Agilent Modular Products

M9392A PXI Vector Signal Analyzer Multichannel Streaming Solution

Application Note

Challenge the Boundaries of Test

Agilent Modular Products

Using RF recording techniques to capture and analyze interference in the signal environment

The airwaves are becoming increasingly crowded as demand for RF spectrum continues to grow. As a result, every type of wireless communication system faces a complex and unpredictable signal environment.

By capturing and analyzing intermittent problems at high frequencies and wide bandwidths—with Agilent's two-channel PXI gapless recording system—engineers can troubleshoot a wide range of problems in the development of new RF and microwave devices.

This application note will walk you through the issues and take a close look at the solution and results.

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Introduction

The purpose of this application note is to take a closer look at the challenges of capturing data from an RF environment and how this is simplified with Agilent's multichannel PXI recording and analysis solution to achieve successful RF and microwave product design.

Description

The recommended solution consists of:

- A two-channel, 50 MHz to 26.5 GHz, Agilent M9392A vector signal analysis system
- Software applications:
  - Agilent's free data viewer
  - Agilent 89600 VSA software
  - X-COM Spectro-X signal analysis toolkit

Your Benefits

- Achieve successful wireless designs
- Capture and analyze intermittent problems at
  - high frequencies
  - wide bandwidths
- Troubleshoot a wide range of problems in the development of RF and microwave devices

Applications

- Aerospace and defense
- Wireless communications
- Radar and wideband signal capture
- Electronic test

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OVERVIEW

Using RF recording techniques to capture and analyze interference in the signal environment

The airwaves are becoming increasingly crowded as demand for RF spectrum continues to grow. As a result, every type of wireless communication system faces a complex and unpredictable signal environment.

Going forward, the development of successful wireless designs depends on the ability to thoroughly analyze and model real-world sources of interference. These tasks are made difficult by a diverse range of possible interference signals with attributes such as complex timing, burst characteristics, dynamically changing modulation schemes, and variable power levels. Troubleshooting becomes especially challenging when the interference problems are intermittent.

When dealing with intermittent interference, traditional measurement techniques that rely on swept spectrum analyzers are at risk of missing important information during and between every sweep. An emerging alternative uses two high-speed digitizers, two local oscillators (LOs) and gapless recording of the RF spectrum to a RAID system[1].

Captured data is analyzed using tools such as data viewer software and a signal analysis toolkit with search capabilities. Once the interfering signal has been identified, its characteristics can be used as trigger parameters for one digitizer as it monitors in-channel or adjacent-channel signals. A trigger event initiates in-band acquisition with the other digitizer. To capture a more complete view of the interference, pre-trigger delay can be used to acquire signal data for a specified time prior to the trigger event (within the capacity of the buffer memory).

To illustrate the gapless recording method, this application note uses an example based on an intermittent signal interfering with a new 802.11ac device. The remaining pages of this note present the problem, a two-channel solution and a set of measurement results.

2 channel streaming with M9392A and M9302A PXI local oscillator.

