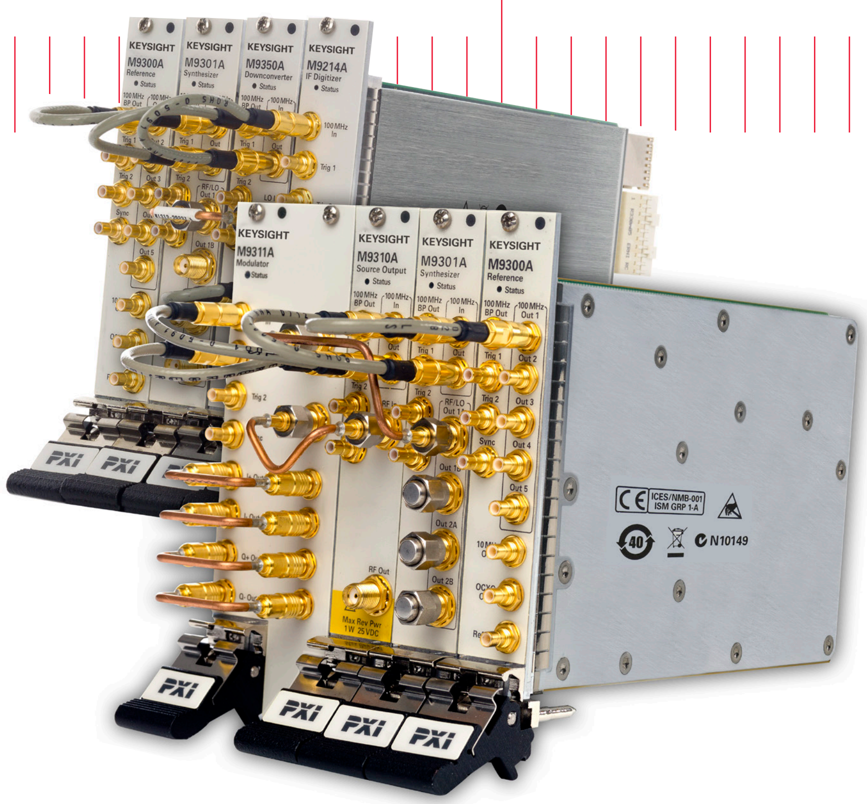
Keysight Technologies
Optimize Transceiver Test Throughput with the Keysight PXIe Vector Signal Analyzer and Generator

Application Note



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Accelerate transceiver test throughput with the Keysight M9391A PXIe Vector Signal Analyzer and M9381A PXIe Vector Signal Generator. Achieve cost reductions in test while maintaining high test quality.

Abstract

Transceivers are one of the basic building blocks of modern communication systems. They are used in a variety of devices including mobile phones, wireless LAN access points and cellular infrastructure. Engineers who test transceivers are looking for solutions that will enable an increased level of calibration required by modern communication standards and synchronization to the test system. At the same time, pressure on prices of these devices place greater demands on engineering teams to reduce the cost of test and increase production and test throughput.

The Keysight Technologies, Inc. M9381 PXIe Vector Signal Generator (PXI VSG) and the M9391A PXIe Vector Signal Analyzer (PXI VSA) offer features that enable the engineer to quickly cover a large range of test requirements. The PXI VSG provides fast switching, flexible timing and synchronization, as well as the ability to use a variety of modulated waveforms. The PXI VSA provides fast power level changes and frequency offsets as well as on-board integrated power measurements with list mode capabilities that further accelerate measurement speeds.

Introduction

This application note provides an overview of the key issues in transceiver test as it relates to the selection and performance of the RF signal analyzer and generator. Further, it describes how the Keysight M9381A PXIe VSG (PXI VSG) achieves superior performance in transceiver test systems through offering fast switching times, list mode and flexible timing and frequency synchronization. Likewise, the Keysight M9391A PXIe VSA (PXI VSA) completes the high performance transceiver RF test set with its fast power level changes and frequency offsets.

