Peak-to-Average Power Ratio Reduction in Interleaved OFDMA Systems

The 15th International Symposium on Signal Processing and Information Technology
(ISSPIT'15)

Presented by
Shamael Al-Shuhail

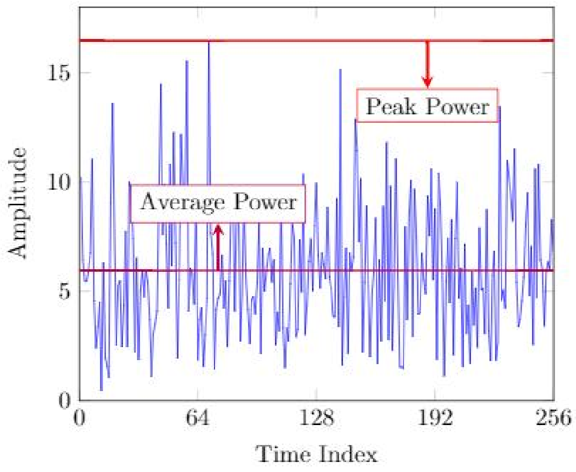
King Abdullah University of Science & Technology
Computer, Electrical and Mathematical Sciences and Engineering

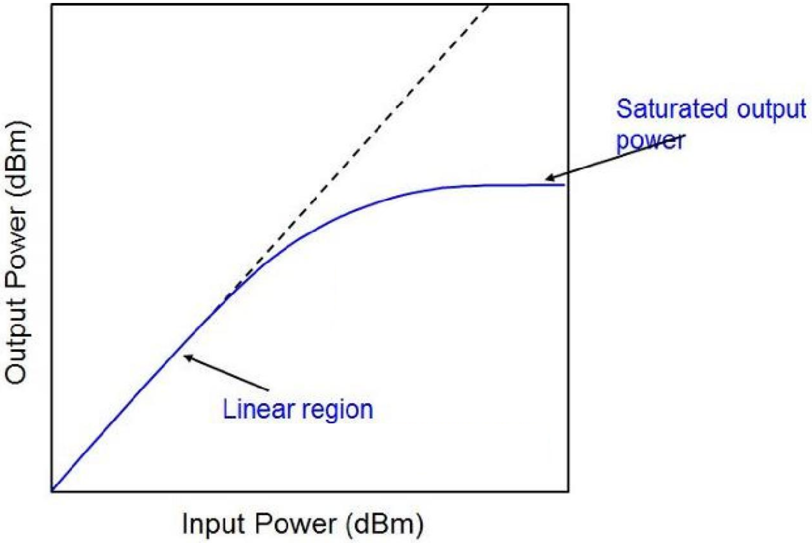
Outline

- Introduction
  - OFDMA systems
  - Compressive Sensing (CS)
- PAPR Reduction in OFDMA
- Clipping Distortions in OFDMA
- Self-inflected Clipping Distortions
- Theoretical Proof
- Numerical Results
- Conclusions

OFDMA Systems

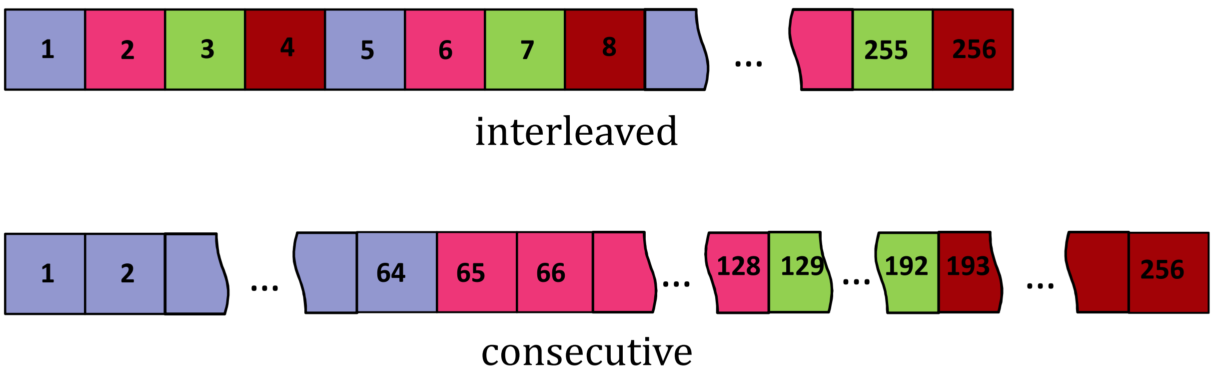
- OFDMA is multi-carrier modulation scheme that uses orthogonal carriers.
- Some OFDMA advantages: Robustness against multi-path fading and high data rate.
- Main drawback is the high PAPR.
- High peak signal at the output of the power amplifier is distorted because its operating in the saturation region.





