COST 289 Spectrum and Power Efficient Broadband Communications

Multi-user detection of nonlinearly distorted MC-CDMA symbols by microstatistic filtering

Jozef Krajňák*, Marc Deumal†, Pavol Pavelka*, Dušan Kocur*,
Joan Lluís Pijoan†, Pavol Galajda*

*Department of Electronics and Multimedia Communications
Faculty of Electrical Engineering and Informatics, Technical University of Košice, Slovakia
†Department of Communications and Signal Theory
La Salle School of Engineering, Ramon Llull University, Barcelona, Spain

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Outline

Multicarrier systems with nonlinear amplifiers

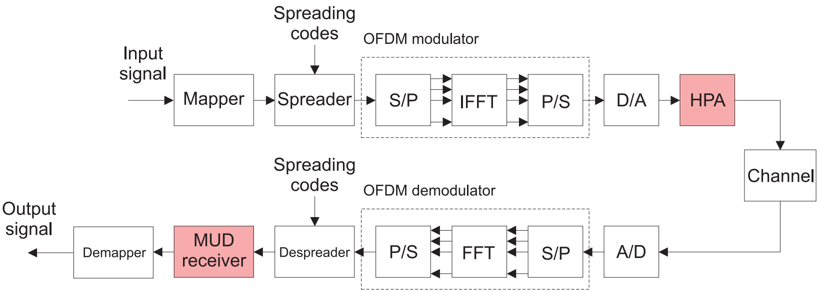

Fig.1. Block scheme of nonlinearly distorted MC-CDMA transmission system.

Nonlinear HPA model

- **Saleh model**

$$\text{AM/AM: } G(u_x) = \frac{\kappa_G u_x}{1 + \chi_G u_x^2}$$

$$\text{AM/PM: } \Phi(u_x) = \frac{\kappa_\Phi u_x^2}{1 + \chi_\Phi u_x^2}$$

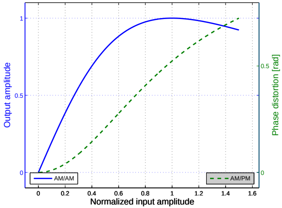

Fig.2. Saleh model.

Nonlinear HPA produce:

- **Spectral outgrowth**
  - Generated by the intermodulation products outside the transmission bandwidth.
  - It interferes neighboring communication systems.
- **The signal constellation is largely distorted**
  - Generated by the in-band intermodulation products.
  - It increases the error rate.

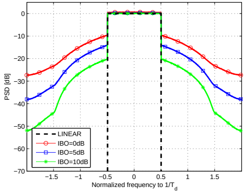

Fig.3. Spectral outgrowth of NL distorted signal.

Compensation techniques

- **Linearization**
  - Linearize the amplifier response.
  - Performed at the transmitter side: both the spectral outgrowth and the BER performance degradation may be reduced.
- **Reducing the envelope fluctuations of the transmitted signal**
  - By reducing the envelope fluctuations we reduce the performance degradation.
  - Performed at the transmitter side: both the spectral outgrowth and the BER performance degradation may be reduced.
- **Post-processing**
  - Processes the received signal with the aim to eliminate the distortion term introduced by the transmitter nonlinearity.
  - Performed at the receiver: Multi-user detection (MUD), only the BER performance degradation is reduced.

Microstatistic filtering based MUD

- **The MSF-MUD is based on its nonlinear, but piece-wise linear structure**
  - It is able to compensate different types of a complex-valued nonlinearity.
  - High flexibility and simplicity.
- **MUD designed**
  - Mean-square error criterion.
  - A training sequence.

Block scheme of MSF-MUD

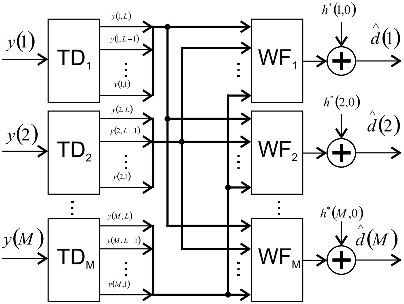

Fig. 4. Block scheme of MSF-MUD.

- M - the number of input/output channels
- $y(i)$ - i-th input complex signal
- $\hat{d}(k)$ - k-th output complex signal
- M complex valued threshold decomposers
- A set of M multichannel Wiener filters
- $h(k, 0)$ is applied in order to obtain an unbiased estimation of desired signal, at the output of WF_k.

