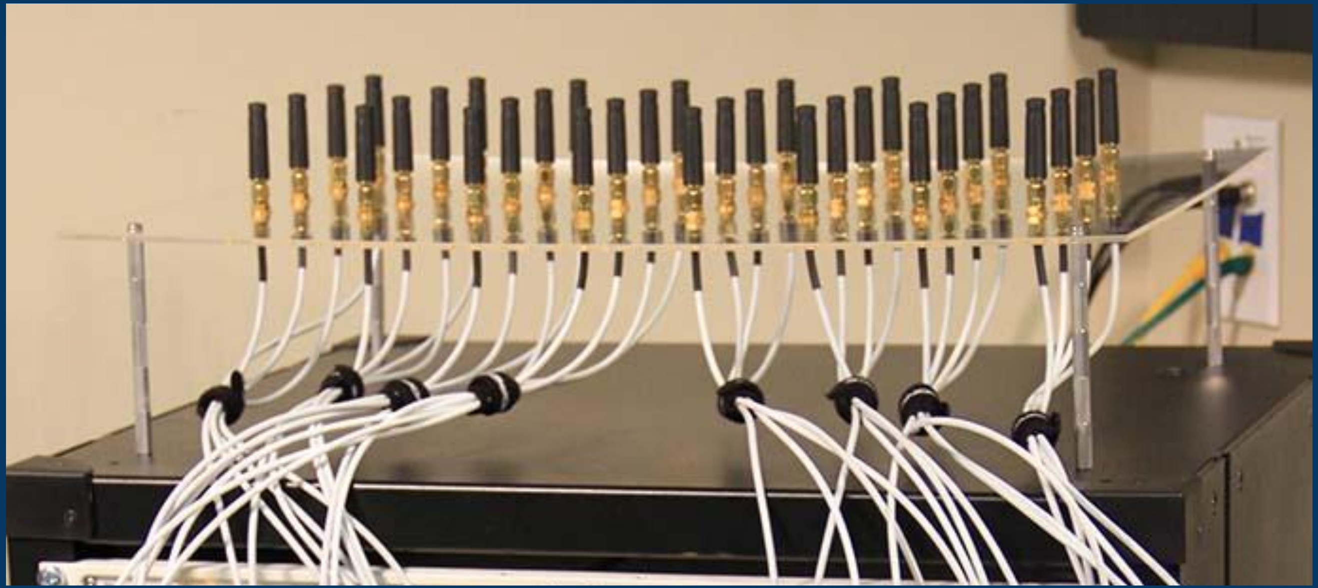
Solution 1: MIMO

Send more data at once.

We can use Multiple Input Multiple Output (MIMO) to increase throughput and service more users!



MIMO Rack



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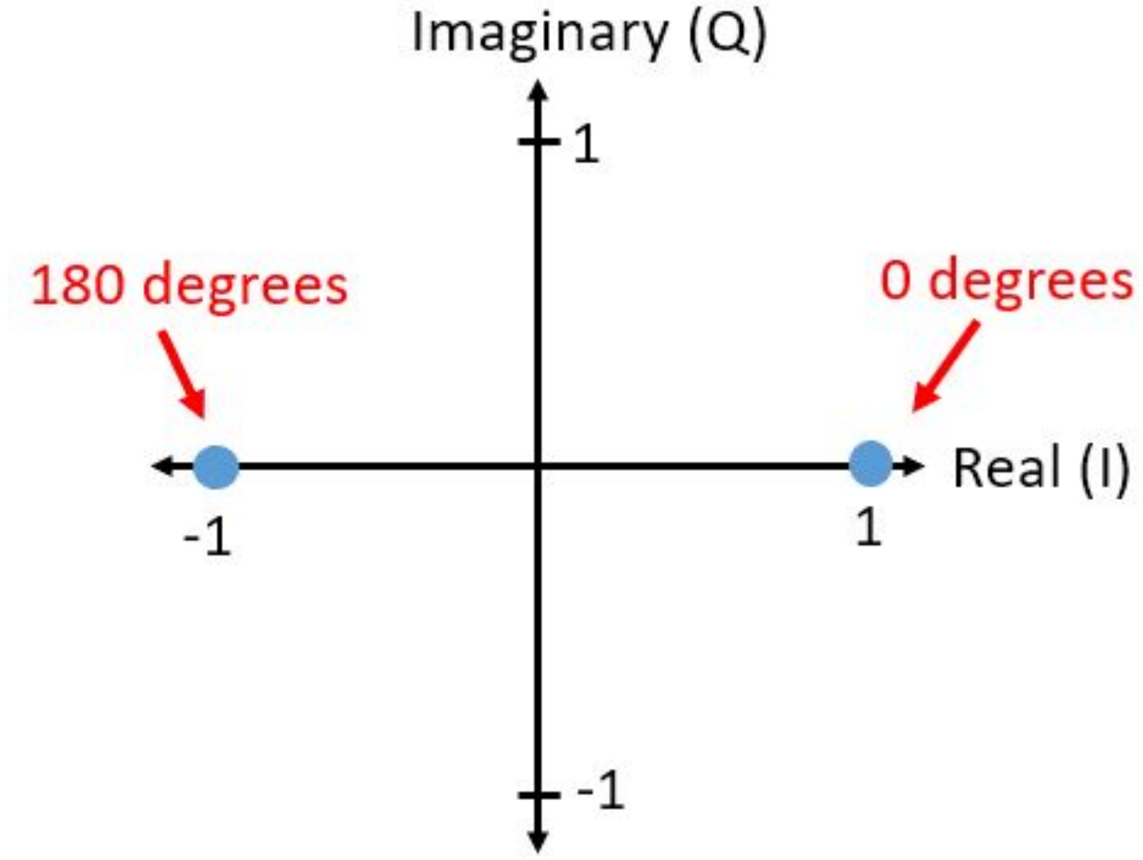
Problem

Transmitted messages are exact "symbols" (like 1s and -1s)



