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LITEPOINT

Advanced Characterization Techniques for RF Components

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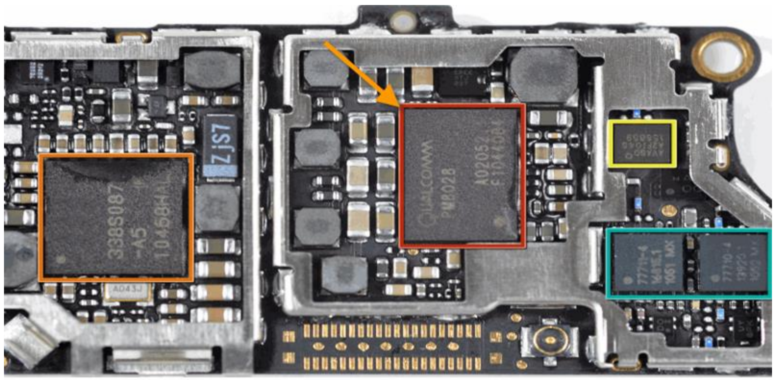
GM, Design Test Solutions



Expand into Wireless Components & Design Test

Purpose Built Test Solutions

- Providing the right tool for the job at hand
- Focus on providing solutions, not tool kits

Flexible Modular Instrumentation

Perfect for Design Verification

Simple Robust Instrumentation

Perfect for Volume Production

Outline

- Mobile device design constraints
- Dynamic EVM
- Digital pre-distortion (DPD)
- Envelope tracking (ET)

Mobile Device Design Constraints

Mobile Device Design

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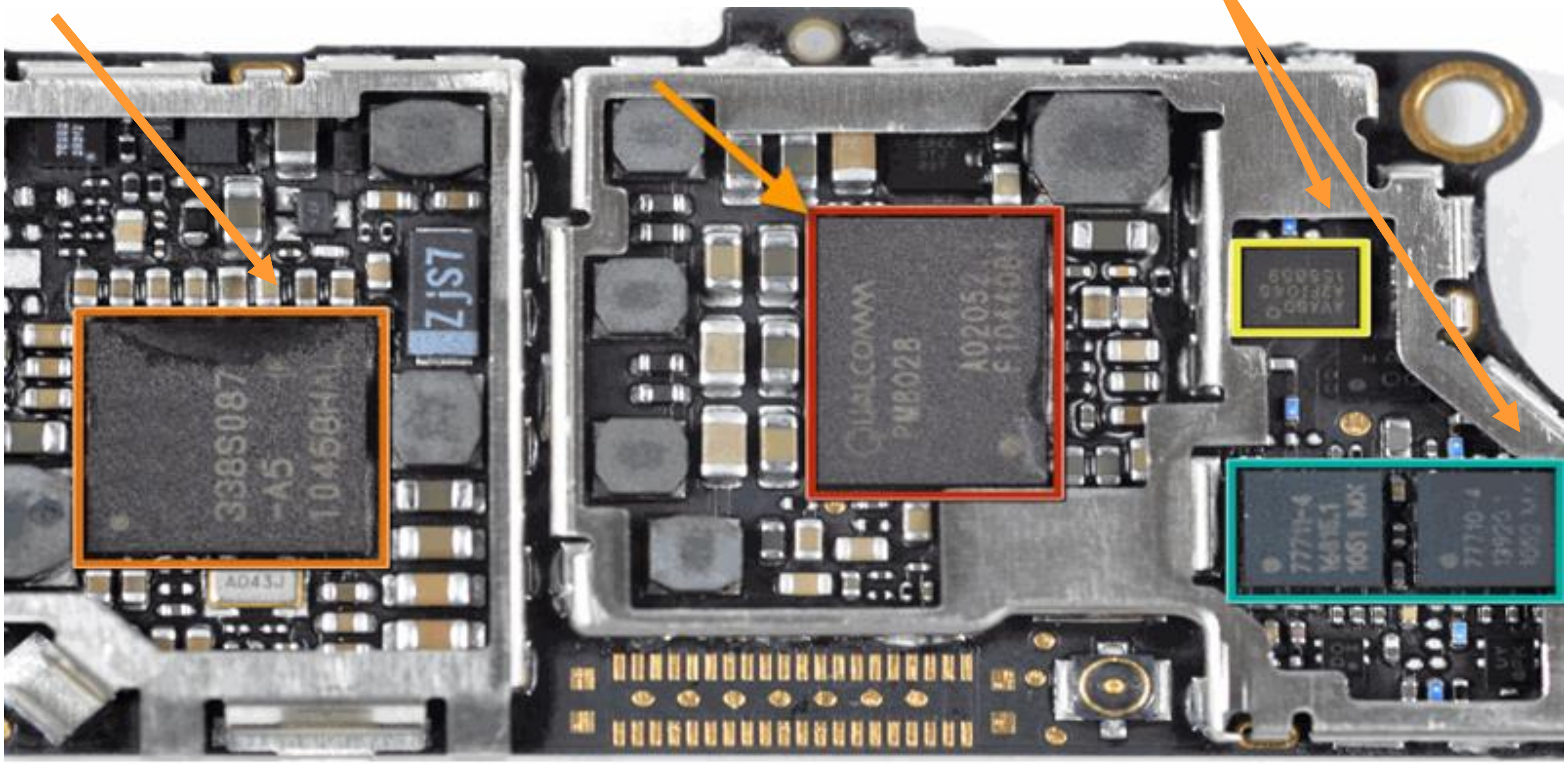
Main Processor

Cellular Radio Chipset

Front End Module (FEM)
Power Amplifier (PA)



Teardown of Mobile Phone

Mobile Device Design Challenges

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Standard	Peak-Average Ratio (dB)	Peak-Minimum Ratio (dB)	Max Bandwidth (MHz)
GSM	0	0	0.2
EDGE	3.2	17	0.2
CDMA 2000	4-9	∞	1.25
LTE	8-12	∞	20
802.11a/b/g	8-10	∞	20
802.11ac	8-14	∞	160

- More bandwidth (160MHz for 802.11ac, 100MHz for LTE-A)
- High-density modulations (256QAM for 802.11ac)
- Lower EVM contribution (e.g. 1.5% for 802.11ac 80MHz)
- Higher Peak-Avg. (PAR) → lower efficiency
- Infinite Peak-Min. → RF envelope drops to zero

Mobile Device Design Constraints

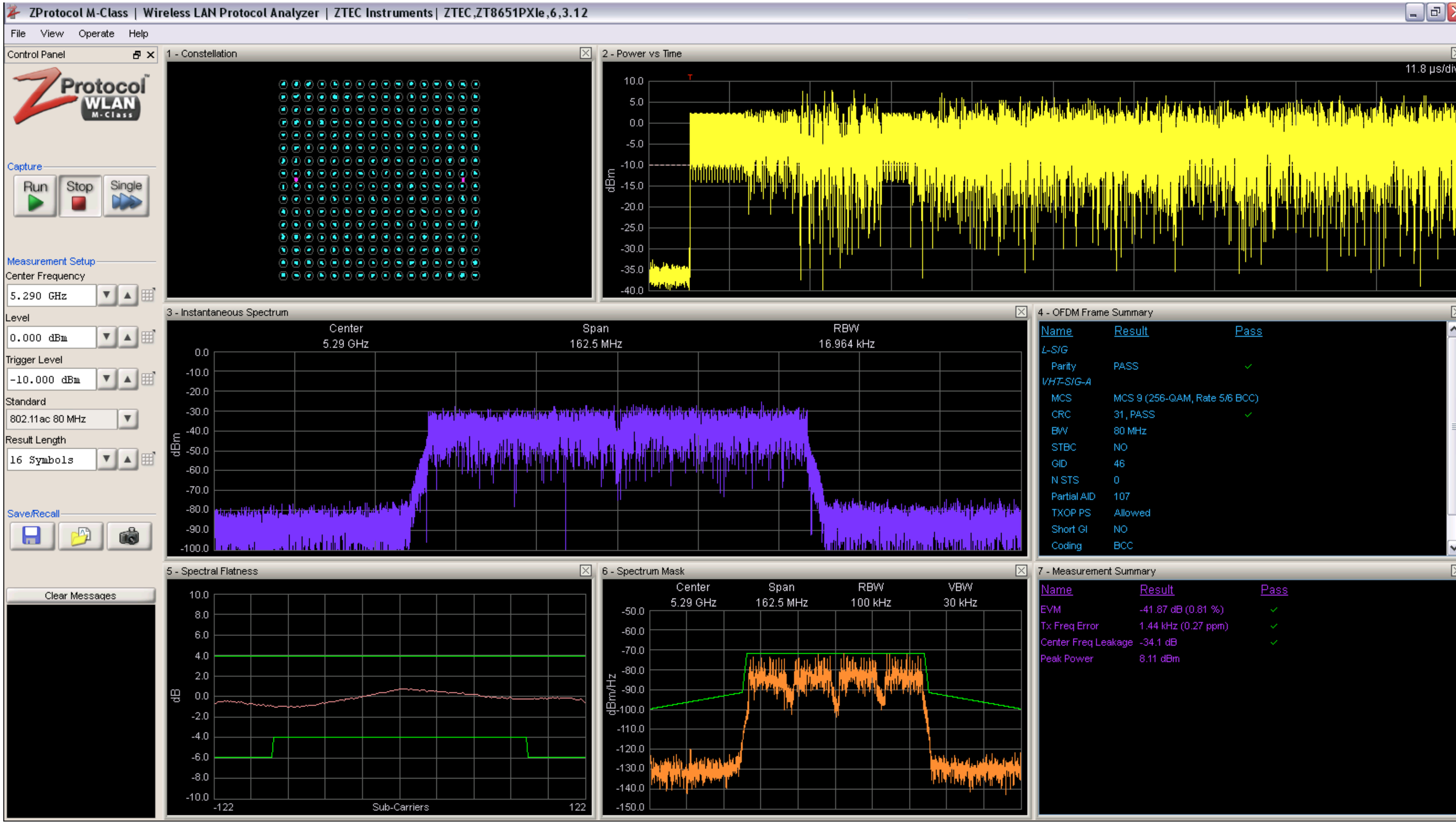
- Considerations driven by PA/FEM
  - Greater coverage area
  - Higher data rates
  - Longer battery life