Key Issues faced in Transceiver Production Test

This application note addresses transceiver test challenges faced by engineers including:

- The need to quickly cycle through a large range of pre-defined signal frequencies and power levels by the VSG for receiver calibration.
- The need for timing and frequency synchronization in list mode as well as operational mode.
- The need to quickly verify in-channel and out-of-channel power levels, as well as spurious and harmonic emissions

Receiver calibration

Transceiver receiver calibration is an important part of the test process as many modern communication systems require very accurate measurement of the receiver input power and accurate setting of the transmit output power. Typically, the calibration procedure of the receiver consists of providing an RF input over a wide range of frequencies and power levels and then recording the receiver signal strength indicator (RSSI) level at each step. Historically, this calibration was performed with nested software loops that set up the device under test (DUT) and the RF signal generator to the correct frequency and power level and then read back the RSSI level at each step in the loop. As signal generator switching times were reduced, the software overhead for controlling the DUT became the bottleneck in test time. To overcome this, many manufacturers developed special test modes which allow the DUT to cycle through a large number of frequency and amplitude states and record the RSSI value at each step all from a single software command to the DUT. This methodology requires the RF signal generator to cycle through the corresponding frequency and amplitude states with the exact same timing as the DUT. This is typically accomplished using a list mode in the signal generator. List modes typically allow frequency and amplitude states in the signal generator to be predefined and cycled through with specific timing or from an external trigger. To cover the range of requirements, list modes must provide a large number of points, fast switching between points, flexibility in timing and synchronization and the ability to use a variety of modulated waveforms.

Timing and frequency synchronization

The two primary drivers for synchronization between the VSG and the transceiver DUT are the use of list modes mentioned before, and testing of the transceiver in an operational mode.

There are two basic synchronization methods with list modes. First, there is a single trigger event that starts the lists in both the VSG and the DUT and the entire list is timed from that single trigger. If the beginning of point N is timed from the beginning of point N-1, small errors in timing can accumulate and cause the VSG and DUT to lose synchronization over time. In this mode, it is very important for every step in the list to be accurately scheduled relative to the trigger event. This requires a VSG with accurate list mode timing and the ability to lock to the DUT frequency reference. Transceiver calibration typically uses this approach and relies on both the DUT and the VSG to accurately time the list.

The second synchronization method for list modes is a point by point handshaking between the VSG and either the DUT or a signal analyzer. In this method, the VSG will tune to a point when it receives an input trigger. When the VSG output is settled at that value, it will output a trigger to the DUT or analyzer that will then start the measurement of that point. When the measurement is complete, the DUT or signal analyzer will output a trigger that will cause the VSG to start the next point. This method can be useful when measurement time of the DUT or signal analyzer cannot be exactly predetermined and can provide the fastest throughput as there is little or no guard time required in the lists. However, this mode does require two dedicated trigger signals on each instrument or DUT used in the test.

Typically, complete transceivers, such as mobile phones or picocell and femtocell base stations are tested in an operational mode, using either the operational software for the transceiver or a version of the software that has minor modifications to support test. The impact of this on the VSG depends on the type of device being tested. For mobile phones, the DUT will synchronize to the timing and frequency of the VSG. In this case, the timing of the waveform on the VSG remains constant through any frequency, amplitude or waveform changes. If the VSG is not able to maintain this timing, the DUT will need to be resynchronized to the VSG, which can be a time consuming operation.

For picocell and femtocell test, the synchronization requirements are more difficult. In operational modes, the base station is the frequency and timing master in the system. During test, the VSG must synchronize to the frequency and timing references in the DUT. For frequency synchronization, it is common to lock the VSG reference input to the oscillator in the DUT.

One challenge with this requirement is that the typical frequency in the DUT is not the standard 10 MHz reference. These reference frequencies are more likely to be 13 MHz, 26 MHz or 52 MHz. To meet this requirement, the VSG must be able to lock to a selectable input frequency, not just the default 10 MHz reference. For timing synchronization, the DUT will typically output a trigger pulse that is aligned with the frame boundary of the wireless standard. The VSG needs to start the playback of the modulated waveform aligned with the frame trigger to allow the DUT to demodulate the input signal. The timing error typically must be less than ± 2 μs.

