Predistortion Linearization Measurement Results for Power Amplifiers with Memory Effects

Hua Qian, Lei Ding, G. Tong Zhou,
and J. Stevenson Kenney

School of Electrical and Computer Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0250, USA

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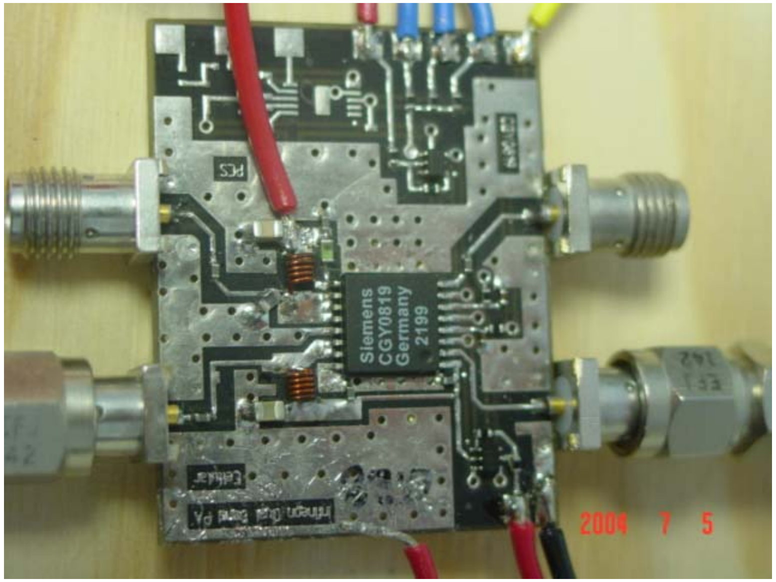
Outline

- Introduction
  - Linearity vs. efficiency
  - PA memory effects
- Digital baseband predistortion (PD)
  - Polynomial model
  - Orthogonal polynomials
  - Memory polynomial model
- Test-bed for the digital baseband PD
- Measured predistortion linearization results
- Conclusions