- PA/FEM competing requirements
  - Higher RF power output
  - Higher Linearity
  - Higher Efficiency


WiFi
Zigbee
WiFi
WiMAX
MIMO
4G
FM
Bluetooth
WAVE
3G
GPS
WiFi
MIMO
4G
LTE
Bluetooth

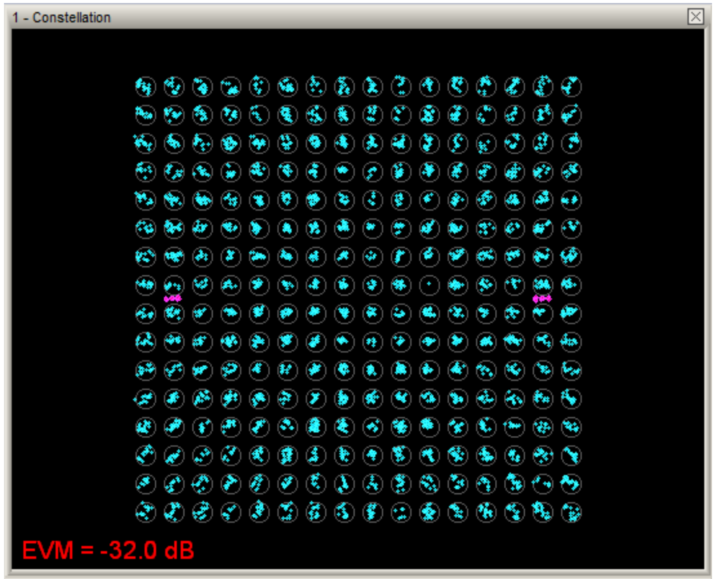
Dynamic EVM

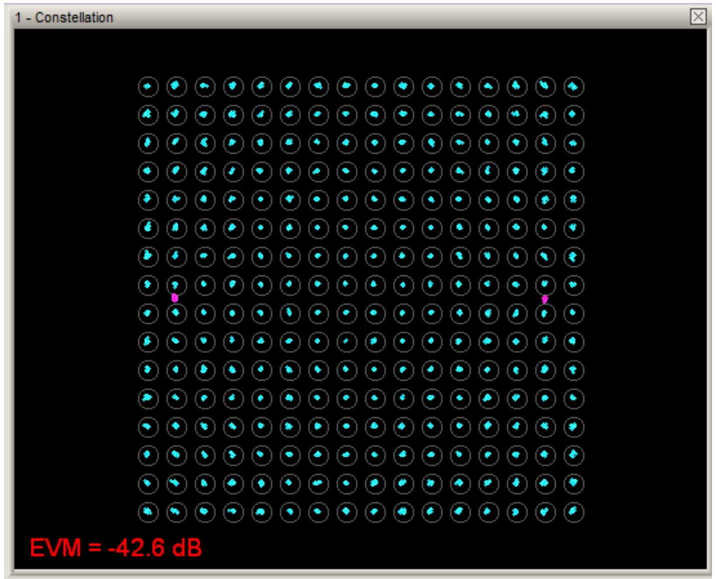
Digital Radio Testing



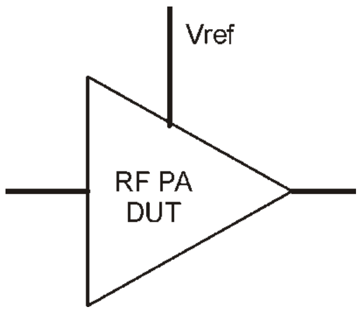
What is EVM?

- Error Vector Magnitude
  - Rapid high coverage test technique
  - Comprehensive figure of merit for digital radio testing
  - First used by LitePoint in 802.11 WLAN production testing

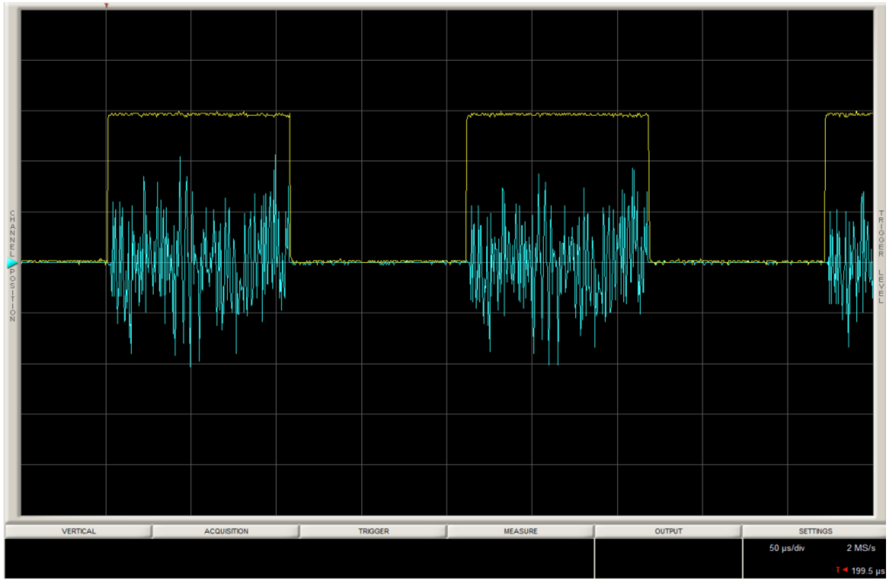


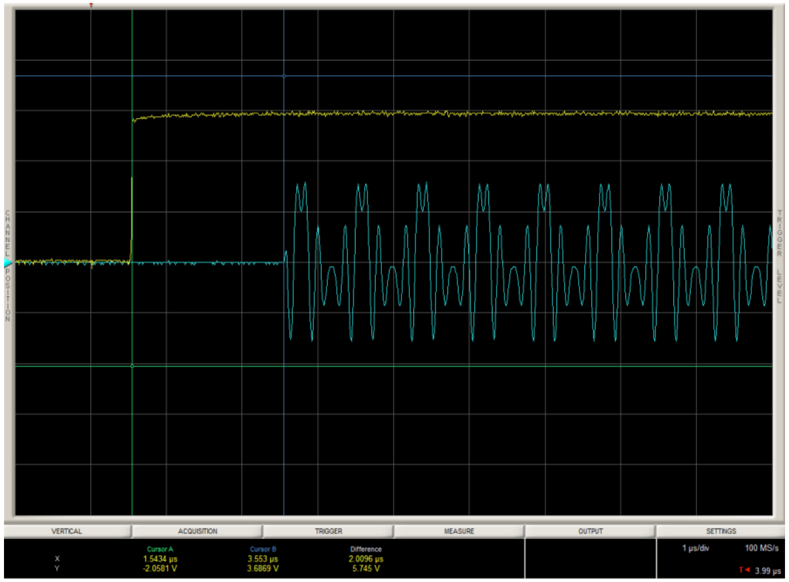


Pulsed Radio Operation



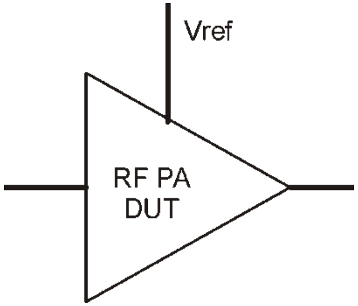
- Conserve battery life
  - Digital radios used pulsed RF
  - Disable radio PA when not in use