Transmitter output power verification

Transmitter output power is a key attribute of any communication system. Power measurements are grouped either as in-band or out-of-band. The in-band measurements are further differentiated as either in-channel or out-of channel. Verification of power emissions in these various channels and bands is a must during production test. Maintaining precise channel output power is critical for optimizing battery life while maintaining channel link performance. At the same time out-of-channel power must be low to prevent inference to other users.

In-channel power calibration is commonly done on transmitters. As RF propagation characteristics change with distance, power settings to the transmitter will likewise be changed to match channel requirements. Excessive power output reduces efficiency while very low power output reduces channel throughput.

Out of channel power measurements typically verify the that the transmitter meets required standards essential to prevent interference to other channel users. Adjacent channel power measurements are made while the transmitter is actively using the main channel. During the transmit cycle, the power in the main and adjacent channels is measured and calculated as a ratio in dBc. Transmitter spurious and harmonic emissions are also measured. These emissions may be within the band of allocated transmitter frequencies (in-band) or outside of the allocated frequency band (out-of-band). Spurious frequency emissions may be generated by internal transmitter clocks or other unintended oscillations. Harmonic emissions are predictably located at harmonics of the main channel. Typically spurious and harmonic emissions are tested by capturing a specific band of frequencies or searching a broad section of the spectrum.

Transmitter in-channel and out-of-channel power measurements

Transmitter power output is often measured with the modulation present which best matches the intended end-use. With modulation present the transmitter output power will be spread over a band of frequencies within the channel. To measure the transmitter total power the power spectrum must be integrated over the specified channel bandwidth. Power integration may be computationally intensive so integrating the power within the instrument hardware can dramatically improve measurement times.

Out-of-channel power measurements are typically done over multiple channels above and below the main channel. Both the main channel power as well as adjacent channel power must be measured. Alternate channels (2x above and below main channel) may also be measured. Selecting VSA instrumentation with wide analysis bandwidths allows quick capture of multiple in-band channels of interest. Further, on-board digital tuning and integrated power measurements make very fast multi-channel power measurements possible.

Transmitter spurious in-band and out-of-band power measurements

To hunt for spurious and harmonic emissions, large sections of the spectrum may need to be measured. Tuned VSA instruments with wide input bandwidths work well for in-band measurements. However, for out-of-band measurements, the front-end down-converter is tuned as needed to the spectrum of interest. Time searching for out-of-band spurious may be reduced significantly by using a list mode similar to that described for receiver testing. List mode allows the user to define portions of the spectrum to tune and measure. When the list runs, it can quickly tune and measure the bands of interest without software or controller interaction. This, combined with integrated on-board power measurements supports fast spurious and harmonic emission searches.

Using the M9381A PXI VSG to Increase Test Throughput and Quality

The Keysight M9381A PXI VSG provides high performance and high throughput for test systems for transceiver test by offering:

– A list mode that allows for 3,200 steps with the fast switching speed.

– Flexible timing and frequency synchronization.

– Lists which are generated using the normal programming interface, allowing for easy transition from a programmed mode to a list mode.

The PXI VSG also offers frequency and amplitude switching modes. The traditional RF frequency and amplitude tuning can provide a minimum step time in list mode of less than 250 µs. These frequency changes can be over the entire frequency and amplitude range of the PXI VSG. The PXI VSG also offers an innovative baseband power and frequency offset tuning methodology that allows for frequency changes across the entire modulator bandwidth and amplitude changes of up to 20 dB without degrading the modulation performance. The PXI VSG comes with 40 MHz bandwidth, but can be upgraded to 100 MHz or 160 MHz. The baseband tuning minimum step time in list mode can be as fast as 10 µs. Figures 2 and 3 show plots of the PXI VSG output over a list of five amplitude changes and three frequency changes in each of the RF and baseband tuning modes.

In addition to the frequency and amplitude values, each point in the PXI VSG list also has an end event that defines how the list will proceed to the next point. This event can either be a trigger or a time event. In the case of the timed events, the user can select either the total step time or the dwell time. The dwell time is defined as the time after the VSG frequency and amplitude is settled. Typically, the total step time will be used in a situation like the transceiver calibration while the triggered end event supports the handshake list mode.