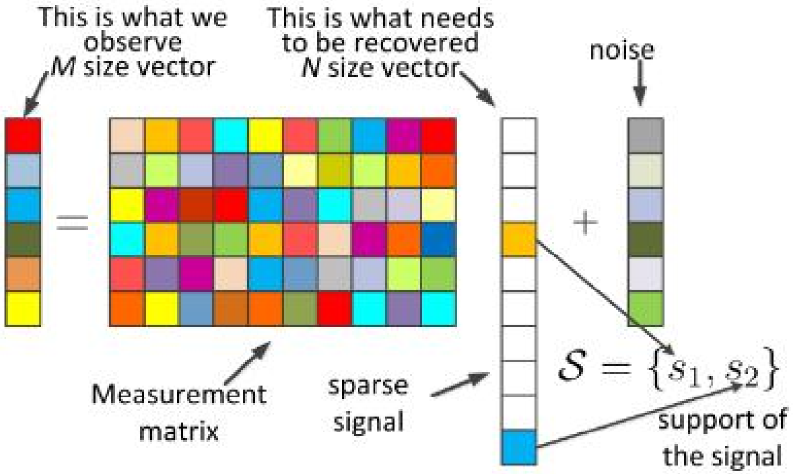
OFDMA

- OFDMA assigns a subset of available subcarriers for each user.
- Users are allocated to subcarrier in either an interleaved or consecutive manner.



Compressed Sensing

- CS is a signal processing tool that solves underdetermined system of linear equations.
- CS is one such tool that allows recovering any sparse signal.
- It requires only a few measurements in a domain that is incoherent with the domain of sparsity.
- Examples of sparse recovery schemes: OMP, IT, ℓ_1-minimization and other Bayesian methods.



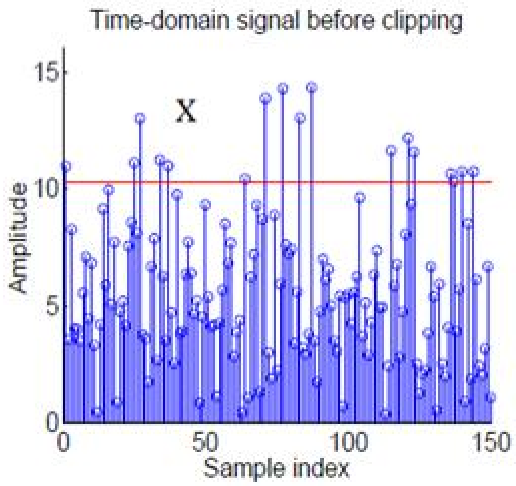
CS in OFDMA

- A solution we use for PAPR reduction is clipping.

- Due to the high PAPR nature of the OFDMA signal, only a few instances are clipped.

- Resulting in clipping distortions (clipping signal) that is sparse.

- By employing CS we are able to recover the sparse clipping signal back.

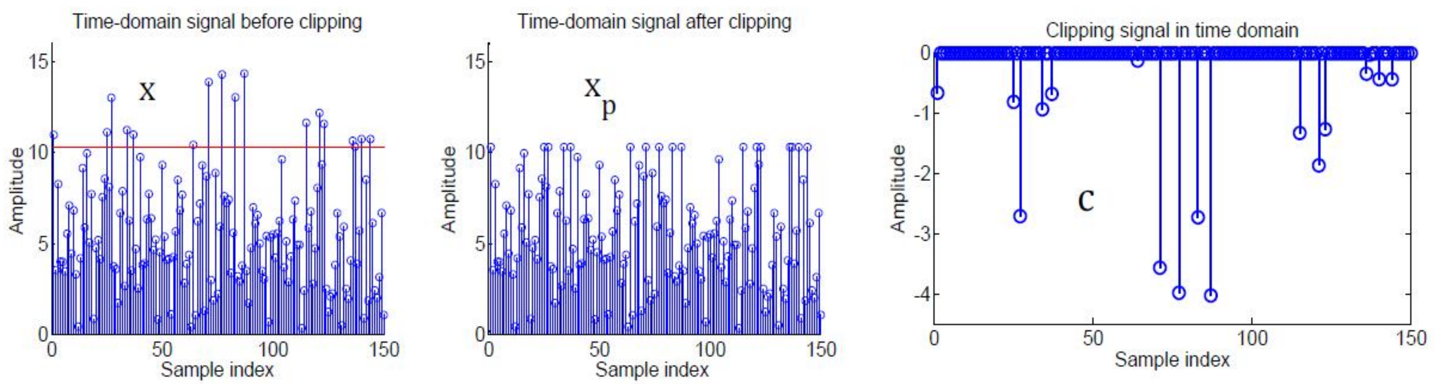


PAPR Reduction in OFDMA

- One of the simplest approaches used for PAPR reduction is clipping.
- The clipping operation of the signal