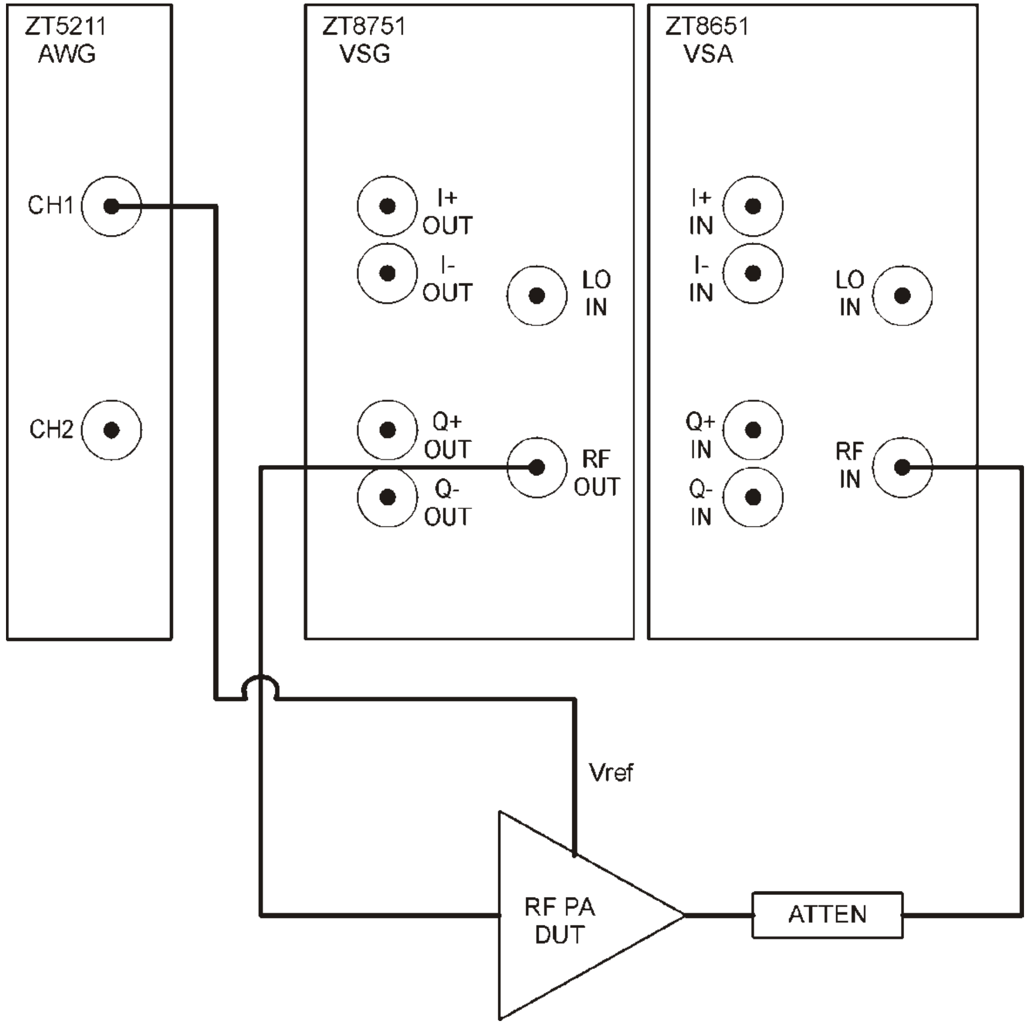


Pulsed Radio Operation

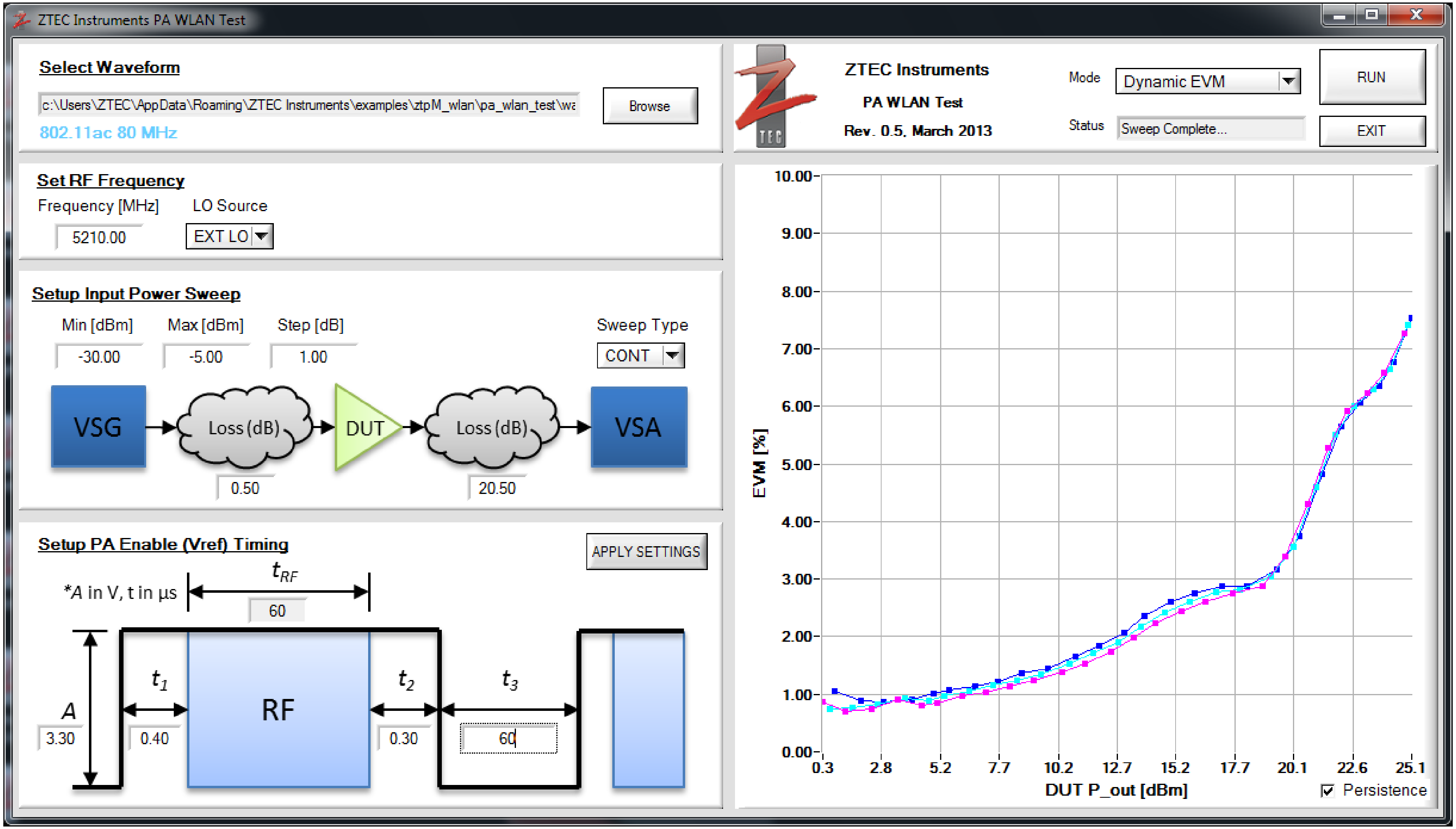
- System-level operation with pulsed RF & VREF
- Square wave applied to VREF
- Transient response distorts preamble
- Dynamic EVM shown to be worse than static EVM
  - S. Yoon, Marvell, IEEE-MTT 2007
  - mobile device production failures: dynamic EVM is now required!



