A NOVEL MASSIVE MIMO FOR 5G SYSTEMS

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PIERS
Progress In Electromagnetics Research Symposium
PIERS 2017 in St Petersburg, Russia, 22-25 May, 2017

OUTLINE

- Introduction
- System Characterization for m-MIMO using Precoding
- Interference Cancelation
- Performance Results
- Conclusions

MOTIVATION

- Develop a **Simplified Precoding system** for the downlink of Massive MIMO using mm-Waves

INTRODUCTION

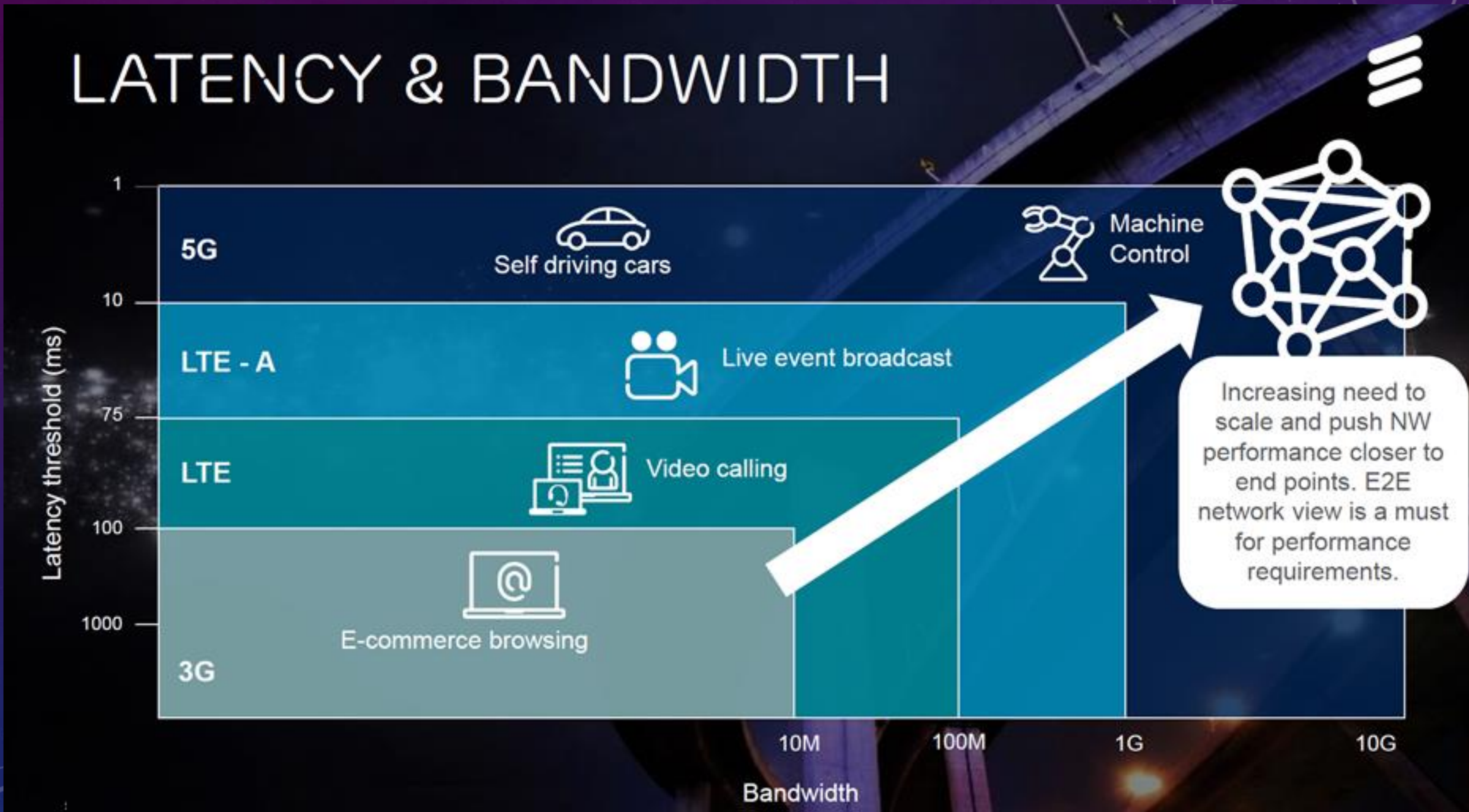
- This paper considers the use of m-MIMO (Massive MIMO) combined with SC-FDE modulations, associated to mm-Wave communications.
- A comparison of the proposed m-MIMO using precoding and post-processing is performed.
- We consider three different types of algorithms: Zero Forcing (ZF), Maximum Ratio Combining (MRC), and Equal Gain Combiner (EGC), both with iterative detection schemes.
- The advantage of both MRC and EGC relies on avoiding the computation of pseudo-inverse of matrices, as required by ZF, and thus it reduces the complexity and computation requirements.
  - Nevertheless MRC and EGC generate interference. We consider an interference canceller.

INTRODUCTION

- 5G systems (2020) are supposed to have much higher throughputs, capacity and spectral efficiency requirements than current systems, and many techniques are independently emerging for these systems (support of 1 to 10 Gbps and IoT with low 1-10 ms latency)
- Massive MIMO schemes involving several tens or even hundreds of antenna elements are expected to be central technologies for 5G systems
- mm-Wave communications (30-300GHz - EHF) are expected to be a crucial part of 5G systems due to their increased channel coherence bandwidth, as compared to centimeter Wave. These systems use carrier frequencies of 30 - 70 GHz, where we have large unoccupied bandwidth. Ex: IEEE802.11ad uses 2.16 Ghz of BW in 60 GHz band (ISM band), supporting up to 7 Gbps. However, mm-Wave suffers from high path loss and rain and oxygen absorption.
  - Moreover, the distance between antennas is reduced, facilitating a higher number of antennas elements (Massive MIMO)
- Block transmission techniques, with appropriate cyclic prefixes and employing FDE techniques, have been shown to be suitable for high data rate transmission over severely time-dispersive channels.
- SC-FDE signals presents lower PAPR than OFDM signals.

INTRODUCTION

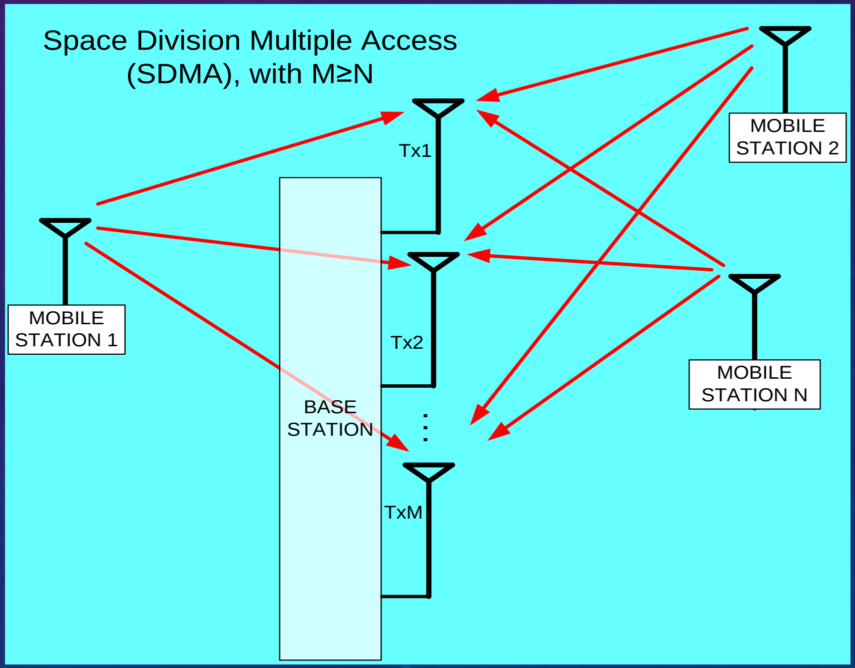
- In this paper, we avoid matrix inversion of ZF by implementing the m-MIMO using MRC and EGC, following both the precoding and post-processing approaches.