Device Under Test

- Two RF PAs

Ericsson 45 W basestation PA



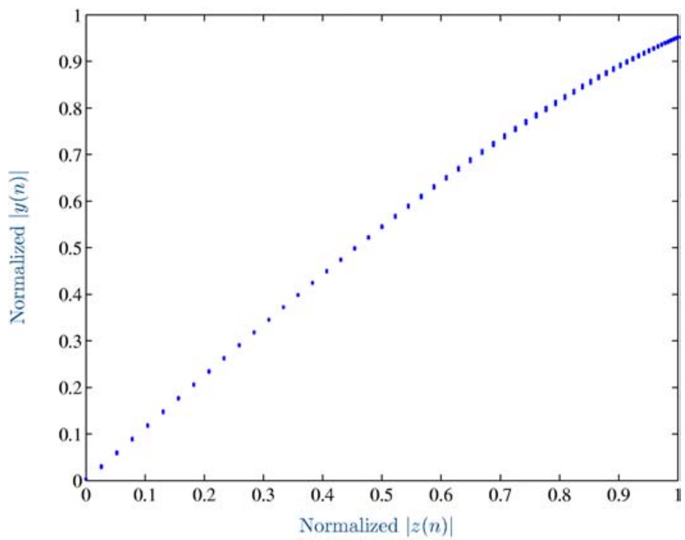
Siemens 1 W handset PA

Efficiency vs. Linearity

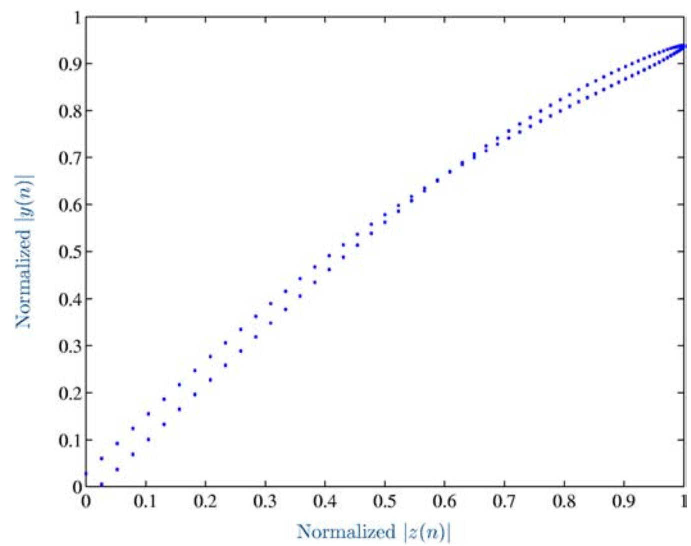
- The PA efficiency $\eta = P_{RF}/P_{DC}$.
- High efficiency PAs are desirable
  – For the handset, long battery life
  – For the base station, reduced operating costs
- High efficiency PAs are usually nonlinear. Nonlinearity causes
  – Spectral regrowth (broadening)
  – In-band distortion and hence increased BER
- PA linearization is often necessary

PA Memory Effects

- For high PAs and/or wideband signals, PA memory effects can be significant.
- Memoryless linearization becomes less effective.
- The hysteresis behavior in the AM/AM response of the Ericsson PA is a sign of memory effects.



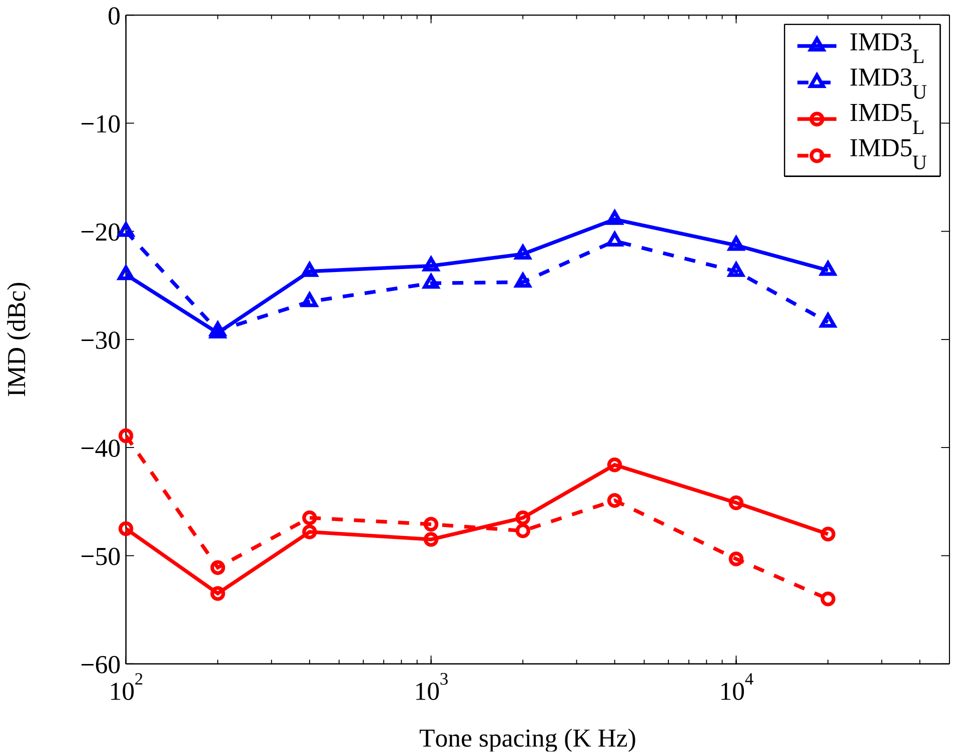
AM/AM characteristics of the Siemens 1 W PA



AM/AM characteristics of the Ericsson 45 W PA

PA Memory Effects (Cont'd)

- The asymmetric IMDs in the lower and upper sidebands also indicate memory effects.



The IMD products vs. tone spacing for the Ericsson 45W PA.