Dynamic EVM Testing



Dynamic EVM Testing



Dynamic EVM vs. Static EVM - Duty Cycles: 5%, 50%, 100%

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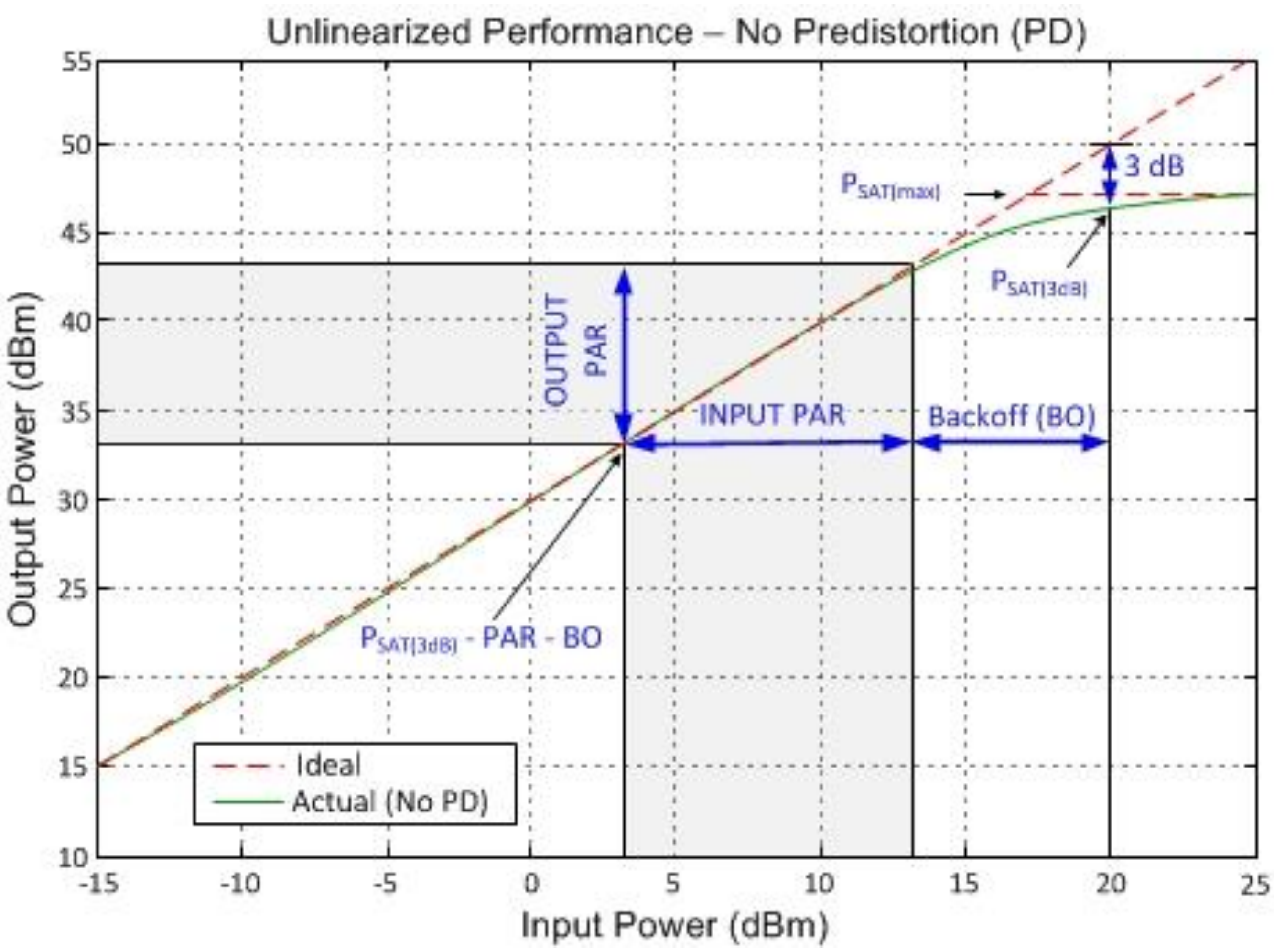
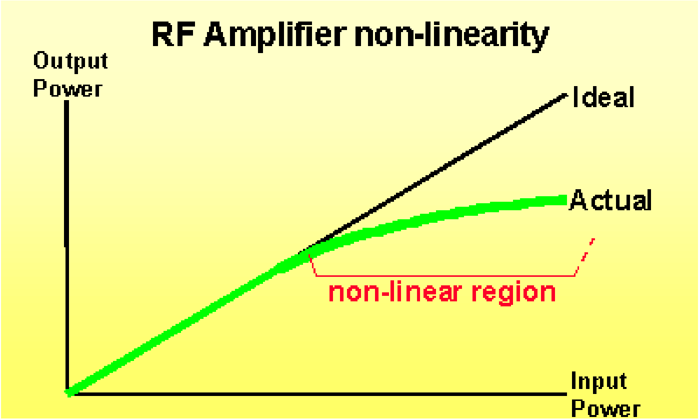
Digital Pre-Distortion (DPD)

PA Linearity



PA Linearity

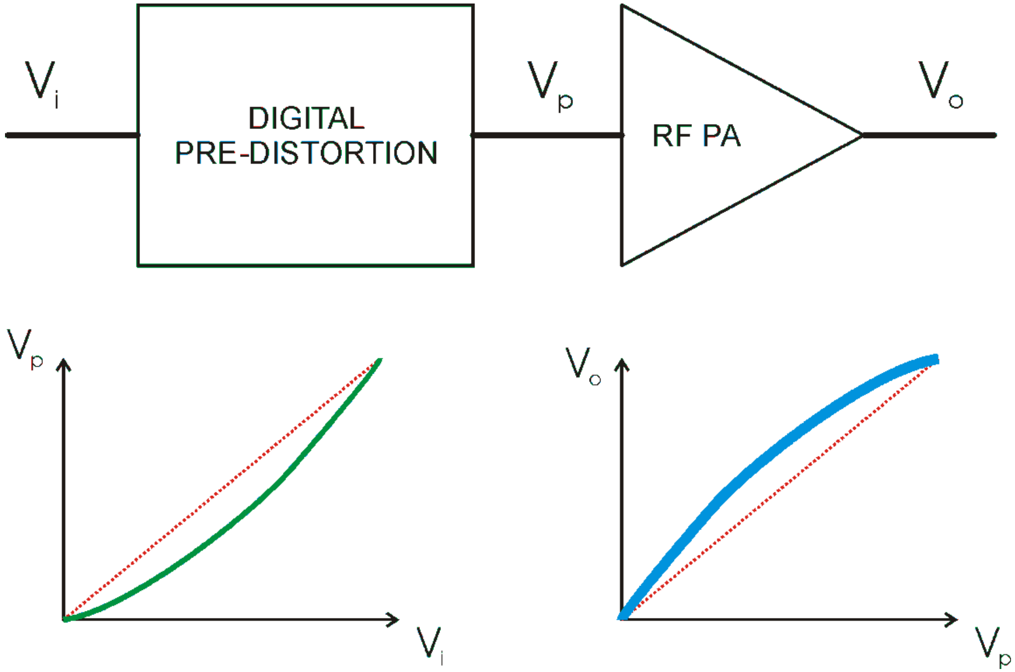
- Linearity measures
  - Spectral Mask
  - Adjacent Channel Power Ratio (ACPR)
  - Third Order Intercept Point (IP3)
  - 1 dB compression point
  - AM-to-AM, AM-to-PM distortion



- Strategies for handling high PAR
  - Back off – operate PA in linear region (inefficient)
  - Crest factor reduction – limit peaks before reaching PA
  - Pre-distortion – compensate for PA nonlinearity

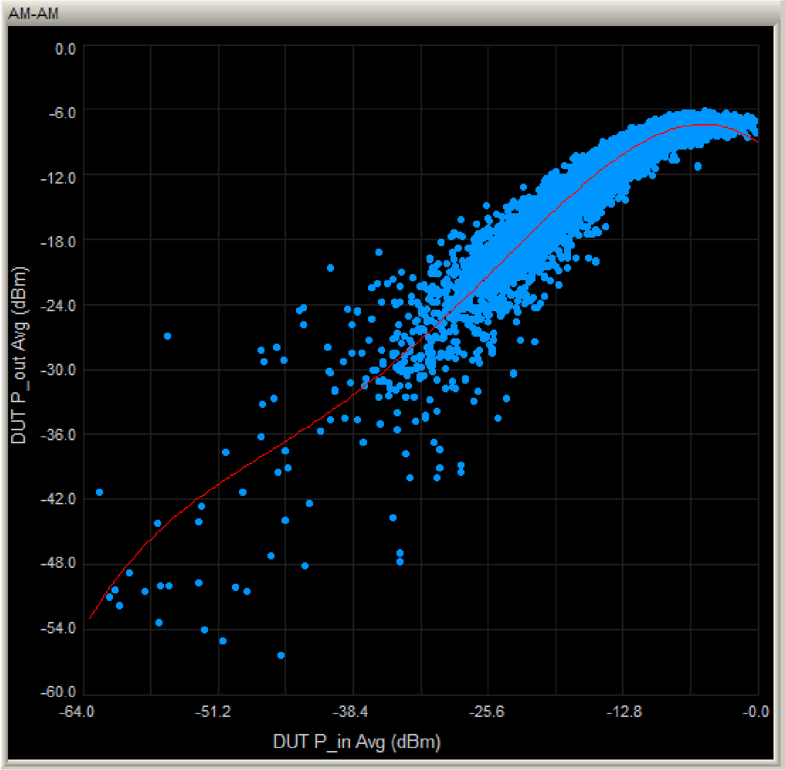
Digital Pre-Distortion (DPD)

