Accelerate power amplifier test throughput and high speed harmonic testing to achieve cost reductions, while maintaining high test quality.

Abstract

Power amplifier designs for mobile handsets are becoming more complex, which directly impact test demands and the cost of test. Complexity increases with the introduction of new, wider bandwidth standards and an increased number of radios in each device. At the same time, demand for improved battery life is driving efficiency improvements, such as digital pre-distortion and envelope tracking. Ongoing pressure to reduce device prices continues to place demands on engineering teams producing power amplifiers.

Engineers who validate mobile power amplifiers and front end modules designs or test those products on the production line are looking for solutions to reduce test cost through maximizing speed and throughput while ensuring that the devices meet required performance levels.

This application note provides an overview of the key issues in a power amplifier and front end module test system related to the RF signal analyzer and generator. It then describes a solution for achieving fast test throughput using the Agilent M9381A PXIe vector signal generator (PXI VSG), and the M9391A PXIe vector signal analyzer (PXI VSA) or M9393A PXIe performance VSA.
Key issues faced by power amplifier test engineers

This application note addresses test challenges faced by power amplifier engineers including the need to:

• Reduce test times by providing fast input power adjustment and fast power measurements.
• Assess modulation performance quickly with high quality and trusted measurements.

Figure 1 shows a simplified block diagram of a RF vector signal analyzer and signal generator in a typical power amplifier/front end module test system. Typical power amplifier modules require an input power level of 0 to +5 dBm, digitally modulated according to communication standards such as WCDMA or LTE. The specified performance of the power amplifier or front end module is normally set at a specific output level of the DUT. If the devices have small variations in gain, it may be necessary to adjust the power level from the PXI VSG to get the correct output level of the DUT. Only after the DUT output level is set at the correct value, can the specified parameters be tested. The time spent adjusting the PXI VSG to get the correct DUT output power can be a major contributor to the test time and the overall cost of test.

The PXI VSG is connected to the DUT using a cable and switches. The switching may be used to support testing of multi-band modules or multi-site testing. The combination of the RF cables and the switching network can add several dB of loss between the output of the PXI VSG and the input of the DUT, which requires higher output levels from the PXI VSG. Since the tests are performed with a modulated signal, the PXI VSG must also have adequate modulation performance at the higher power levels.

The PXI VSA is also connected to the DUT using switches and cables. If the PXI VSA is not able to make fast and accurate power measurements, a power meter may also be required on the DUT output. The signal analyzer needs to perform measurements of power, ACPR, EVM, harmonics and other parameters. It needs to measure all of these parameters quickly and accurately and be able to switch between measurement modes in minimal time.

Using the PXI VSAs and PXI VSG to increase test throughput and quality

The Agilent M9391A and M9393A PXIe VSAs and M9381A PXIe VSG offer unique features that:

• Increase test throughput with fast amplitude and frequency switching as well as hardware accelerated power measurements.
• Enable synchronization with an arbitrary waveform generator for envelope generation to support test of envelope tracking devices.
• Provide good modulation performance, particularly at high power levels and very linear power level changes.
• Achieve continuity of measurement results from R&D to manufacturing, as well as from benchtop test systems by using shared measurement applications
• Further reduces test development time through code reuse.

The PXI VSG reduces the overall switching time through a powerful, innovative tuning methodology. It further increases throughput by providing good linearity and repeatability which reduces the number of iterations required to get the DUT to the correct power output level. The PXI VSG also offers high modulation quality so you can drive amplifiers directly without having to add external amplification.

Several other vector signal generations offer amplitude and frequency switching times of less than 1 ms when used in list modes. However, since the output level of the signal generator cannot be predetermined for each test, list modes cannot be used for power amplifier testing. Other signal generators require significantly longer switching time when controlled through a normal programming interface. The PXI VSG offers the fastest switching time on the market of 250 μs from its programming interface and 10 μs in list mode, with fasttune, an exclusive baseband tuning technology innovation.
The 40 MHz bandwidth PXI VSG is upgradable to 100 or 160 MHz bandwidth. The baseband frequency offset can be programmed to any offset within the purchased modulation bandwidth. For example, the 160 MHz bandwidth option allows the baseband frequency offset to be set to ±80 MHz. The baseband power offset can be set to 20 dB below the programmed RF power level and still achieves high quality modulation performance. To take advantage of this feature for power amplifier testing, engineers can set the RF frequency to the center of the band being tested and the RF power level to the maximum required for all tests. From there, baseband frequency adjustments are made to test at multiple frequencies across the band and the baseband power level is adjusted to servo the DUT output level to the correct value.

