EDI CON 2019
Electronic Design Innovation Conference
电子设计创新大会
April 1-3, 2019
China National Convention Center
Beijing, China

Model Derivation from Direct DPD (Digital Pre-Distortion)

Dr. Florian Ramian
Martin Weiß
presented by Fabrício Dourado

Agenda

- Introduction: DPD and Direct DPD
- Model based DPD
- How to convert the results of Direct DPD into a model based DPD
- Summary

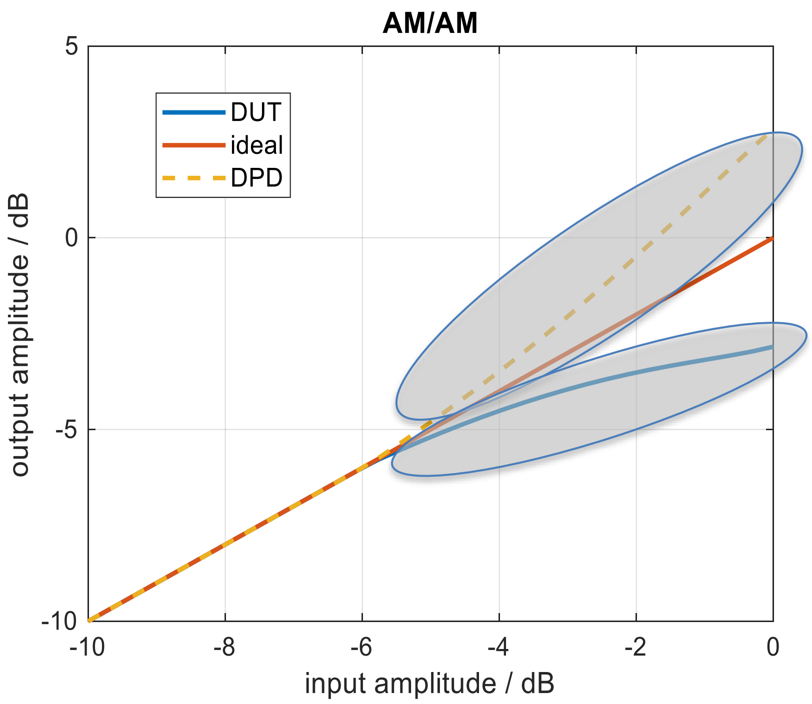
Introduction

Efficiency:

- Maximum around $P_{out,max}$
- Operating cost / battery lifetime
- Linearity degradation: out of band emissions, higher EVM

Pre-Distortion:

- Modify the DUT input signal so that the output of the DUT is linear



Challenges

Challenges:

- Know-How required on how to “fit” the algorithms for effectiveness
- DUT specific, adaption required for new devices
- Find the right trade-off, cost of DPD (complexity, energy consumption) vs. PA back-off

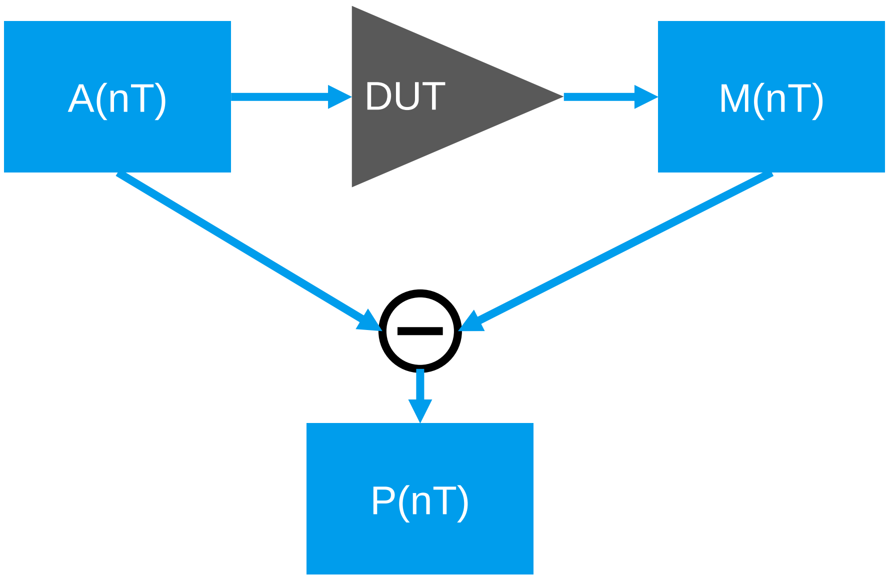
➔Device, application, maybe even vendor specific

