Amplifier Nonlinearities in OFDM Multiple Antenna Systems

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Outline

- Introduction
- Peak to Average (PAR)
- Clipping
- Diversity in OFDM
- Clustered OFDM
- Interleaved OFDM
- Simulations and discussion
- Conclusions
- References
- Homework

Introduction

- Array Antenna Systems
  - Increase spectral efficiency.
  - Reduce co-channel interference.
  - Increase the reutilization factor.
  - Increase the complexity.
- OFDM
  - High Bit Rate.
  - Combat multipath fading.
  - High Peak-to-Average-Power Ratio

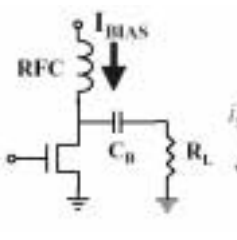
Introduction

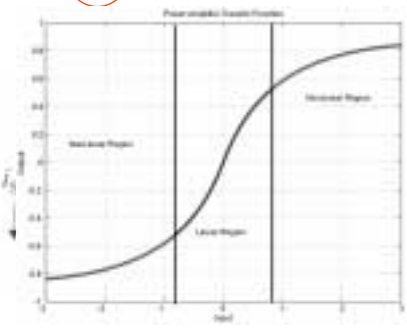
- Amplifier Nonlinearities.
  - Create Intermodulation Distortion.
  - Increase the interference level.
  - Radiate intermodulation products in different directions.

For small inputs this term is dominant

$$Y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \ldots$$

  - Large Back off
    - Power efficiency. ⬇
    - IMD ⬇
  - Small Back off
    - Power efficiency. ⬆
    - IMD ⬆

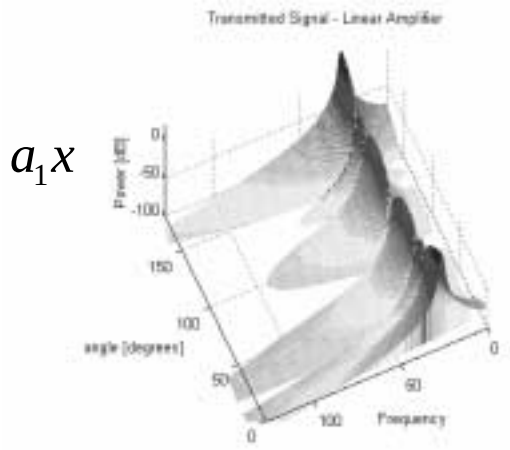


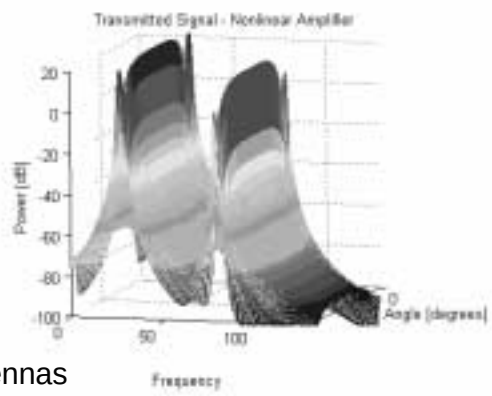


- Amplifier NonLinearities.

$$Y = a_1 x + a_3 x^3$$

$$Y = a_1 x$$



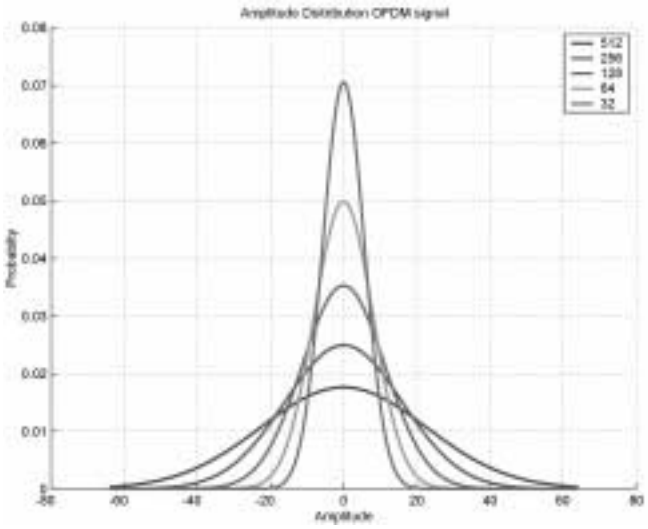


- 4 Tx Antennas
- 4 Users
- DOA =[35 45 90 150]

