APPLICATION NOTE

Power Amplifier Digital Pre-Distortion (DPD) Measurement Solution

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As modern mobile communications expand their capabilities and grow more complex, the associated growth in bandwidth, power consumption and linearity drive the need for new approaches for device characterization. Designers face challenges in generating accurate device models, minimizing design cycles, and certifying their RF device conformance.

Power amplifiers (PAs) are essential in modern RF communication chains. They convert a low-power signal to a higher-power one but are inherently non-linear. This non-linearity generates spectral regrowth that leads to adjacent channel interference and violation of the out-of-band emissions standards that regulatory bodies mandate. Non-linearity also causes in-band distortion, which degrades the bit error rate (BER) and data throughput of the communication system.

As one of the biggest power consumers, PAs turn increasingly to efficiency techniques like digital pre-distortion (DPD). Engineers can test their devices using DPD techniques without adding cost or test time.

Power Amplifier Non-Linearity Characterization

PA characterization provides information about a device's performance quality and value and is critical for designers, customers, and the market. While linear performance characterization offers basic amplifier behavior information, designers need accurate non-linear characterization to fully understand a PA's efficiency and standard compliance.

While there are plenty of test parameters for robust amplifier characterization, the most critical parameters for PA modeling are error vector magnitude (EVM) and adjacent channel power ratio (ACPR). These two parameters are essential as they quantify PA non-linearity. Designers need these data to avoid non-linearities that directly affect signal demodulation and BER, and cause spectral regrowth, creating interference in frequency bands outside the channel of interest.

For PAs that have stimulation from wideband input signals, non-linearity causes in-band and out-of-band distortion products. Correction of linear distortion is straightforward, but non-linear effects are harder to address. Designers must quantify the PA's non-linearity to ensure that the device meets performance specifications and follows strict standards for EVM and ACPR. Essentially, "good" linearity indicates that the PA will amplify the input signal without adding distortion. EVM represents in-band amplifier distortion, while ACPR represents out-of-band distortion.

How to reduce non-linearity?

To reduce non-linearity, the PA will operate at lower power or on a backed off basis to run within the linear portion of its operating curve. However, newer transmission formats, such as wideband code division multiple access (WCDMA) and orthogonal frequency-division multiplexing (OFDM), have high peak-to-average power ratios (PAPR) and significant fluctuations in their signal envelopes. These formats require the PA to back off well below its maximum saturated output power to handle infrequent peaks that result in extremely low efficiencies at typically less than 10%.

DPD 101

DPD is the most cost-effective linearization technique. The DPD approach features an excellent linearization capability and the ability to preserve overall efficiency while taking full advantage of advances in digital signal processors (DSPs) and analog-to-digital (A / D) converters. The approach adds expanding non-linearity to the baseband that complements the compressing characteristic of the RF PA. Ideally, the pre-distorter and the PA cascade become linear, and a constant gain amplifies the original input. With the pre-distorter, you can use a PA up to its saturation point while still maintaining good linearity to increase efficiency. As Figure 1 shows, DPD can be seen as an “inverse” of the PA.

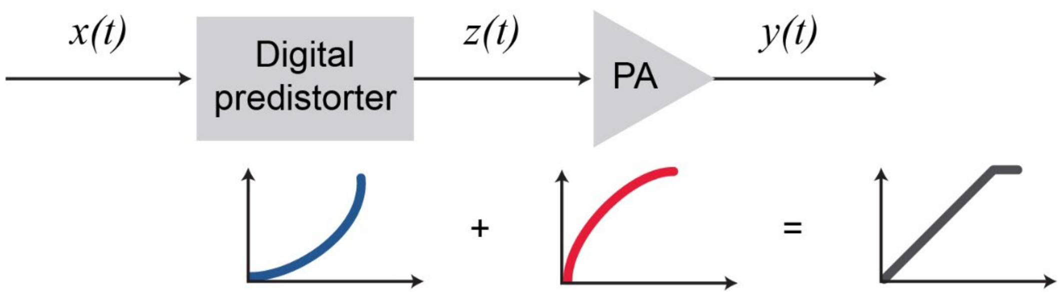

Figure 1. DPD-PA cascade

The DPD algorithm must model the PA behavior accurately and efficiently for successful DPD deployment.