Questions:

- What is the maximum EVM/ACLR of my PA, if I had the perfect DPD?
- Is there a generally valid approach to compare different amplifier designs?
- **Can I convert this theoretical performance into something usable?**

Direct DPD

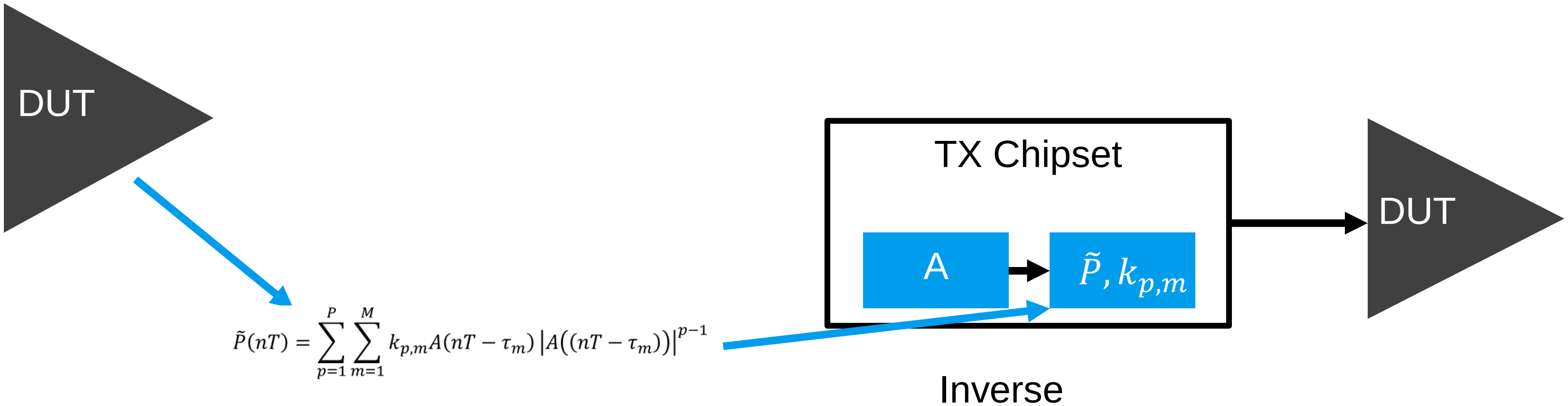
- The original waveform A is pre-distorted sample-by-sample
- The amount of pre-distortion is based on the measurement M
- M is compared to A, and the complex difference is used to generate the pre-distorted waveform P
- No "algorithm" involved, that describes the dependency between A and P
- Iterative process



Model Based DPD

Traditional:

- Reference algorithm, e.g. Polynomial, Memory-Polynomial, Volterra, etc.
- Highly sophisticated derivation of coefficients (save computational effort)
- Fits for one specific DUT
- Can be applied to all signals (waveforms), i.e. real-time application
- Inverse of DUT model

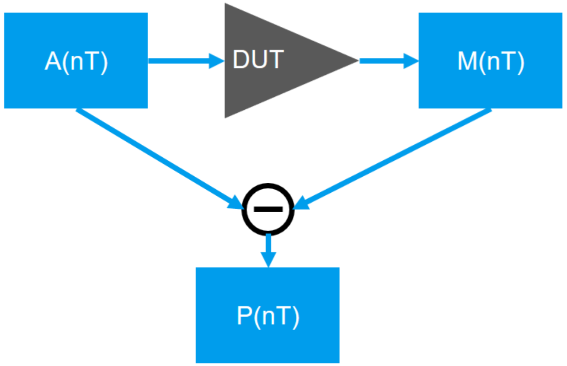


Deriving a Model from Direct DPD

- Least Squares Fitting of a configurable Memory Polynomial (Polynomial Order P, Memory Depth M) in Matlab