Threshold level decomposer

- **Threshold level estimation**
  Scanning method, Genetic algorithm based method, method of cumulative distribution function, histogram based method, ...
- **Input signal**

  $$y(i) = Y(i)e^{j\phi(i)}$$

- **Modul decomposition of input signal**

  $$Y(i,j) = \begin{cases} 0 & \text{if} \quad Y(i) < I(i,j-1) \\ Y(i) - I(i,j-1) & \text{if} \quad I(i,j-1) \leq Y(i) < I(i,j) \\ I(i,j) - I(i,j-1) & \text{if} \quad I(i,j) \leq Y(i) \end{cases}$$

  for $1 \leq j \leq L$, where L is number of threshold levels
- **Output signals**

  $$y(i,j) = Y(i,j)e^{j\phi(i)}$$

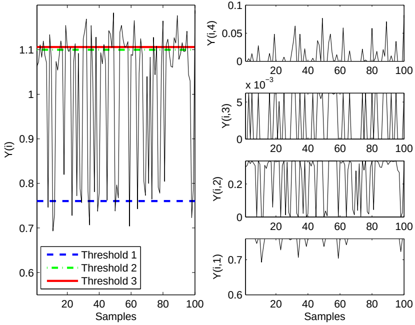

Fig. 5. Signal decomposition.

System configurations

- Conventional MC-CDMA system
- Downlink scenario
- AWGN channel
- Length-16 and -32 Hadamard spreading codes
- 16-QAM, 64-QAM and 256-QAM baseband modulation schemes
- Different user loads
- Average PAPR is minimized
- FFT length of 1024 subcarriers, with oversampling rate 4
- Saleh model of nonlinearity
- EVM performance evaluation:

$$EVM = 10log_{10}\left(E[|R_n - I_n|^2]/P_{ref}\right)$$

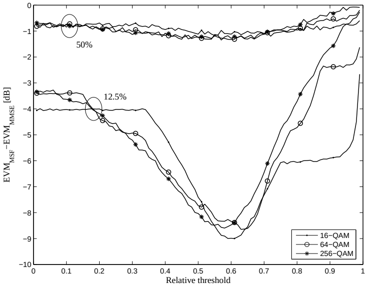

Fig. 6. EVM reduction with respect to MMSE-MUD as a function of the threshold level. 16, 64 and 256-QAM, length-32 Hadamard codes with 12.5% and 50% user load, and Saleh NL operating at IBO=20dB is used.

Simulations and results

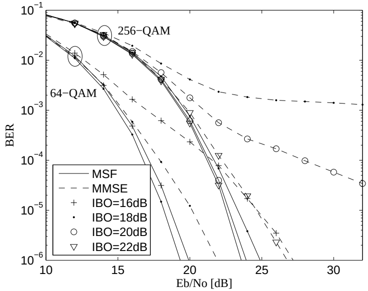

Fig.7. BER performance of a nonlinearly distorted MC-CDMA system using MSF-MUD and MMSE-MUD. 12.5% user load and SF=16 is used.

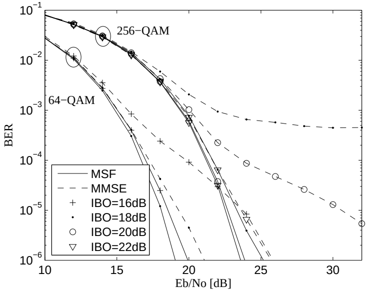

Fig.8. BER performance of a nonlinearly distorted MC-CDMA system using MSF-MUD and MMSE-MUD. 31.25% user load and SF=16 is used.

Simulations and results

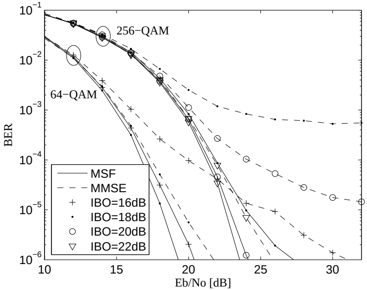

Fig.9. BER performance of a nonlinearly distorted MC-CDMA system using MSF-MUD and MMSE-MUD. 12.5% user load and SF=32 is used.

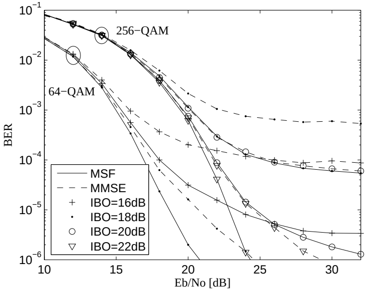

Fig.10. BER performance of a nonlinearly distorted MC-CDMA system using MSF-MUD and MMSE-MUD. 31.25% user load and SF=32 is used.

Conclusions

- High sensitivity of MC systems to nonlinear amplification introduced by HPA
- Nonlinear amplification destroys properties of spreading codes (orthogonality)
- No a priori information about the HPA are not need for MSF-MUD
- MSF-MUD is based on training sequence
- Performance of MSF-MUD is allways better than, or at least equal to that of MMSE-MUD
- Performance improvement is achieved for low user load ($\leq 50\%$)
- MSF-MUD is promissing tool for suppressing of nonlinear distortion due to HPA.

Thank you very much for your attention.