1. RAID: redundant array of independent disks

Interference Issues

Measurement Solution Overview

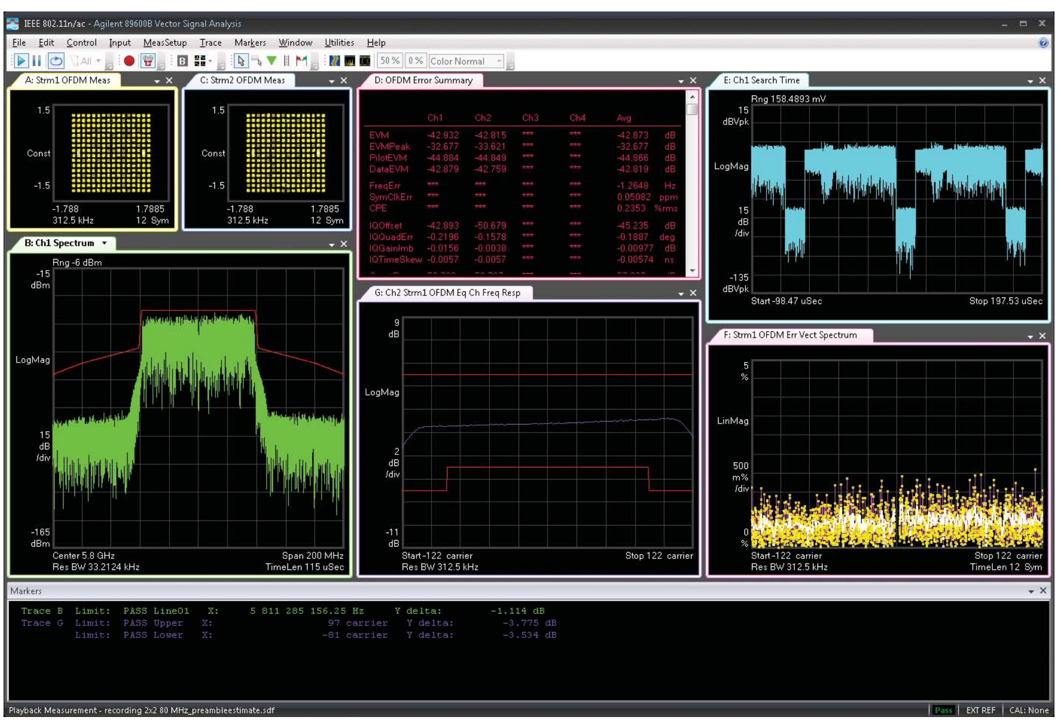
The loss of information due to interference can range from consumer applications to business and military applications. In some cases the cause may be internal to the device in the form of an issue with the design of a circuit, assembly or system. In other cases the problems may be due to external causes such as poor frequency planning or noncompliant transmitters.

For this discussion, the problem scenario centers on validation testing of a new 802.11ac device. During directly cabled tests the device performed well; however, during testing in a real RF environment the device was falling short of expected average throughput performance. Problems occurred infrequently and, because the causes were nondeterministic, it was difficult to pinpoint the cause.

Measurements made with a spectrum analyzer provided a clue: a few of the channels under test were noisier than expected. This clue came from a few hours of averaged wideband swept measurements focused on two 80-MHz ranges. These covered WLAN 802.11 channels 100 through 112 and 149 through 161 and the frequency ranges 5.490 GHz to 5.570 GHz and 5.735 GHz to 5.815 GHz, respectively. Unfortunately, the resulting amplitude envelope of the cumulative swept measurements didn't provide useful information about the timing or duration of the interfering signal, which exhibited some burst characteristics.

From these clues, it seemed likely that the intermittent signals could be some other form of 802.11 signal. The reason: when strong 802.11a or 802.11n signals are present, a collision-avoidance process ensures that there is no interference between the various 802.11 transmissions. Unfortunately, this process also means the 802.11ac device cannot transmit freely because it is waiting for an available time slot. This could be one possible explanation for the reduction in average data throughput.

A digitizer-based solution with deep, gapless recording capability could provide information about frequency, amplitude and timing. However, a cursory look at such an approach produced a few potential concerns. First, the digitizers must provide at least 80 MHz of bandwidth to capture the signals of interest. Next, the acquisition and storage process must be fast enough to eliminate any gaps in the recorded spectrum data. Finally, the system must be equipped to mitigate any timing differences between digitizers: These will affect signal coherence and thereby reduce the quality of cross-channel measurements such as phase offsets or differences in time-of-arrival.



Sample dual channel measurement for 802.11ac including SEM mask limits and subcarrier flatness limits.

Solution

The foundation of the recommended digitizer-based system is a two-channel Agilent M9392A PXI vector signal analysis system (50 MHz to 26.5 GHz) and three software applications: Agilent's free data viewer application, the Agilent 89600 VSA software and the X-COM Spectro-X signal analysis toolkit. An illustration of the proposed solution is shown in Figure 1.