Better linearity, repeatability and resolution offered by the PXI VSG further reduces the test time by enabling the servo loop to converge in fewer steps. After the DUT output level is measured by the signal analyzer, the new value of the PXI VSG output power is calculated based on the difference between the measured power and the desired power. Then, the PXI VSG is adjusted by the amount necessary to achieve the correct DUT output power.

The PXI VSG provides high modulation quality, particularly at high output power levels. In many cases, signal levels as high as +15 dBm may be needed to overcome the loss between the PXI VSG and the DUT input. As shown in Figure 2, the PXI VSG has excellent adjacent channel power (ACPR) at high output power levels. At +10 dBm, there is little or no degradation of the ACPR and at +15 dBm, the ACPR level is still near 60 dBc.

The M9391A and M9393A PXIe VSAs reduce the overall test time through a hardware accelerated power measurement methodology. Power measurements are accumulated in real time in the digitizer, requiring only a single value to be returned to the application program and no computation of power from the IQ data in the controlling PC. In addition, the PXI VSAs provide very repeatable power measurements, with acquisition times as low as 10 µs. Figure 3 shows the repeatability of the M9391A PXIe VSA’s power measurements with acquisition times from 10 µs to 1 ms at power levels from the expected input level to 75 dB below the expected input level. For power levels as low as 25 dB below expected input level, the PXI VSAs can provide a power measurement with 0.005 dB standard deviation in a total execution time of less than 400 µs. When combined with the power level switching speed of the PXI VSG, the step time for a power servo loop can be less than 1 ms.

Power servo and ACPR measurements can be made using the hardware accelerated power measurement technique mentioned in the preceding paragraph or by using hardware accelerated FFT acquisition mode. The FFT acquisition mode offers similar accuracy and repeatability, but enables ACPR to be calculated from a single acquisition that spans all of the desired adjacent channels. By re-using the last acquisition from the power servo loop, the ACPR values can be calculated with no additional measurement time.

Emerging power efficiency technologies, such as envelope tracking, can be supported by synchronizing the PXI VSG with an arbitrary waveform generator. The PXI VSG enables fast time alignment with the envelope signal through an automated, real-time hardware adjustment of the IQ waveform delay. Resolution of ±1 picosecond is achievable in hundreds of microseconds, without stopping the waveform playback.

The PXI VSAs and PXI VSG can be used with the same measurement applications that run on corresponding Agilent bench top instruments, including Signal Studio, 89600 VSA software or X-Series measurement applications. Using a combination of Agilent bench top and modular equipment with Agilent measurement applications can result in excellent correlation of measurement results at multiple points in your product design cycle. Additionally, it offers a common programming interface, enabling code reuse and reduced test development time.

### Figure 2

![WCDMA UL ACPR](image)

Figure 2. Note the M9381A shows little ACPR degradation below 10 dBm and is better than 60 dBc at 15 dBm.

### Figure 3

Repeatability of power measurements using the M9391A.

<table>
<thead>
<tr>
<th>Acquisition Time</th>
<th>Power Level Relative to the Expected Input Level</th>
<th>Test Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 µs</td>
<td>0 dB: 1.767, -23.244, -65.047</td>
<td>0.0003</td>
</tr>
<tr>
<td></td>
<td>-25 dB: 0.033</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>-75 dB: 0.550</td>
<td>0.550</td>
</tr>
<tr>
<td>100 µs</td>
<td>0.007</td>
<td>0.168</td>
</tr>
<tr>
<td></td>
<td>1.895</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>-23.113</td>
<td>-65.073</td>
</tr>
<tr>
<td></td>
<td>0.007</td>
<td>0.005</td>
</tr>
<tr>
<td>1 ms</td>
<td>1.758</td>
<td>0.0024</td>
</tr>
<tr>
<td></td>
<td>-23.246</td>
<td>-65.059</td>
</tr>
<tr>
<td></td>
<td>0.003</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>0.0588</td>
<td>0.0588</td>
</tr>
</tbody>
</table>
Harmonic measurements provided by the M9393A PXI VSA

Harmonics measurements are part of the typical characterization test bench because all RF PA amplifiers exhibit harmonic distortion to some extent. Generally, a spectrum analyzer that can perform measurements with a low noise floor, minimal images, and high dynamic range is used to determine harmonic content and spurs. Since cellular and wireless connectivity applications cover up to 6 GHz, the required frequency range of the test bench’s spectrum analyzer should be at least 18 GHz in order to measure the 3rd harmonic. For characterization or manufacturing, one of the main challenges is to combine these requirements with high-speed test.