LATENCY & BANDWIDTH
Latency threshold (ms)
1
10
75
100
1000
5G
Self driving cars
Machine Control
LTE - A
Live event broadcast
LTE
Video calling
3G
E-commerce browsing
10M
100M
1G
10G
Bandwidth
Increasing need to scale and push NW performance closer to end points. E2E network view is a must for performance requirements.

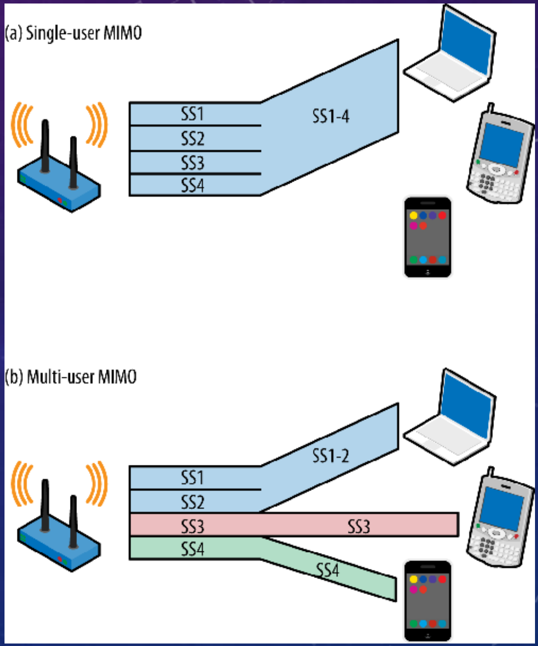
SPACE DIVISION MULTIPLE ACCESS (SDMA)

- SDMA allows multiple users exploiting spatial diversity as a multiple access technique, while using the same spectrum
- Typically employed in the **uplink** of cellular network
- Similar to multi-layer transmission, this belongs to the **spatial multiplexing** group, allowing the use of the V-BLAST detector (nulling w/ ZF/MMSE + SIC)



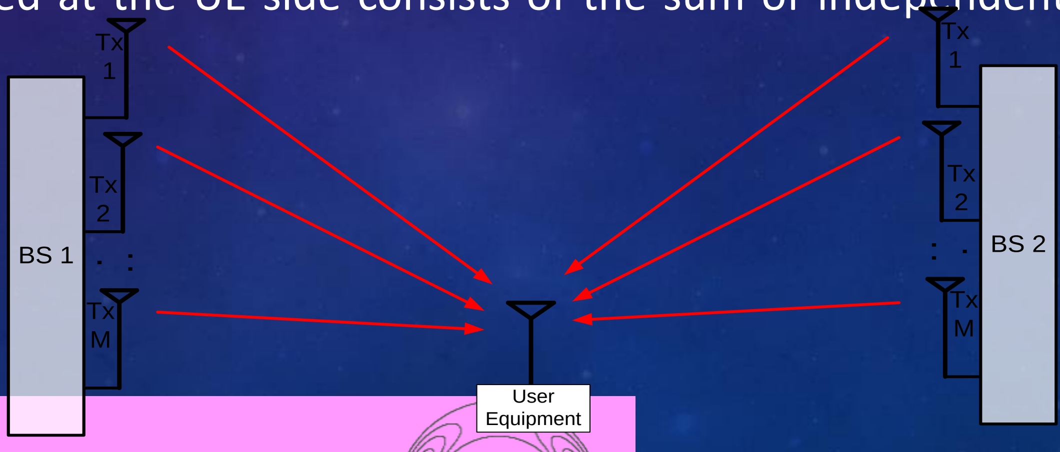
MULTI-USER MIMO

- SU-MIMO considers data being transmitted from a single user into another individual user (widely used in the uplink)
- Alternatively, MU-MIMO considers **multiple streams of data** sent by a single transmitter (typically a BS) simultaneously allocated to a certain user to increase throughput (or to multiple users to increase capacity), **using the same frequency bands** **(and the Tx supports more antennas than the Rx)**
  - When the aim is improved performance, instead of different streams of data, STBC or STD is employed
- The approach behind **MU-MIMO is similar to SU-MIMO multi-layer transmission**. Nevertheless, while multi-layer Tx (or SDMA) is typically employed in the uplink, the MU-MIMO is widely implemented in the **downlink**
- In this case, instead of performing the **nulling algorithm** at the receiver side, the nulling algorithm needs to be performed using a **pre-processing** approach at the transmitter side (BS)
  - Number of Tx antennas (BS) must be equal to or higher than the number of Rx antennas (MT)
  - Use pre-coding such as ZF, MMSE, dirty paper, etc. (we propose MRC/EGC)
- This typically **requires downlink CSI** at the Tx side (in FDD)
- Similar concept can be employed in Base Station Cooperation (Coordinated Multi-Point Transmission) and in Multihop Relaying to improve SNR or throughput at the cell edge



COORDINATED MULTI-POINT TRANSMISSION (COMP)

- **CoMP Transmission** is an important technique that can mitigate inter-cell interference, improve the throughput, exploit diversity and, therefore, improve the spectrum efficiency.
  - Mitigates **shadowing**, **path loss** and inter-cell **interference**, at the **Cell Edge**.
- In case each BS uses the MIMO scheme, the resulting MIMO can be viewed as a "giant MIMO", consisting of a combination of independent antenna elements from different BSs
- Coordinated Multi-Point transmission (CoMP) comprises the coordinated transmission of signals from adjacent base stations (BS), and the corresponding reception from UE. The signal received at the UE side consists of the sum of independent signals sent by different BSs.