Peak to Average Ratio

- PAR $$PAR = \frac{\max |x(n)|^2}{E_n[|x(n)|^2]}$$
  - The amplitude distribution of OFDM signal

$$E[|x(t)|] = N\mu$$
$$VAR[|x(t)|] = N\sigma^2$$



Clipping

- Clipping Amplifier limits the amplitude of the transmitted signal

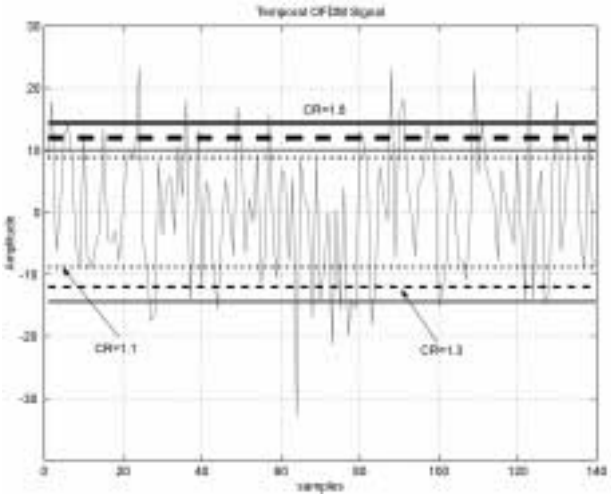
$$HPA = \begin{cases} x & |x| < A \\ A & |x| < A \end{cases}$$

Clipping Level

- Clipping Relation CR.

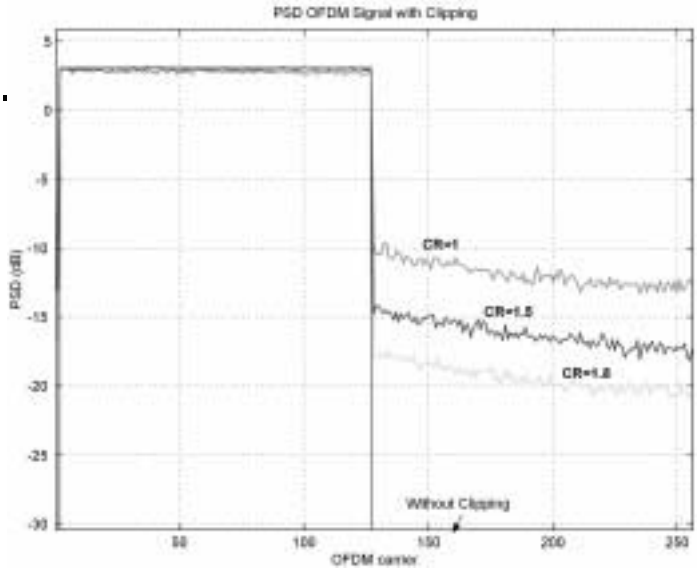
$$CR = \frac{A}{\sqrt{E[|x(t)|]}} = \frac{A}{\sqrt{N}}$$

