Solutions for

Emerging 4G Communications Systems

Making Digital Pre-Distortion Fast and Practical for all Engineers

Application Note

Overview

A transition is now underway in the wireless communications industry as wireless service providers migrate from 3G to 4G technologies like LTE-FDD, LTE-TDD and WiMAX™ to keep pace with emerging devices like smart phones. For the engineer, this transition means a host of new challenges. For example, they must determine exactly how far away their design is from being able to operate in 4G and whether or not it will need to be completely redesigned to do so. The hardware must also meet or exceed standards-based performance requirements such as ACPR, EVM or throughput (e.g., BLER, BER and PER), while meeting product design goals.

Because smart phones and other advanced wireless devices rely so heavily on battery power, getting the most efficiency out of a design is critical. The RF power amplifier (PA) plays a key role here since it directly impacts device hardware and its requirements for 4G operation. As a result, one of the biggest challenges today's engineers face is choosing and designing the right PA to meet design goals at the lowest possible cost.

Problem

Power amplifiers are an essential component in the overall performance and throughput of wireless communications systems, and are inherently nonlinear. That nonlinearity generates spectral re-growth, which leads to adjacent channel interference and violations of the out-of-band emissions standards mandated by regulatory bodies. It also causes in-band distortion, which degrades the BER and data throughput of the communications system. Operating the PA at a lower power is one way to reduce this nonlinearity. However, this reduces the service area and increases both the capital and operating expenses of the service provider. Linearization enables the PA to be operated in its high power-added-efficiency (PAE) region, near saturation and without significant signal distortion, thus reducing expenses. Digital pre-distortion (DPD) is a cost effective way to accomplish linearization, but often requires a highly specialized skill set for modeling and implementation.

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Solution

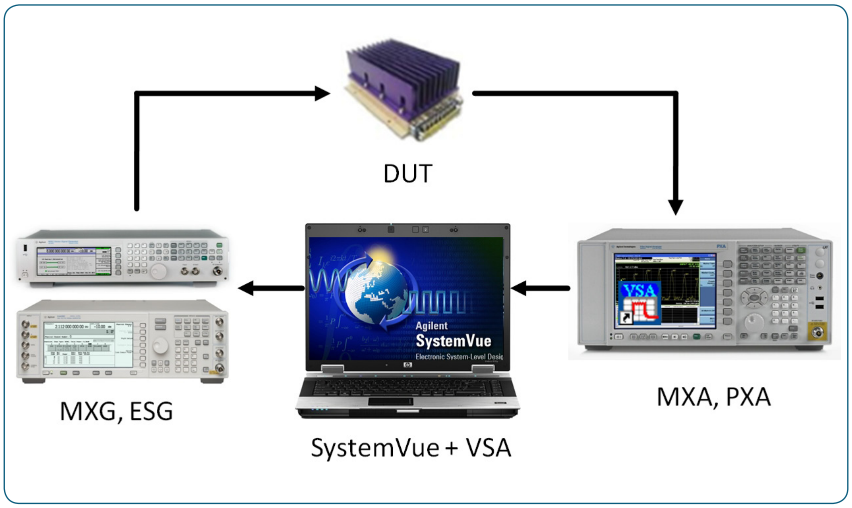

FIGURE 1. In this setup, the MXG with Signal Studio software for LTE and WiMAX provides the standard-based signals required for component test, while the PXA running Agilent's embedded Vector Signal Analysis (VSA) software captures the signal in order to measure the PA's nonlinearities. Using SystemVue with the MXG and PXA automates and controls the entire DPD design flow process.

Engineers migrating to 4G require a solution that makes implementing DPD fast and practical for 4G communications systems - one that can be used by engineers at all levels of expertise and requires minimal equipment. The tool set should be accurate, avoid dependence on a vendor-specific chipset or hardware implementation for the initial modeling, and able to absorb custom DPD into the rest of the baseband processing, preserving a lower bill-of-material. Moreover, it must support connectivity with a range of other tools for hardware verification.

One solution that meets this criterion is Agilent Technologies' SystemVue platform with its add-on DPD personality - the W1716 DPD Builder. This utility features an easy, wizard-based user interface that helps users quickly model and correct common sources of 4G memory effects in both low and high-power PA's, as well as transceiver IC's, and even automatic gain control modules.

