APPLICATION NOTE

Accelerating RF Power Amplifier Testing

RF power amplifier test solutions: faster, repeatable tests with envelope tracking and digital pre-distortion using test system techniques and modular vector transceiver using envelope tracking and digital pre-distortion

KEYSIGHT

Overview

As wireless mobile devices grow in capability and complexity, the associated growth in power demand drives the need for new battery utilization and power efficiency approaches. One of the largest power consumers in a wireless handset is the RF Power Amplifier (PA), so improved efficiency techniques like Envelope Tracking (ET) and Digital Pre-Distortion (DPD) are being increasingly utilized. However, testing these devices with this additional capability can potentially increase test costs and overall time.

This application note will discuss various approaches to maximizing test equipment utilization and reducing test times for such component RF PAs and front-end modules, whether in design, characterization, or manufacturing tests.

Challenges: Striking a Balance Between Speed and Repeatability

Higher test speeds are increasingly demanded for both design validation and production tests of RF PAs, which support multiple modes, frequency ranges, and modulation formats. Consequently, the validation phase requires thousands of tests. During RF PA production tests, manufacturers must address several critical issues, such as speed, repeatability, cost, maintainability, and upgradability. However, the biggest challenge is balancing speed and repeatability, where an increase in test speed usually results in a decrease in repeatability. Manufacturers are constantly struggling to find the right balance while also managing cost and maintainability.

The speed challenge is further complicated by the fact that PAs are being manufactured in increasingly higher volumes to meet the growing demand for wireless mobile devices, and the PAs themselves have become more complex. Techniques such as DPD and envelope tracking are often employed to help linearize the PA and improve its power efficiency, but they add to the testing requirements during production, which further slows down the process.

With PA manufacturers looking to reduce overall test times from 1.5 seconds to 500 ms or less, these slow-downs are no longer acceptable. Thus, finding ways to balance speed, repeatability, and cost is critical to meet the needs of today's market.

Figure 1. Envelope Tracking

Solution

Fast power servo processing

To address the challenges facing PA validation and manufacturing teams, it is crucial to increase test speed while maintaining repeatability. Fortunately, several test system techniques are now available to manufacturers for this purpose. One such technique involves speeding up the PA power servo loop (Figure 2). The power servo loop is a "test and adjust" process, in which the engineer sets the RF input power level to the Device Under Test (DUT), checks the RF output of the DUT, and adjusts the input level as necessary until the correct output power level is achieved.

Only then can the engineer proceed to making measurements on the DUT. By streamlining this process and enabling engineers to move quickly onto taking measurements, it is possible to significantly reduce the overall RF PA test time.

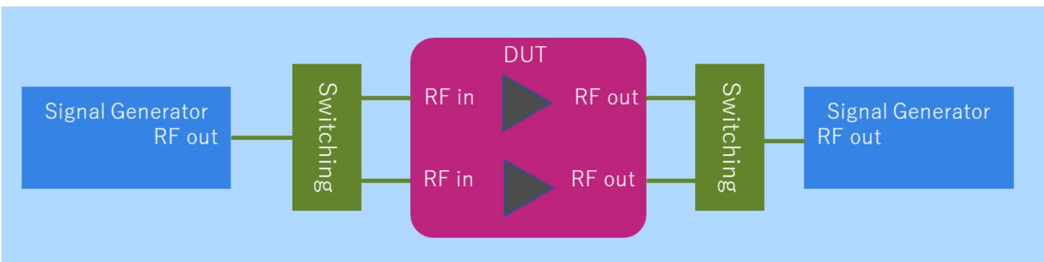

Figure 2. System-level block diagram for a multi-DUT test using a signal generator and signal analyzer. The RF PA Power servo loop is a key requirement in PA testing and must be performed at each test condition

One solution able to quickly perform the power servo loop is the PXIe vector transceiver, which combines vector signal generation and analysis in a single 2-slot or 3-slot unit. This solution aims to double manufacturing test throughput or more while minimizing the use of valuable floor space.