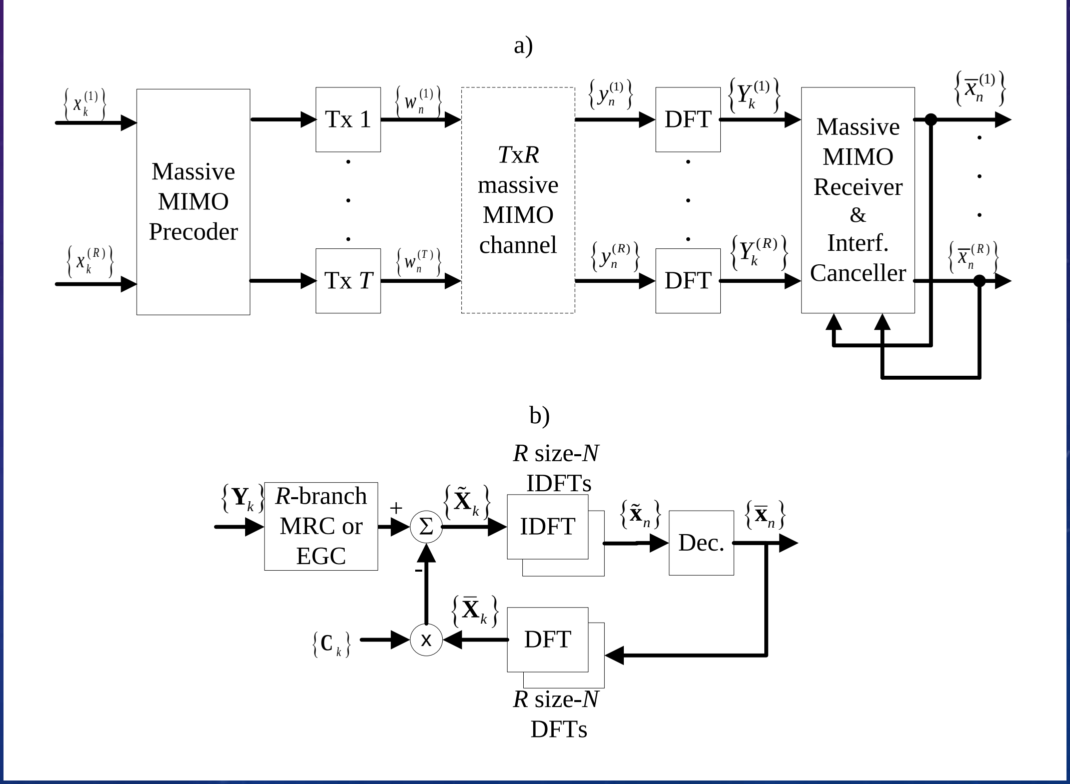


SYSTEM CHARACTERIZATION FOR M-MIMO USING PRECODING

- Transmission between a BS with *T* antennas and a MS with *R* antennas, to send multiple streams of data.
- *T*≫*R*.

$$\mathbf{Y}_k = \left[Y_k^{(1)}, \ldots, Y_k^{(R)} \right]^T = \mathbf{H}_k \mathbf{W}_k + \mathbf{N}_k$$

$$\mathbf{W}_k = \mathbf{B}_k \mathbf{X}_k$$



SYSTEM CHARACTERIZATION FOR M-MIMO USING PRECODING

1. Using the zero forcing transmitter (ZFT)[1] algorithm $\mathbf{B}_k$ comes:

$$\mathbf{B}_k = \mathbf{H}_k^H \left(\mathbf{H}_k \mathbf{H}_k^H \right)^{-1}$$

2. Using the MRT algorithm $\mathbf{B}_k$ comes:

$$\mathbf{B}_k = \mathbf{H}_k^H / T$$

where T stands for the number of transmit antennas.

3. Using the EGT algorithm $\mathbf{B}_k$ comes:

$$\mathbf{B}_k = \exp\left\{ j \arg\left(\mathbf{H}_k^H \right) \right\} / T .$$

Matrix inversion

SYSTEM CHARACTERIZATION FOR M-MIMO USING PRECODING

- The elements outside the main diagonal of $\mathbf{H}_k\mathbf{B}_k$ are much lower than the ones at its diagonal, but they still represent interference.
- To overcome this problem, we propose the iterative interference canceller (receiver), defined by:

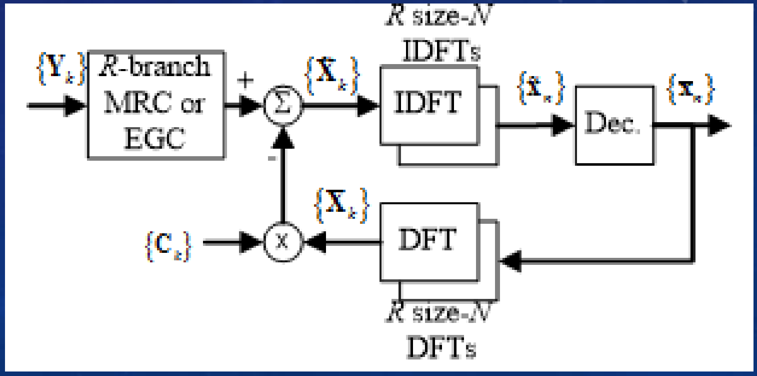
$$\tilde{\mathbf{X}}_k = \mathbf{Y}_k - \mathbf{C}_k\bar{\mathbf{X}}_k$$

$$\mathbf{C}_k = \mathbf{H}_k\mathbf{B}_k - \mathbf{I}$$

(Replica of interference estimate, for subtraction)

$\mathbf{I}$ is an $R \times R$ identity matrix.

- With $\bar{\mathbf{X}}_k$ denoting the frequency-domain average values conditioned to the FDE output for the previous iteration.



PERFORMANCE RESULTS

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- We present a set of performance results (Monte Carlo simulations) concerning the proposed m-MIMO scheme optimized for mm-wave associated to SC-FDE signals using both precoding (pre-processing) and post-processing.
- Each block has N = 256 symbols selected from a QPSK constellation.
- Our channel has 16 equal power paths with uncorrelated Rayleigh fading.