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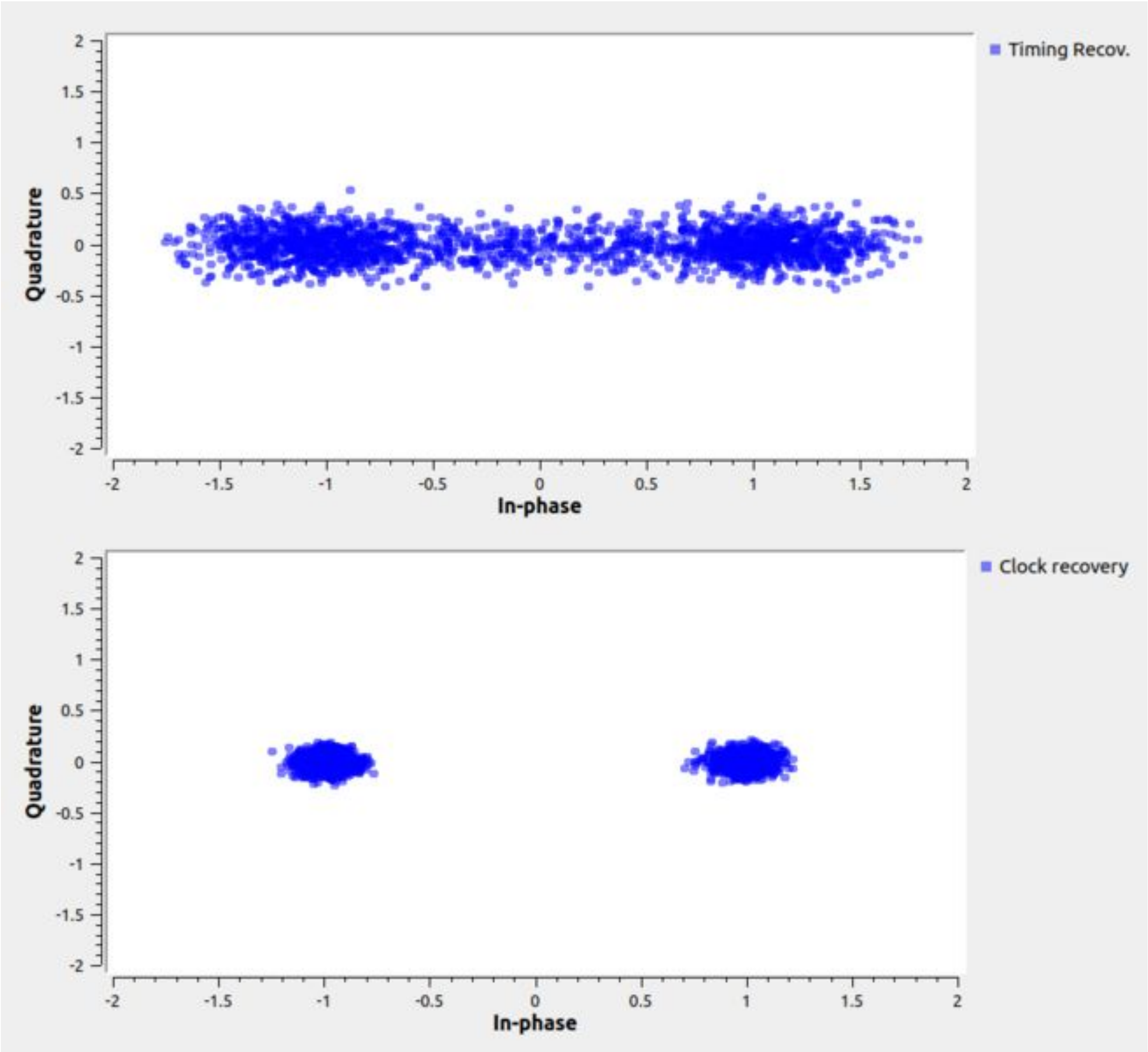
Problem

Noisy channel conditions can disrupt the message

What was the intended message?



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Problem 1: Low Performance

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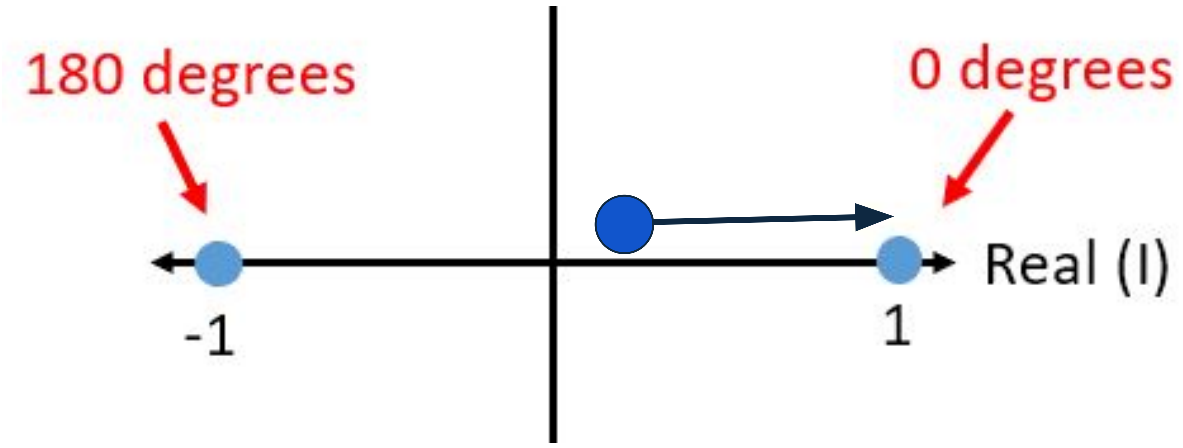
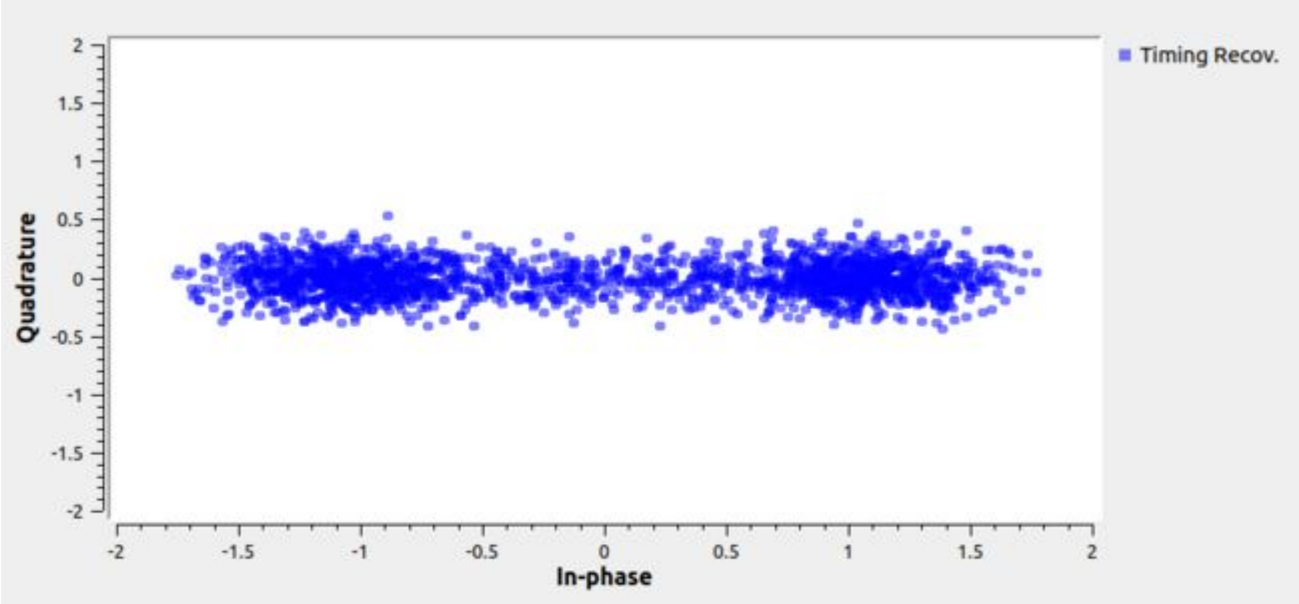
Solution: MIMO Detection