The PXI VSG uses the M9300A frequency reference module to provide all system clocks. This module has an internal 10 MHz reference and can also use an external frequency reference. The frequency reference input to the M9300A can be any value between 1 MHz and 110 MHz, allowing synchronization to the oscillator frequencies used in typical wireless communication systems. The PXI VSG allows the playback of waveforms to be started from an external trigger input. The resolution of the trigger delay will be 1 over the sample rate of the data. For a typical W-CDMA signal the trigger delay resolution will be 65 ns, much better than the required ± 2 µs required to synchronize to a picocell or femtocell.

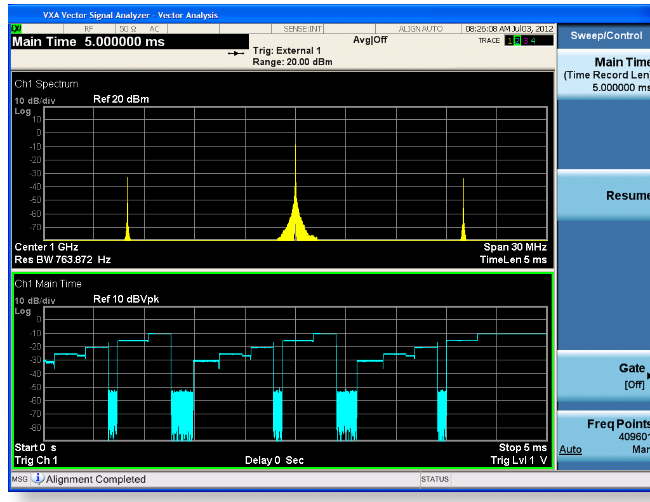

Figure 1: 220 µs step time for RF frequency and amplitude offset changes in list mode

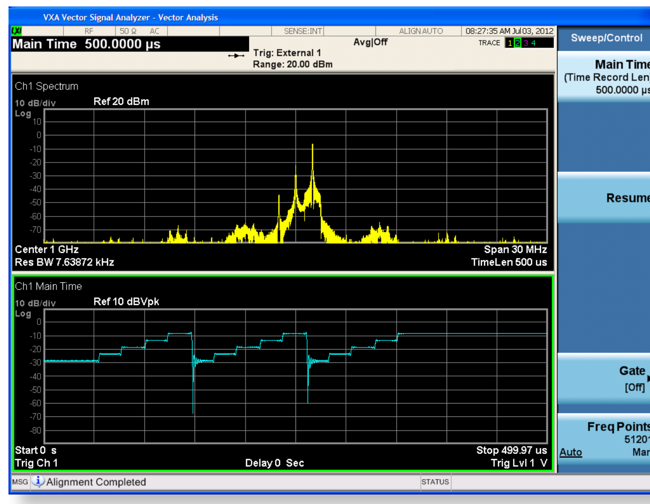

Figure 2: Less than 10 µs step time for baseband frequency and amplitude offset changes in list mode.

Using the PXI VSA to Increase Test Throughput and Quality

The Keysight M9391A PXI VSA provides high performance and high throughput for transceiver test systems by offering:

– Wide-analysis bandwidth up to 160MHz

– High speed digital baseband tuning

– Hardware based integrated power measurements

– List mode that allows for up to 3,200 steps supporting fast setup/captures

Wide analysis bandwidth allows useful spectral information to be captured over a wide frequency band in a single pass. The PXI VSA comes standard with a 40 MHz analysis bandwidth and optional 100 MHz or 160 MHz bandwidths are available. These wide bandwidths are a must for wide-band digital modulation formats and also essential for support of fast adjacent and alternate channel power measurements.

The PXI VSA uses digital tuning for fast baseband power level changes and frequency offsets while maintaining calibration accuracy. Multiple channels may be captured very quickly using baseband tuning as opposed to RF channel tuning. For example within the analysis bandwidth of the VSG, frequency offset changes can be as fast 310μs. When this is combined with the PXI VSA hardware based integrated power measurements, adjacent and alternate channel power measurements can be accomplished very quickly.