Number of carriers



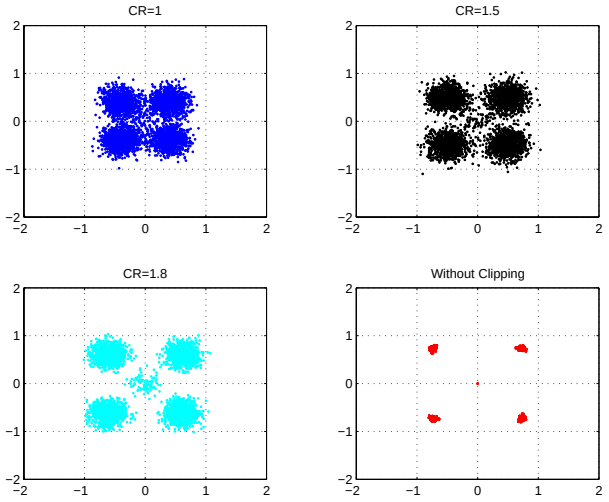
Clipping effects

- Spectral spreading.
- Intermodulation.
- Constellation



Clipping effects

- Spectral spreading.
- Intermodulation.
- Constellation distortion

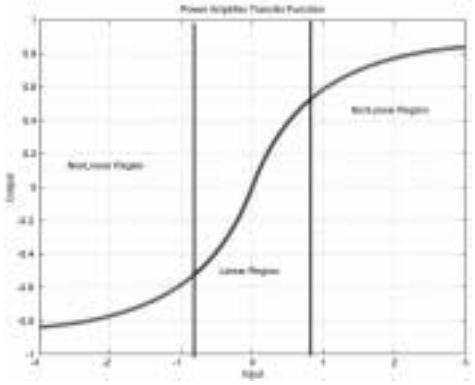


N=64

SNR=100dB

Clipping effects

- CR
  - Spectral spreading is reduced.
  - Constellation Distortion is small.
  - Power amplifier have to work with big levels of input signals →



Low efficiency region

Diversity in OFDM

- OFDM + MIMO
  - Higher Bit rate
  - Bigger Capacity
- Space Time Diversity
  - Delay Diversity.
  - Phase Diversity.
  - Cyclic Diversity.

Promising results in MIMO OFDM systems without nonlinearities

- Multiple Antennas transmit delayed versions of the original signals.
  - Level signals are similar to conventional OFDM.
  - The restrictions in the PA linearity are maintained

Linearity in the PA

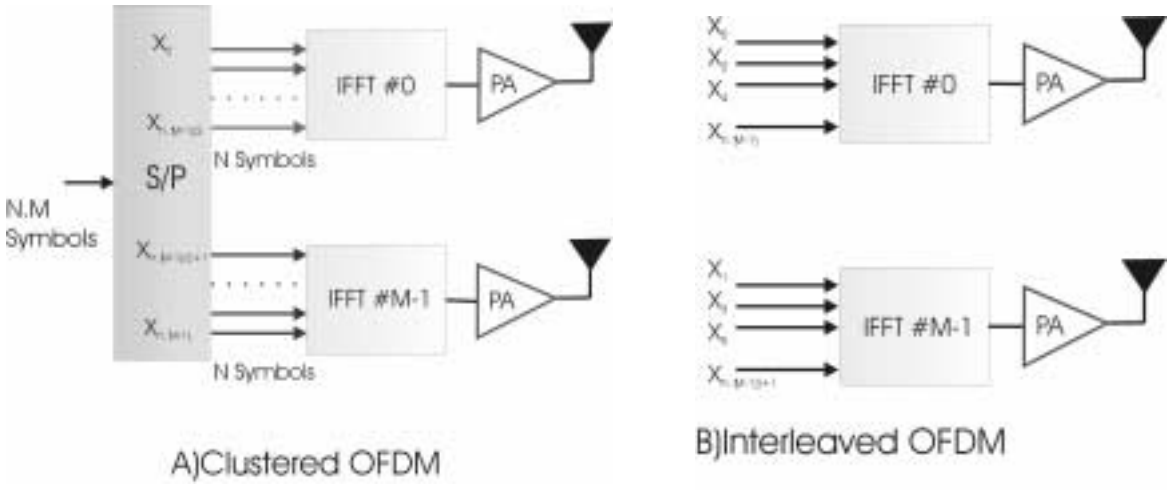
- Reducing the linearity restrictions in the PA
  - Predistortion techniques.
  - Coding or selective mapping.
  - Clipping.
  - Clustered OFDM

Clustered OFDM

- Split an OFDM symbol into group of subcarriers, which are processed, amplified and transmitted over separate antennas.
- The peak value for each block is reduced
  - Less spectral spreading
  - Less back off for each PA

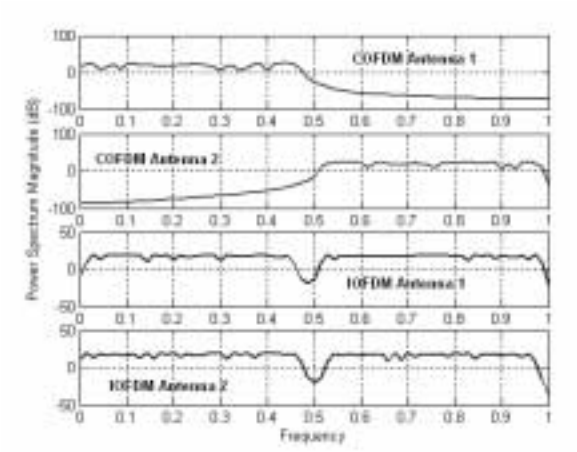
N	PAR_o	PAR_{c2}	PAR_{c4}
64	18dB	15dB	12dB
128	21dB	18dB	15dB