MIMO Detection maps the observed signal back to the intended message

In noisy environments, this is challenging.





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Problem 1: Low Performance

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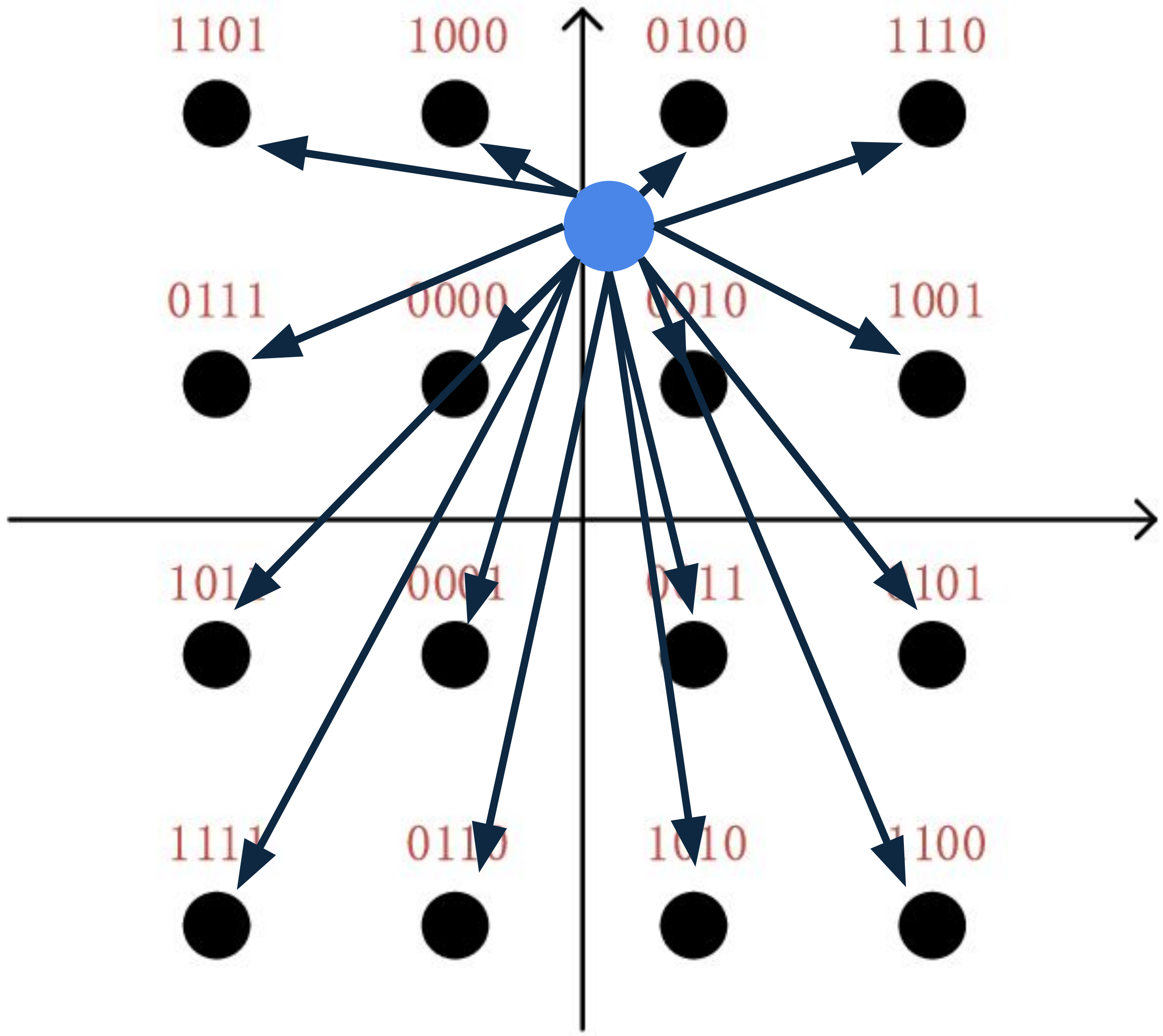
Maximum Likelihood (ML) MIMO Detection

Compute distance of every combination.

The closest message is most likely to be correct.



