LINEARIZATION OF RF POWER AMPLIFIERS
CONNECTING SIMULATION AND MEASUREMENTS ON PHYSICAL DEVICES

Markus Loerner
Market Segment Manager RF & Microwave Components

ROHDE & SCHWARZ
Make ideas real
AGENDA

- Intro: Linearization and predistortion on power amplifiers
- Modelling of non linear devices
- Power of combining simulation and real measurements
  - Example with basic Power Amplifier (PA)
  - Example with Gallium Nitride (GaN) Device Under Test (DUT)
- Memory polynomial Digital Predistortion (DPD) with real DUT
- Summary
WHY LINEARIZATION?

► Challenging RF signals on RF frontends
  - 5G in mmWave and RF, mMIMO, beamforming, increasing bandwidth, higher order modulations, digital payloads, wideband Electronic Warfare (EW)

► Significant power consumption is in the RF Front-End (RFFE)
  - Operating close to saturation offers best energy efficiency
  - Technologies such as GaN absolutely require digital predistortion for linear operation

► Various PA topologies studied
  - Doherty, Load Modulated Balanced Amplifier (LMBA), Outphasing, …

► PA gains in efficiency but remains highly non-linear
  → Linearization is a \textit{MUST}
WHY LINEARIZATION?

► Two areas of interest:
  - compression
  - memory effect

Figure 4 Overview plot: measured AM/AM, ideal output, pre-distorted input signal, and target output signal (hard clipped)
DIGITAL PREDISTORTION: BEFORE AND AFTER
WHY MODELLING?

► Modelling is an essential step in PA design, optimization and linearization
  – The more accurate the better
  – Various PA topologies
  – Different linearization approaches
  → Modelling allows us to test various linearization approaches in an easy and efficient way

► MATLAB® / Simulink® is a widely used platform in research and development and offers the tools needed

► Having an accurate model can simplify development widely and allow deeper insight to optimization
COLLECTING DATA ON A REAL POWER AMPLIFIER

LAN for control and data transfer

R&S®FSW-K18D Direct DPD

- Iterative approach
- Compensates for memory effects
- Excellent performance especially for amplifiers with memory effects

- Reference for best possible
  - Suppliers typically do not have access to DPD algorithms used by system integrators
CREATING ENHANCED MODEL

► No pre-existing PA or DPD model

► Start with measuring input and output signals with and without direct DPD

► Build PA model on power transfer functions

► Refine the model using direct DPD signal to linearize data
MODELLING IN MATLAB® / SIMULINK®

► RF Blockset™ PA model used in Simulink® simulation
► Real measurement data used to fit PA model
  – Teamwork by F. Ramian, G. Lloyd, M. Loerner (Rohde & Schwarz) and G. Zucchelli (MathWorks)
► Verifying approach with different data sets from various PA’s and operation conditions
  – Easy exchange of data sets from measurements into simulation
  – Straightforward loading IQ data sets into MATLAB®
MODELLING IN MATLAB® / SIMULINK®

Power monitor
Input signal

Conversion
Samples – RF

Power amplifier

Power monitor
Output signal

Spectrum analyzer

Measured output signal
Model path 1
No Linearization
Model path 1
No Linearization

Model path 2
Linearization in real measurement
PA MODEL FITTING BASED ON HIGH-POWER SIGNAL

Signal standard deviation = 3.2697%
ACPR data = -29.1832 -29.6387
ACPR fit = -29.2544 -29.6458
TESTING THE MODEL WITH PREDISTORTED SIGNAL

Signal standard deviation = 9.1142%
ACPR data = -30.5317 -30.3716
ACPR fit = -28.5583 -29.6007
TESTING THE MODEL WITH LOW-POWER SIGNAL

Signal standard deviation = 4.533%
ACPR data = -39.8968, -39.7403
ACPR fit = -40.5179, -40.3225
BASIC PA: SIMULATION RESULTS
rc = "NR-FR1-TM3.1"; % Reference channel (NR-TM or FRC)
% Select the NR waveform parameters
bw = "100MHz"; % Channel bandwidth
scs = "30kHz"; % Subcarrier spacing
dm = "FDD"; % Duplexing mode
GAN PA, USING PREDISTORTED DATA AS BASELINE VDD=20V

Standard memory polynomial

Memory polynomial w/ cross terms
Creating the Memory Polynomial DPD in FSW

- Memory polynomial model based on Direct DPD result
- Modeling can be adopted in order and memory depth
- Model verification on DUT
- Proves easy linearization of RFFE solution

- Iterative approach
- Compensates for memory effects
- Excellent performance especially for amplifiers with memory effects
- Reference for best possible
  - Suppliers typically do not have access to DPD algorithms used by system integrators

R&S®FSW-K18D Direct DPD

R&S®FSW-K18M memory polynomial

LAN for control and data transfer

DUT
MEMORY POLYNOMIAL USING FSW INTERNAL FEATURE

- Comparing results
  - good match between memory polynomial on the 2 platforms using fitted PA model in simulation and using measured data in FSW
SUMMARY

► RF PA’s use dedicated topologies and linearization to improve efficiency

► Modeling is essential in speeding up development and optimization of RF PA capabilities
  – Predict behavior with different linearization techniques
  – Optimize DPD for a given PA

► Comparison with real world behavior allows qualification of model and DPD possibilities

► Reached goal of faster and more accurate design process for an efficient RF front end

► BIG THANKS to Giorgia Zucchelli and Florian Ramian for the hard work to make this happen!