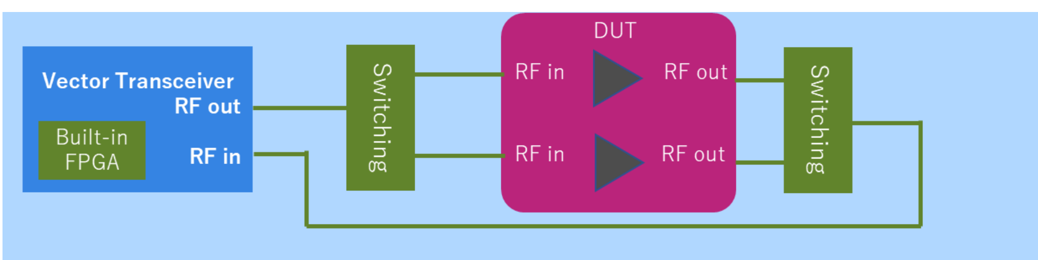

Figure 3. System-level block diagram for a multi-DUT test using vector transceiver (VXT). Built-in FPGA-based measurements have been utilized to increase measurement speed

Keysight's M9410A/11A/15A PXIe vector transceiver (Vector transceiver, see Figure 3) is purpose-built for rapid solution creation and faster throughput in manufacturing tests of wireless components and IoT devices. The built-in servo routine accurately determines the final PA output power to control PA distortion. Traditional power measurement methods have involved swept or I/Q acquisitions followed by software processing. Though the software processing speed can scale with the capability of the processor, FPGA-based measurements have recently been utilized to further increase measurement speed. The PXIe VXT features real-time FFTs that enable high-speed measurements of signal power and adjacent-channel power ratio (ACPR), which can compress the power servo and ACPR test time from 70 to 110ms to a handful of milliseconds, as shown in the table below. The VXT's built-in software and FPGA-accelerated measurements allow manufacturing system developers to easily create test solutions for power amplifiers (PA) and front-end modules (FEM).

Power servo time comparison among traditional sweep acquisition, fast I/Q acquisition, and FPGA accelerated processing together with PXIe VXT hardware.

Time	Swept acquisition and software processing	Fast I/Q acquisition, mixed hardware, and software processing	FPGA accelerated processing with VXT
Power Servo WCDMA	70 ms	20 ms	5.5 ms
Power Servo FDD LTE	110 ms	20 ms	5.5 ms

Fast signal processing

Once the power level is set correctly, the need for speed and accuracy switches to signal analysis. VXT provides 4 receiver acquisition modes. You can choose the appropriate mode to achieve the fastest measurement speed while maintaining repeatability for each measurement item.

Receiver acquisition mode of VXT

Receiver acquisition mode	Use case	Difference
Power Acquisition	Get the channel power directly	Fast power calculation
Spectrum Acquisition	Get the spectrum data based on span and RBW setting	More data points than FFT acquisition Lower DANL and better dynamic range
FFT Acquisition	FFT method to get the spectrum data	Faster SA data capture speed than spectrum acquisition Up to 2048 data points Lower dynamic range
IQ Acquisition	IQ data output	Easy for post analysis

Optimizing repeatability and test time

When it comes to optimizing repeatability and test time when making power measurements, several techniques are available. One technique involves using an immediate trigger to start the measurement. This technique enables fast measurements because the engineer can measure at any time in the waveform and does not have to wait for an external trigger; however, the measurement itself is often poor due to the significant variability throughout the waveform. Variations in power level add to the measurement uncertainty in power and ACPR measurements. Repeatability can be improved by increasing the measurement duration, but this increases the test time. Another option is to use an external trigger to start the measurement. In this case, repeatability improves because the engineer is always measuring at the same time within the waveform, and there is no variation in the modulation signal during the measurement. Unfortunately, repeatability comes at the expense of measurement time. Only one point in the waveform can be measured at any given time, and the delay in waiting for an external trigger is, on average, half the total time of the waveform. Since the engineer isn't actually making measurements during most of the waveform, this is wasted time.

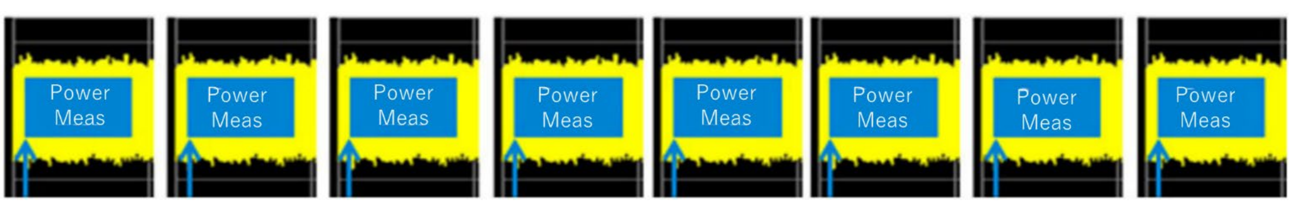

Figure 4. Using an external trigger with a short waveform is the ideal way to optimize repeatability and test time.

