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Receiver-based Recovery of Clipped OFDM Signals for PAPR Reduction: A Bayesian Approach

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OFDM

- OFDM is a multi-carrier modulation scheme that uses orthogonal carriers.
- Main Advantages include
  - Robustness against multi-path fading.
  - High data rate.
  - Easy single tap equalization.
- The main disadvantage is **High PAPR!** [1]

High PAPR

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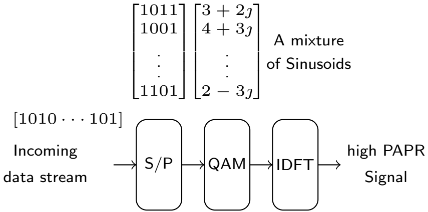

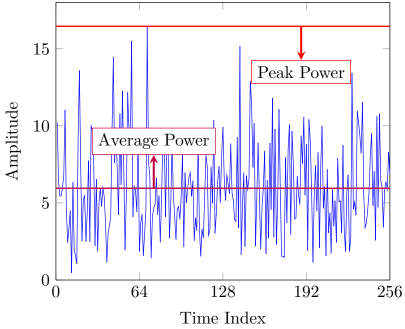

Transmitter based schemes

- coding, partial transmit sequence (PTS), selected mapping (SLM), interleaving, tone reservation (TR), tone injection (TI) and active constellation extension (ACE).
- Transmitter-based techniques are complex.

Clipping

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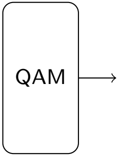
- We follow a clipping scheme
- clip signal above a prespecified threshold γ

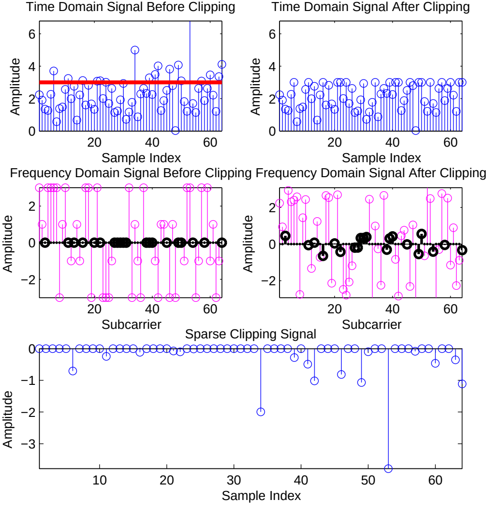
$$x_p(i) = \begin{cases} \gamma e^{\jmath \angle x(i)} & \text{if } |x(i)| > \gamma \\ x(i) & \text{otherwise} \end{cases}$$

- $x_p(i) = x(i) + c(i)$



$$\begin{bmatrix} 3+2\jmath \\ {\color{red}0} \\ \vdots \\ 2-3\jmath \end{bmatrix}$$

- Implications:
  - Clipping signal is **sparse**!
  - Pilot contamination.
  - Inter-user Interference.



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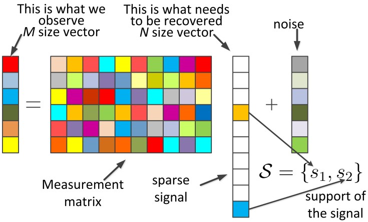
Implications of Sparsity

- Signal can be reconstructed using sparse signal recovery methods.
- Few Measurements will be required.

Why Bayesian Recovery?[a]

- Low Complexity.
- Signal statistics are not required.
- Agnostic to distribution.
- Noise statistics are utilized.



[a] By Bayesian recovery, we refer to the utilized SABMP scheme [2].

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Reliable Perturbations

- Reserved tones reduce bandwidth efficiency.
- Some data carriers (called Reliable tones) can be used as measurements.

Question

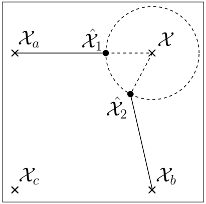
How to select the tones which are most likely to be in their correct decision region?

- Calculate the metric [3]

$$\mathfrak{R} = \frac{\text{Pr}(\lfloor \hat{\mathcal{X}}(i) \rfloor = \mathcal{X}(i))}{\text{Pr}(\lfloor \hat{\mathcal{X}}(i) \rfloor \neq \mathcal{X}(i))}$$

$\lfloor \cdot \rfloor$ denotes hard decision.