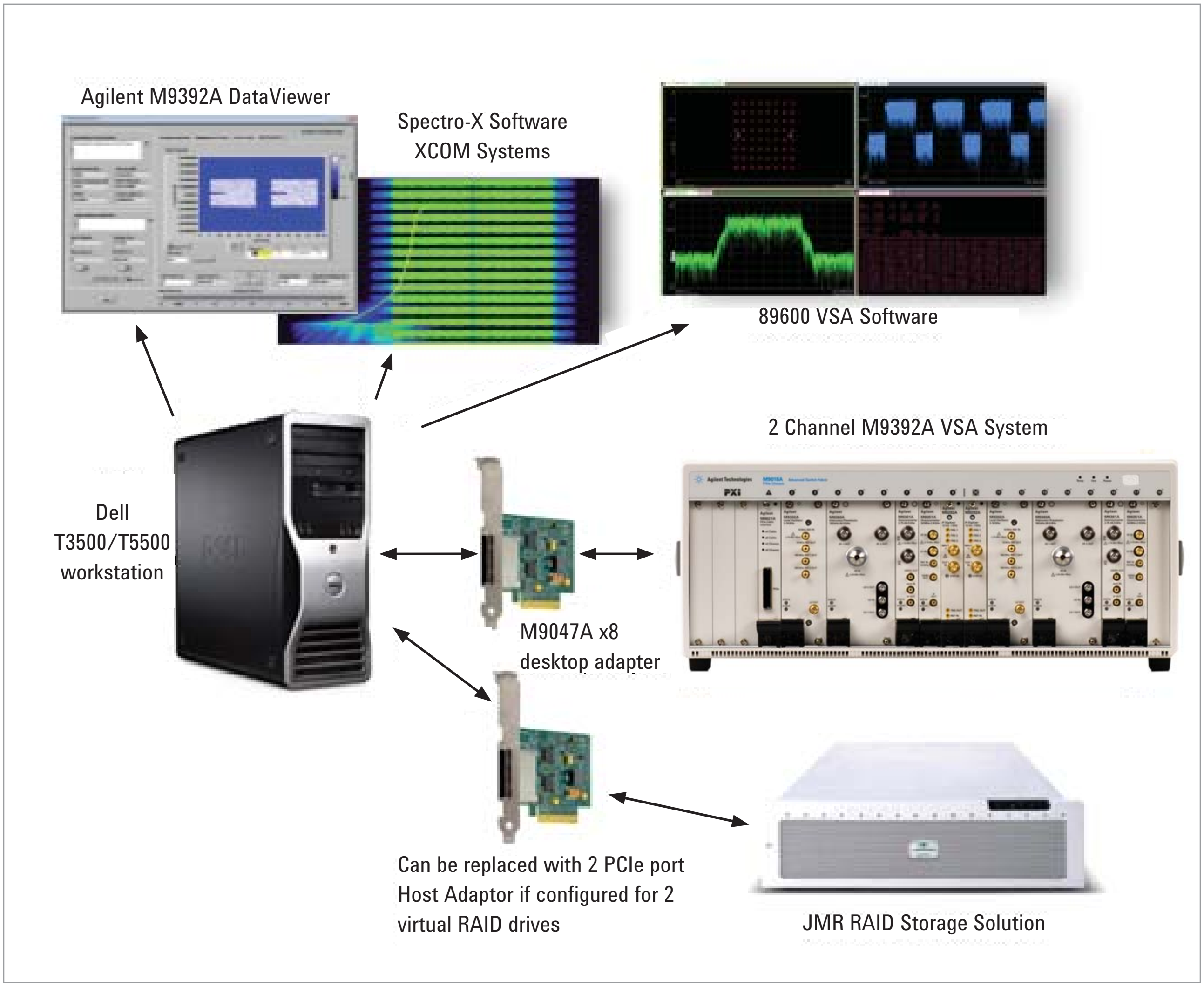


Figure 1. The recording-and-analysis solution includes two digitizers, two independent LOs and the necessary signal-analysis software tools.

Solution (continued)

Taking a closer look

Figure 2 shows a detailed block diagram of the PXI modules included in the two-channel M9392A vector signal analysis system. Within each channel, the major elements are an M9202A PXI Express wideband IF digitizer and an M9302A PXI local oscillator (2.75 GHz to 10 GHz).

Continuing from left to right in each measurement channel, the system also includes the following modules:

- M9360A PXI attenuator/preselector (100 kHz to 26.5 GHz)
- M9361A PXI microwave downconverter (2.25 GHz to 26.5 GHz)
- M9351A PXI RF downconverter, (50 MHz to 2.9 GHz)

All are mounted in an Agilent M9018A 18-slot PXI Express chassis. To ensure optimal performance, the M9018A contains an advanced PCIe® switch fabric that operates at up to x8 Gen 2 speeds.