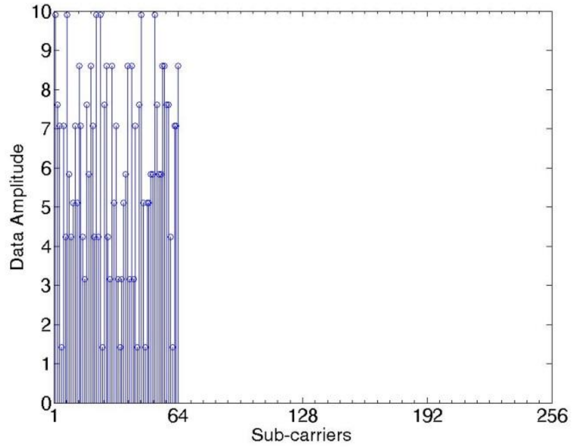
$$x_p(i) = \begin{cases} \gamma \exp(j\angle x(i)) & if\ |x(i)| > \gamma \\ x(i) & otherwise, \end{cases}$$

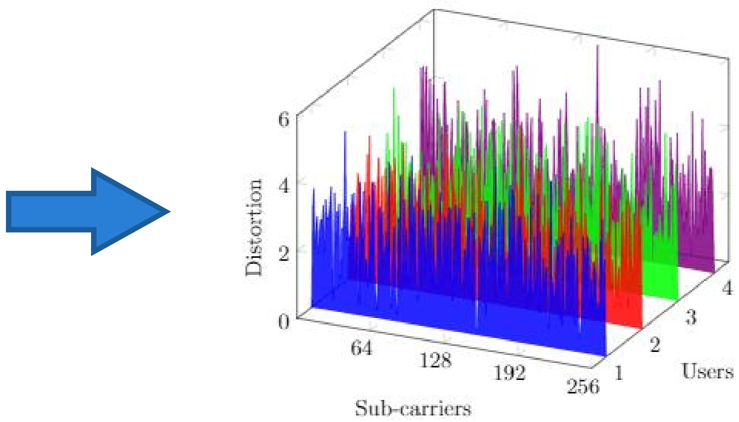
- γ depends on a clipping ratio $CR = \frac{\gamma}{\sigma}$ where σ is the root mean squared power of the transmitted signal.



Clipping in OFDMA

- The challenge here is that with many users subjected to clipping, clipping distortions tend to overlap in frequency domain.





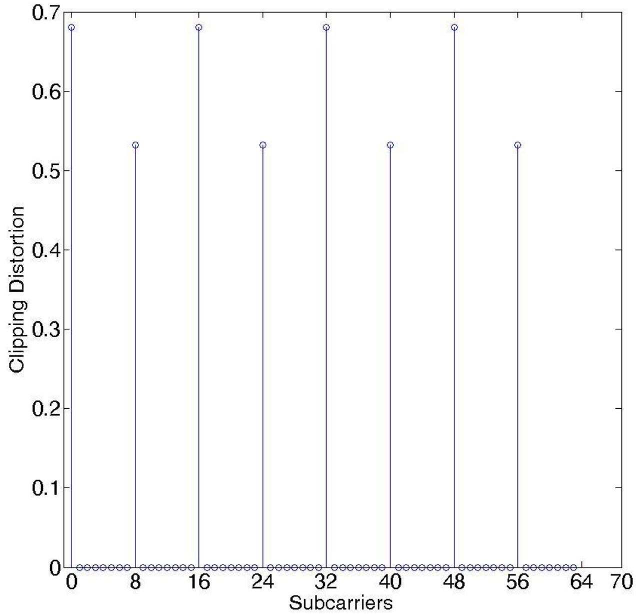
- However, it is observed that interleaved OFDMA, clipping distortions are only self-inflicted (mathematical proof authenticating the observation)

Self-inflected Clipping Distortions

- Two ways for OFDMA assignment:
  - Interleaved
  - Consecutive

- Interleaved assignment is robust against frequency selective fading.

- An interesting phenomena in interleaved OFDMA is self-inflected clipping distortions.



when $N = 64$ subcarriers
$U = 8$ users
0^{th} user clipped

Theoretical Observation

- Data generated and allocated for user u

$$\mathbf{X}^u = \begin{bmatrix} \mathbf{0}_u & X^u(0) & \mathbf{0}_{U-1} & X^u(1) & \dots & X^u(P-1) & \mathbf{0}_{U-(u+1)} \end{bmatrix}^\top$$