DPD methods

PAs with high PAPR signals can generate problems with non-linearity. When you apply a high-power signal to the PA input, the PA cannot linearly amplify the signal and may result in gain saturation and distortion. This, in turn, can lead to signal quality degradation and poor ACPR and EVM. Use DPD technology to compensate for the non-linear behavior of the PA.

DPD implementation methods classify as either memoryless or memory models (Figure 2), and convey the memory effect on a PA.

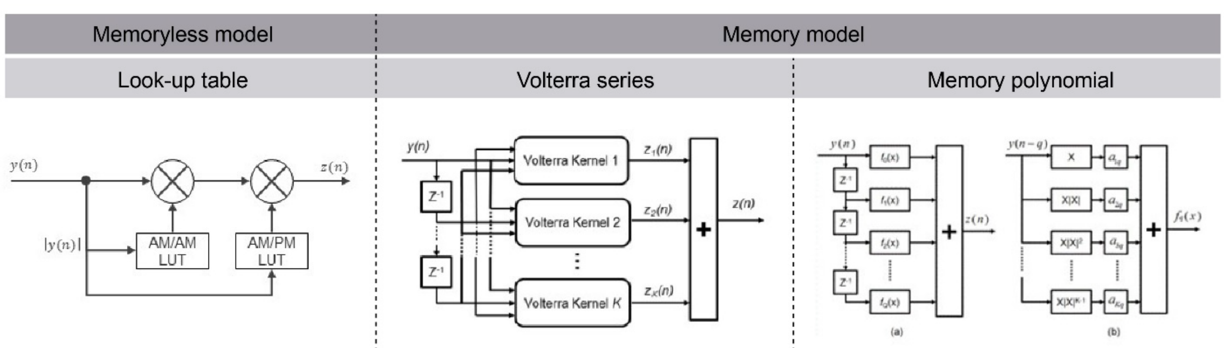

Figure 2. DPD models and algorithms

Memoryless models

Memoryless models focus on the PA with a memoryless non-linearity; the current output depends only on the current input through a non-linear mechanism. This instantaneous non-linearity is usually characterized by the amplitude to amplitude (AM / AM) and AM / Phase (PM) responses of the PA, where the output signal amplitude and phase deviation of the PA output serve as functions of the amplitude of its current input. A lookup table-based (LUT) algorithm is a key algorithm for memoryless models.

Memory model

Designers turn to memory models as the signal bandwidth gets wider. For wider bandwidth, PAs begin to exhibit memory effects. This is especially true for the high-power amplifiers that wireless base stations use. The causes of memory effects are due to the thermal constants of active devices or components with frequency-dependent behaviors in the biasing network. As a result, the current output of the PA depends not only on the current input but also on previous input values. In other words, the PA becomes a non-linear system with memory.

Memoryless pre-distortion can achieve a very limited linearization performance for the PA. Therefore, DPDs must have memory structures. The Volterra Series is the most important algorithm for models with memory for DPD implementations. However, the large number of coefficients makes the Series unattractive for practical applications. Several Volterra derivatives, including the memory polynomial model, are popular for DPDs.

To summarize, memoryless models only provide an instantaneous response, while memory models offer a series of data that you can use to model the memory effect.

Keysight Solution: A Simple Setup with a Single Connection

Many PA designs incorporate DPD capabilities, so it is essential to enable DPD when measuring PA performance. When the power level is low, PAs mainly operate in linear functions. As power increases, the spectral regrowth in adjacent channels degrades ACPR dynamic range. In addition, gain compression causes constellation points to spread, eroding EVM. These impacts are the result of PA distortions due to non-linearity. If you enable DPD while maintaining the same power level, you can see ACPR and EVM improve significantly, and they appear much closer to linear operation.