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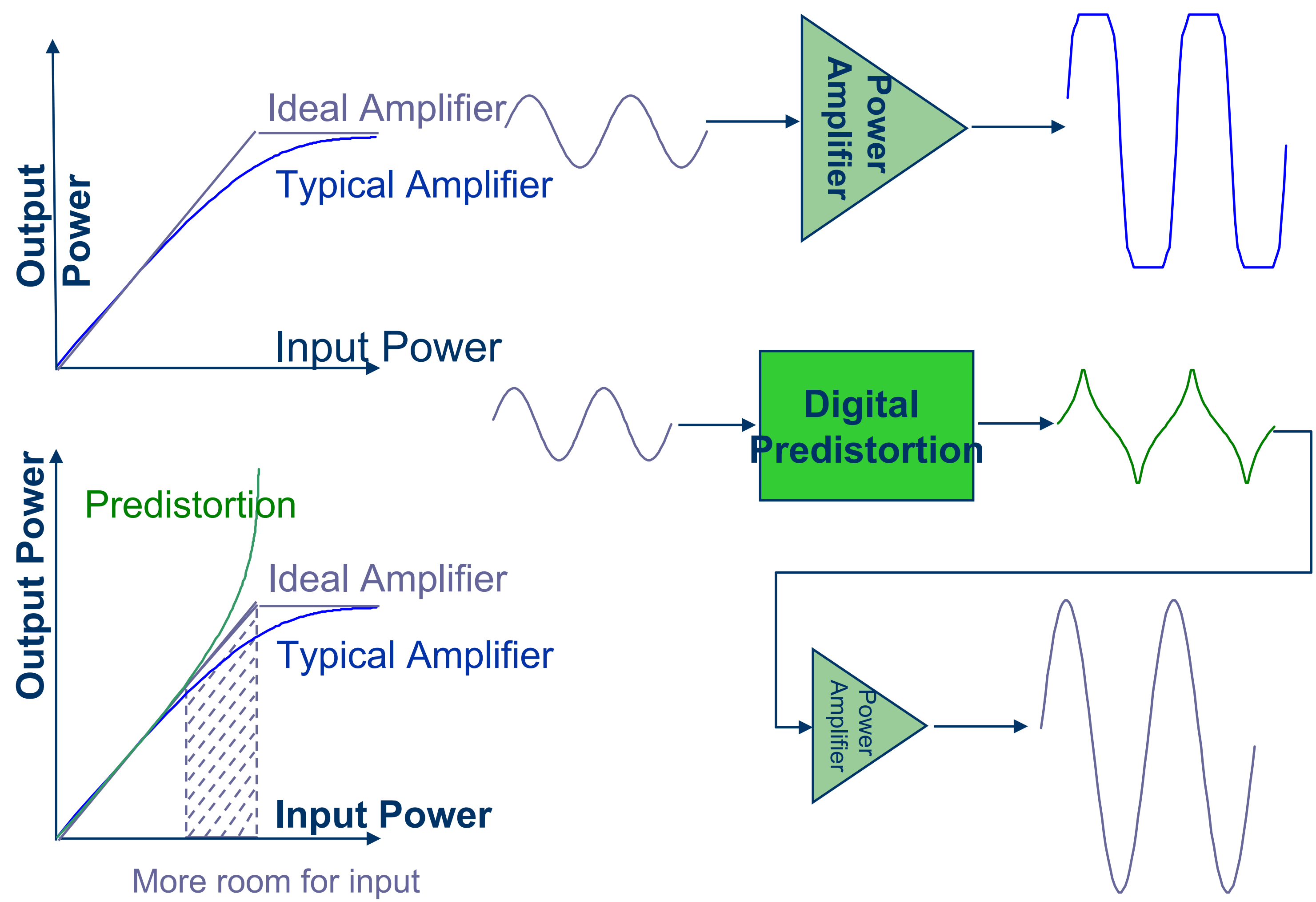
Digital Baseband Predistortion



Memoryless Polynomial Model

- Memoryless polynomial PD model

$$z(n) = \sum_{k=1}^{K} a_k \; x(n)|x(n)|^{k-1}$$

- Can be used to model weak *memoryless* nonlinearities.
- Both even- and odd-order polynomials are included to improve the modeling accuracy [Ding-Zhou'04].
- Typical polynomial order: K = 5 ~ 7.

