Improving Power Amplifier Manufacturing Test Speed

Presented by Joan Gibson
Solutions Marketing Engineer
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Agenda

Key Test Challenges

Test system techniques to optimize throughput

New emerging technologies such as envelope tracking and DPD and their implications

Agilent’s PA Reference Solution
Power Amp Production Test: Top 10 Things Concerning PA Manufacturers

- Speed
- Repeatability
- Cost
- Maintainability
- Upgradeability

Reduce test time while maintaining repeatability
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Agilent’s PA Reference Solution
Power Amplifier
Output Power Level Servo Loop

- DUT specifications are at a specific *output power level*
- Need to adjust signal generator level for each device
- Start at signal generator level based on expected gain of DUT
- Measure power with signal analyzer
- Signal generator level must be iteratively adjusted to achieve the correct DUT output power

*Key Item in PA Testing: Must be Performed at Each Test Condition*
Baseband Frequency and Amplitude Offset with the M9381A Vector Signal Generator

• Signal Processing ASIC in baseband generator supports changing Frequency and Amplitude of RF Signal without Adjusting Analog Hardware (fastune technology innovation)

• Power Servo Loop Approach:
  • Set the “RF Power Level” to the maximum level that may be required from the source
  • Use the “baseband power level” to adjust the power level to the required input level
  • Up to 20 dB amplitude changes in 200 µs using command interface

![Diagram of M9381A Vector Signal Generator]
Data Acquisition Modes for Fast Signal Processing with the M9391A Vector Signal Analyzer

Two Data Acquisition Modes are of most interest for Power Measurements

Power Mode:
• Configurable Bandwidth, Acquisition Time and Channel Filter
• Single Value for Integrated Power Measurement from IQ time record averaged in FPGA

FFT Mode
• Data Output in Frequency Domain via Hardware FFT with 64 to 512 bins including averaging and windowing
Choosing the Best Technique

Input Power Servo & ACPR Measurement Test times will vary depending on the procedure used.

Three methods will be presented

- Power Acquisition For Servo and ACPR
- Power Acquisition For Servo, FFT for ACPR
- FFT Acquisition For Servo and ACPR
Power Acquisition For Servo and ACPR

Set up VSG Output Level from Target Output Power and Expected Gain

Use VSA Power Acquisition to Measure DUT Output Power
  • $P_{out}$ Should be Close if Expected Gain Set Correctly

Check if Output is within Tolerance
  • If Not, Adjust VSG Baseband Power Offset based on error in $P_{out}$ Measurement

Repeat Until $P_{out}$ is Within Tolerance
  • If unable to achieve $P_{out}$, set Baseband Power Offset to 0 for maximum $P_{out}$ of DUT, Count set to -1

Calculate $P_{in}$ and Gain from VSG Output

Use Power Measurements to measure power in each channel for ACPR Measurement using fastunetune to minimize time between measurements
  • Requires 4 to 6 power measurements
Power Acquisition For Servo, FFT for ACPR

Set up VSG Output Level from Target Output Power and Expected Gain

Use VSA Power Acquisition to Measure DUT Output Power

- $P_{\text{out}}$ Should be Close if Expected Gain Set Correctly

Check if Output is within Tolerance

- If Not, Adjust VSG Baseband Power Offset based on error in $P_{\text{out}}$ Measurement

Repeat Until $P_{\text{out}}$ is Within Tolerance

- If unable to achieve $P_{\text{out}}$, set Baseband Power Offset to 0 for maximum $P_{\text{out}}$ of DUT, Count set to -1

Calculate $P_{\text{in}}$ and Gain from VSG Output

Use One FFT Measurement to measure and calculate power in All Channels for ACPR Measurement
FFT for Power Servo and ACPR

Set up VSG Output Level from Target Output Power and Expected Gain

Use VSA FFT Acquisition to Measure and Calculate DUT Output Power

- $P_{out}$ Should be Close if Expected Gain Set Correctly
- FFT Sample Rate high enough to include adjacent Channels

Check if Output is within Tolerance

- If Not, Adjust VSG Baseband Power Offset based on error in $P_{out}$ Measurement

Repeat Until $P_{out}$ is Within Tolerance

- If unable to achieve $P_{out}$, set Baseband Power Offset to 0 for maximum $P_{out}$ of DUT, Count set to -1

Calculate $P_{in}$ and Gain from VSG Output

Use Last FFT from Power Servo to Calculate all Channels for ACPR Measurement

ACPR in 0 ms!
Optimizing Repeatability and Test Time

Immediate Trigger with Full Waveform

Fastest Measurement Time:
- Measure at Any Time
- No Delay to Wait for External Trigger

Measurement Repeatability May be Poor:
- Variations in Power Level during Waveform will Add To Measurement Uncertainty in Power and ACPR Measurements
- Can be Improved by increasing measurement duration
Optimizing Repeatability and Test Time

External Trigger with Full Waveform: VSG Sync Output as External Trigger to VSA

Measurement Repeatability Improved:
• Always measuring at Same Time within Waveform
• No Variation in Modulation Signal During Measurement