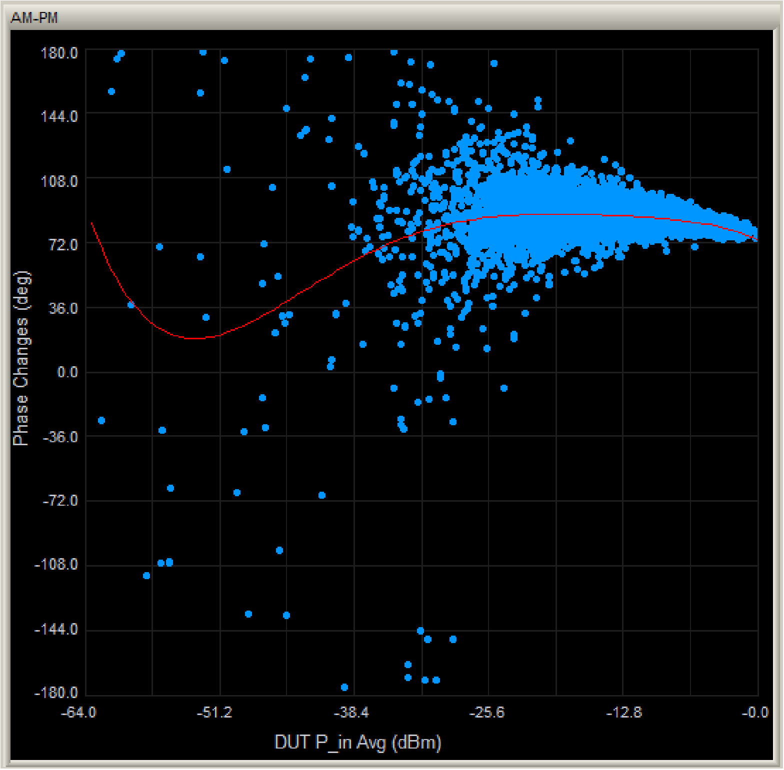
- Latest chipsets support DPD
  - Use an inverse operation to linearize PA
  - Compensate for AM-to-AM and AM-to-PM distortion
  - Algorithms
    - Look-up tables (LUT)
    - Memory Polynomial



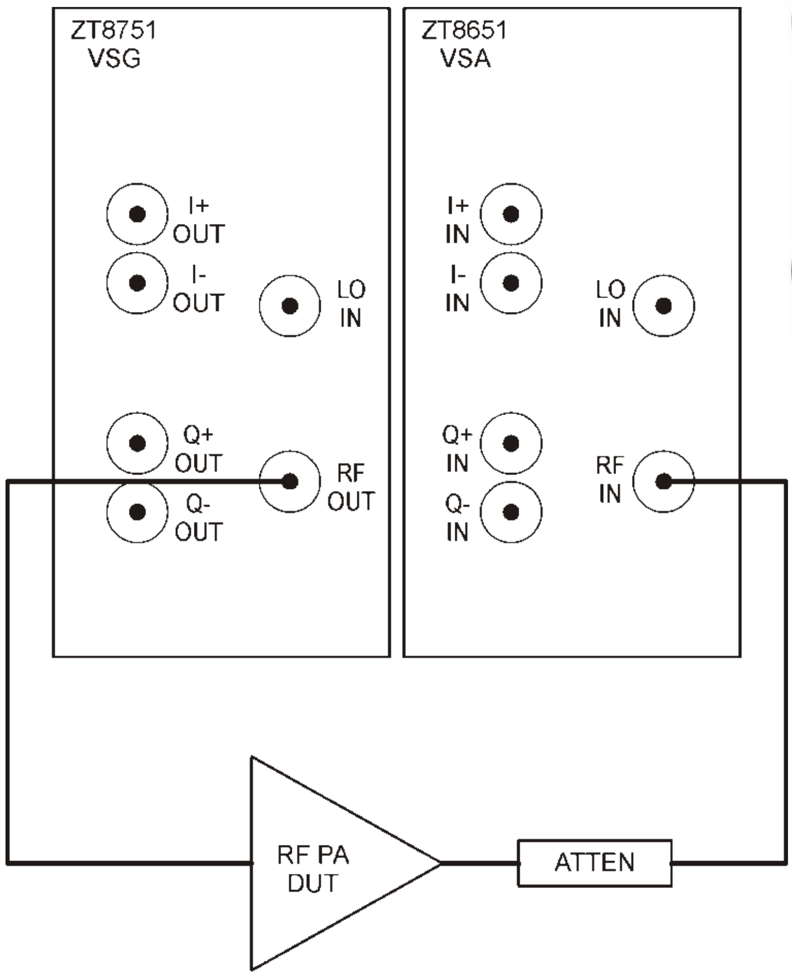
Digital Pre-Distortion (DPD)

- PA memory
  - Transient behavior exposed by high PAR
  - More memory → more spread in distribution





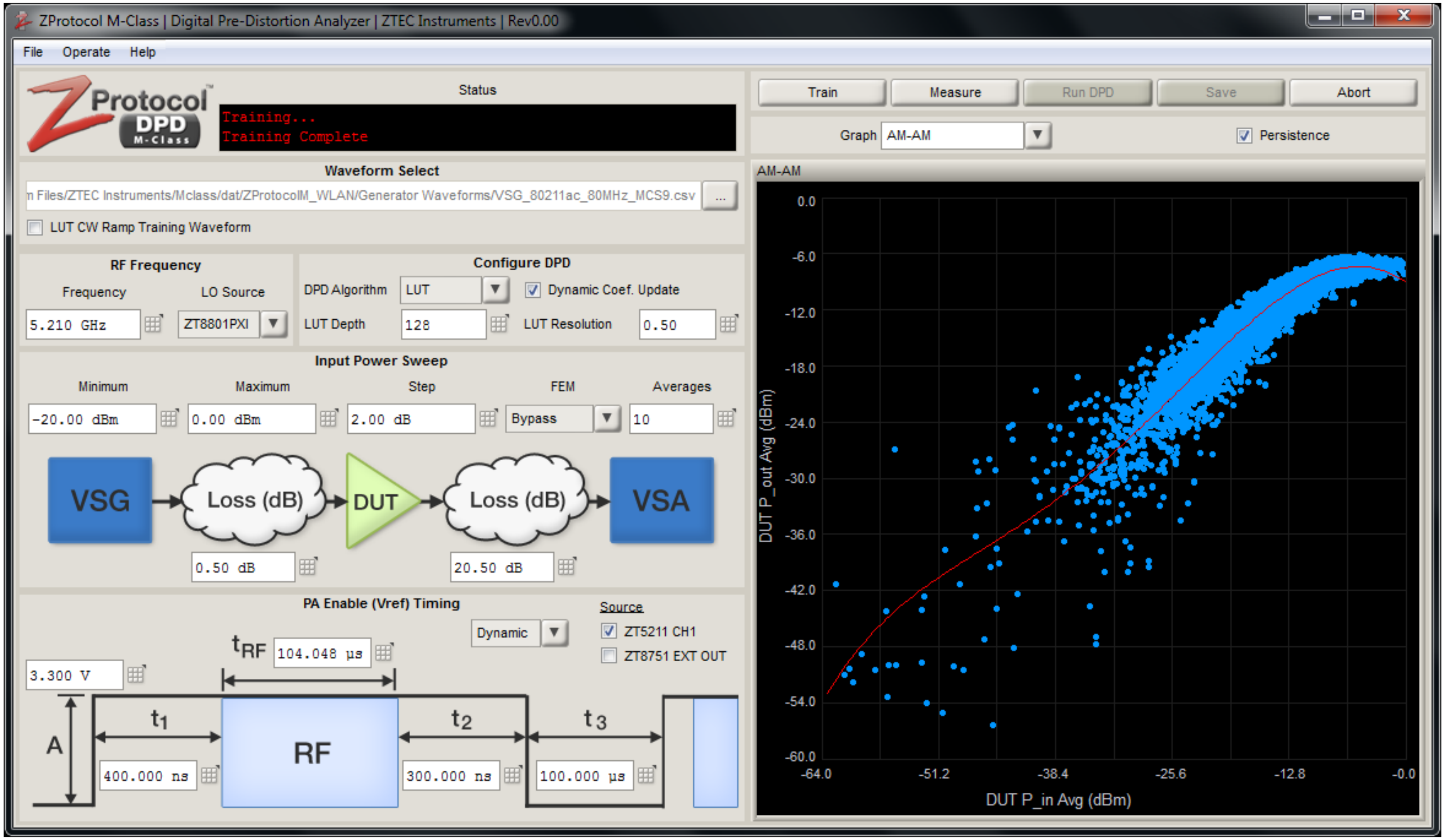
DPD Testing



Test sequence

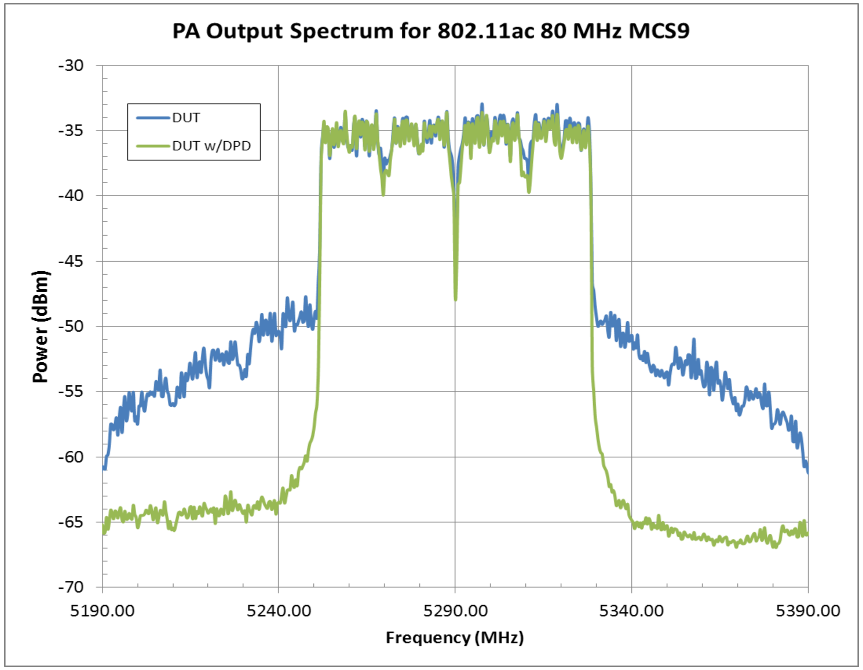
- Training
- Calculate DPD coefficients
- Create DPD waveform