The W1716 DPD is aimed at early R&D architecture and component studies by wireless system architects using common, off-the-shelf test equipment already in a test lab. Whereas proprietary DPD solutions force a number of premature implementation decisions simply to perform a 4G feasibility study, by using the W1716 DPD, wireless architects can now assess in minutes how "linearizable" a component will be, while still retaining ultimate hardware flexibility and full 4G measurement confidence. Agilent enables this thanks to several key advantages: the power and ease of the Agilent DPD algorithms; the open, vendor-neutral and technology-neutral approach taken to the DPD and PA hardware; the high performance and flexibility of the Agilent instruments; and the realistic, standards-compliant waveforms (such as LTE with Crest Factor Reduction (CFR)) that are used for the characterizations.

CFR supplements and improves the effectiveness of DPD. For modern communication systems, spectrally efficient wideband RF signals have a peak-to-average power ratio (PAPR) as high as 13 dB. CFR preconditions the signal to reduce signal peaks without significant signal distortion. By reducing PAPR, CFR allows the PA to operate more efficiently. It also enables the signal to better comply with spectral mask and EVM specifications.

The result is that the W1716 DPD has the ability to correct for wider bandwidths, higher dynamic range and a variety of amplifier topologies. Moreover, it performs this initial design inside a full baseband/DSP design environment (Agilent's SystemVue software). This allows the architect to use SystemVue to transition the pure DPD algorithms into a custom hardware implementation, or to absorb the DPD algorithms into an existing FPGA or ASIC to maintain a small bill-of-materials.

Unlike other task-specific, chipset-specific, or measurement-specific approaches to DPD, this Agilent approach takes a designer's perspective by featuring flexible, built-in links to instruments like Agilent's MXG signal generator and PXA spectrum analyzer for hardware verification (Figure 1). The raw performance of the underlying measurement system is absolutely essential when characterizing nonlinear devices for high-bandwidth, high-dynamic range communications standards.

Power of X for DPD

A number of capabilities make the MXG and PXA well suited for DPD. The MXG, for example, features a 100 MHz demodulation bandwidth with flat amplitude and frequency response for accurate characterization and maximum DPD suppression. It also features the highest dynamic range in the world, which ensures accurate device characterization, and high-power output to drive the device-under-test into compression. The PXA features a 140 MHz demodulation bandwidth with flat amplitude and frequency response, as well as 75 dB spurious free dynamic range for accurate device characterization. Its deep waveform capture and the world's highest dynamic range also enable accurate characterization during post signal analysis.

Figure 2 illustrates the theoretical limit to the amount of correction (cancellation) that can be achieved in the PA. The gradient curves (0 dB, 0.05 dB, 0.1 dB, etc.) show cumulative RF error in decibels. Essentially, the diagram shows the AM-AM correction performance that can be achieved in the implementation. The correction limits are determined by the accuracy with which the amplitude and phase of the distortion products can be measured and corrected. For example, when the amplitude correction error is 0.1 dB and the phase correction error is 0.7 degrees, the maximum theoretical correction is –35 dB.

Higher performance can be achieved through careful consideration of the linearity, flatness and dynamic range of the signal generation and analysis tools. If, for example, the design goal is to achieve 30 dB cancellation performance of the feedback loop, the measuring equipment must be able to provide amplitude and phase measurement accuracies that fall within the grayed area of the graph (between 16 and 22 dB of cancellation). In order to achieve these accuracies, it is essential to correct for instantaneous amplitude and phase flatness, accurately measure the lower-level distortion products, and then consider the dynamic range and measurement accuracy limits of the signal analyzer, which ultimately determine the limits of correction.

The MXG and PXA offer the performance necessary to meet these goals (Figure 3). The MXG's high-performance internal calibration of wideband RF output makes it ideal for DPD applications. Its performance reduces the residual errors of an RF signal generator, thereby improving the characterization of the device. The PXA's high-performance internal calibration of wideband IF also makes it ideal for DPD applications. It combines wideband, high dynamic range with excellent phase and amplitude flatness performance and linearity. Its accurate wideband, high-dynamic-range analysis enables better response measurements of devices.