Geometrical representation of adopted reliability criteria.



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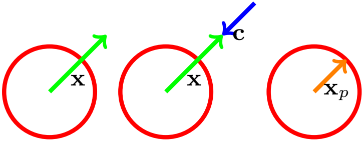
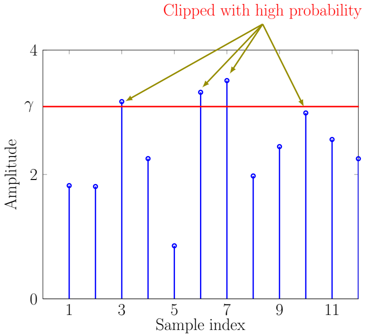
Phase and Likelihood

- Clipping operation does not affect the phase.

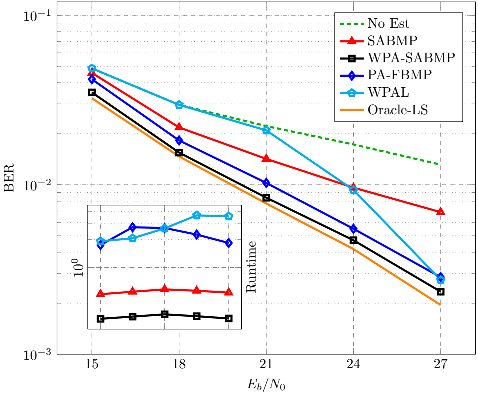


- Phase of the clipping signal can be retrieved from the received clipped signal.
- This helps in increasing the measurements.



- Probability of a clipping element is high, if received signal is closer to threshold.
- Find the dominant support faster and accurately.

Simulation Results



Simulation Parameters:

- Subcarriers: 512
- QAM Order: 64
- Reliable Carriers: 128
- Clipping Ratio: 1.61

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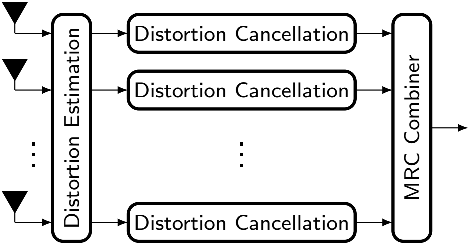
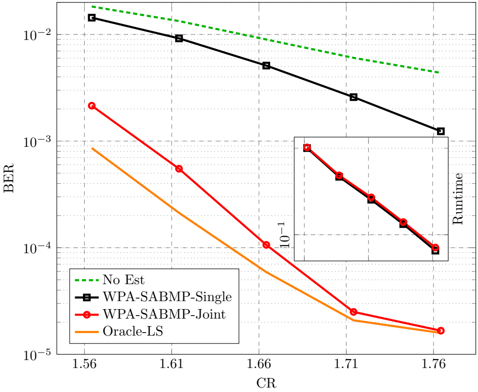
Same clipping on all antennas

- Multiple receiver antennas provide more measurements for clipping reconstruction.
- Use measurements from all antennas together to improve clipping mitigation [4].

$$\begin{bmatrix} \bar{\boldsymbol{\mathcal{Y}}}_1 \\ \bar{\boldsymbol{\mathcal{Y}}}_2 \\ \vdots \\ \bar{\boldsymbol{\mathcal{Y}}}_L \end{bmatrix} = \begin{bmatrix} \bar{\boldsymbol{\Phi}}_1 \\ \bar{\boldsymbol{\Phi}}_2 \\ \vdots \\ \bar{\boldsymbol{\Phi}}_L \end{bmatrix} \mathbf{c} + \begin{bmatrix} \bar{\boldsymbol{\mathcal{Z}}}_1 \\ \bar{\boldsymbol{\mathcal{Z}}}_2 \\ \vdots \\ \bar{\boldsymbol{\mathcal{Z}}}_L \end{bmatrix},$$



Simulation Results



Simulation Parameters:

- Subcarriers: 512
- QAM Order: 64
- Reliable Carriers: 77
- Eb/N0: 27 dB
- Antennas: 2