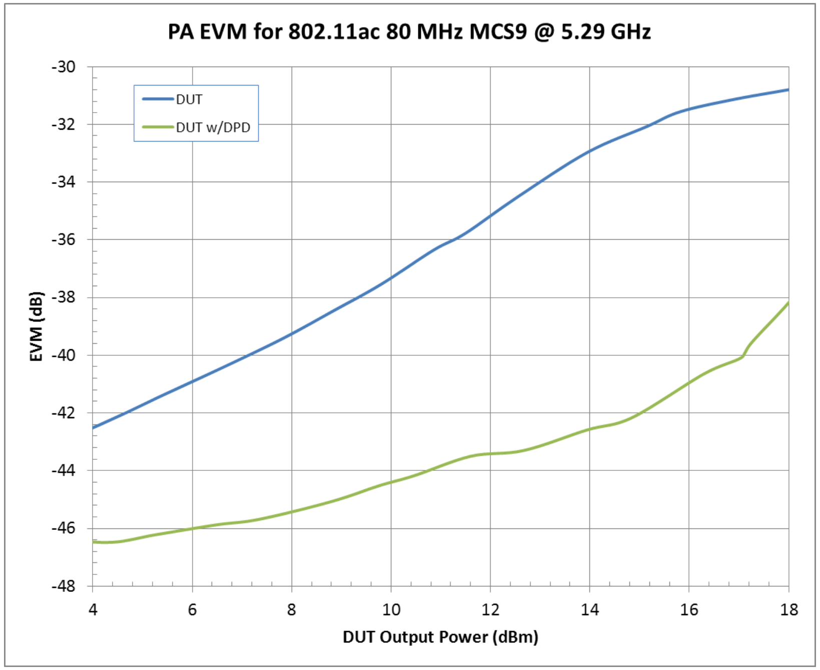
DPD Testing



ZProtocol M-Class | Digital Pre-Distortion Analyzer | ZTEC Instruments | Rev0.00
File
Operate
Help
Status
Training...
Training Complete
Train
Measure
Run DPD
Save
Abort
Graph
AM-AM
Persistence
Waveform Select
n Files/ZTEC Instruments/Mclass/dat/ZProtocolM_WLAN/Generator Waveforms/VSG_80211ac_80MHz_MCS9.csv
LUT CW Ramp Training Waveform
RF Frequency
Frequency
LO Source
5.210 GHz
ZT8801PXI
Configure DPD
DPD Algorithm
LUT
Dynamic Coef. Update
LUT Depth
128
LUT Resolution
0.50
Input Power Sweep
Minimum
Maximum
Step
FEM
Averages
-20.00 dBm
0.00 dBm
2.00 dB
Bypass
10
VSG
Loss (dB)
DUT
Loss (dB)
VSA
0.50 dB
20.50 dB
PA Enable (Vref) Timing
Dynamic
Source
ZT5211 CH1
ZT8751 EXT OUT
3.300 V
104.048 µs
A
RF
400.000 ns
300.000 ns
100.000 µs
AM-AM
DUT P_out Avg (dBm)
DUT P_in Avg (dBm)
0.0
-6.0
-12.0
-18.0
-24.0
-30.0
-36.0
-42.0
-48.0
-54.0
-60.0
-64.0
-51.2
-38.4
-25.6
-12.8
-0.0

DPD Improvements

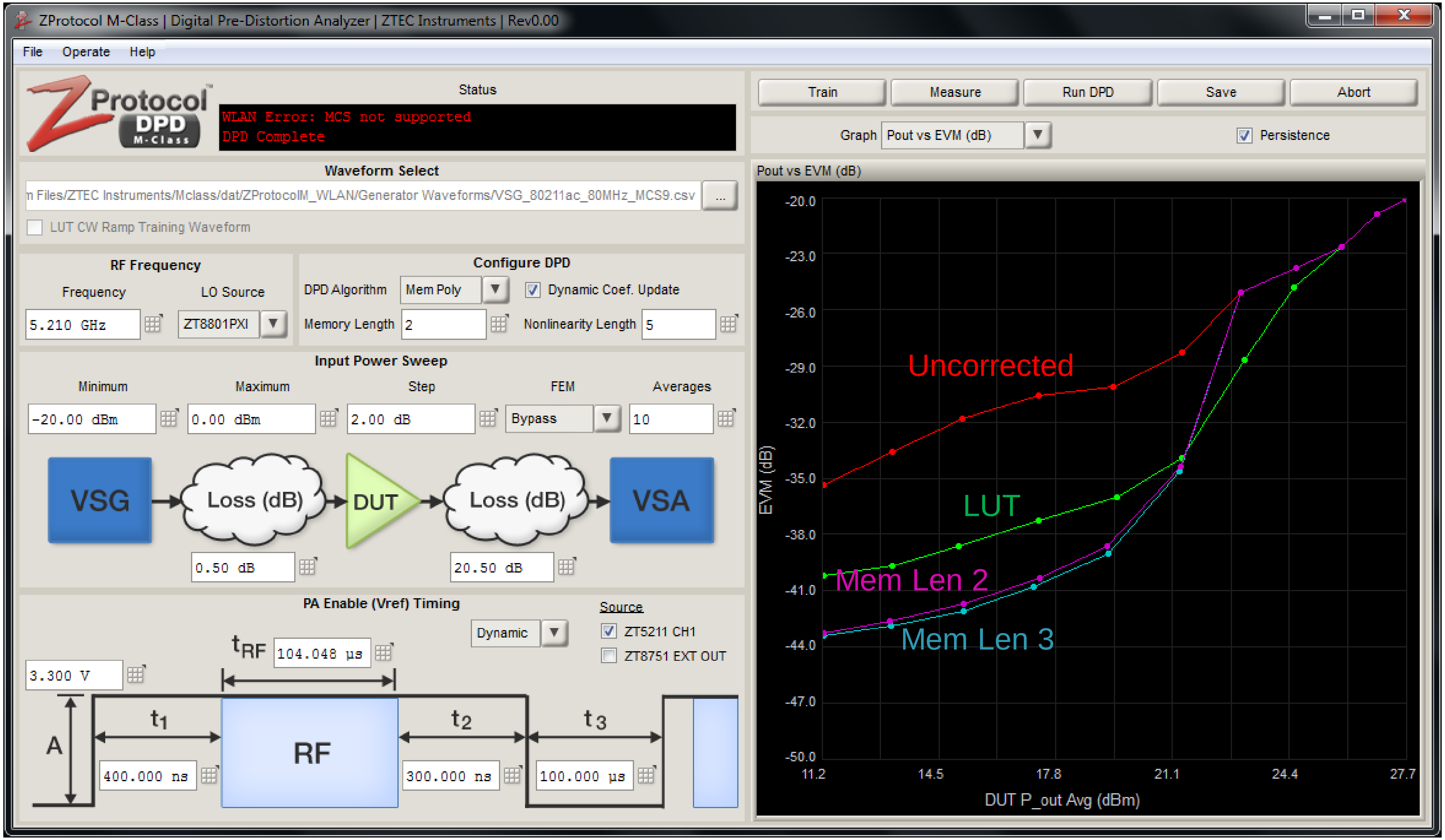




Spectral Mask Improvements

EVM Improvements

DPD Algorithms



Envelope Tracking (ET)