Maximum Likelihood (ML) MIMO Detection

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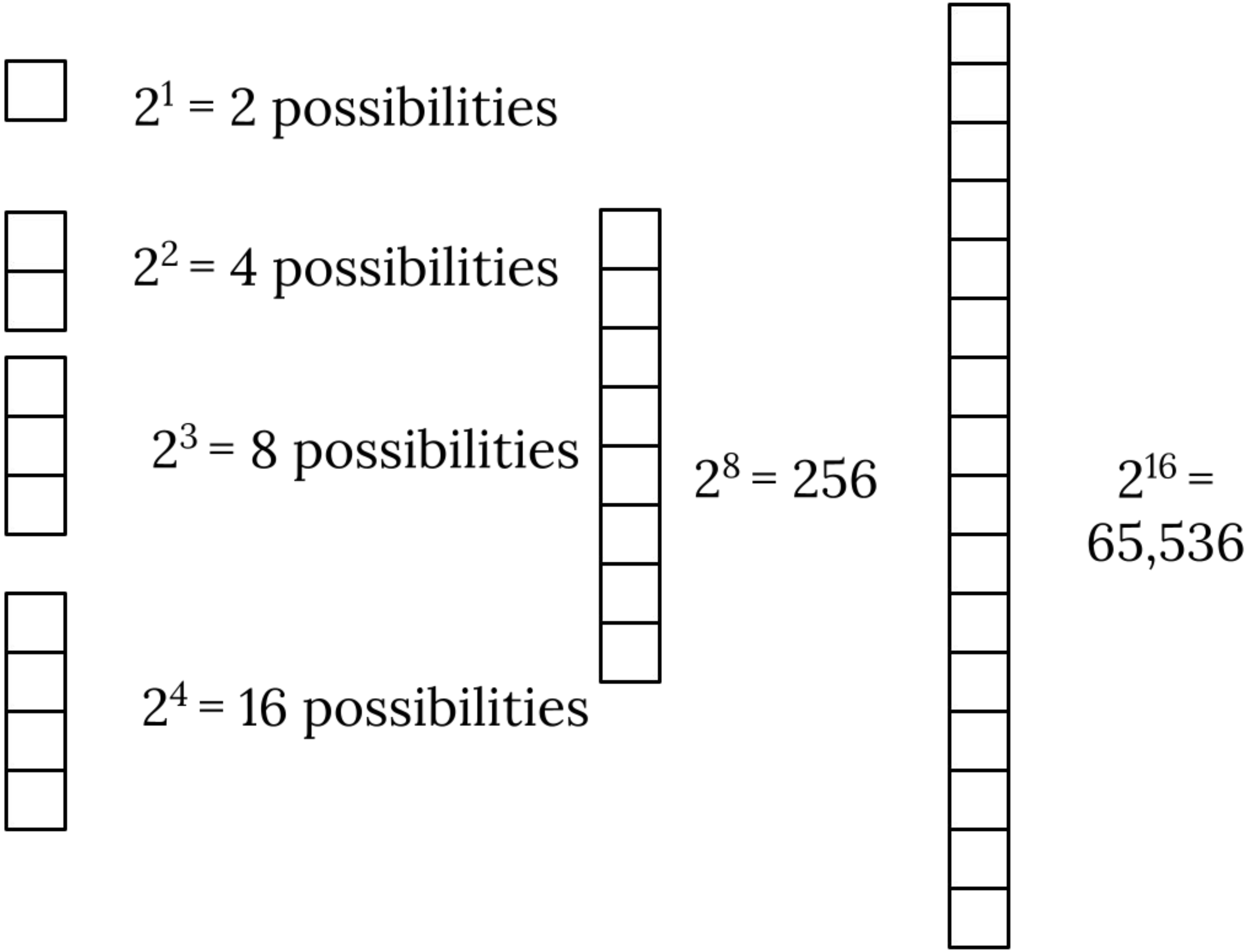

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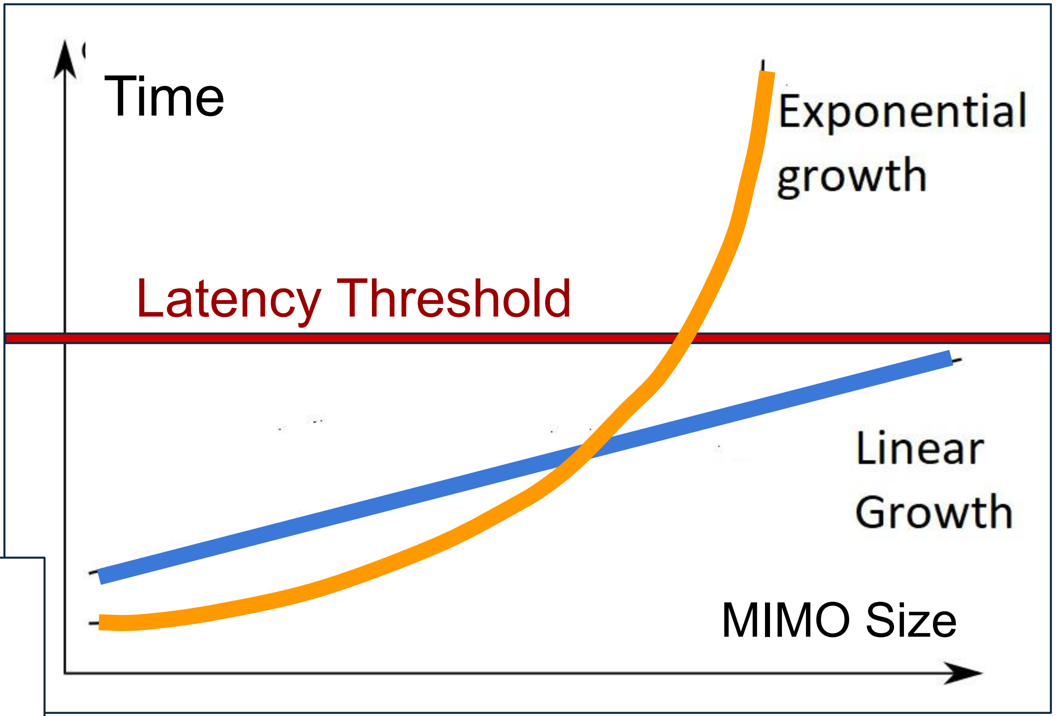
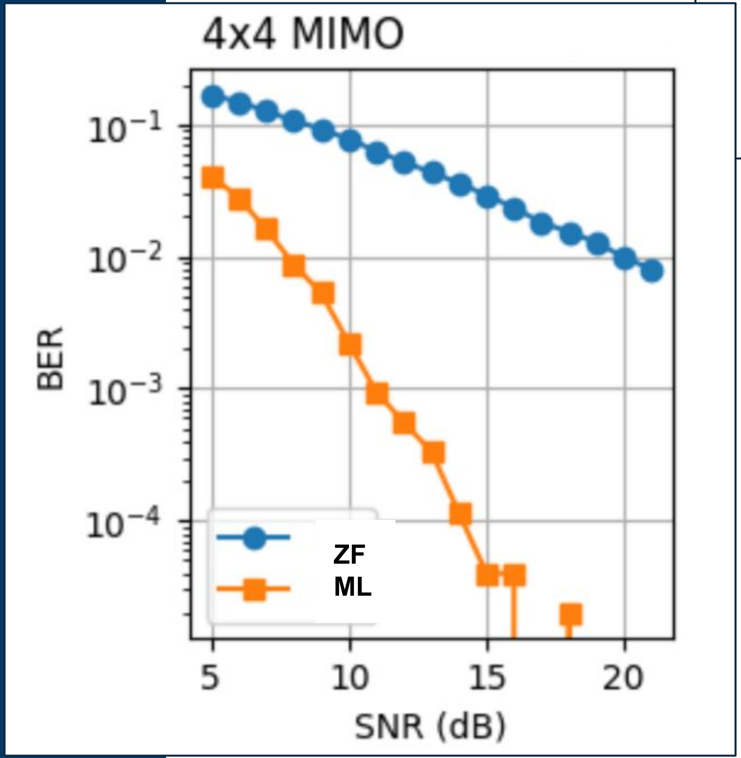
Maximum Likelihood (ML) MIMO Detection