- $F(A(nT), P, M) \,! = P(nT)$

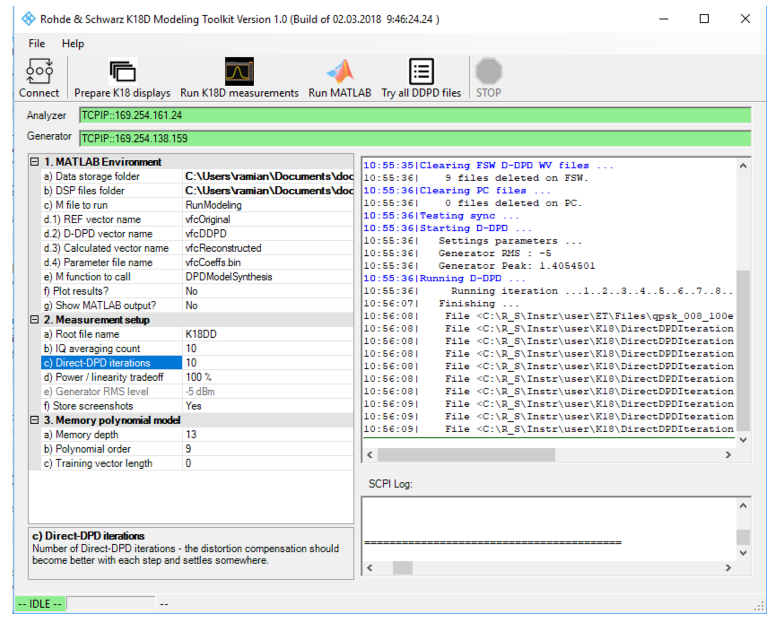
- Result: Memory Polynomial describing the pre-distortion $\tilde{P}(nT)$
- Generate calculated pre-distorted signal $\tilde{P}(nT)$