An alternate approach involves shortening up the waveform by cutting it to just longer than the measurement acquisition time and always measuring at the same point within the waveform. The test engineer measures at one point in the waveform, and the delay to wait for an external trigger is half the total time of the waveform, but since there is a much shorter waveform, the wait time is significantly reduced. The result is improved repeatability and significantly faster measurement time (Figure 4). Although, when using this method, it's important not to get too aggressive with reducing the length of the waveform. Otherwise, the next trigger might be missed, and the test time would increase. Ideally, to optimize waveform length, the waveform should be set to just longer than the whole cycle time, including the measurement time and processing time (Figure 5).

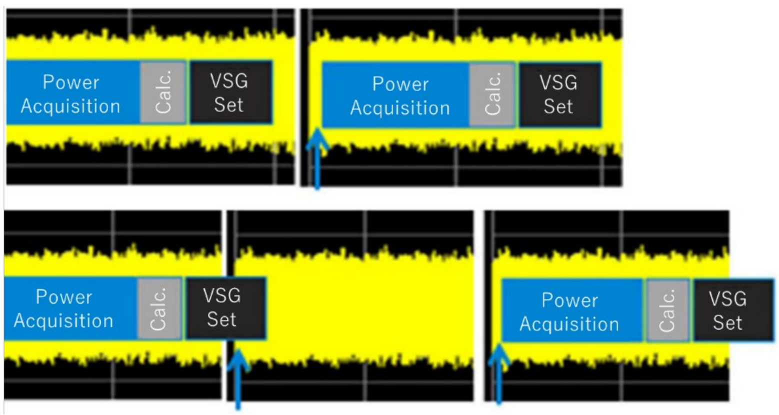

Figure 5. When optimizing short waveform length, getting too aggressive can increase the test time if the waveform is too short, as shown in the bottom graphic. Instead, the waveform should be set to just longer than the whole measurement cycle time, including the measurement and processing times, as shown in the top graphic.

Dealing with the implications of emerging technologies

Emerging technologies such as ET and DPD are commonly used to improve PA performance; however, their inclusion further burdens the manufacturer with additional testing. ET is a technique employed to improve the power efficiency of the amplifier by allowing the amplifier's drain bias to track the magnitude of the input signal envelope. With this technique, a small reduction in gain enables the amplifier to be more linear, reach higher peak powers, and operate more efficiently. DPD is a technique often employed to correct the PA's nonlinearities caused by operating the PA in its region of high Power-Added Efficiency (PAE). This technique achieves gain expansion, resulting in higher-performing power amplifiers. Any new tests required as a result of ET or DPD will run counter to engineers' need to reduce test time.

For more information

Read the following application notes if you wish to learn more about ET and DPD

- Solutions for Implementing Envelope Tracking in Power Amplifiers
- Envelope Tracking and DPD Power Amplifier Testing

A typical characterization and test solution for testing PAs with ET and DPD is shown in Figure 5. The solution includes waveform generation software (Pathwave signal generation) and PA test software for ET and DPD(X-Apps). It also includes the hardware required for RF signal generation/Analysis(VXT2,3), envelope waveform generation(AWG), power(SMU), RFFE control(DSR), and S-parameter analysis(VNA), are included.

Also, M9415A(VXT3) covers a full frequency range from 380MHz to 12GHz, and it can measure the latest frequency requirement up to 7.125GHz for Wi-Fi 6E and5G NR FR1 and up to 10.6GHz for UWB in a single 3-slot module.