We want to use optimal MIMO detectors since they have lower error rate, but they're too slow.





Note: Lower is better on both plots

Problem 1: Low Performance

Solution 1: MIMO

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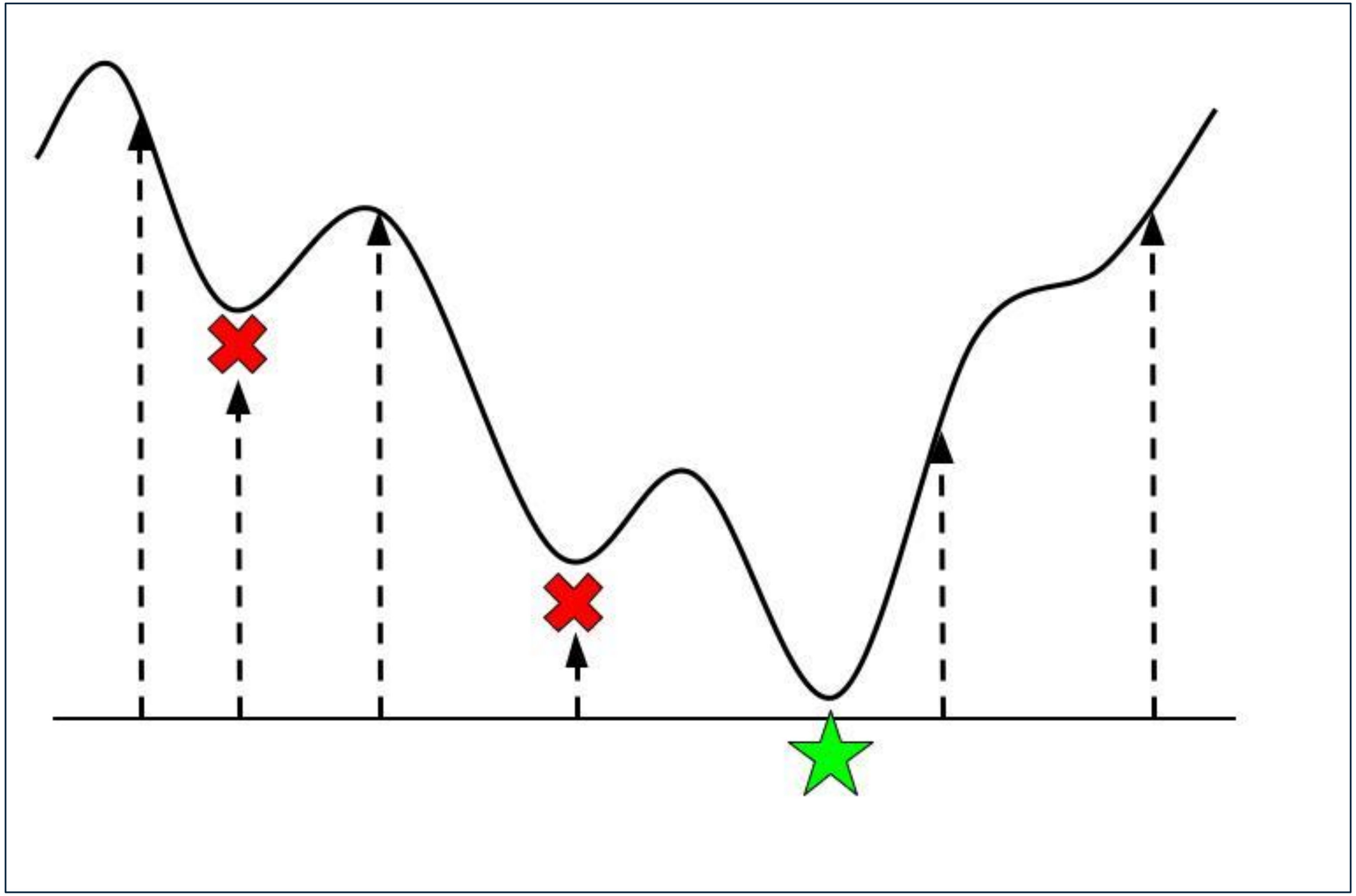
ParaMax
MIMO Detection

Instead of trying all values.

Sample possible values and start to settle into a minima if we find one.