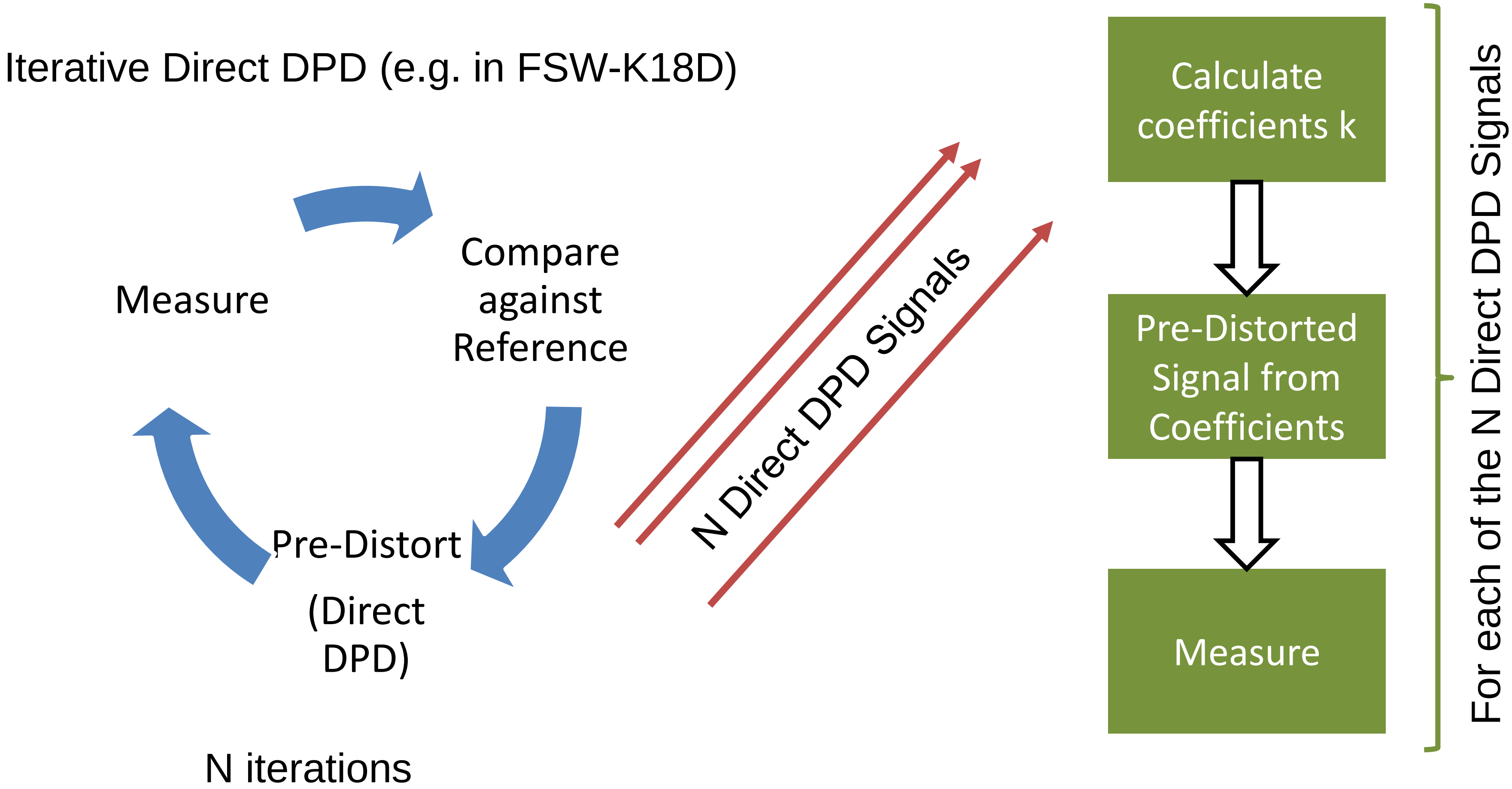
$$\tilde{P}(nT) = \sum_{p=1}^{P} \sum_{m=1}^{M} k_{p,m} A(nT - \tau_m) \left| A\big((nT - \tau_m)\big) \right|^{p-1}$$

Deriving a Model from Direct DPD Requirements

- Matlab license required
- Any other function can be supplied in a Matlab function
  - Volterra
  - Simplified memory polynomial
- Pre-distorted signals required
- R&S FSW-K18D, FPS-K18D, or FSV3-K18D deliver the pre-distorted waveforms
- Using K18D, Matlab, and the R&S tool, no programming knowledge is required
- With recommended tools, process is fully automated

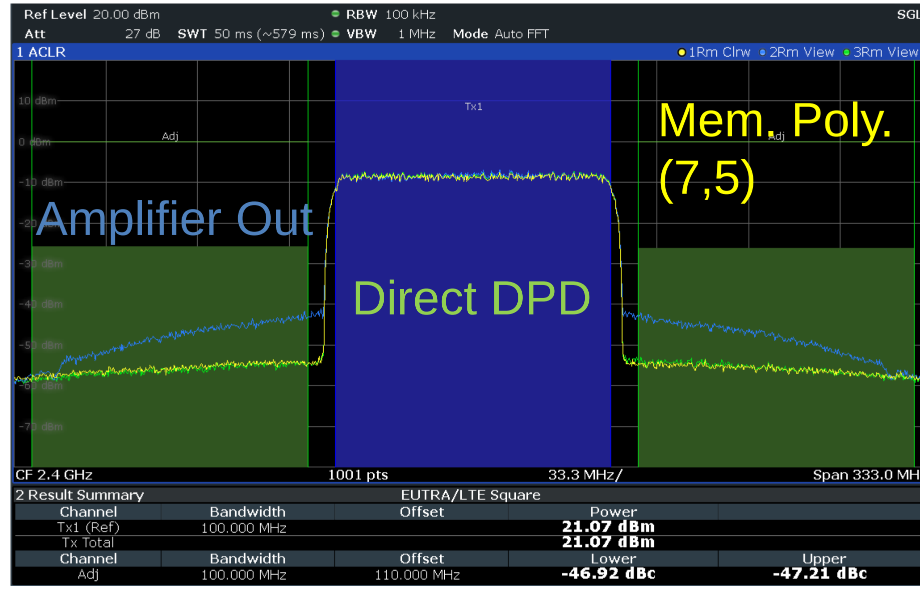


Deriving a Model from Direct DPD Signal Flow



Deriving a Model from Direct DPD Iterative Approach

- Iterative approach converges
- After convergence, noise (from measurement) is the main difference between consecutive results
- Overview of all measurement results allows directly picking the best fit