Clustered OFDM & Interleaved OFDM



Both techniques are feasible for OFDM multiple antenna Systems affected by nonlinearities in the PA

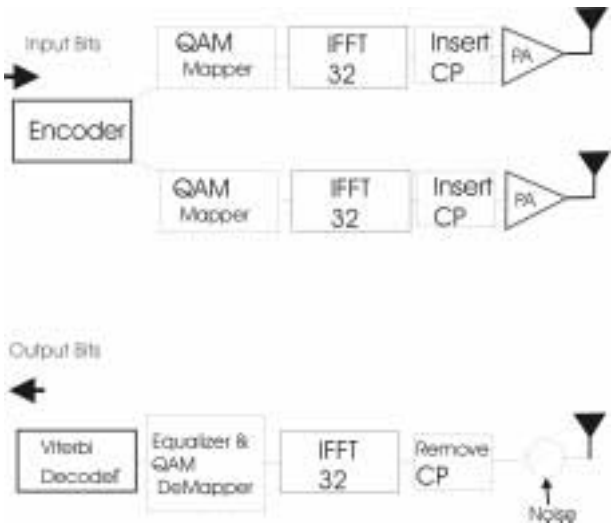
Clustered OFDM & Interleaved OFDM



Interleaved OFDM : The sub carriers transmitted for each antenna are spread over the whole frequency bandwidth, maximizing the frequency diversity

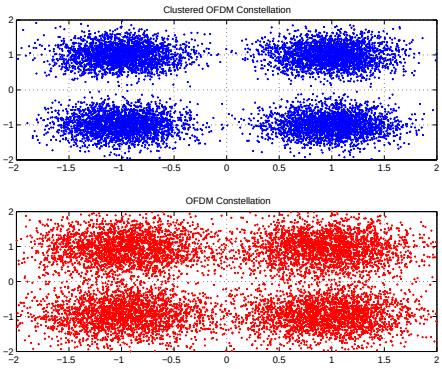
Simulations

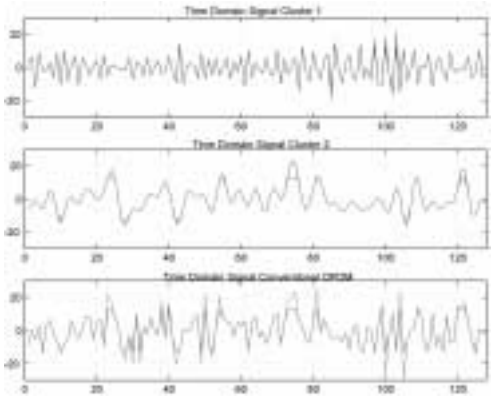
- WLAN Implementation
  - Conventional OFDM
  - Clustered OFDM
  - Interleaved OFDM
- Parameters
  - Sampling Frequency 20 MHz
  - Cyclic Prefix Length = 12
  - Clipping Ratio =1,2
  - Convolutional Encoder
  - Hard Viterbi Decoder
  - Channel delay Spread = 15 ns



Simulations

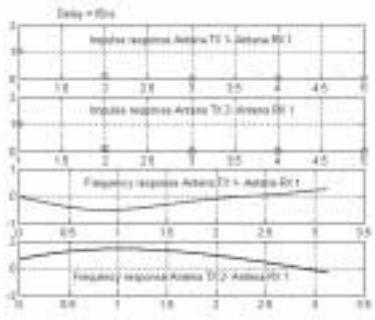
- Temporal Signals
- Constellation CR=1.1 SNR=12 dB