PERFORMANCE RESULTS

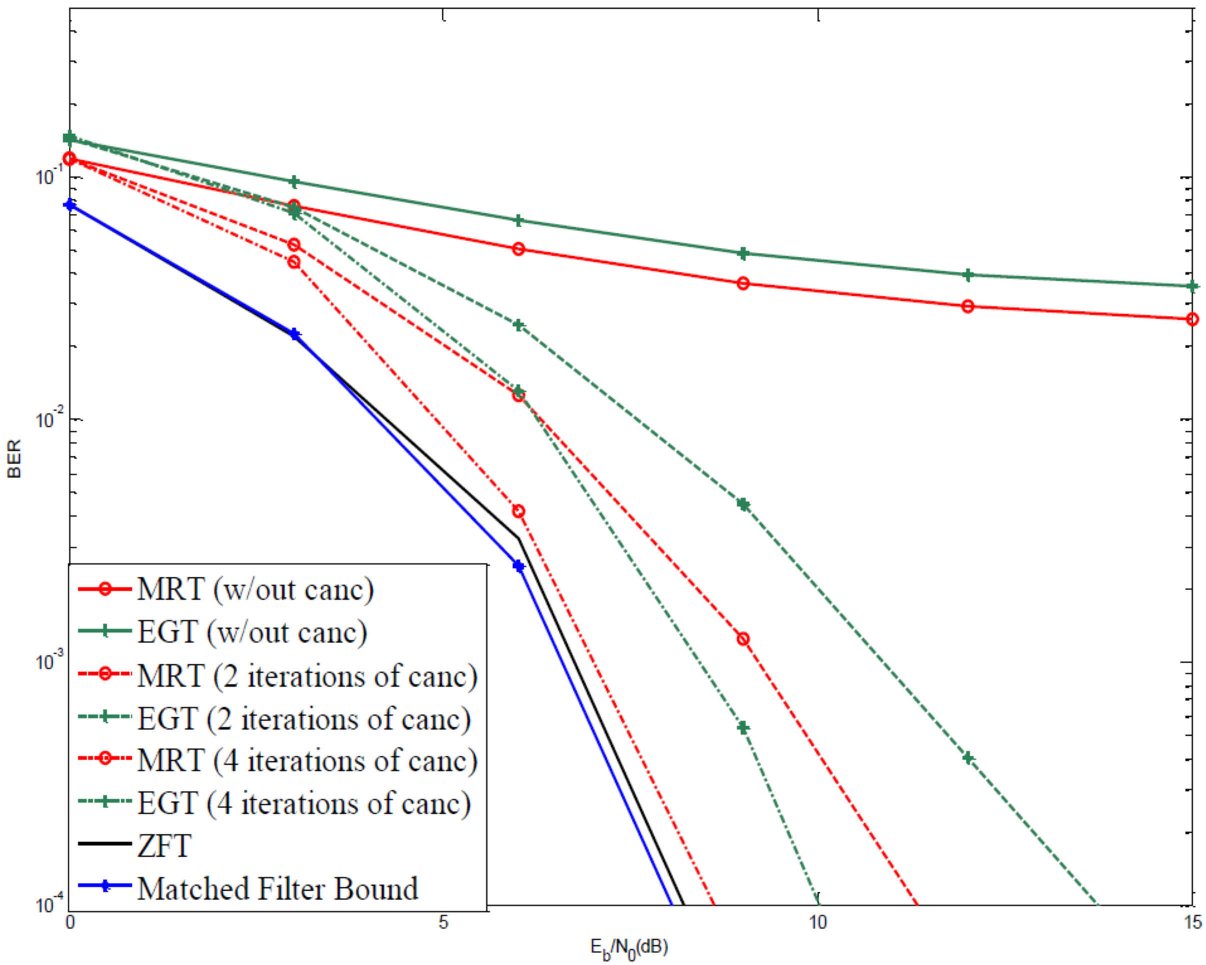


Figure 3 – BER results with 32×8 m-MIMO using Precoding

- 32x8 - 8 parallel streams of data

PERFORMANCE RESULTS

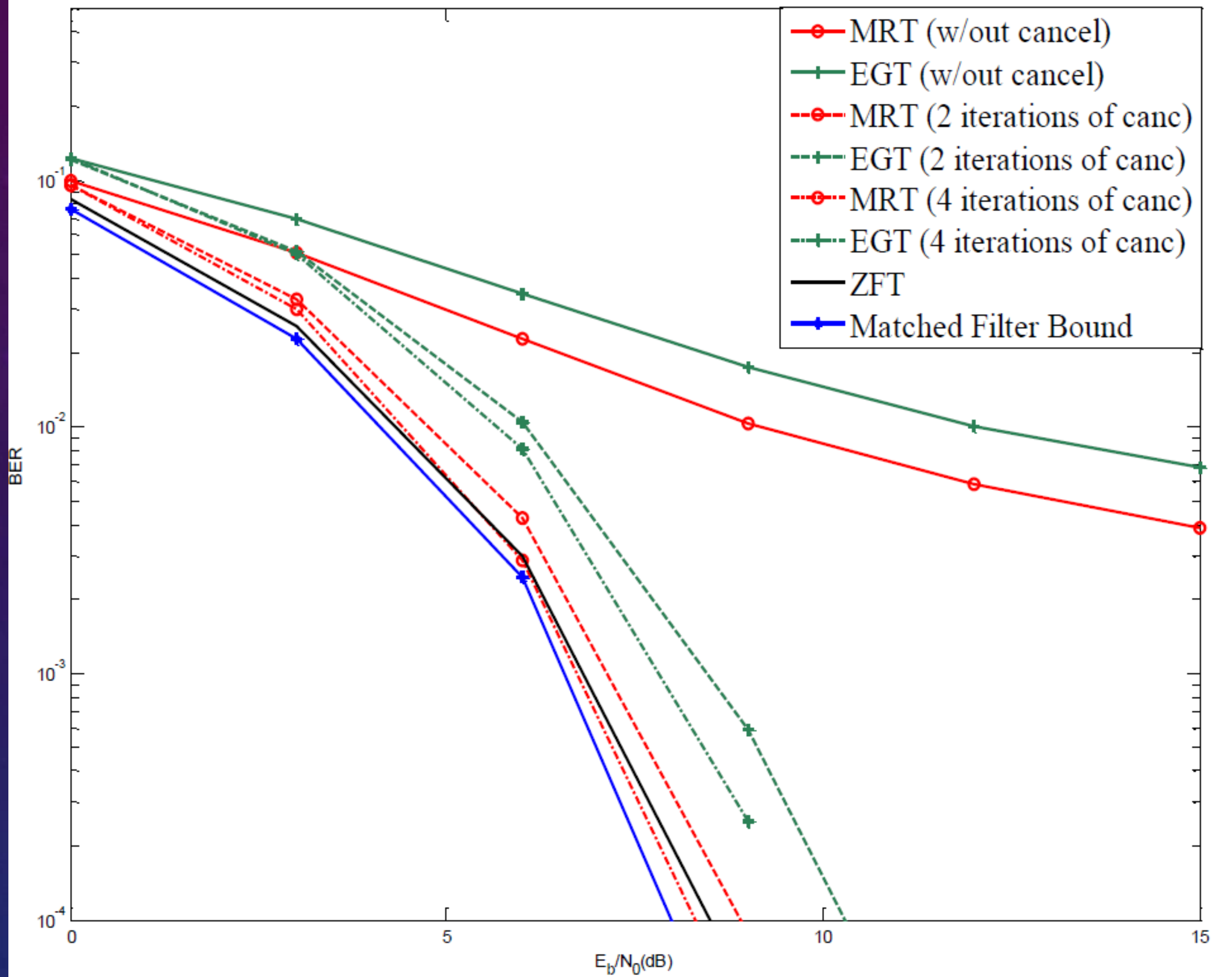


Figure 4 – BER results with 64×8 m-MIMO using Precoding

PERFORMANCE RESULTS

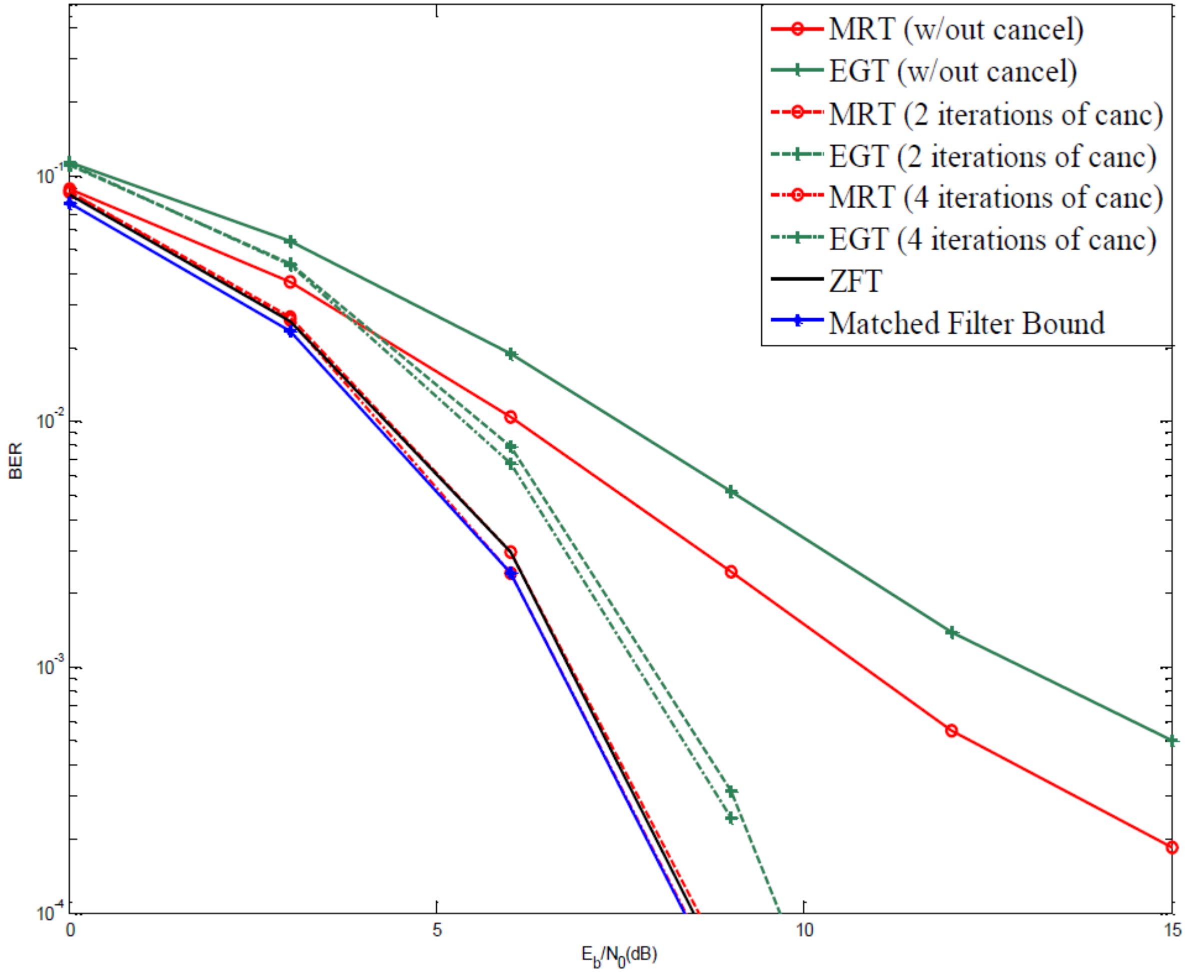