Hardware based integrated power measurements reduce the time required for power measurements by reducing I/O traffic and off-loading computational work to high speed hardware based DSP. For example, the PXI VSA can return integrated power results for a 3.84 MHz channel in less than 4ms. There is no need to transfer the raw waveform data back to the controller for software post processing and the hardware based integration algorithms for power measurements are fast and efficient. Combining PXI VSA hardware based integrated power measurements with fast baseband tuning allows fast adjacent and alternate channel power measurements to be made.

Completing the VSA power measurement feature set is the built-in step list functionality. This feature is helpful when searching for both in-band and out-of-band spurious emissions. Lists with up to 3200 steps may be defined. Once the VSA is triggered it will proceed to step through the list settling in less than 300μS for arbitrary frequency changes. At the completion of the list the integrated power within the steps can be queried directly from the hardware using the M9391A on-board integrated power measurements. This significantly speeds up the process of searching for both in-band and out-of-band spurious emissions.

Conclusion

In summary, the cost of test and technical challenges require careful selection of the test equipment in a transceiver test system. The Keysight M9381A PXIe VSG provides several key features include the fastest possible test throughput and the flexibility to support the required ranges of timing and frequency synchronization. The Keysight M9391A PXIe VSA includes built-in features that significantly improve power measurement speeds while maintaining trusted Keysight measurement integrity.

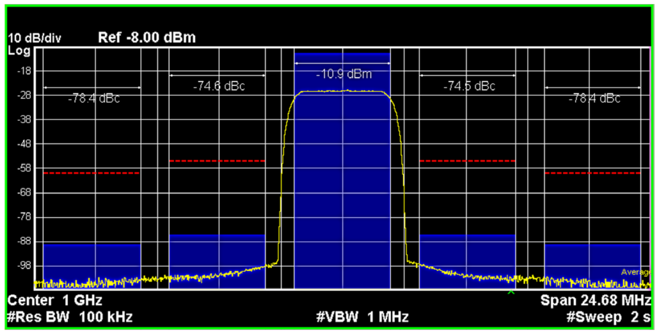

Figure 3. Main and adjacent channels as measured by the VSA

Repeatability vs. Acquisition Time vs. Power Level					
Acquisition	Power Level Relative to the Expected Input Level				Test
Time		0 dB	–25 dB	–75 dB	Time
10 μs	Avg	1.767	– 23.244	– 65.047	0.0003
	Std Dev	0.033	0.032	0.550	
100 μs	Avg	1.895	– 23.113	– 65.073	0.0004
	Std Dev	0.007	0.005	0.168	
1 ms	Avg	1.758	– 23.246	– 65.059	0.0024
	Std Dev	0.003	0.001	0.0588	

Figure 4. Repeatability of power measurements using the M9391A.

Ordering Information

Model	Description
M9381A	PXIe Vector Signal Generator 1 MHz to 6 GHz Includes: M9301A PXIe Synthesizer M9310A PXIe Source Output M9311A PXIe Digital Vector Modulator
M9391A	PXIe Vector Signal Analyzer 1 MHz to 6 GHz Includes: M9301A PXIe Synthesizer M9350A PXIe Downconverter M9214A PXIe IF Digitizer
M9381A-300	PXIe Frequency Reference 10 MHz to 100 MHz Adds M9300A PXIe Frequency Reference which supports multiple M9391A or M9381A instruments
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-M05	Memory: 512 MSa
M9381A-1EA	High output power
M9381A-UNZ	Fast switching
M9391A-F06	Frequency range: 1 MHz to 6 GHz
M9391A-B10	Analysis bandwidth: 100 MHz
M9391A-M05	Memory 512 MSa
M9391A-UNZ	Fast switching
M9381A-300	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 environ-ments	VisualStudio, (VB NET, C#, C/C++), VEE, LabVIEW, Lab/Windows,CVI, MATLAB
Keysight IO Libraries Version 16.3 or newer	Includes: VISA Libraries, Keysight Connection Expert, IO Monitor

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