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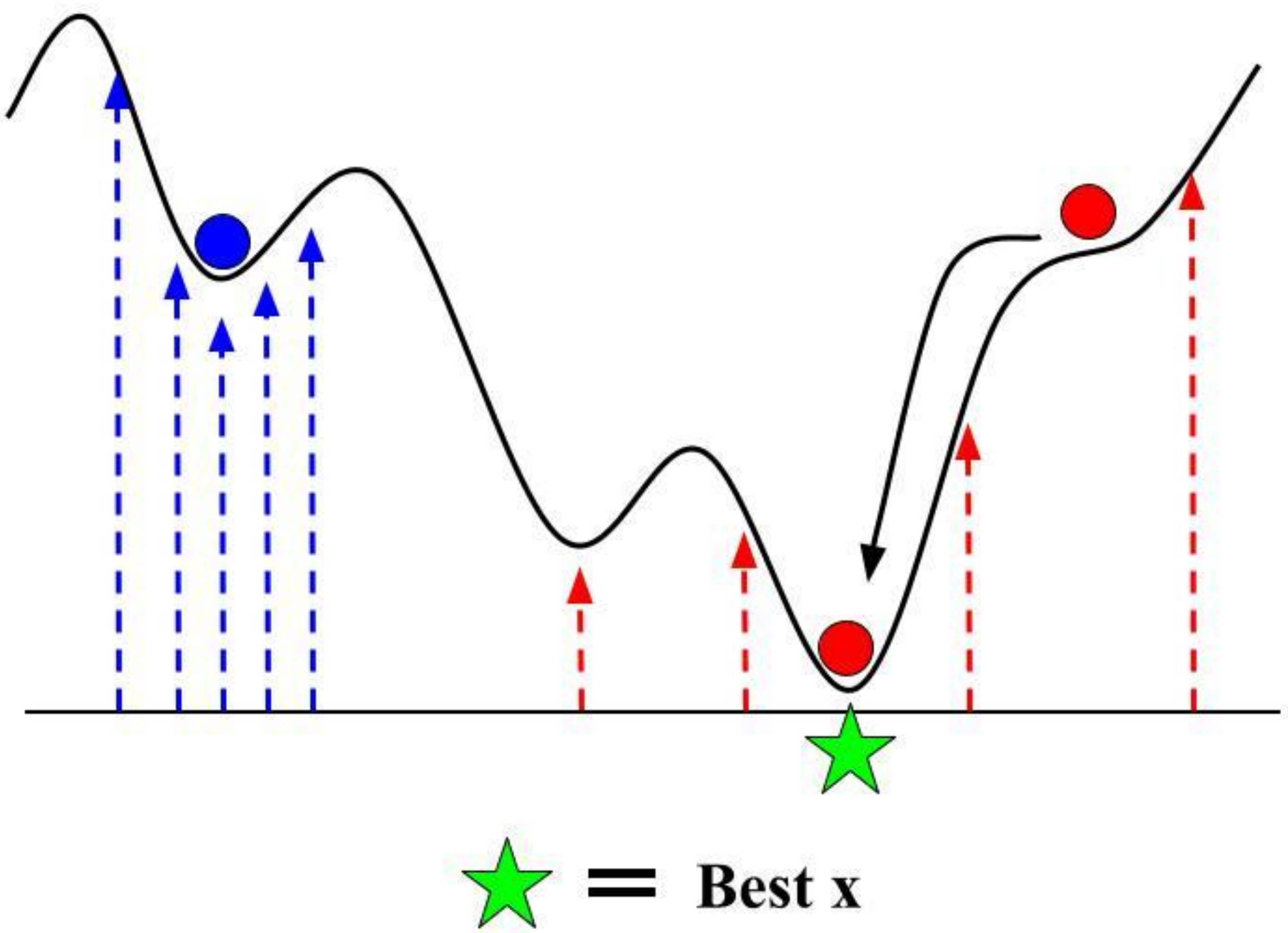
ParaMax
MIMO Detection

Add multiple parallel annealers, one that stays near the best solution so far and one that explores for a better minima.



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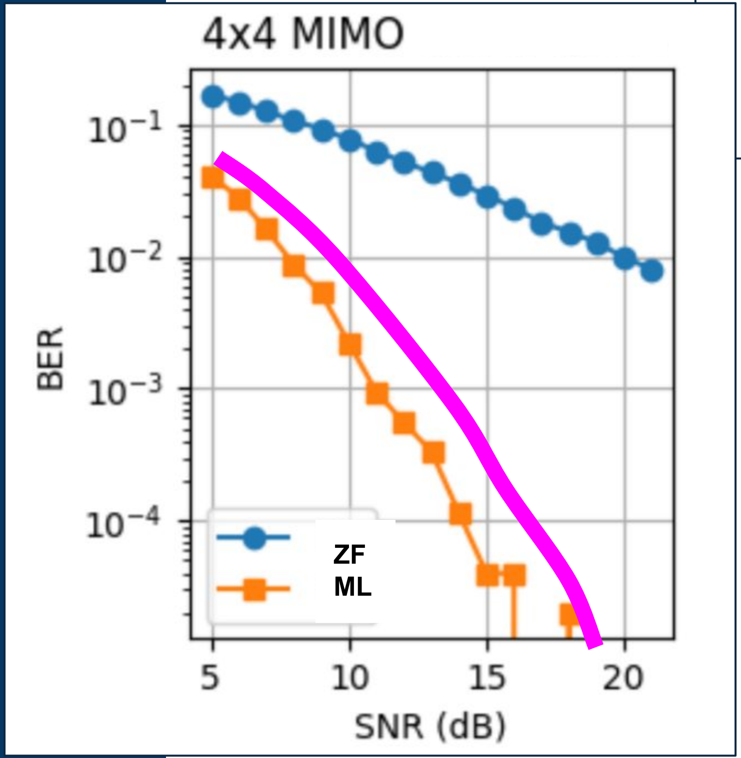
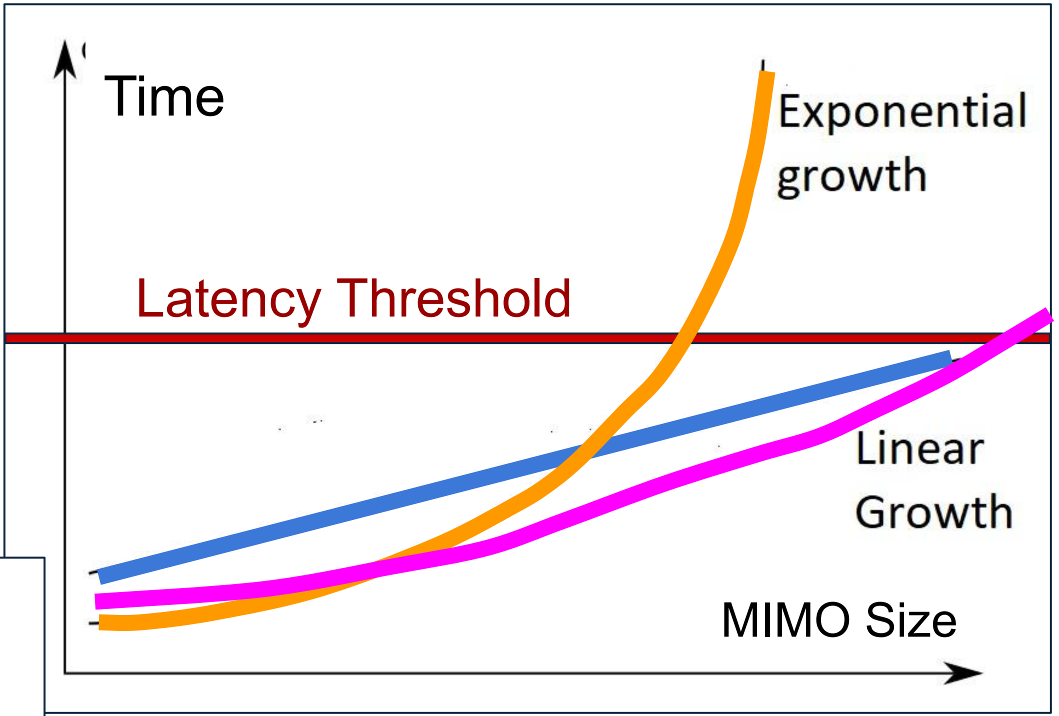
ParaMax
MIMO Detection

ParaMax is designed to provide near-optimal BER and run quickly.