Figure 5 – BER results with 128×8 m-MIMO using Precoding

PERFORMANCE RESULTS

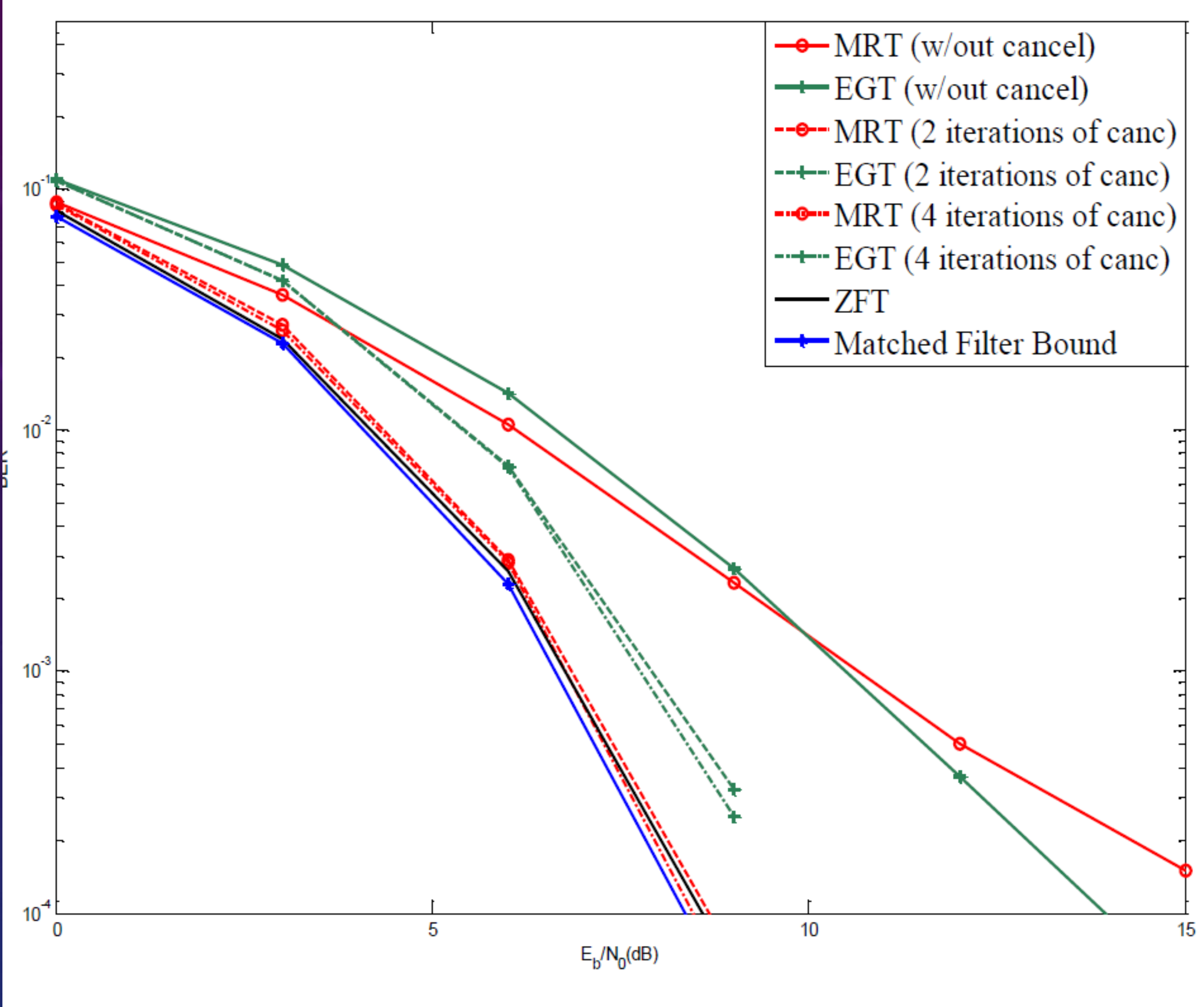


Figure 6 – BER results with 32×2 m-MIMO using Precoding

- 32x2 - 2 parallel streams of data

PERFORMANCE RESULTS

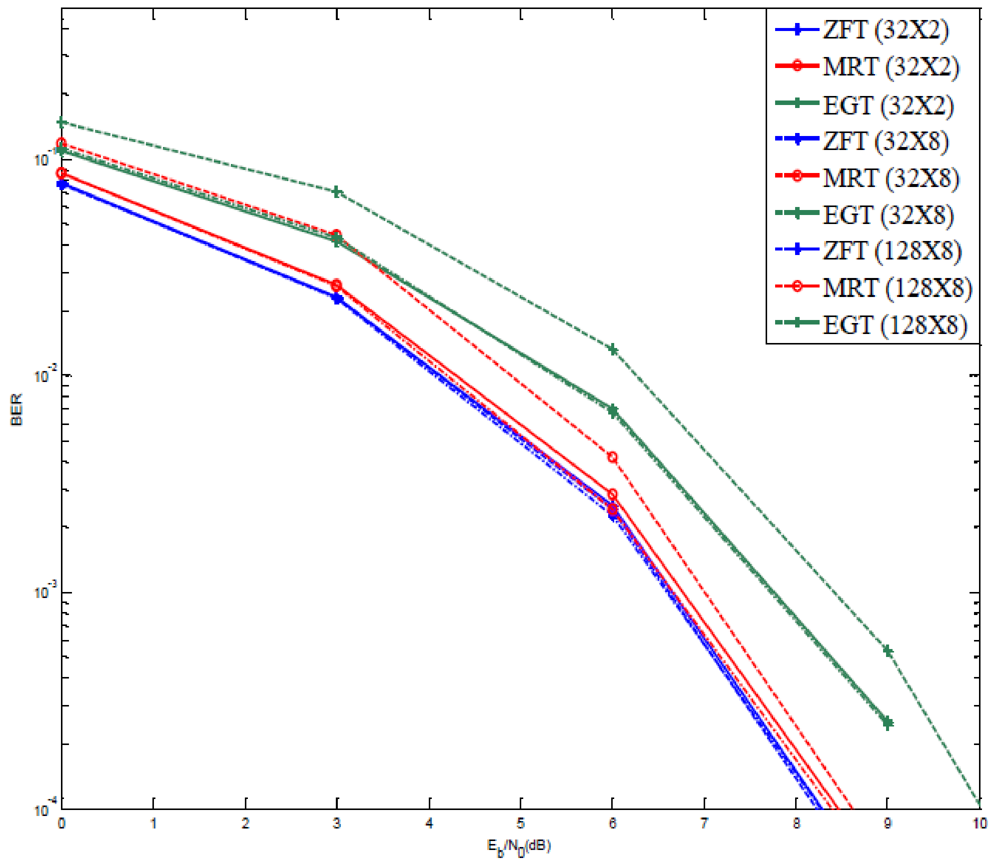


Figure 7 – BER results for m-MIMO with different number of transmit and receiving antennas using Precoding (MRT and EGT have 4 iterations of interference cancellation)

PERFORMANCE RESULTS

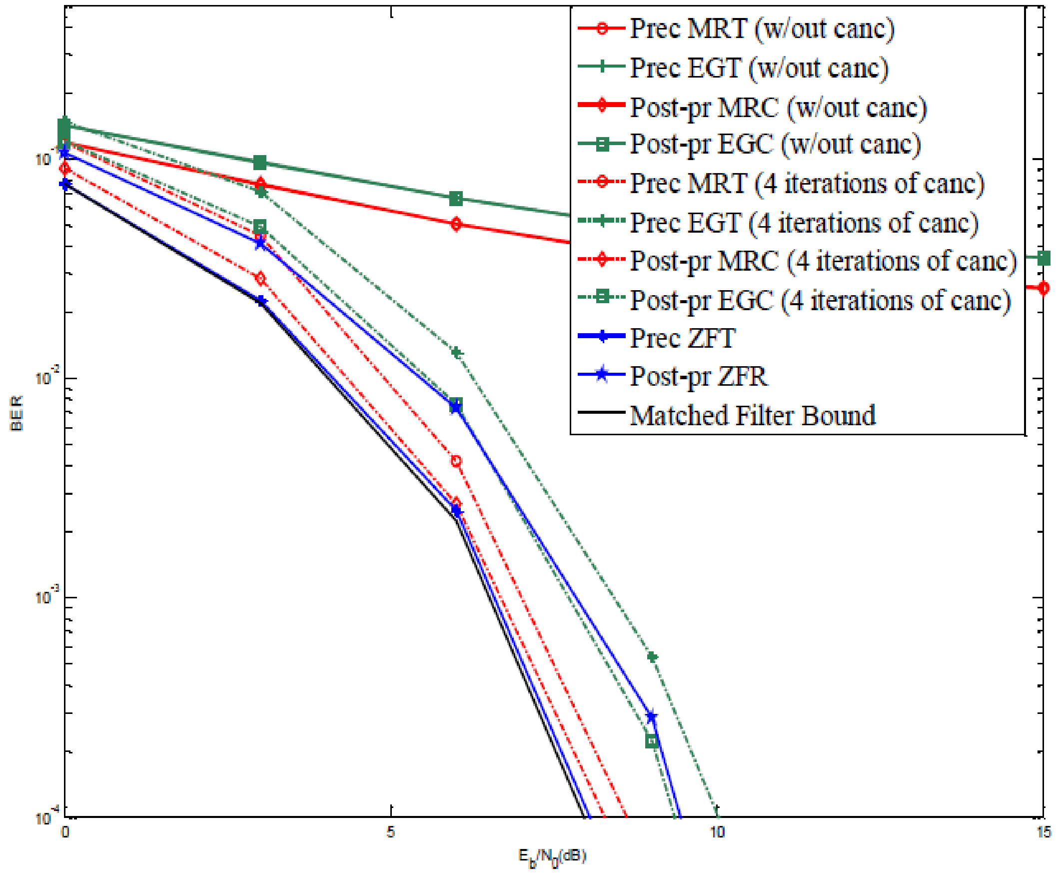


Figure 8 – BER results with m-MIMO using precoding (32×8) versus post-processing (8×32)

PERFORMANCE RESULTS

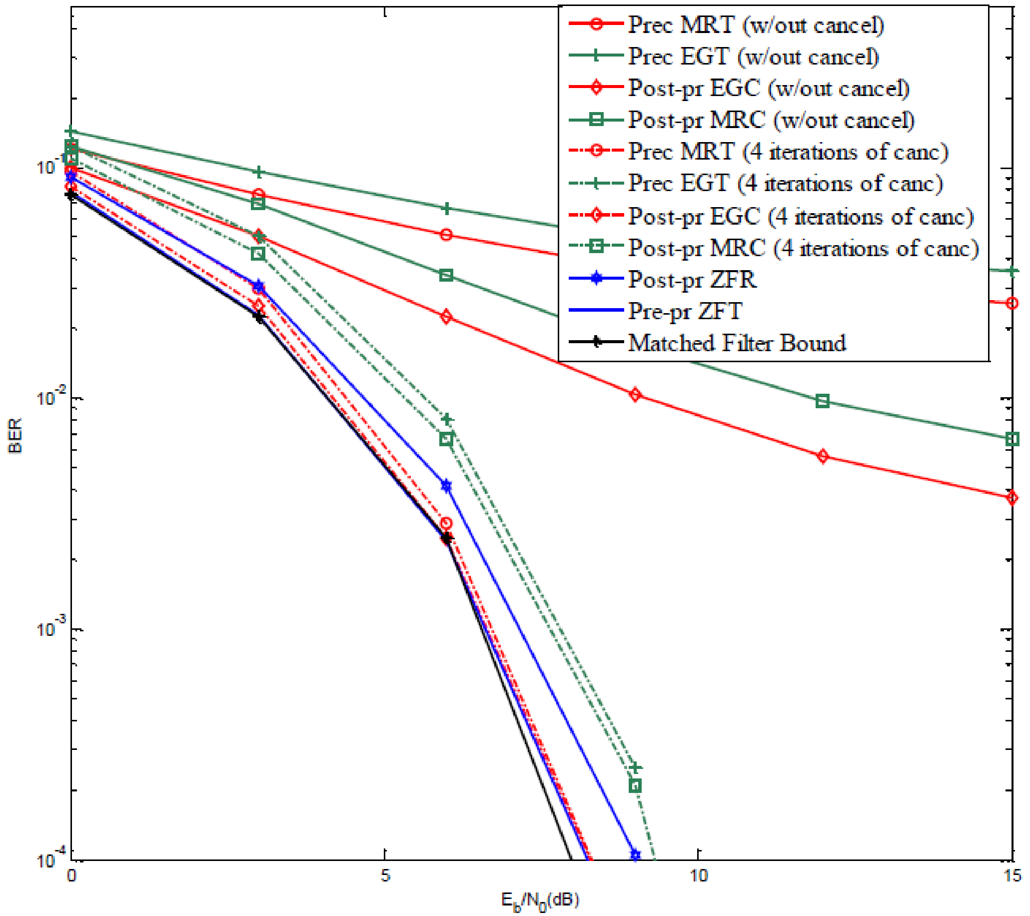


Figure 9 – BER results with m-MIMO using precoding (64×8) versus post-processing (8×64)