Orthogonal Polynomials

- When *K* is large, the regressor matrix in the least-squares coefficient estimation is ill-conditioned and causes numerical instability.
- Orthogonal polynomial basis can be applied to improve the numerical stability [Raich-Qian-Zhou'04]

$$\psi_k(x) = \sum_{l=1}^{k} \frac{(-1)^{l+k}(k+l)!x\,|x|^{l-1}}{(l-1)!(l+1)!(k-l)!}$$

- Conv. polynomial basis: $\phi_k(x) = |x|^{k-1}x$
- Conv. polynomial PD: $z(n) = \sum_k a_k\, \phi_k(x(n))$
- Ortho. polynomial PD: $z(n) = \sum_k \alpha_k\, \psi_k(x(n))$

Memory Polynomial Model

- Memory polynomial PD model [Ding et al.'04]

$$z(n) = \sum_{k=1}^{K} \sum_{q=0}^{Q} a_{kq}\, x(n-q)|x(n-q)|^{k-1}.$$

  - When $Q=0$, memoryless PD
  - Includes memory structure, a special case of Volterra
  - $K(Q+1)$ parameters: simpler than Volterra
  - Simple parameter estimation: linear least-squares

- Orthogonal polynomial basis also helps to improve the numerical stability of the model

$$z(n) = \sum_{k=1}^{K} \sum_{q=0}^{Q} \alpha_{kq}\, \psi_k(x(n-q)).$$

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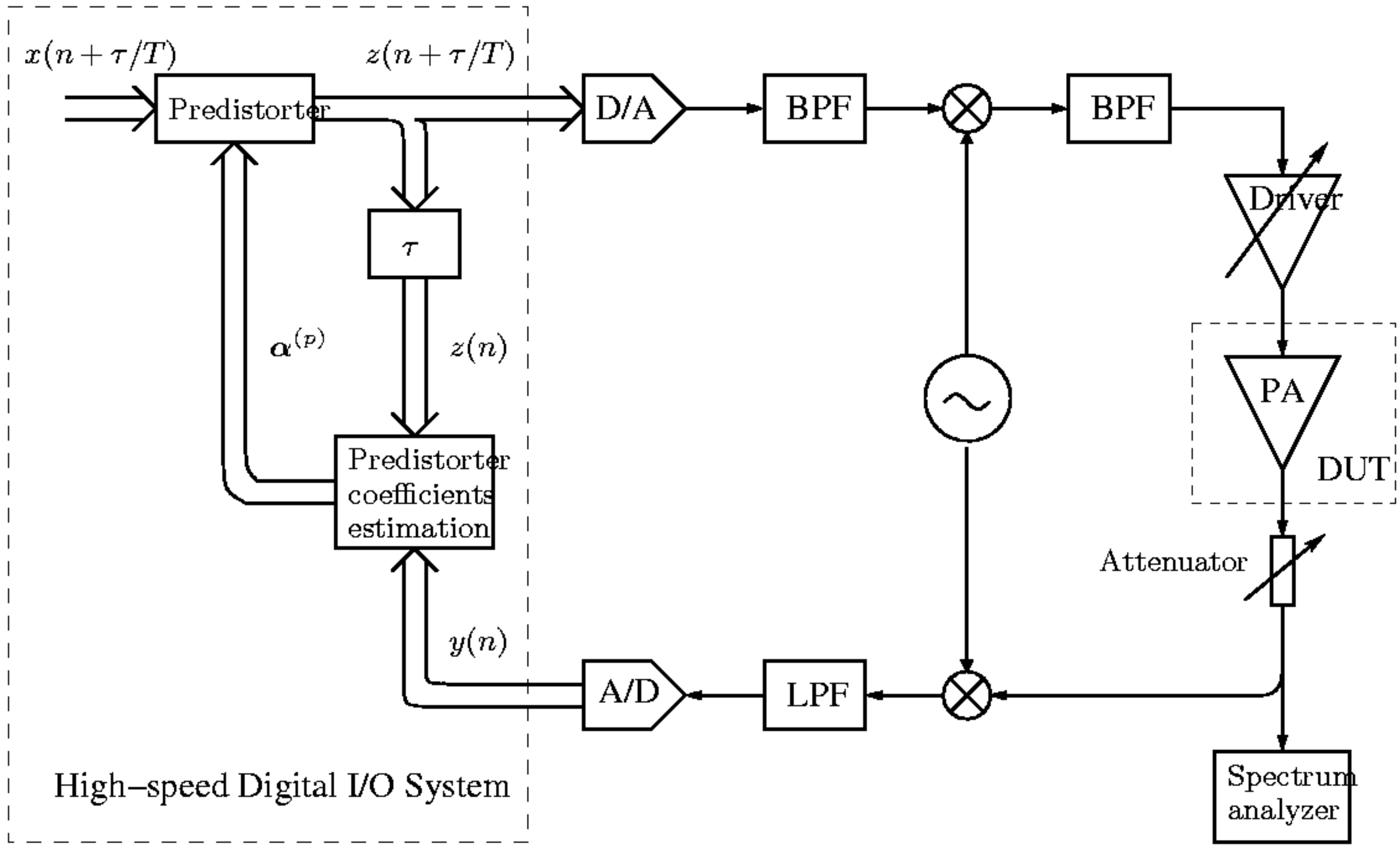
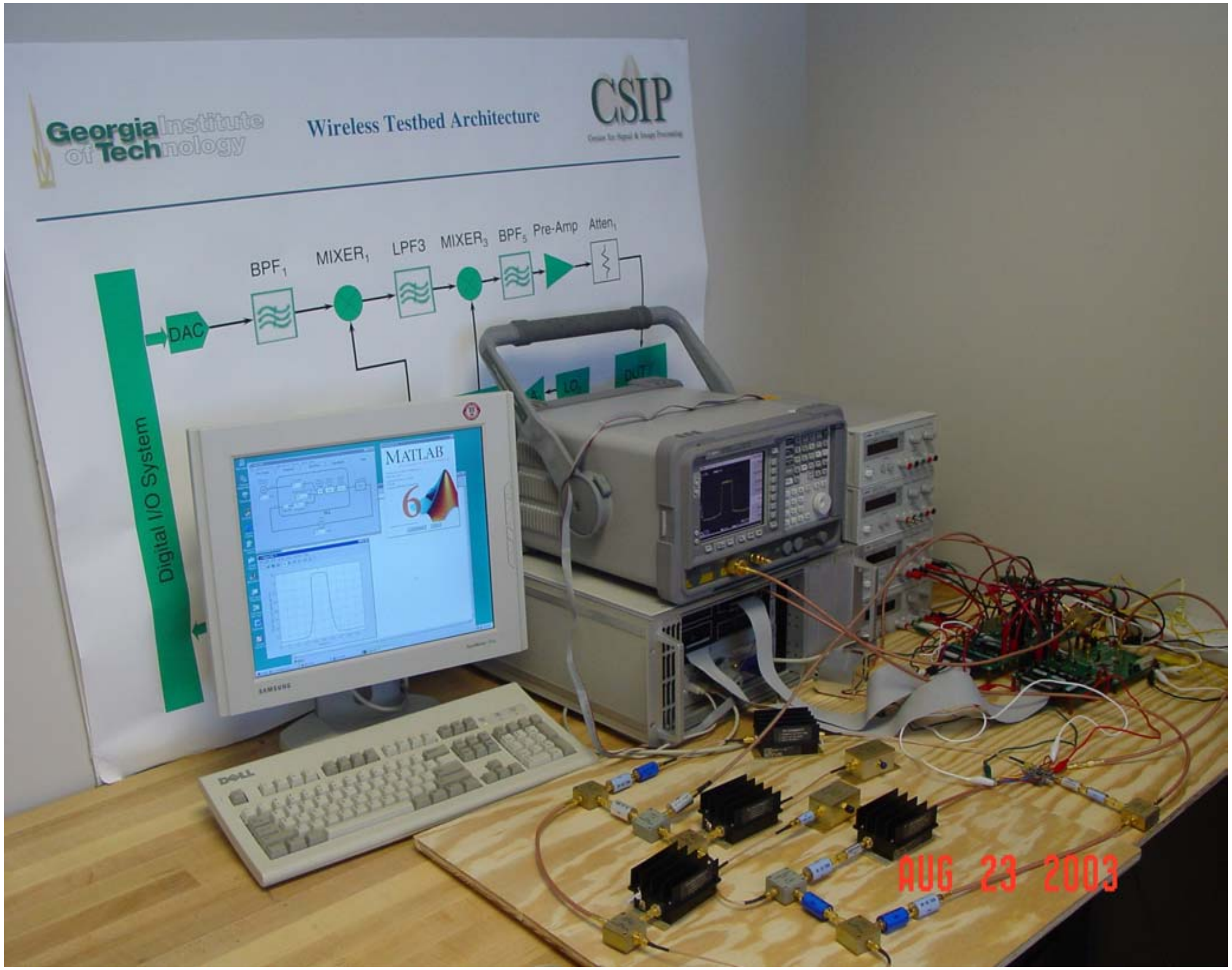
System Diagram of the Test-bed