Measurement setup

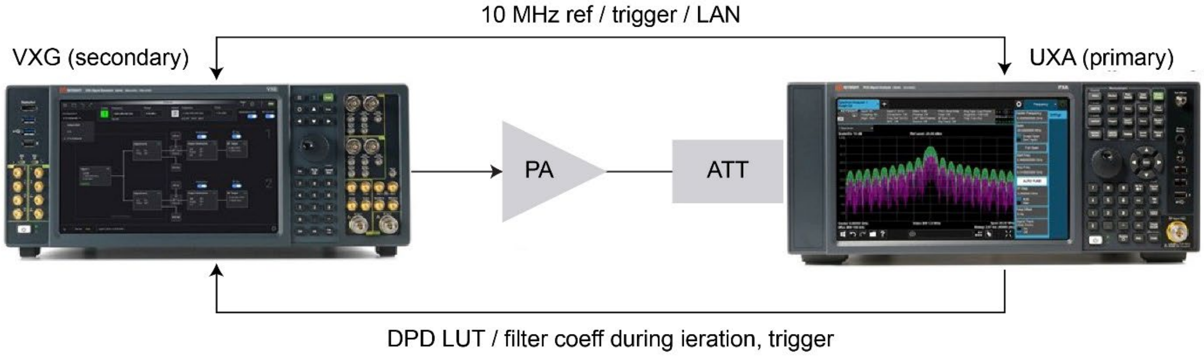

Figure 3. Keysight PA and DPD measurement setup

The Keysight solution for PA testing uses the Keysight Signal Generator (VXG), Signal Analyzer (UXA), and the N9055EM0E application running on the UXA to control the VXG. The VXG signal generator delivers a modulated signal to the PA, while the UXA signal analyzer measures the output of the PA. As a best practice, insert an attenuator into the PA output to prevent damage to the analyzer's input port with high output power from the PA. Connect a 10 MHz reference output and trigger output from the VXG to the UXA's respective inputs to establish timing and frequency synchronization (Figure 3).

The signal analyzer (X-app) extracts the DPD model, then transfers model parameters such as LUT or coefficients to the signal generator. The signal generator applies pre-distortion to the waveform, and then the waveform plays back to the device under test (DUT) PA.

The M9484C VXG supports DPD LUT, memory polynomial, and the Volterra Series models with the FW version A.06.xx or later. The N9055EM0E PA measurement application does not need to download the pre-distorted waveform into the M9484C VXG. The N9055EM0E PA measurement application sends the DPD LUT or memory polynomial coefficients directly to the VXG via SCPI command, which can significantly improve the PA's test speed.

The Keysight X-Series signal analyzer UXA N9042B, together with the M9384B or M9484C VXG, can support a maximum bandwidth of up to 2.5 GH. These units can provide bandwidth for analyzing DPD-applied waveforms with 400 MHz 5G NR FR2 signals or 320 MHz WLAN 802.11be signals.