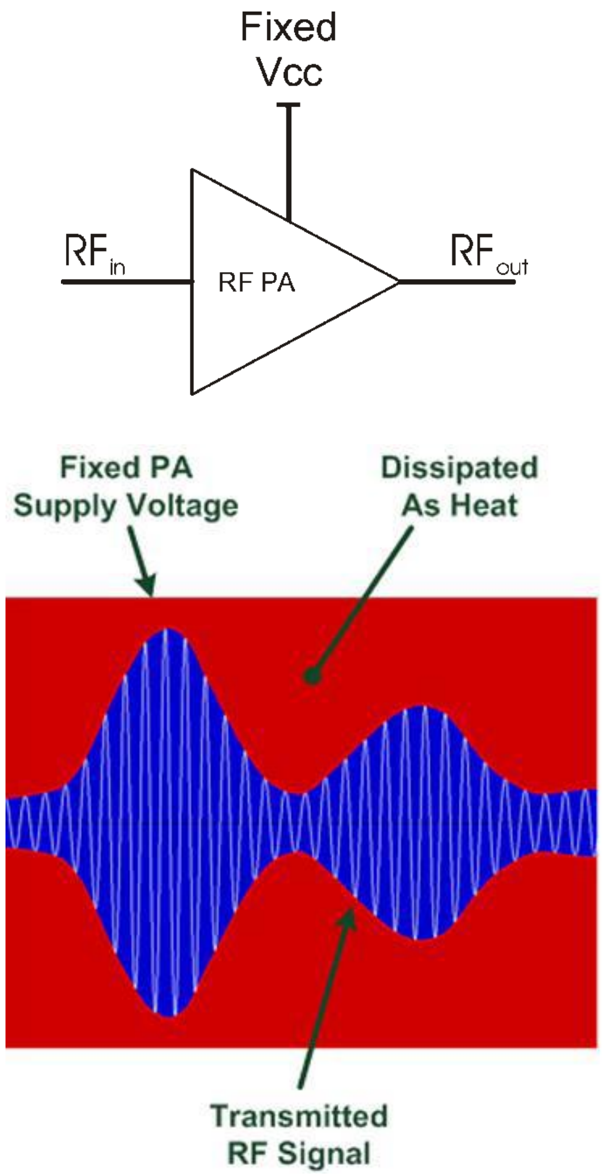
PA Efficiency

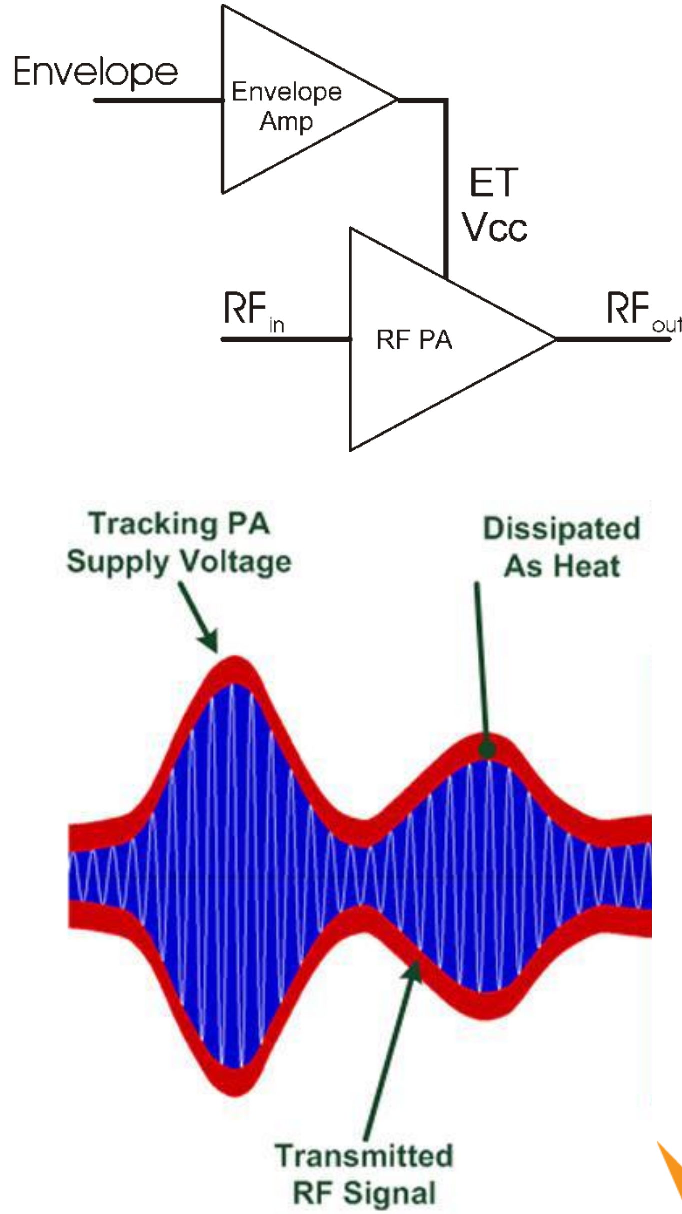
- Higher PAR → greater back-off → lower efficiency

- Power Added Efficiency (PAE)
  - DC → RF efficiency
  - PAE $= \frac{Pout - Pin}{PDC}$ x 100%
  - Example: PA class AB
    - Fixed Vcc → 20% PAE
    - ET Vcc → 30-35% PAE

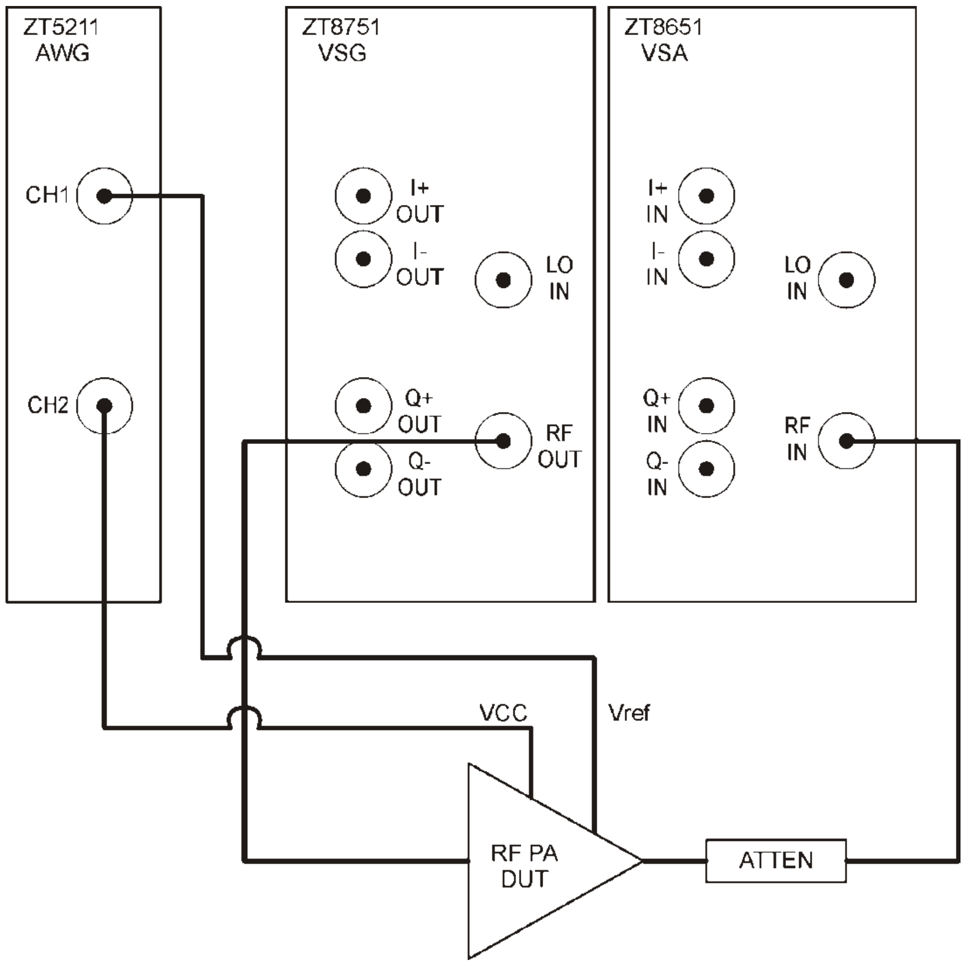
- Envelope Tracking (ET) improves system efficiency
  - Maintains PA in constant-compression

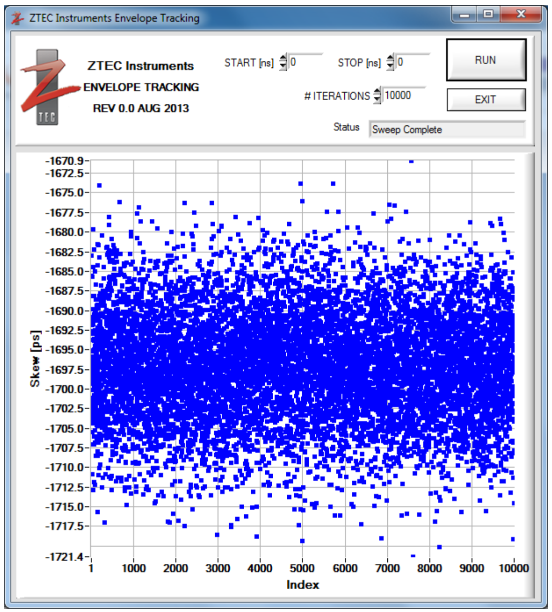
Envelope Tracking (ET)