Each M9202A digitizer includes a built-in hardware digital downconverter (DDC). In the configuration used here, the hardware digital downconverter (DDC) decimates data from 2 GSa/s down to the desired sample rate. This solution supports rates of 15 kSa/s to 125 MSa/s for gapless acquisition.

The resulting data consists of complex I/Q pairs in the form of 16 bits of in-phase data interleaved with 16 bits of quadrature data. As a result, the maximum sample rate of 125 MSa/s is equivalent to an instantaneous bandwidth of 100 MHz.

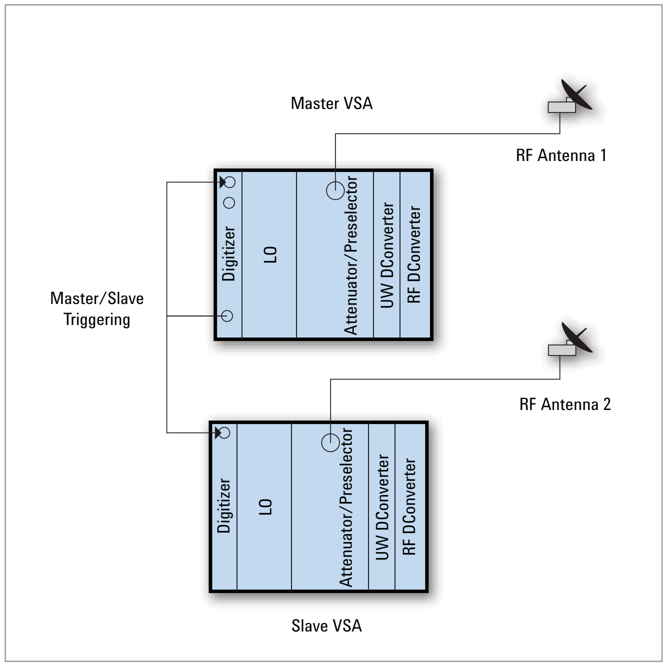


Figure 2. The use of independent LOs on each channel enables simultaneous in-band and adjacent-channel measurements at different center frequencies.

Solution (continued)

Identifying the source of interference

This configuration supports two relevant acquisition modes—two-channel recording and master/slave triggered recording—that enable a two-part analysis process. The two-channel mode is used to acquire and record gapless signal information on both channels for a period of time that depends on the available storage medium.

Using the independent LO, one channel was centered on the 802.11ac band at 5.530 GHz while the other was centered on 5.775 GHz (Figure 3). This upper frequency is the center of the unlicensed industrial, medical and scientific (ISM) band, which includes cordless phones and a host of other possible interferers. The two-channel vector signal analysis system made it possible to measure both bands simultaneously while looking for possible sources of noise and interference[3].

To accelerate the analysis of a long capture, the data is analyzed in two steps. First, one of the software elements—data viewer, signal analysis toolkit or VSA software—is used to identify and characterize the interfering signal. Second, the signal analysis toolkit with search capabilities is used to find and tag all similar occurrences within the data record. Once the key attributes of the interfering signal have been identified, its characteristics can be used to configure trigger parameters in the master/slave mode. In this mode of operation, the master channel acquires data and if this data correlates to the interfering signal then a recording is initiated on the slave channel. The recording can be duration limited or unlimited. In unlimited mode the program must control when the recording stops.

During a triggered measurement, the first occurrence of the intermittent signal will activate acquisition with the slave digitizer for a user-specified period of time within the capacity of the storage medium. To ensure a complete picture of the signal environment, pre-trigger delay can be used to acquire signal data for specified time prior to the trigger event within the capacity of the buffer memory.