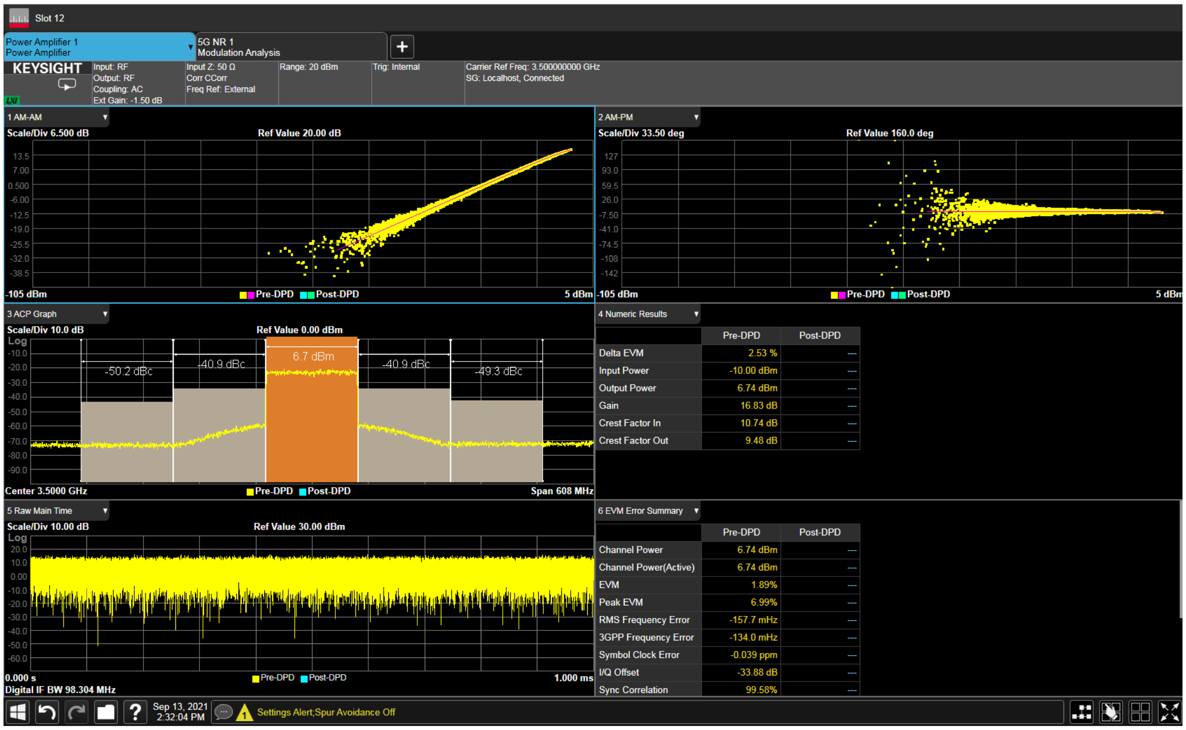

Figure 4. PA before applying DPD

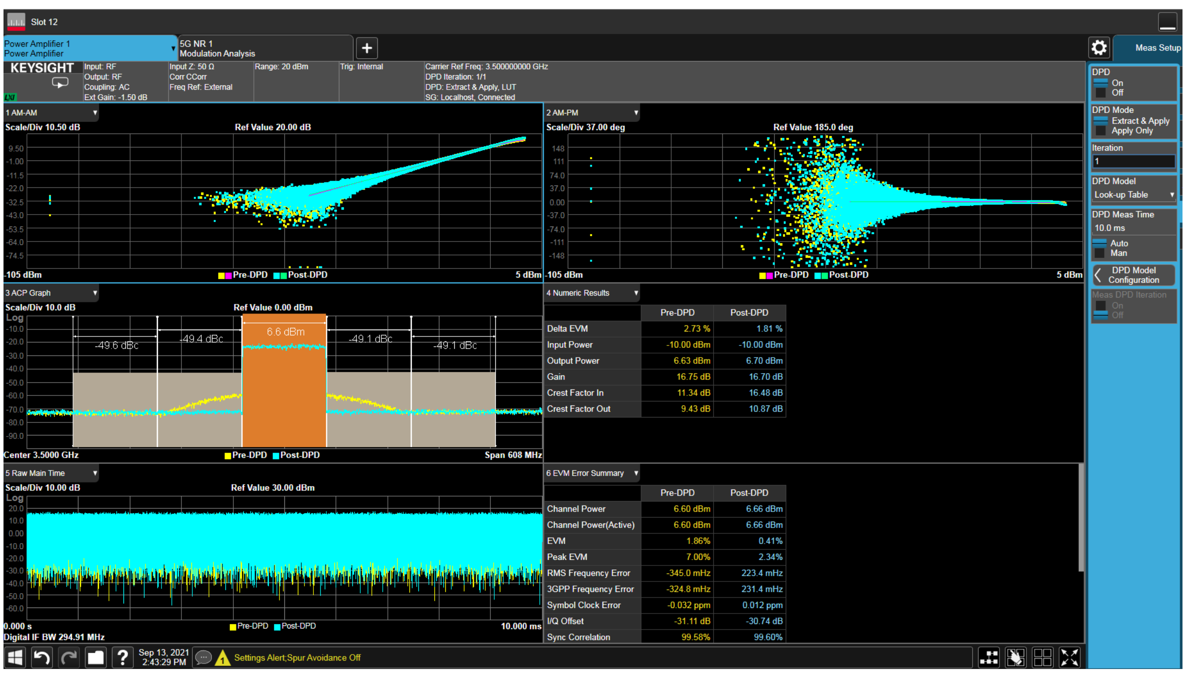

Figure 5. PA after applying DPD

You can see the differences between the pre-DPD (in yellow) and post-DPD (in cyan) in ACPR and Delta EVM. The DPD improves both ACPR and delta EVM performance significantly.

Power amplifiers are a core component in wireless communication devices such as mobile phones and base stations. Therefore, the application of DPD techniques becomes critical to prevent limited linearization of the PA and improve its performance and efficiency.

The Keysight PA DPD solution provides a comprehensive set of tools for pre-DPD and post-DPD PA measurements to enable engineers to measure and troubleshoot their PA DUT in different scenarios with complete confidence and flexibility.

Learn More

Power amplifier DPD measurement

- Application Note: N9055EM0E Power Amplifier Measurement Application Demo Guide
- Technical Overview: N9055EM0E Power Amplifier Measurement Application
- Data Sheet: N9042B UXA X-Series Signal Analyzer
- Data Sheet: M9484C VXG Vector Signal Generator

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