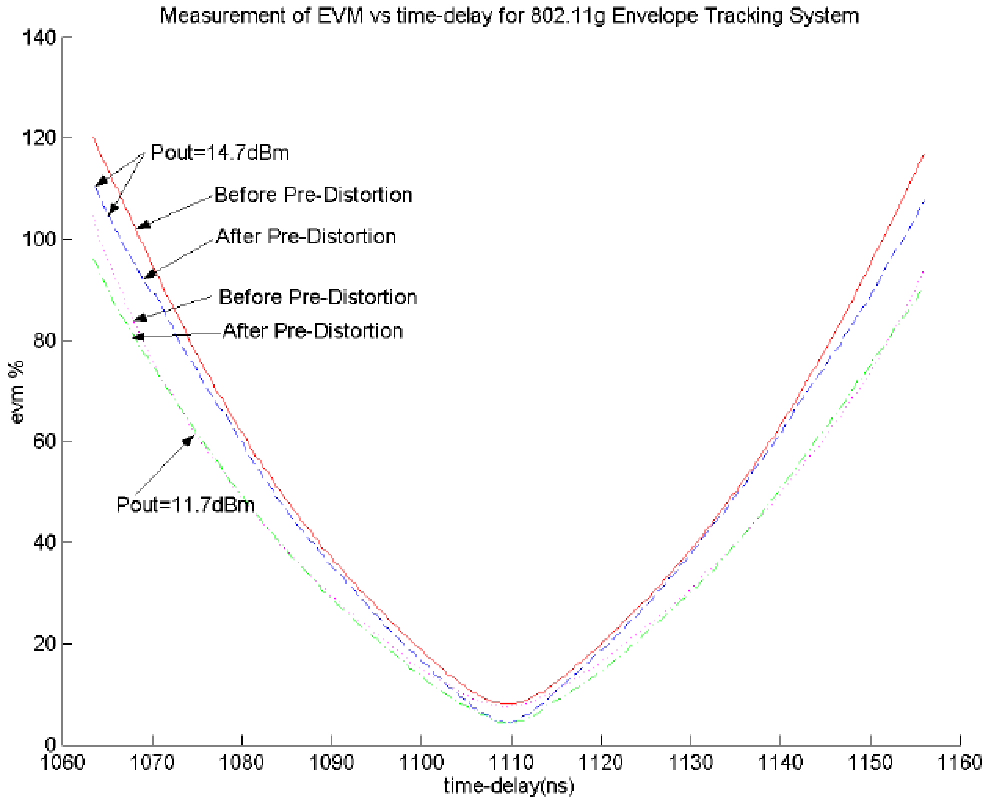
ET Testing



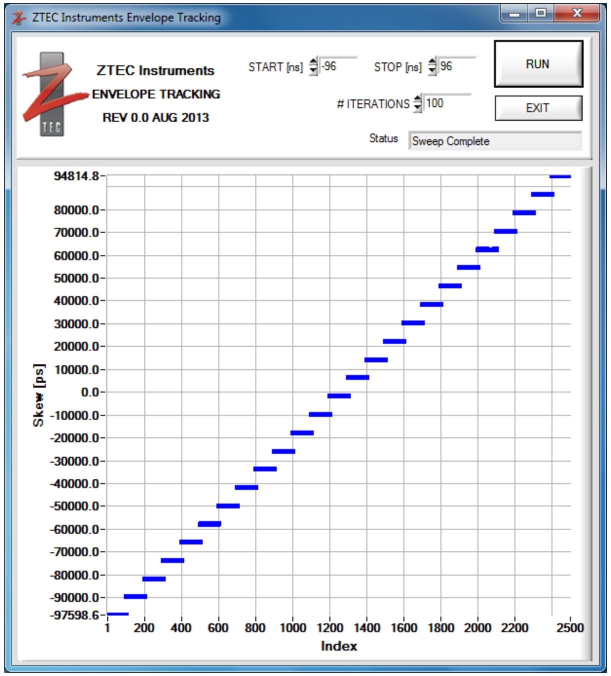


RF-to-Envelope Jitter:
50 ps peak-to-peak
6.6ps std. dev.

ET Testing



Graph courtesy of P. Draxler, Qualcomm, IEEE-IMS 2013

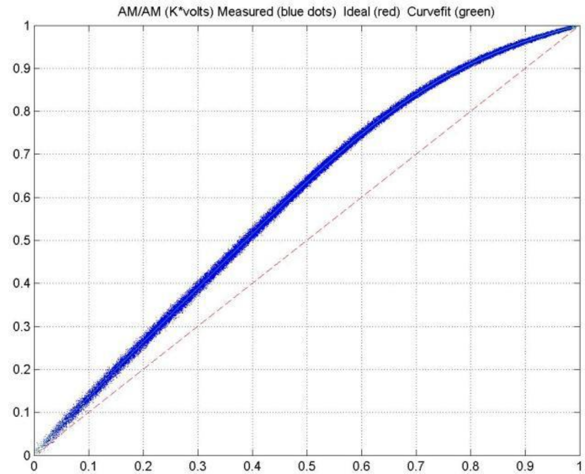


RF-to-Envelope Stepping
-96ns to +96ns
8ns steps

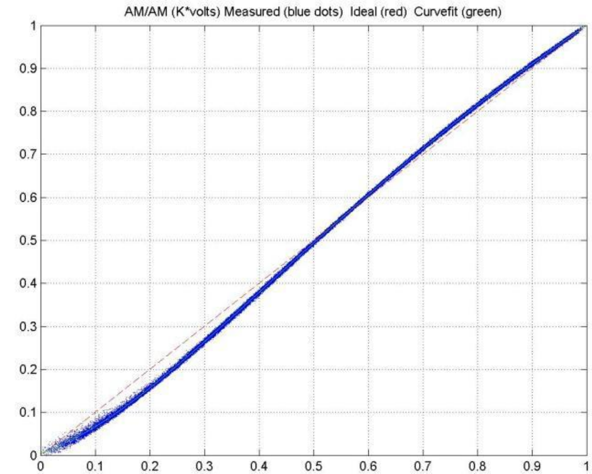
ET + DPD

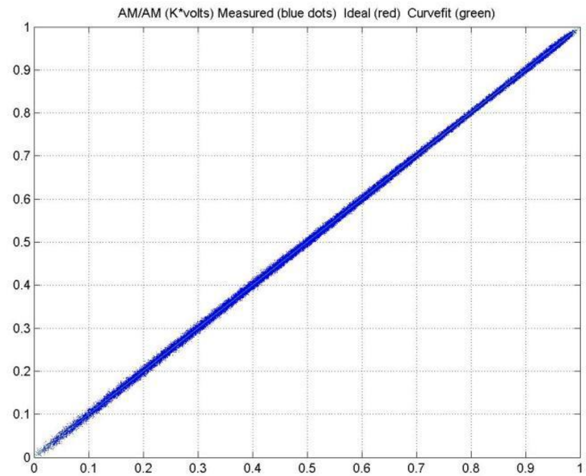
Fixed Vcc

ET Vcc

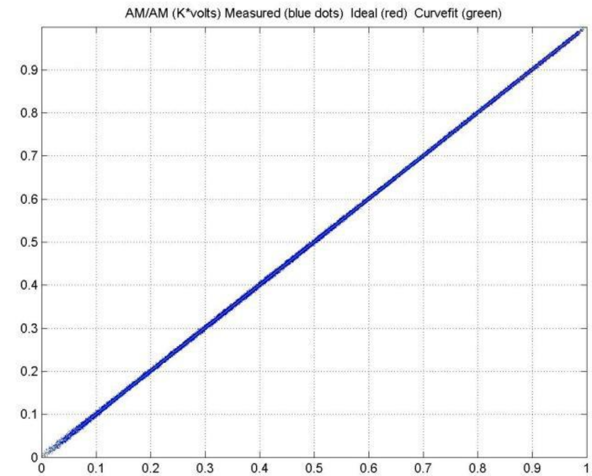


Before DPD





After DPD



Graph courtesy of P. Draxler, Qualcomm, IEEE-IMS 2013

Conclusions

- There is a significant amount of cutting-edge technology in today's mobile devices
- PA/FEM selection drives significant design considerations for wireless coverage, max data rate, and battery life
- Advanced PA/FEM characterization is made possible with the latest generation of modular RF test equipment

Q&A

- Thank You!
- Questions?
- Come see us at Booth #4
  - Wireless Test Set Demo
  - Supplemental Application Note
- Contact Information
  - Chris Ziomek, chris.ziomek@litepoint.com