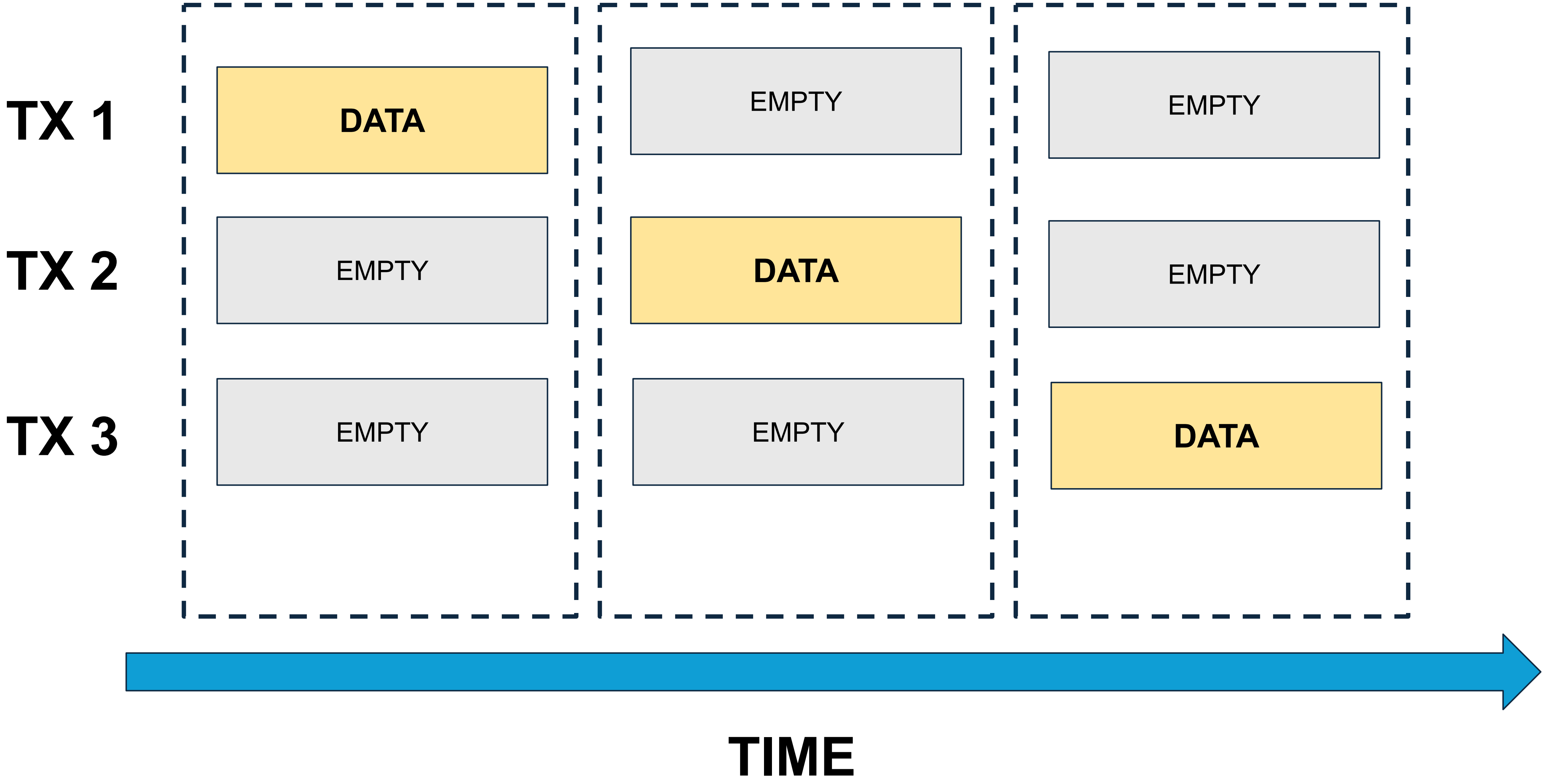


Note: Lower is better on both plots

Our goal:
Hardware Implementation of ParaMax

First ever hardware implementation of a quantum-inspired MIMO detection algorithm

Internship Results
&
Relation to Quantum-Inspired Computing and Project Objectives