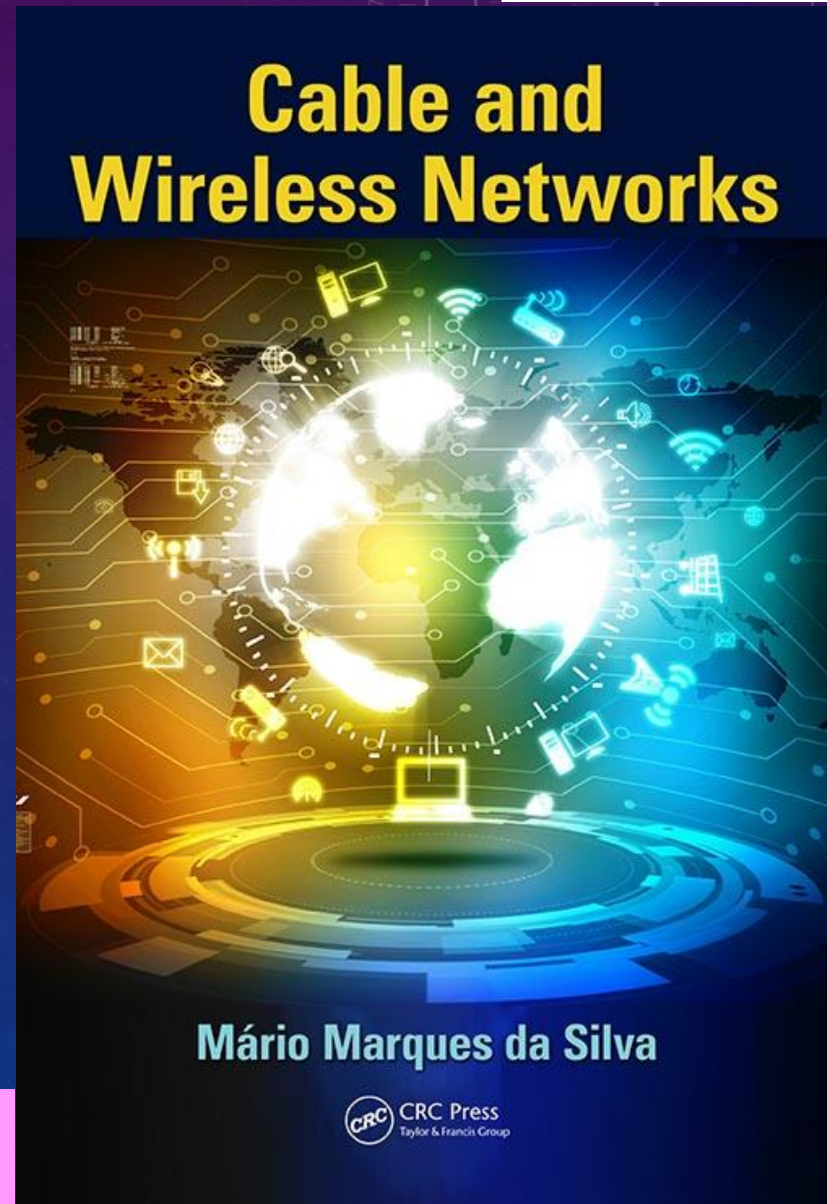
PERFORMANCE RESULTS - **ANALYSIS**

- ZF (decorrelator) in precoding (ZFT) achieves a performance very close to the MFB, while the ZF in post-processing (ZFR) presents a worse performance. ZFR presents noise enhancement, while ZFT does not.
- A disadvantage of the ZF relies on the need to compute the pseudo-inverse of the channel matrix, for each frequency component.
- To simplify this process, we proposed the use of the MRT/MRC and EGT/EGC (using either pre or post-processing), with the disadvantage of generating a certain level of interference.
- The post-processing tends to achieve a performance slightly better than those achieved with the pre-processing (precoding), except for ZF.
- The MRT/MRC with interference cancellation always performs better than the EGT/EGC (for the same number of iterations), either in pre-processing or post-processing.
- With 4 iterations of the interference cancellation, the performance obtained with the MRC using post-processing approximates that of the MFB, while the MRT using pre-processing presents a slightly worse performance.
- The advantages of the interference cancellation are more visible for lower number of Tx antennas (MRT & EGT) or lower number of Rx antennas (MRC & EGC).

CONCLUSIONS

- We considered the massive MIMO using precoding, with different algorithms optimized for mm-Wave. For the sake of comparison, the post-processing methodology was also described, analyzed and compared, using the same algorithms as those utilized in precoding.
- It was viewed that the precoding ZFT achieves a performance very close to the MFB, while the post-processing ZFR does not, due to the noise enhancement.
- To avoid matrix inversion and simplify this process, we have proposed the use of the MRT/MRC and EGT/EGC, but a certain level of interference is generated. A new interference canceller is proposed to mitigate this.
- It was viewed that the MRT/MRC tends to outperform the EGT/EGC.
- These algorithms implemented in post-processing achieve a performance slightly better than in the pre-processing methodology.
- Implementing the MRT/MRC and EGT/EGC algorithms for m-MIMO with mm-Wave, associated to the interference cancellation, we avoid the computation of the pseudo-inverse matrix, and therefore simplify the processing (either pre or post-processing), while achieving a performance very close to the MFB, especially with 4 iterations of the interference canceller.
- Due to its simplicity, the proposed processing (pre or post) can even be implemented by a Mobile Terminal.

BOOK: CABLE AND WIRELESS NETWORKS: THEORY & PRACTICE (CRC PRESS)



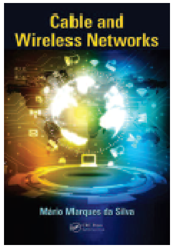
BOOK: CABLE AND WIRELESS NETWORKS: THEORY & PRACTICE (CRC PRESS)

NEW

EMONA Information Sheet

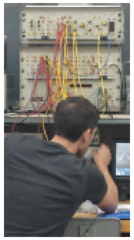
Wireless Textbook: Theory & Practice with TIMS

Emona TIMS experiment platforms support the practical component of a new wireless textbook by renowned author and educator, Professor Mario da Silva.



Cable and Wireless Networks: Theory and Practice - ISBN: 978-1-49-874681-6 - aimed at undergraduate and graduate readers, is a comprehensive textbook covering wireless communications and networking security. It demonstrates the fundamentals of communications, identifies the key components of networks and communication systems, and covers many key aspects concerning the development and understanding of current and emergent services.

This wide-ranging textbook combines theory along with hands-on exercises which utilise the EMONA TIMS and ETT-101 range of equipment. Thorough coverage is given to emergent and current topics into a single source, enabling students to develop deeper understanding of these systems' interconnections.

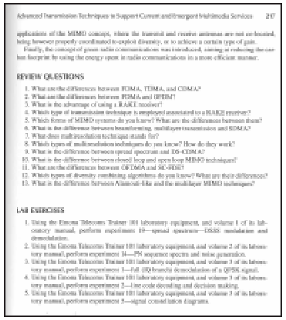


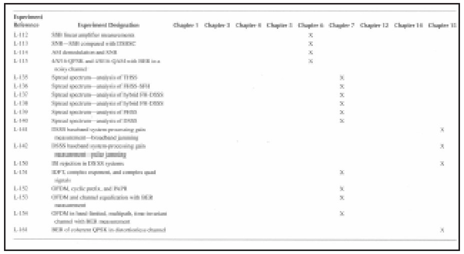
The Author of the book, **Mário Marques da Silva** is an associate professor and the director of the Department of Sciences and Technologies at Universidade Autónoma de Lisboa, Lisbon, Portugal. His research interests include networking and mobile communications, namely Internet protocol (IP) technologies and network security, block transmission techniques, interference cancellation, MIMO systems, and software-defined radio. He is a Cisco certified instructor, a member of the IEEE and AFCEA, and reviewer for several international scientific IEEE journals and conferences.