Test-bed Picture



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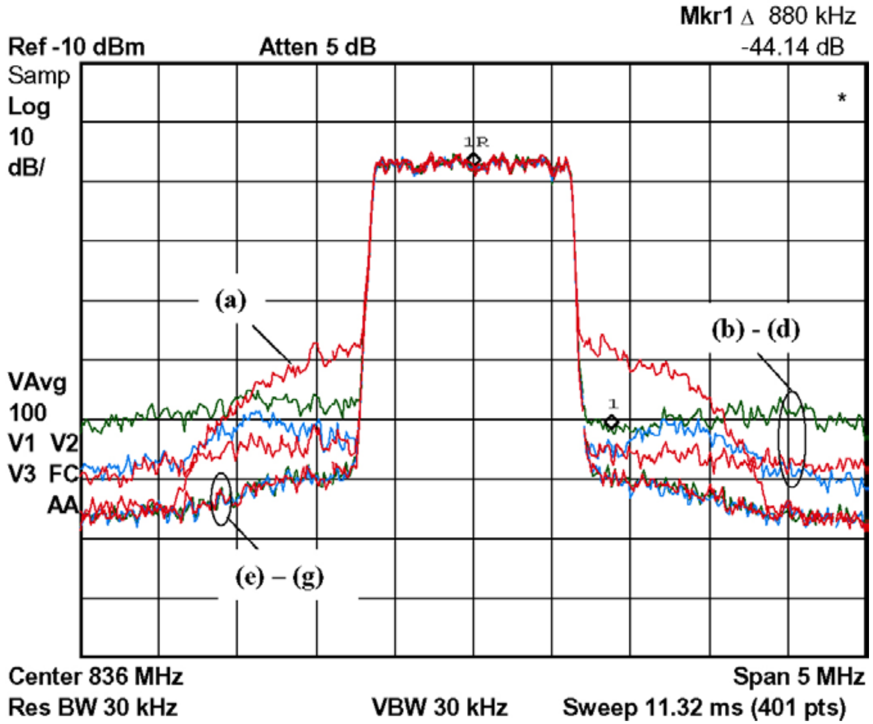
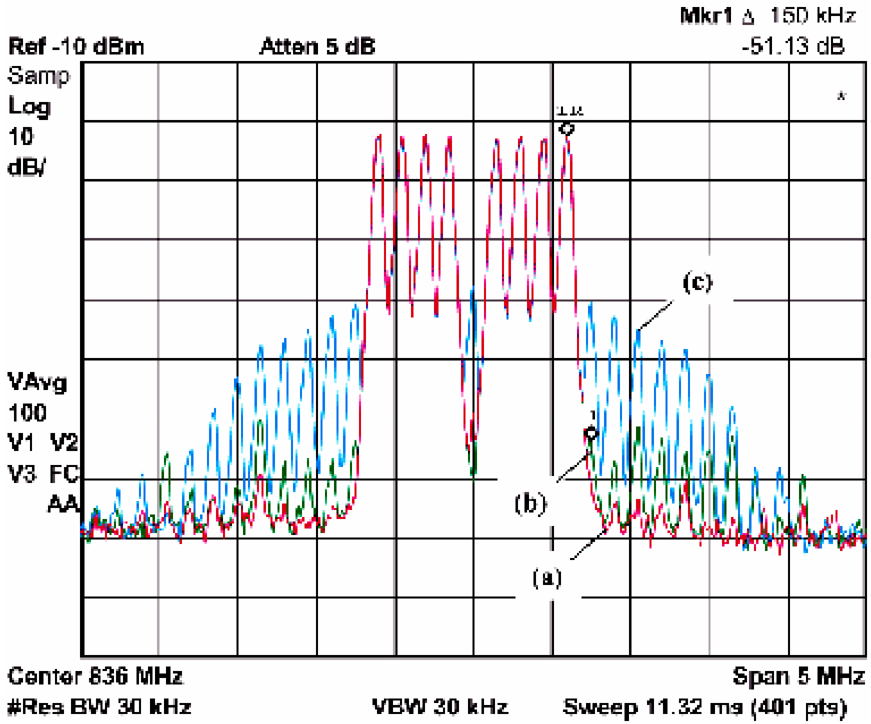
Conventional vs. Orthogonal Polynomials