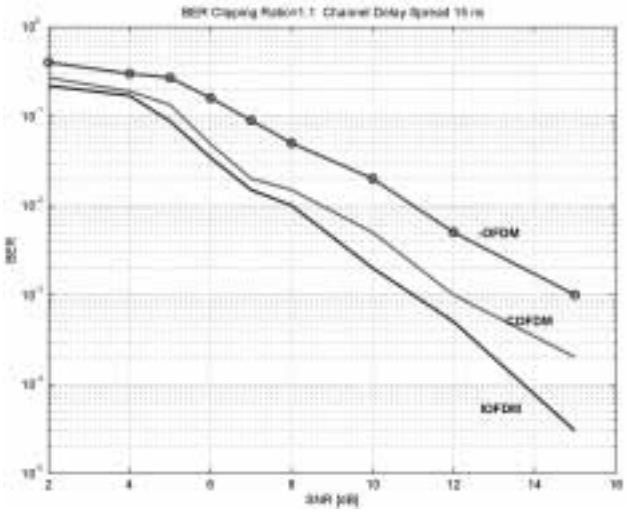




Simulations

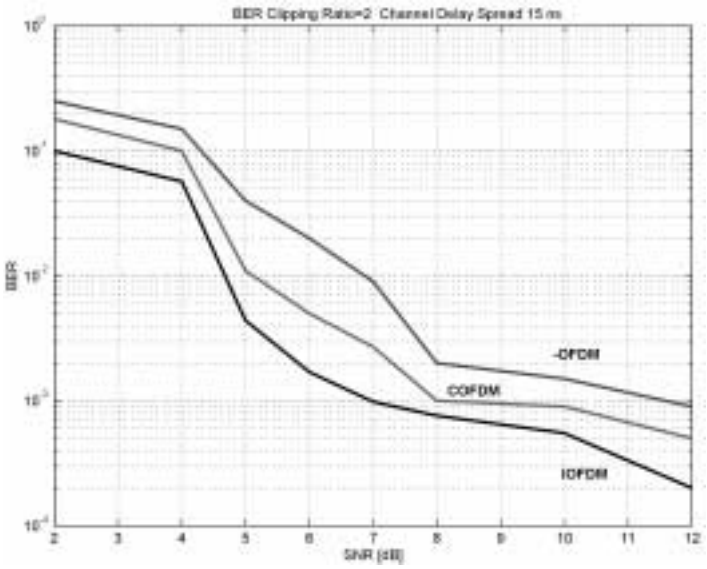
- BER
  - CR=1.1
  - Channel Delay Spread=15ns





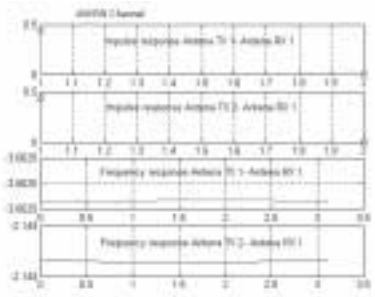
Simulations

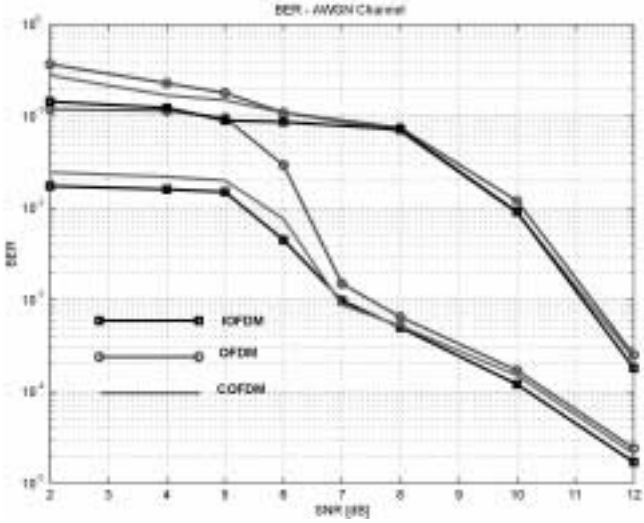
- BER
  - CR=2
  - Channel Delay Spread=15ns



Simulations

- BER
  - CR=1,1 , 2
  - AWGN Channel





Conclusions

- IOFDM and COFDM reduce the linearity restrictions in the PA.
- IOFDM has better performance in multipath channels than COFDM.
- Future Work : A beamforming structure can be added in order to reduce the IMD radiation.

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Homework

- An Interleaved OFDM (IOFDM) system has better performance than Clustered OFDM (COFDM) in a multipath channel.

Why?

Justify.