Traditional spectrum analyzer designs use YIG oscillators which provide tuning sweeps generally taking tens of milliseconds, which may not be fast enough for today’s throughput requirements. The M9393A PXIe performance vector signal analyzer is designed with Voltage Controlled Oscillators (VCO) instead of YIGs, combined with a stepped FFT technique. It eliminates band switching penalties and dramatically improves harmonics measurement speed. With the fast tuning LO, 160 MHz analysis bandwidth, and high speed back-end processing, the M9393A allows extremely fast "sweeps," across the entire 27 GHz frequency range, in a fraction of a second.

Because not all RF PA characterization and production test systems require harmonic test capabilities, it is important to ensure that the various PXI VSAs share common architecture to maximize test code leverage and to reduce test development time. Using the same high speed signal processing and measurement software across Agilent’s line of PXIe VSAs offers consistency in measurements and programming in frequency ranges from 3 GHz to 27 GHz. The M9393A and M9391A PXIe VSAs share similar programming models and can be used with the same X-Series measurements applications without the need to purchase new software licenses.

Figure 4. 3.6 to 27 GHz sweep, measuring fundamental and two harmonics with the M9393A PXIe VSA.
### Ordering information

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>M9381A</td>
<td>PXIe Vector Signal Generator 1 MHz to 6 GHz</td>
</tr>
<tr>
<td></td>
<td>Includes: M9301A PXIe Synthesizer</td>
</tr>
<tr>
<td></td>
<td>M9310A PXIe Source Output</td>
</tr>
<tr>
<td></td>
<td>M9311A PXIe Digital Vector Modulator</td>
</tr>
<tr>
<td>M9391A</td>
<td>PXIe Vector Signal Analyzer 1 MHz to 6 GHz</td>
</tr>
<tr>
<td></td>
<td>Includes: M9301A PXIe Synthesizer</td>
</tr>
<tr>
<td></td>
<td>M9350A PXIe Downconverter</td>
</tr>
<tr>
<td></td>
<td>M9214A PXIe IF Digitizer</td>
</tr>
<tr>
<td>M9393A</td>
<td>PXIe Performance Vector Signal Analyzer 9 kHz to 27 GHz</td>
</tr>
<tr>
<td></td>
<td>Includes: M9308A PXIe Synthesizer</td>
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<tr>
<td></td>
<td>M9365A PXIe Downconverter</td>
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<tr>
<td></td>
<td>M9214A PXIe IF Digitizer</td>
</tr>
<tr>
<td>M9300A</td>
<td>PXIe Frequency Reference 10 MHz to 100 MHz</td>
</tr>
</tbody>
</table>

**Base configuration includes:**
- M9381A-F03 Frequency range: 1 MHz to 3 GHz
- M9381A-B04 RF modulation bandwidth: 40 MHz
- M9381A-M01 Memory: 32 MSa
- M9391A-F03 Frequency range: 1 MHz to 3 GHz
- M9391A-B04 Analysis bandwidth: 40 MHz
- M9391A-M01 Memory: 128 MSa

**Recommended configuration includes:**
- M9381A-F06 Frequency range: 1 MHz to 6 MHz
- M9381A-B10 RF modulation bandwidth: 100 MHz
- M9381A-M01 Memory: 32 MSa
- M9381A-UNZ Fast switching
- M9391A-F06 Frequency range: 1 MHz to 6 GHz
- M9391A-B10 Analysis bandwidth: 100 MHz
- M9391A-M01 Memory 128 MSa
- M9391A-UNZ Fast switching
- M9300A PXIe Frequency Reference

**Harmonic test configuration includes:**
- M9381A-F06 Frequency range: 1 MHz to 6 MHz
- M9381A-B10 RF modulation bandwidth: 100 MHz
- M9381A-M05 Memory: 512 MSa
- M9381A-1EA High output power
- M9381A-UNZ Fast switching
- M9393A-F18 Frequency range: 1 MHz to 18 GHz
- M9393A-B10 Analysis bandwidth: 100 MHz
- M9393A-M05 Memory 512 MSa
- M9393A-UNZ Fast switching
- M9300A PXIe Frequency Reference

### Software information

- **Supported operating systems:**
  - Microsoft Windows XP (32-bit)
  - Microsoft Windows 7 (32/64-bit)
  - Microsoft Windows Vista (32/64-bit)
- **Standard compliant drivers:**
  - IVI-COM, IVI-C, LabVIEW, MATLAB
- **Supported application development environments:**
  - VisualStudio, (VB NET, C#, C/C++), VEE, LabVIEW, Lab/Windows,CVI, MATLAB
- **Agilent IO Libraries Version 16.3 or newer**
  - Includes: VISA Libraries, Agilent Connection Expert, IO Monitor

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Published in USA, April 30, 2014
5991-0652EN