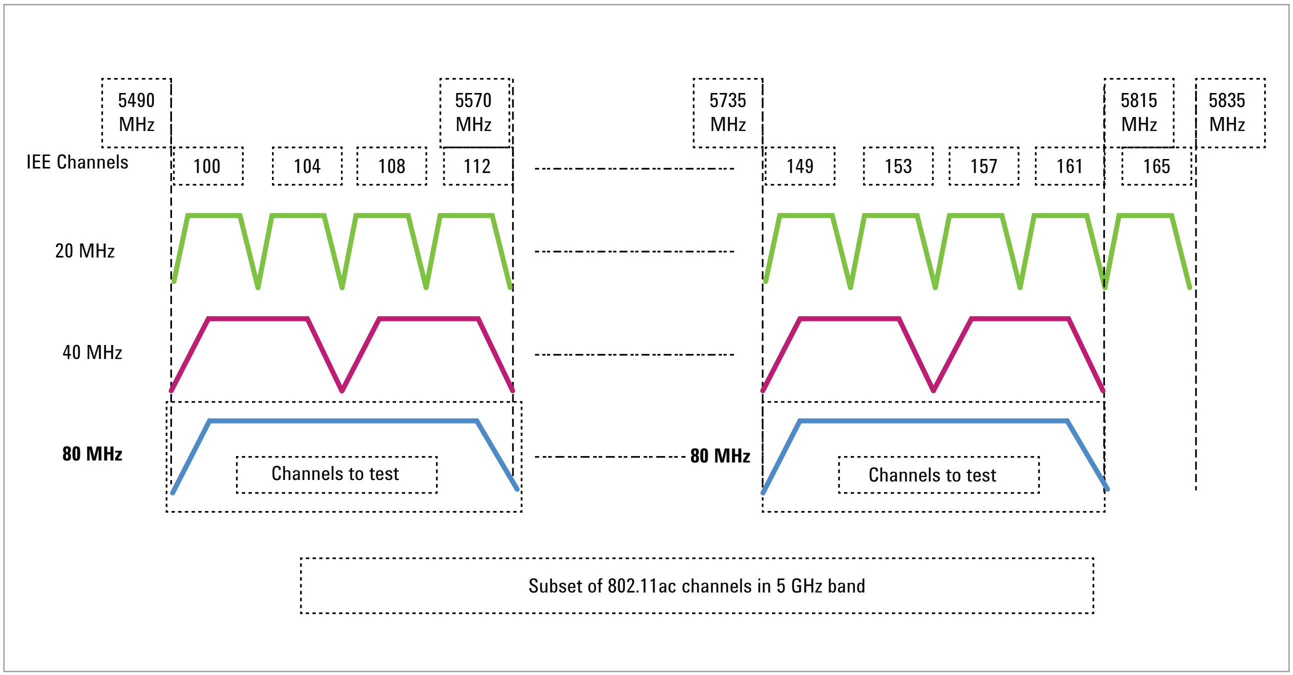


Figure 3. Acquisition, measurement and analysis focused on two subsets of 802.11ac channels.

3. This might be memory within the host PC or disk space in an external RAID array. For related application notes, please see the list of related information at the end of this note.

Solution (continued)

In master/slave triggering recording mode, the slave channel will be triggered after the system PC completes its analysis of the master channel data. In these cases, pre-trigger delay on the slave channel must be used to give the PC sufficient time to analyze the master channel and then decide if a slave-channel recording should be triggered. If so, then the recording channel [from figure 5) can be software triggered from any hardware that can generate a trigger signal, such as the M9300A Frequency Reference or from a very simple trigger issued from the PC's serial / COM port.

Setting up triggered measurements

The triggered measurements can be configured in one of two ways: trigger on the master channel and record data on both the master and slave channels, or trigger on the master channel and record data only on the slave channel. Recording on two channels can be informative if the source of interference is still in doubt; however, this approach can generate very large data records. When the attributes of the interferer are well understood—even though it remains intermittent—then the one-channel recording is potentially more efficient in terms of data volume and analysis time.

Recording on both channels after the trigger

In this case, the master channel is configured to monitor the span centered on 5.775 GHz, trigger on the attributes of the interferer, and then initiate recording on itself and the slave channel. Each of the recordings will produce a header file that indicates the time into each record when the trigger event occurred. In this mode the triggering process is less sophisticated. The master can be set to the expected frequency of the interferer and then a magnitude trigger can be set within the bandwidth of the measurement.