While primarily targeted at engineers migrating from 3G to 4G, the solution's flexibility to use custom test vectors based on live measurements makes it viable for a broad range of applications, including military communications and radar.

Implementing DPD in PA Hardware

Utilizing the W1716 DPD utility for PA hardware is a simple, straightforward process that takes mere minutes using the setup and

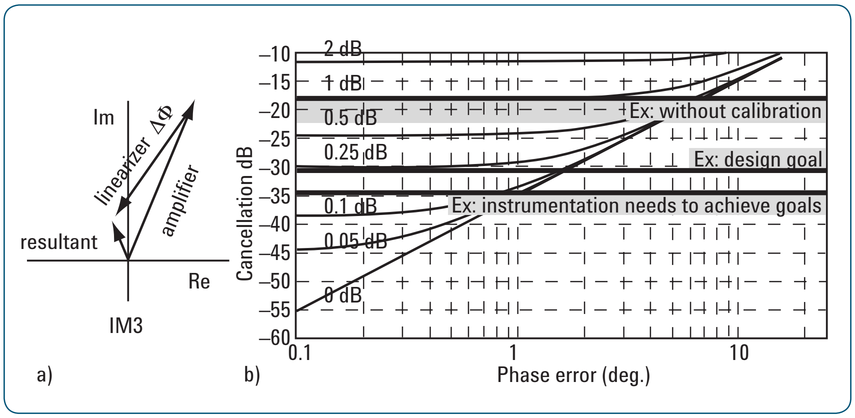

FIGURE 2. Shown here is the impact of phase and amplitude error performance on adaptive cancellation. The vertical axis shows the theoretical cancellation in decibels based on the RF correction performance relative to the absolute phase error correction performance shown on the horizontal axis.