↓ Inverse Fourier Transform

- The result is a time domain periodic signal for period N/U

↓ After clipping

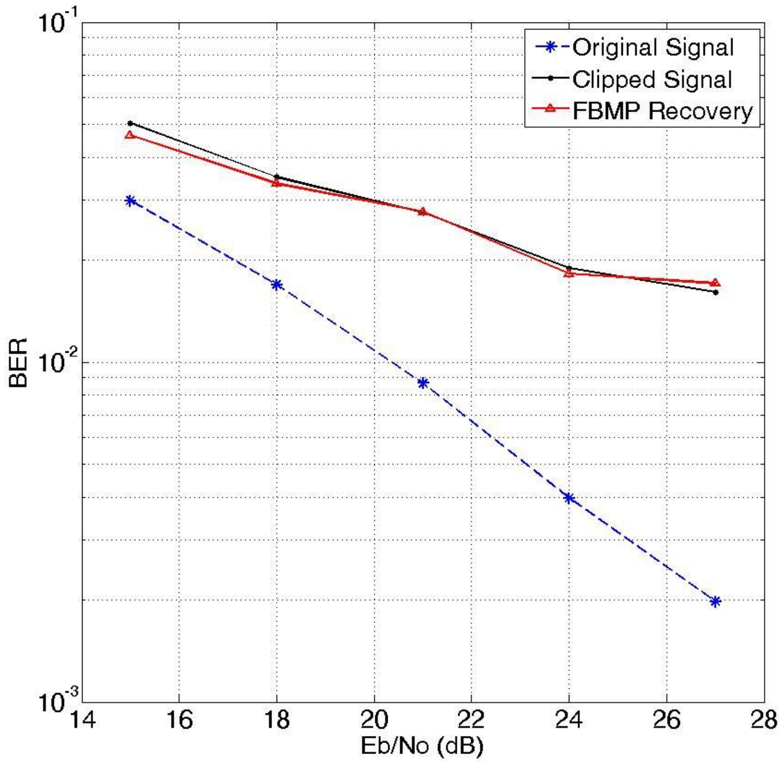
- The time domain clipping signal periodic for period N/U

↓ Fourier Transform

$$\mathbf{C}^u = \begin{bmatrix} \mathbf{0}_u & C^u(0) & \mathbf{0}_{U-1} & C^u(1) & \dots & C^u(P-1) & \mathbf{0}_{U-(u+1)} \end{bmatrix}^\top$$

Based on the reciprocity property of Fourier Transform.

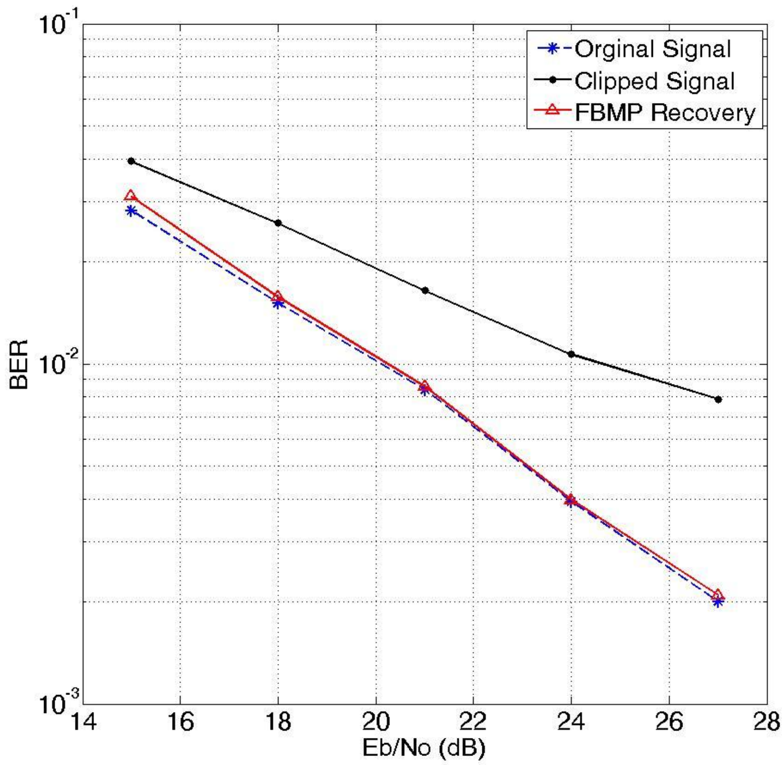
Numerical Results of Consecutive OFDMA



Simulation Parameters:

- Subcarriers = 128
- Users= 2
- QAM order = 64
- Reserved tones = 32 per user
- $CR = \sqrt{3}$

Numerical Results of Interleaved OFDMA



Simulation Parameters:

- Subcarriers = 128
- Users= 2
- QAM order = 64
- Reserved tones = 32 per user
- $CR = \sqrt{3}$

Conclusions

- Due to the periodicity of the time domain clipped signal, the combined OFDMA signal at the receiver is separable in frequency domain.
- A subsystem has been formed for each user and a compressed sensing tool has been used to recover the clipped signal.
- Theoretical observations aligned with the numerical results.

Thank you for your attention!