Slowest Measurement Time:
• Measure only at One Point in Waveform
• Delay to Wait for External Trigger will be \( \frac{1}{2} \) Total Time of Waveform, on Average
• No Measurements During Most of Waveform if Measurement Time is Fast
Optimizing Short Waveform Length

LTE-FDD 900 us, with 300 us Acquisition Time

Ideal Waveform Length

- Waveform Time slightly longer than complete Servo Cycle

Waveform Length Too Short, adds to Test Time

- Waveform Time too short, VSA does not see second trigger, must wait for next trigger

Not Valid for Burst Waveforms such as GSM or LTE-TDD
Optimizing Short Waveform Length

LTE-TDD Waveform Length

- Adjust Burst Length to be slightly longer than Acquisition Time
- Use Off Time for calculation and VSG setting, keeping Duty Cycle close to system value

LTE-TDD 900 µs Burst, 2 ms total, with 800 µs Acquisition Time
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Agilent’s PA Reference Solution
Envelope Tracking - The How & Why

- Improve battery life
- Increase RF amplifier performance over broad frequencies
- Lower distortion
- Reduce heat dissipation
Envelope Tracking Production Test Techniques

Possible Scenarios for test system with added ETPS and AWG

• System Functional Test:
  - Test Same Parameters as before, maybe with different limits
  - Minimal Impact on Test Time

• Parametric Test:
  - Basic Measurements such as Gain Compression, AM/AM, AM/PM Conversion and PAE
  - Moderate Impact on Test Time

• Enhanced Functional Test:
  - New Tests such as ACPR vs. Timing or PAE vs. Time
  - Largest Impact on Test Time

ET Benefits
• Improved ACPR
• Improved PAE
• Lower Operating Temperature
PA Test PXI-based Typical Configuration with support for ET
Dynamic EVM in a Simplified Envelope Tracking Technique

Used for Wireless LAN

- Device is turned off between packets to conserve power
- Testing must ensure device turns on and off quickly without negative transient or thermal effects

Dynamic EVM test method

- Square wave pulse applied to PA enable during RF burst
- Measure EVM to validate performance not impaired by power modulation.

Test equipment same as for envelope tracking
Digital Pre-Distortion (DPD): The How & Why

Modern communication systems
- Signals have high peak-to-average power ratios (PAPR).
- Must operate with high power-added efficiency (PAE).

High PAPR is a consequence of high spectral efficiency
- Multiple-Carrier Signals (MC GSM, MC WCDMA)
- CDMA (WCDMA, CDMA2000)
- OFDM (LTE, WiMAX)

High PAE is achieved when the RF power amplifier (PA) is driven towards saturation

Operation near saturation inherently results in higher signal distortion

DPD corrects PA nonlinearities resulting in higher performing power amplifiers
PA Test PXI-based Typical Configuration with support for ET & DPD
Possible Use Case Scenarios

1. **Standard Waveforms**
   - DPD
   - ET

2. **User Waveform**
   - DPD
   - ET

3. **User Waveform w/DPD**
   - ET

Agilent contribution
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Agilent’s PA Reference Solution
A Reference Solution is…

A combination of hardware, software, and measurement expertise providing the essential components of a test system, enabling engineers to use, enhance, or modify as required to meet specific test application needs.

Solution modification may be provided by Solution Partners, Agilent’s Application Engineering Organization, or by engineers that build their own systems.

It is NOT…

A turnkey system and will not have specs at the solution level
The Benefits of a Reference Solution are…

- Enables easy evaluation of performance and capability
- Enables fast hardware integration
- Reduces test system development time
- Incorporates built-in measurement expertise
- Leverages local field expertise
RF Power Amplifier Test, Reference Solution

Software

- N76XX Signal Studio Waveform Creation
- Envelope Generation

Hardware

- 33522B Arbitrary Waveform Generator
- ETPS
- RF In
- RF Out
- Vcc, V.., V.., Vbat

- M9381A PXie Vector Signal Generator
- M9391A PXie Vector Signal Analyzer
- M9018A PXie Chassis
- M9036/7A Embedded Controller

GUI examples & Test Libraries

- N6700B with N6782A (1 to 4) 4 channel SMU

Anticipate Accelerate Achieve

Agilent Technologies
RF Power Amplifier Test w/Envelope Tracking
LXI Based Solution

Signal Studio’s Envelope Tracking Control Window

33600/33500 series AWG

X-Series Signal Generator

Envelope

ETPS

Trigger

Timing Alignment

RF

ETPA

DUT

N6705B DC Power Analyzer

89600 Vector Signal Analyzer

X-Series Signal Analyzer
Summary

We have presented techniques to meet the biggest challenges for PA Manufacturers: reducing test time while maintaining test accuracy.

• Fastune technology
  - Reduces iteration time to reach specified output power
• FPGA accelerated FFT acquisition
  - Allows faster Power Servo & ACPR measurements
• Use of shorter waveforms with precise triggering
  - Maintains repeatability in high-speed power measurements

We discussed new technologies including Envelope Tracking and DPD, designed to improve PA efficiency

• Add additional challenges to testing, for which new test techniques must be applied.
• Require wider bandwidths than RF signal (up to 2-5x)
• Require tight time alignment (nanosecond) between envelope and RF

We have introduced Reference Solutions to help you more quickly integrate our hardware and software into your larger test system.