Prof Mario da Silva has also written and co-authored numerous titles, including 'Multimedia Communications and Networking', 'Transmission Techniques for 4G Systems', 'MIMO Processing for 4G and Beyond: Fundamentals and Evolution' and more..

INTEGRATED HANDS-ON LAB EXERCISES

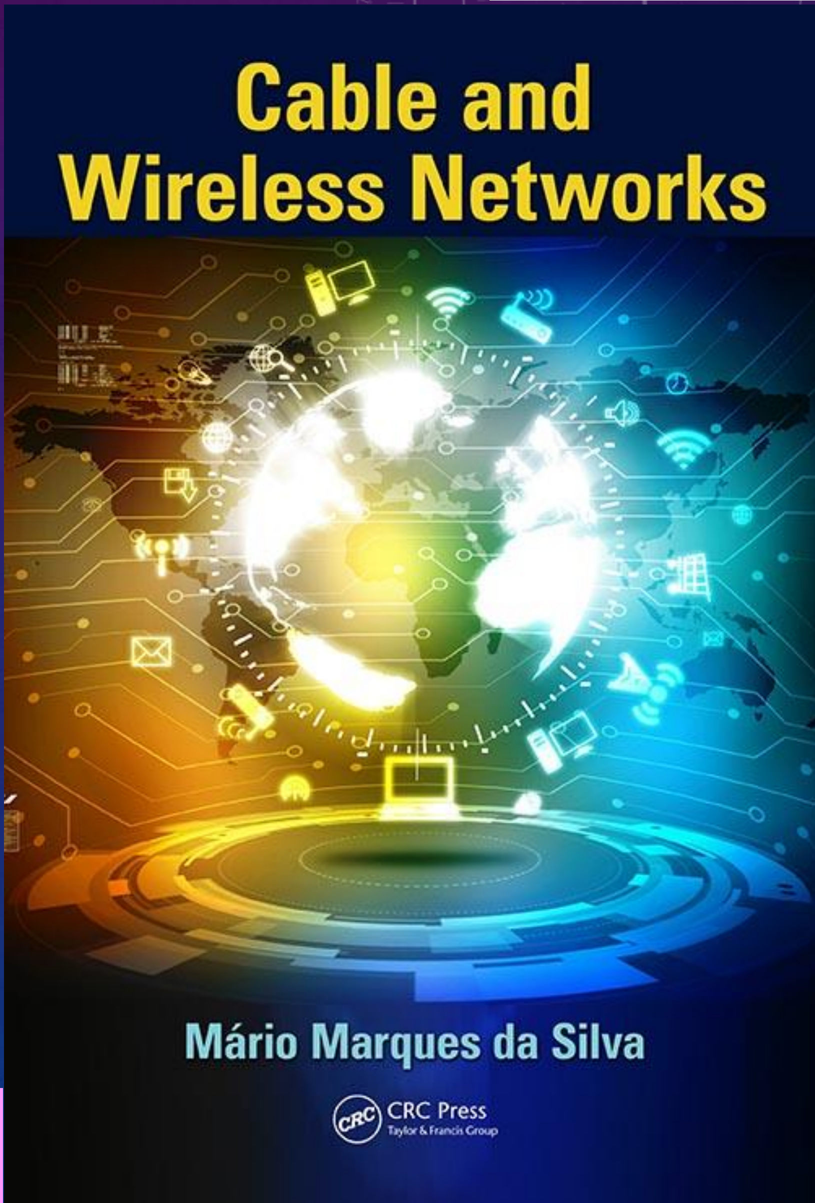
ETT-101 Lab Exercises at the end of each chapter and the APPENDIX listing TIMS-301C experiments



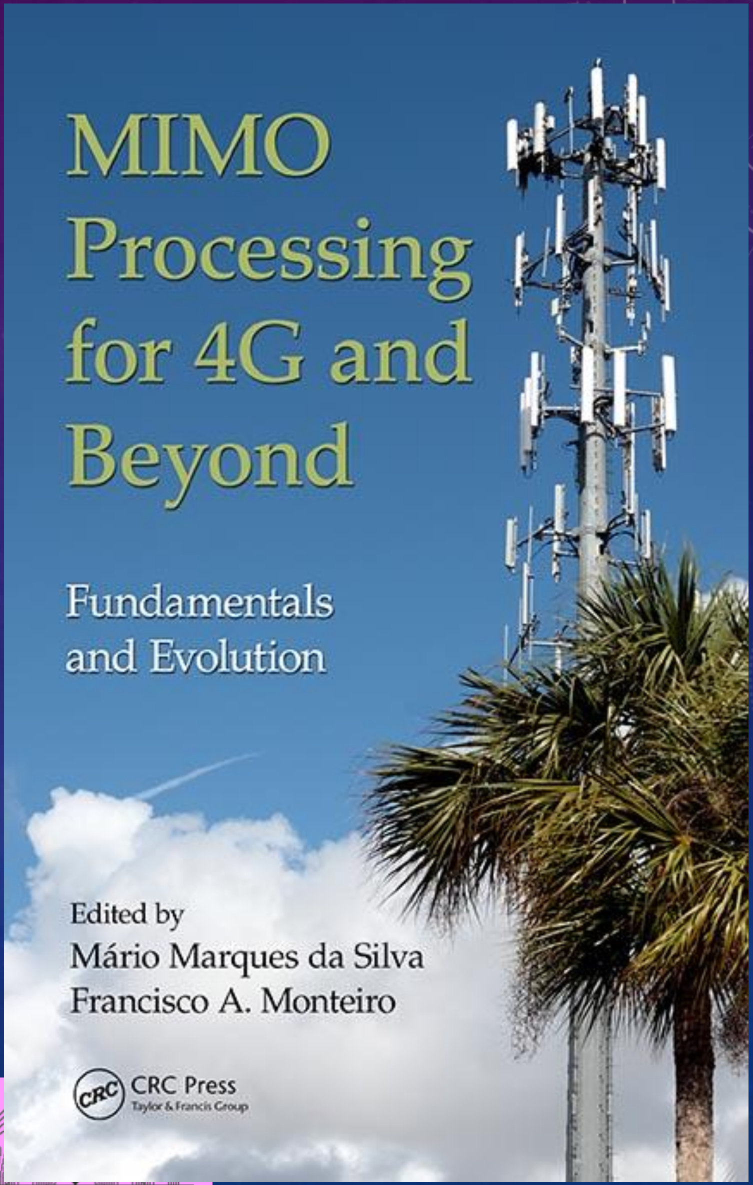


ABOVE : Illustration of the seven page Appendix, tabulating advanced TIMS experiments (Experiment Reference) against textbook chapters.

LEFT : LAB EXERCISES at the end of each chapter reference experiments from the four ETT-101 Lab Manuals.



BOOK: MIMO PROCESSING FOR 4G AND BEYOND (CRC PRESS)



ACKNOWLEDGEMENTS

- This work was supported by FCT project IT UID/EEA/50008/2013