TX 1
TX 2
TX 3
DATA
EMPTY
EMPTY
EMPTY
DATA
EMPTY
EMPTY
EMPTY
DATA
TIME

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ParaMax Implementation

Single Transmitter

Single Receiver

Multiple Transmitters

Multiple Receivers

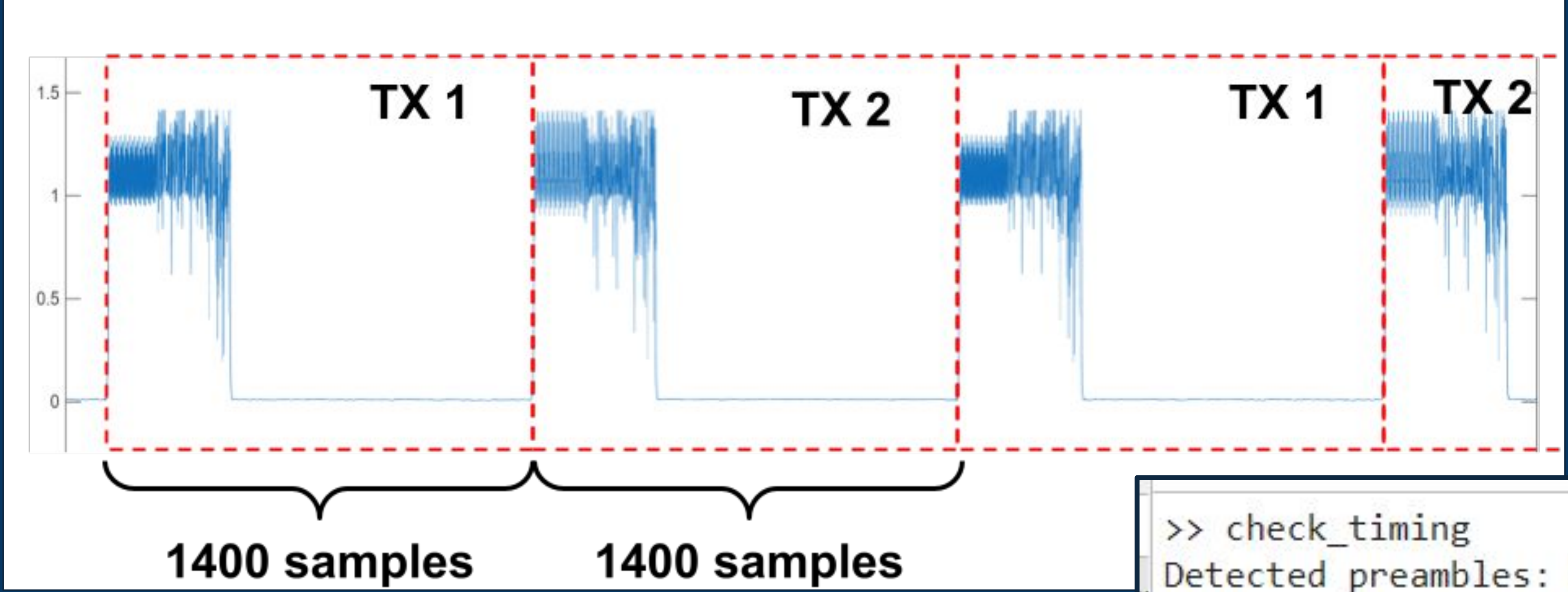
Offline MIMO Detectors

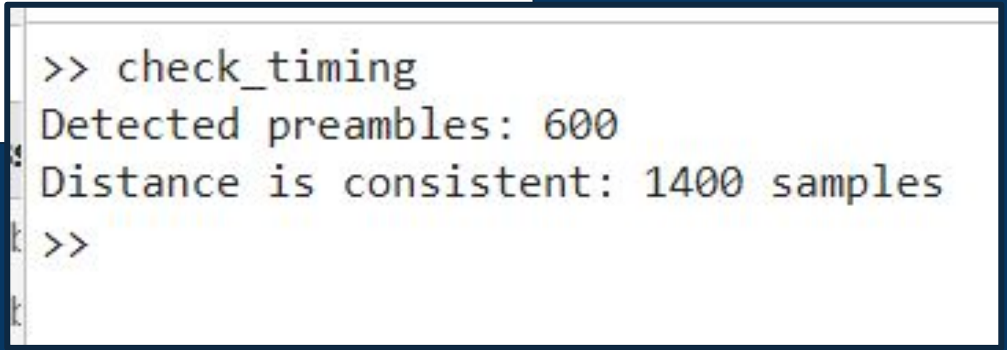
Real-time MIMO Detectors

Blind MIMO

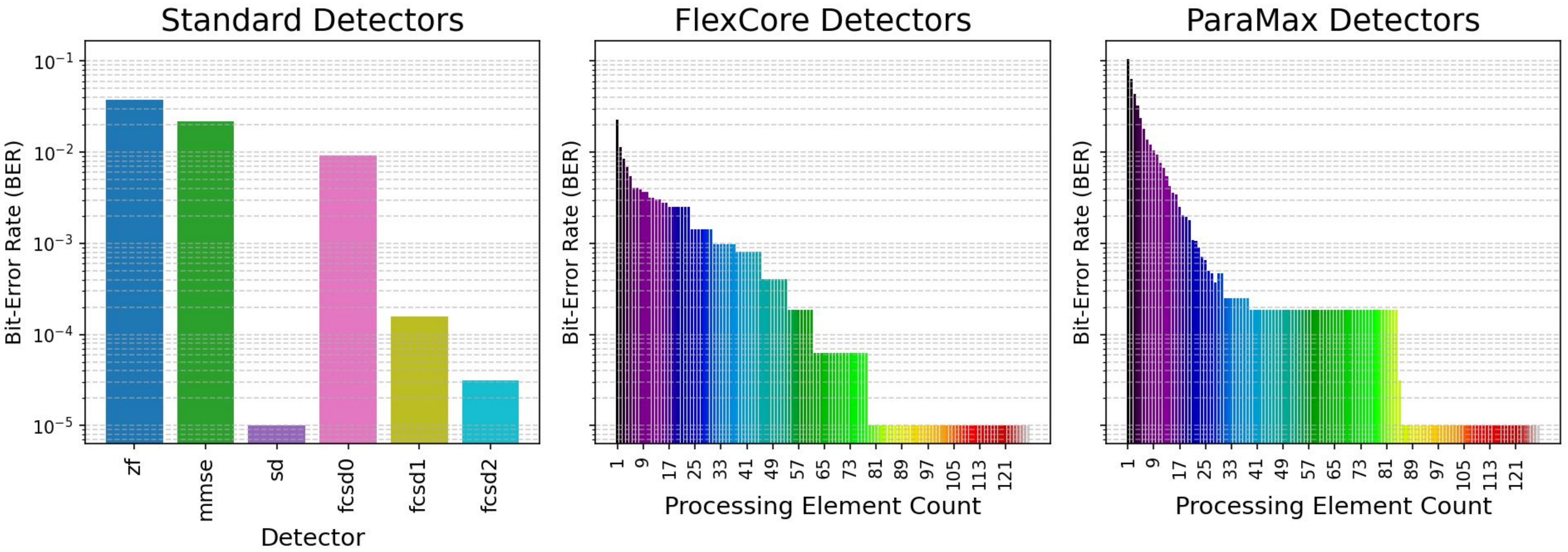
NOMA

We achieved perfect time synchronization, with precision down to 50 nanoseconds - 50 billionths of a second!





Bit Error Rate (BER) by Detector Type at Signal-to-Noise Ratio (SNR) = 25 dB



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ParaMax Implementation

Single Transmitter

Single Receiver

Multiple Transmitters

Multiple Receivers

Offline MIMO Detectors

Real-time MIMO Detectors

Blind MIMO

NOMA (Non-Orthogonal Multiple Access)

Thank you!

Any Questions?