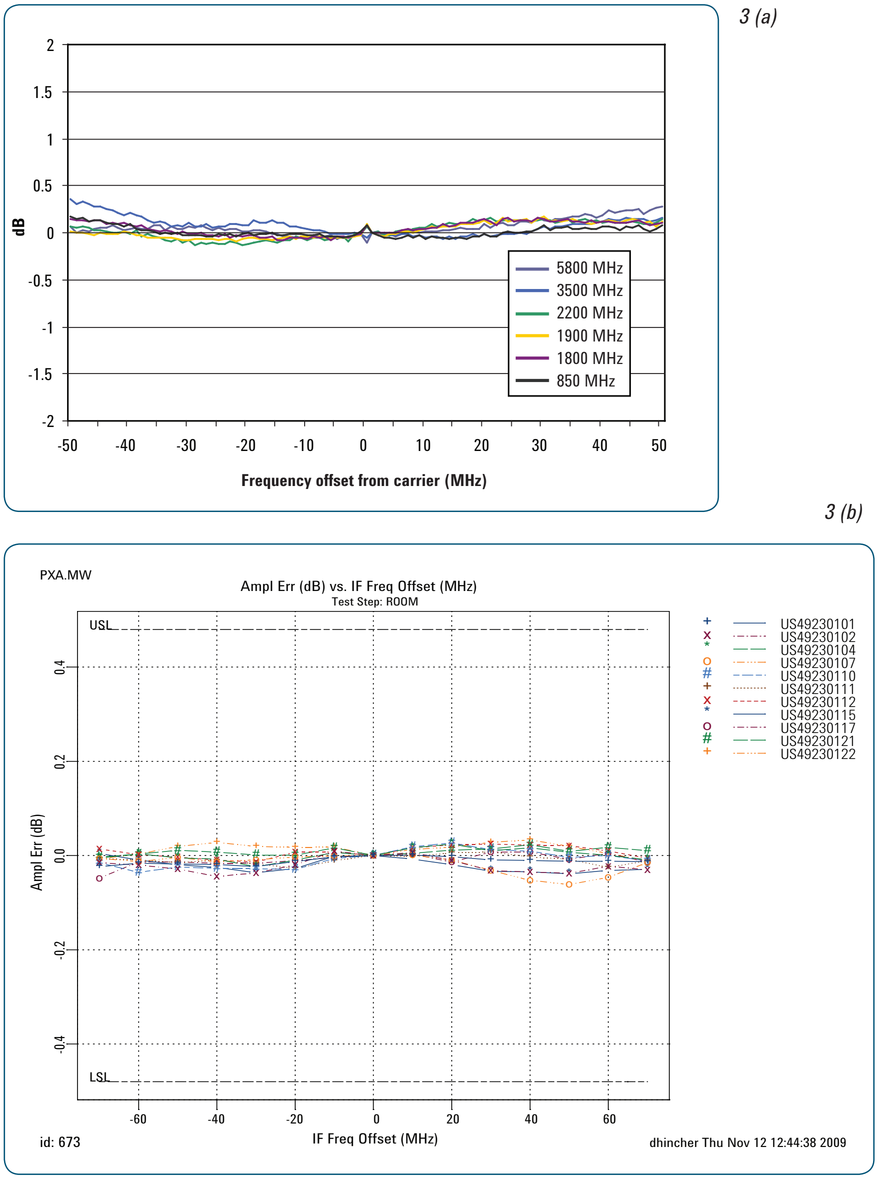

FIGURE 3. (a) An MXG flatness plot across the full 100 MHz BW. (b) A PXA flatness plot across the full 140 MHz BW.

measurement steps shown in Figures 1 and 4, respectively. The five DPD design flow steps include:

1. The DPD stimulus waveform (e.g., LTE, WCDMA or user defined) is created and downloaded via the W1716 DPD wizard into the MXG.
2. The PA's response, both input and output, is captured from the PXA using VSA software. The PA output signal is captured by inserting the PA between the MXG and PXA with appropriate signal calibration, including any signal padding with attenuators.
3. The W1716 DPD compares the captured output waveform to a desired undistorted passthrough waveform. Based on this, the DPD model is extracted and verified.
4. The DPD+PA response is captured by applying stimulus to the extracted DPD model and downloading the DPD output waveform into the MXG. The PA output waveform is then captured from the PXA using VSA software.
5. The DPD+PA response is verified, and the performance improvements possible with DPD can be shown.

This 5-step measurement-based DPD design flow was used for a commercial PA. The result of using SystemVue DPD is shown in Figure 5. Another typical DPD result is shown in Figure 6.

Summary of Results

As engineers migrate to 4G, choosing and designing the right PA to meet design goals at the lowest possible cost becomes an extremely challenging task, both for PAs in base stations and mobile devices. Because DPD enables the PA to be operated in its high PAE region, near saturation and without significant signal distortion, it provides a viable means for engineers to address many base station/mobile device PA design challenges. The SystemVue platform with W1716 DPD utility and the MXG and PXA provides a way for engineers, at all levels of expertise, to quickly, easily and cost effectively implement DPD in 4G communications systems.

For more information, go to:
http://cp.literature.agilent.com/litweb/pdf/5990-6534EN.pdf

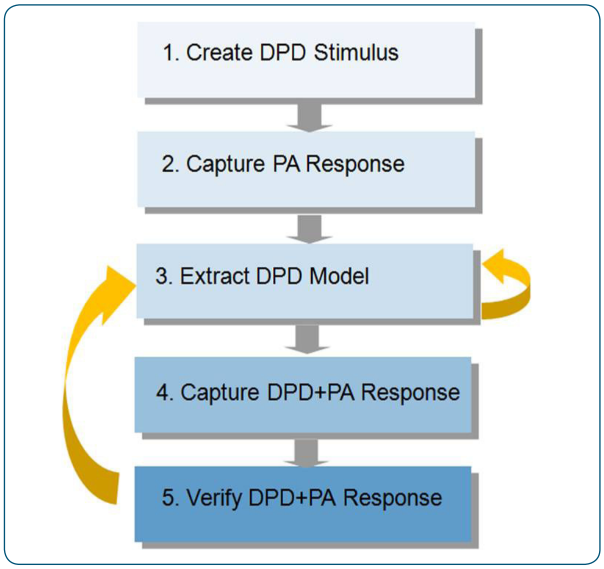

FIGURE 4: Using the setup in Figure 1, the measurement-based DPD modeling flow is a 5-step process.