	Iteration	Raw	Output		Curve width		SMx		ACP		
13:38:22	#	EVM	RMS	Crest	AM/AM	AM/PM	RMS	Peak	Left	Right	
13:38:27	Original	5.61	21.11	4.69	0.097	2.120	-5.00	1.405	-41.2	-41.6	
13:38:32	MEAS1	1.33	21.04	4.91	0.018	0.282	-5.00	1.409	-45.9	-46.3	(K18DD_iterated2.wv)
13:38:38	MEAS2	1.01	21.10	4.93	0.016	0.187	-4.93	1.413	-47.7	-47.7	(K18DD_iterated3.wv)
13:38:43	MEAS3	0.93	21.04	5.03	0.016	0.186	-4.98	1.413	-48.3	-48.1	(K18DD_iterated4.wv)
13:38:49	MEAS4	0.91	21.10	4.99	0.016	0.180	-4.92	1.417	-48.5	-48.3	(K18DD_iterated5.wv)
13:38:54	MEAS5	0.92	21.05	5.03	0.016	0.183	-4.97	1.420	-48.5	-48.4	(K18DD_iterated6.wv)
13:39:00	MEAS6	0.91	21.09	4.97	0.016	0.181	-4.92	1.418	-48.4	-48.3	(K18DD_iterated7.wv)
13:39:05	MEAS7	0.92	21.05	5.01	0.016	0.188	-4.97	1.414	-48.5	-48.4	(K18DD_iterated8.wv)
13:39:11	MEAS8	0.89	21.09	4.96	0.016	0.168	-4.92	1.414	-48.5	-48.4	(K18DD_iterated9.wv)
13:39:16	MEAS9	0.91	21.05	4.99	0.016	0.183	-4.96	1.418	-48.5	-48.4	(K18DD_iterated10.wv)
13:39:22	CALC1	1.50	21.03	4.89	0.026	0.511	-5.00	1.409	-47.2	-47.4	(K18DD_iterated2_calculated.wv)
13:39:27	CALC2	1.46	21.09	4.89	0.026	0.512	-4.93	1.413	-47.6	-47.8	(K18DD_iterated3_calculated.wv)
13:39:33	CALC3	1.47	21.03	4.97	0.026	0.515	-4.98	1.413	-47.5	-47.8	(K18DD_iterated4_calculated.wv)
13:39:38	CALC4	1.48	21.09	4.92	0.026	0.515	-4.92	1.417	-47.1	-47.4	(K18DD_iterated5_calculated.wv)
13:39:44	CALC5	1.50	21.04	4.97	0.026	0.516	-4.97	1.420	-47.0	-47.3	(K18DD_iterated6_calculated.wv)
13:39:49	CALC6	1.49	21.08	4.92	0.026	0.513	-4.92	1.418	-46.9	-47.1	(K18DD_iterated7_calculated.wv)
13:39:55	CALC7	1.50	21.03	4.97	0.025	0.516	-4.97	1.414	-46.9	-47.1	(K18DD_iterated8_calculated.wv)
13:40:00	CALC8	1.51	21.08	4.92	0.026	0.518	-4.92	1.414	-46.8	-47.1	(K18DD_iterated9_calculated.wv)
13:40:06	CALC9	1.51	21.04	4.96	0.026	0.514	-4.96	1.418	-46.9	-47.1	(K18DD_iterated10_calculated.wv)

Summary

- Direct DPD is a convenient method to compare different PA designs
- Iterative approach supported
- High dynamic range measurements possible using I/Q averaging feature
- Model optimization can be done w/o hardware, based on the Direct DPD results