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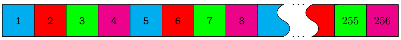
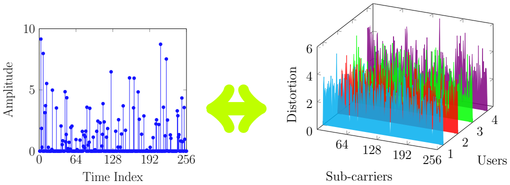
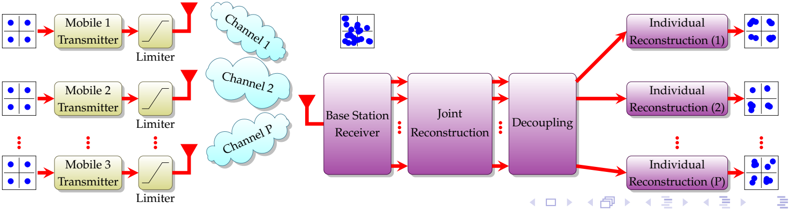
OFDMA System

Orthogonal Channel Allocation



Challenge→ Distortions Overlap in Frequency Domain

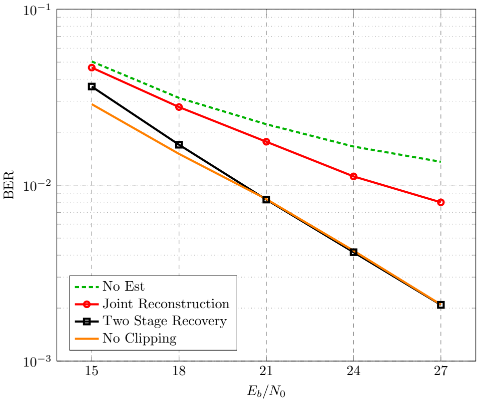




Two Stage Recovery

- Initially reconstruct jointly.
- Form decoupled systems.
- Perform individual reconstruction.

Simulation Results



Simulation Parameters:

- Subcarriers: 512
- Users: 2
- QAM Order: 64
- Reserved Tones: 75
- Clipping Ratio: 1.61

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Contaminated Pilots

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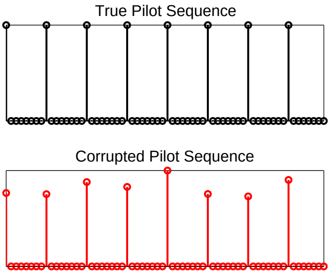
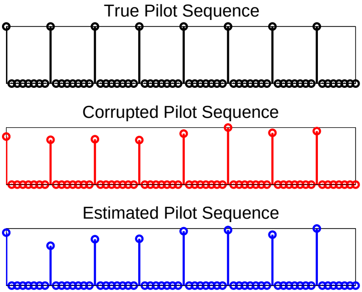




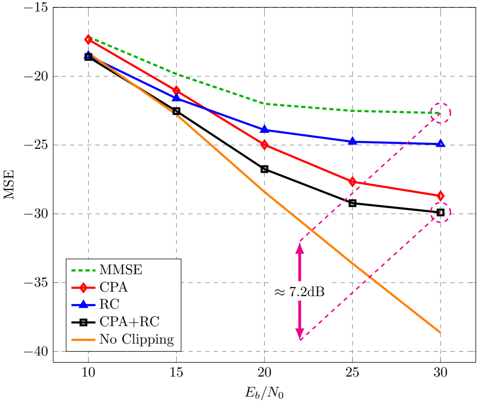
Solutions

- Increase pilots.
- Data Aided pilot Estimation.

Proposed

- Estimate Corrupted Pilots.
- Use estimated and data aided pilots together.

Results



Simulation Parameters:

- Subcarriers: 256
- QAM Order: 64
- Pilot Tones: 16
- Reliable Tones: 16
- Clipping Ratio: 1.73

References

[1] S. H. Han and J. H. Lee, An overview of peak-to-average power ratio reduction techniques for multicarrier transmission, IEEE Wireless Commun., vol. 12, no. 2, pp. 5665, 2005.

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[3] E. B. Al-Safadi and T. Y. Al-Naffouri, "Pilotless Recovery of Nonlinearly Distorted OFDM Signals by Compressive Sensing over Reliable Data Carriers," in Proc. IEEE Int. Workshop on Signal Process. Advances in Wireless Commun. (SPAWC), 2012.

[4] A. Ali, A. Al-Zahrani, T. Y. Al-Naffouri, "Receiver Based PAPR Reduction in OFDMA", in Proc. IEEE Int. Conf. Acoust. Speech Signal Process., 2014.

For more information...

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THANK YOU!