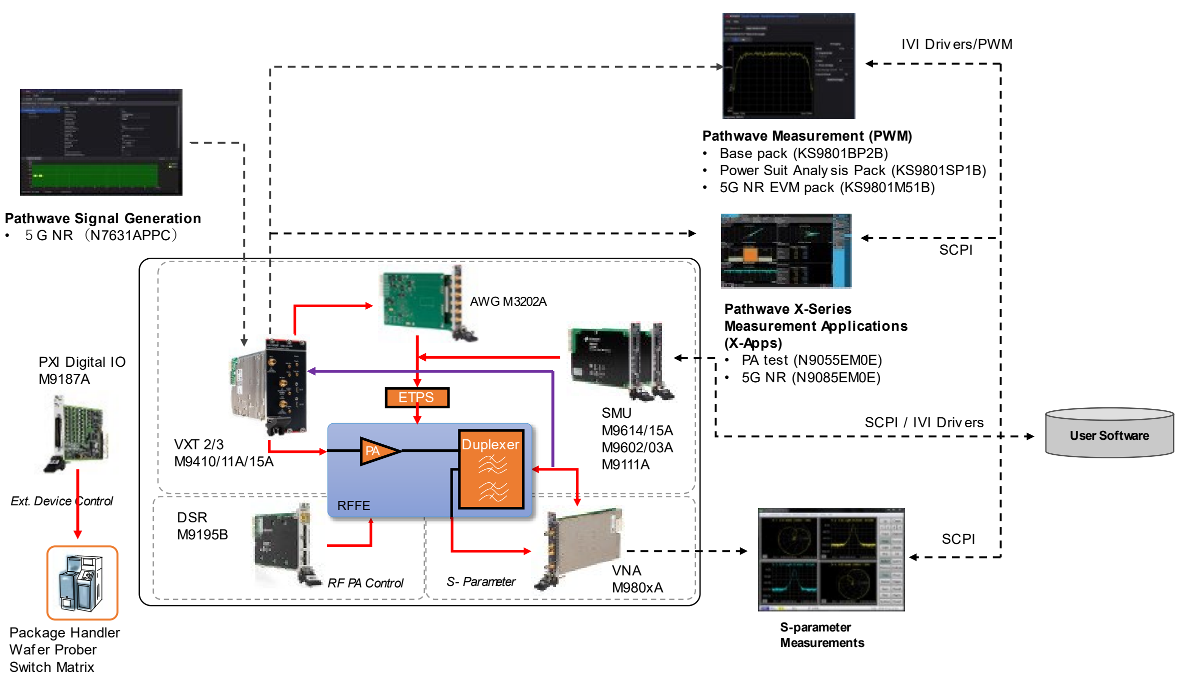

Figure 6. Shown here is a PA production test solution configuration with support for ET. This system is useful for testing PAs with ET and for dynamic EVM, commonly used for Wireless LANs to conserve power by turning the device off between packets

DC bias source solution for more repeatability and early detection of problems

For an ideal RF power amplifier test, it's essential to focus on both the VXT and DC bias source. The Source Measure Unit (SMU) is typically used to supply DC bias to PAs since it has a feedback circuit that ensures a stable voltage output, independent of sink current, and can simultaneously measure current with the built-in ammeter. Keysight's M9602A/03A/14/15A PXIe precision SMUs have these features and offer additional benefits that outperform traditional instruments.

More repeatable RF power amplifier test

In the conventional benchtop system, the timing accuracy when SMU triggers VXT and vice versa is low, and the timing of these operations can vary from test to test. This reduces data repeatability. M9602A/03A/14A/15A PXIe precision SMU has the trigger functions within a few of μs accuracy. It enables the precise trigger input and output timing control to synchronize SMUs and VXTs tightly and easily. Also, their fast recovery time for sink current takes care of your concerns about the low repeatability due to source voltage fluctuations causing the DUT to become unstable.

Detect the problem at the early stage

It is crucial to analyze the waveform and capture abnormal waveform on the power rail, especially for R&D. These were difficult with conventional SMUs due to their limited measurement speed. On the other hand, the M9602A/03A and M9614A/15A can sample at high speeds of 500 ksa/s and 15 MSa/s, respectively, which enables measuring true waveform. This enables the detection of the problem at an early stage.

In addition, Keysight has M9111A PXIe High-Speed SMU specialized in fast return to programmed voltage.

Summary

Reducing validation and manufacturing test times is essential to PA manufacturers, especially in the face of emerging technologies like ET and DPD. Fortunately, this can be accomplished through a combination of real-time signal processing, innovative FFT acquisitions for power servo and ACPR measurements, and the use of shorter waveforms. The Keysight M9410A/11A/15A PXIe VXT, with its built-in FPGA, provides a complete PA test solution that is both fast and compact. Additionally, the PXIe VXT can be used with a range of other test equipment and standards-based software, including Signal Studio, Modular X-Series applications, M9602A/03A/14A/15A SMU, and 89600 VSA, to address the additional tests necessitated by the use of ET and DPD technologies, which are designed to improve PA efficiency.

The Power to Accelerate Wireless Design and Test

Keysight is a leading provider of wireless test solutions, offering high-performance design and testing of wireless devices and networks. With application-focused platforms optimized for existing and emerging standards, Keysight provides optimal R&D and field support, enabling engineers to better understand the intricacies of the continuously evolving wireless industry and accelerate the development of their products. To learn more about Keysight's comprehensive suite of test and measurement products, please visit: www.keysight.com/us/en/industries/communications

Related Applications

- Front-end module test
- Small cell PA test

Related Keysight Products

- MXG
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- PXA