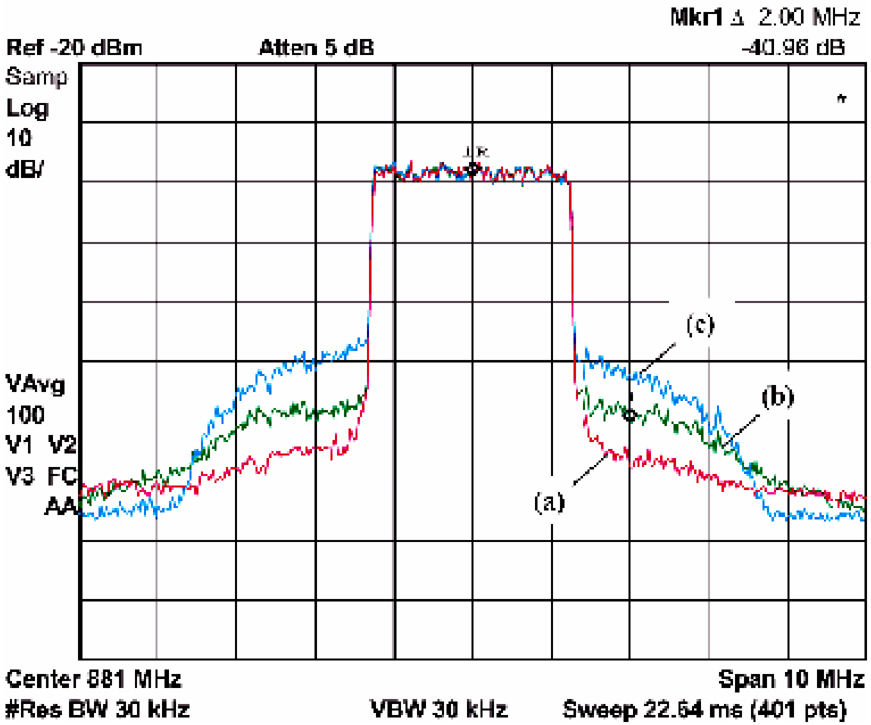
- Siemens 1 W bandset PA. Input: 1.25 MHz bandwidth OFDM signal.
- Measured PA output power spectral densities (PSDs): (a) without predistortion; (b)-(d) with conventional memory polynomial predistortion at iteration numbers 3, 4, and 5; (e)-(g) with orthogonal memory polynomial predistortion at iteration numbers 3, 4, and 5. Both the conventional and the orthogonal polynomial predistorters used K = 5 and Q = 4.