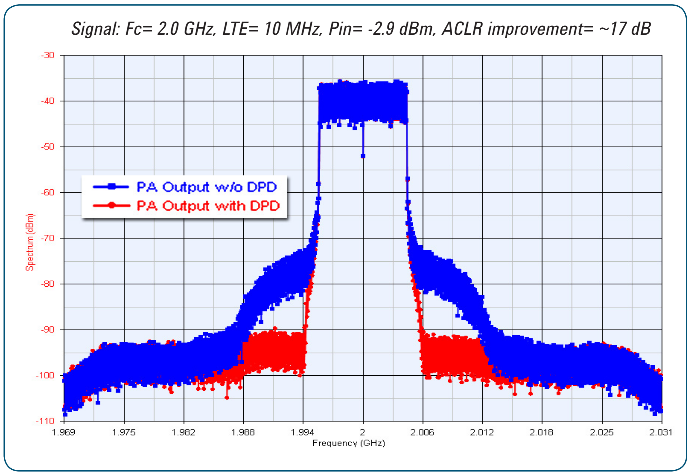

FIGURE 5: This example DPD extraction takes place at RF power = -2.9 dBm. The original raw data is displayed in blue, while the DPD+PA output is shown in red.

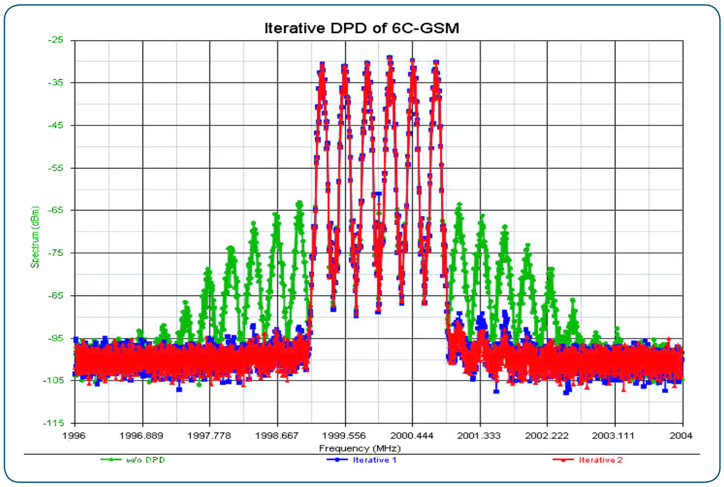

FIGURE 6: Shown here is an approximately 32 dB ACLR improvement for 6-carrier GSM at 2.0 GHz, with a 9.4 dB crest factor. The colors represent different applications of the DPD algorithm. Green represents the initial unimproved result, while blue and red represent iteration 1 and 2, respectively. With each iteration of the algorithm, additional improvement is garnered until a limit is reached.

The Power of X

The Agilent PXA spectrum analyzer and MXG signal generator are key products in Agilent's comprehensive Power of X suite of test products. These products grant engineers the power to gain greater design insight, speed manufacturing processes, solve tough measurement problems, and get to market ahead of the competition.

Offering the best combination of speed and scalability, and created and supported by renowned worldwide measurement experts, Agilent's X products are helping engineers bring innovative, higher-performing products to emerging markets around the globe. To learn more about Agilent's suite of X products please visit: www.agilent.com/find/powerofx.

Related Applications

- Wireless basestation transmitters
- Satellite communication links
- Point-to-point terrestrial microwave links
- Military backhaul communications repeaters
- Avionics
- Narrowband radar

Related Agilent Products

- Signal Studio
- VSA 89600B
- W1461BP SystemVue Comms Architect
- W1716EP SystemVue Digital Pre-Distortion Builder
- W1918 LTE-Advanced Baseband Verification Library (SystemVue)
- E4438C ESG Vector Signal Generator
- E8267D PSG Vector Signal Generator
- N5106A PXB Baseband Generator and Channel Emulator
- N6030A/M9330A Series Arbitrary Waveform Generator
- 81180A Arbitrary Waveform Generator

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