Memoryless vs. Memory Polynomials



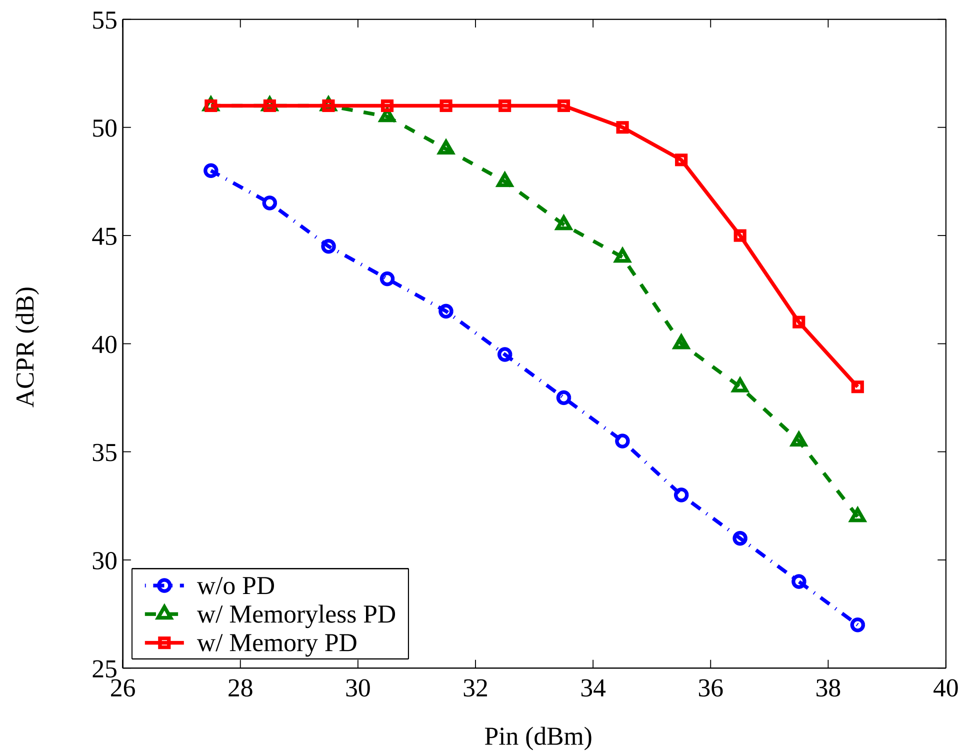
- Siemens 1 W handset PA. Input: 1.2 MHz bandwidth 8-tone signal.
- Measured PA output PSDs: (a) with K=5, Q=9 memory polynomial predistorter; (b) with K=5 memoryless predistorter; (c) without predistortion.

Memoryless vs. Memory Polynomials (Cont'd)



- Ericsson 45 W base station PA. Input: 2.5 MHz bandwidth OFDM signal.
- Measured PA output PSDs: (a) with K=5, Q=4 memory polynomial predistorter; (b) with K=5 memoryless predistorter; (c) without predistortion.

Efficiency Enhancement



- ACPR = adjacent channel power ratio.
- For memoryless polynomial model K=5; for memory polynomial model K=5, Q=4.
- If the spectral mask requires the ACPR to be 45 dB, an average power gain of 7 dB is achieved when the memory polynomial predistorter is applied.

Conclusions

- A wireless test-bed for digital baseband predistortion linearization is developed.
- Orthogonal polynomials have better numerical stability than conventional ones.
- Memory polynomial predistorter is robust and has good linearization performance for PAs with memory effects.