For some applications, it will be useful to see what was happening within the frequency spectrum slightly before the trigger event. Configuring each channel for a pre-trigger delay will capture a finite amount of data before the trigger (Figure 4). The actual time is limited by the available RAM in the host PC, and typically only 75% of the free memory. During an acquisition with pre-trigger delay, the free RAM is configured as a contiguous circular buffer that overwrites the oldest samples after the buffer completes a cycle.

If gapless recording (or "streaming mode") is set using the API, setting the trigger delay value to a negative number will produce a pre-trigger delay. Because the actual delay time depends on the available memory, the length of the data record may be shorter than the user-specified time period.

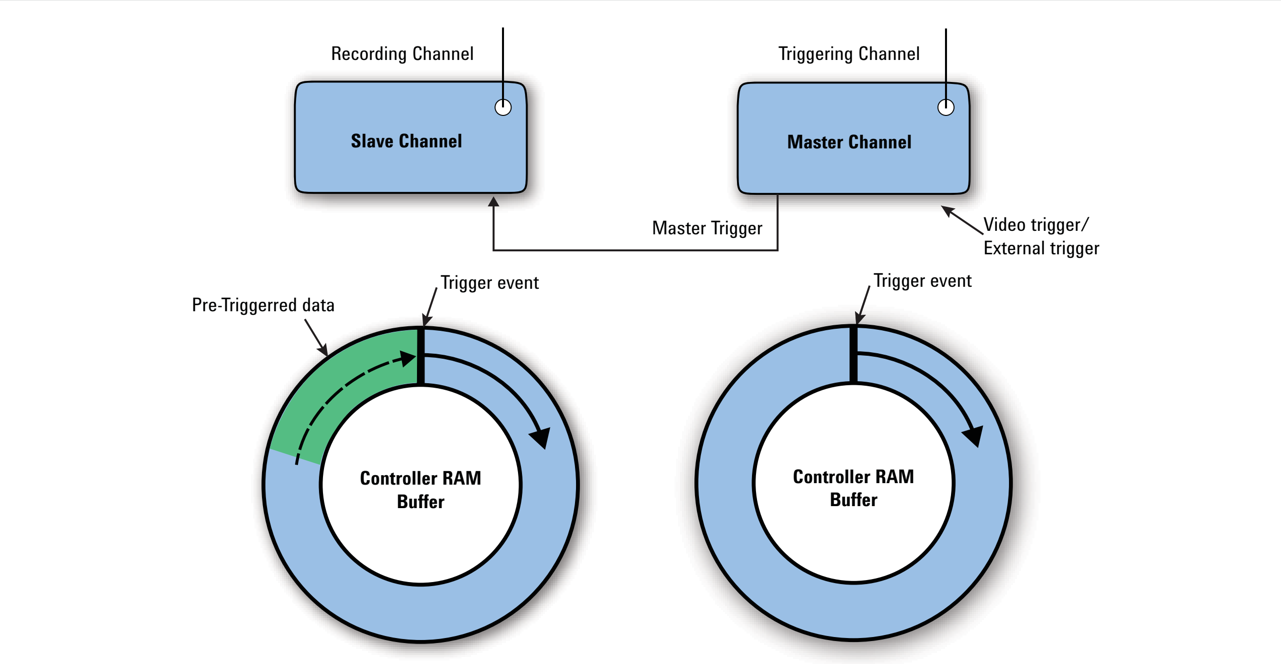


Figure 4. During two-channel master/slave recording, pre-trigger buffers can be used to capture potentially useful information that occurs slightly before the trigger conditions are met.

Solution (continued)

Setting up triggered measurements

In this case, the master channel[4] is configured to monitor the higher-frequency band and issue a trigger command to the slave channel[5] (now centered on the same frequency) when the interference signal is detected. An acquisition under these conditions may produce a modest amount of data that could potentially be stored within the PC rather than external media. Also, because the trigger parameters are based on observed signal attributes, less time will be spent searching through the acquired data.

There is one important caveat: Because the system is relying on the PC to check the trigger conditions, pre-triggering must be used compensate for the delay between acquiring data on the master channel, checking the trigger conditions and sending a trigger to the slave channel. The Slave channel can be triggered from any instrument that can generate an external trigger under software programmed control (Figure 5).

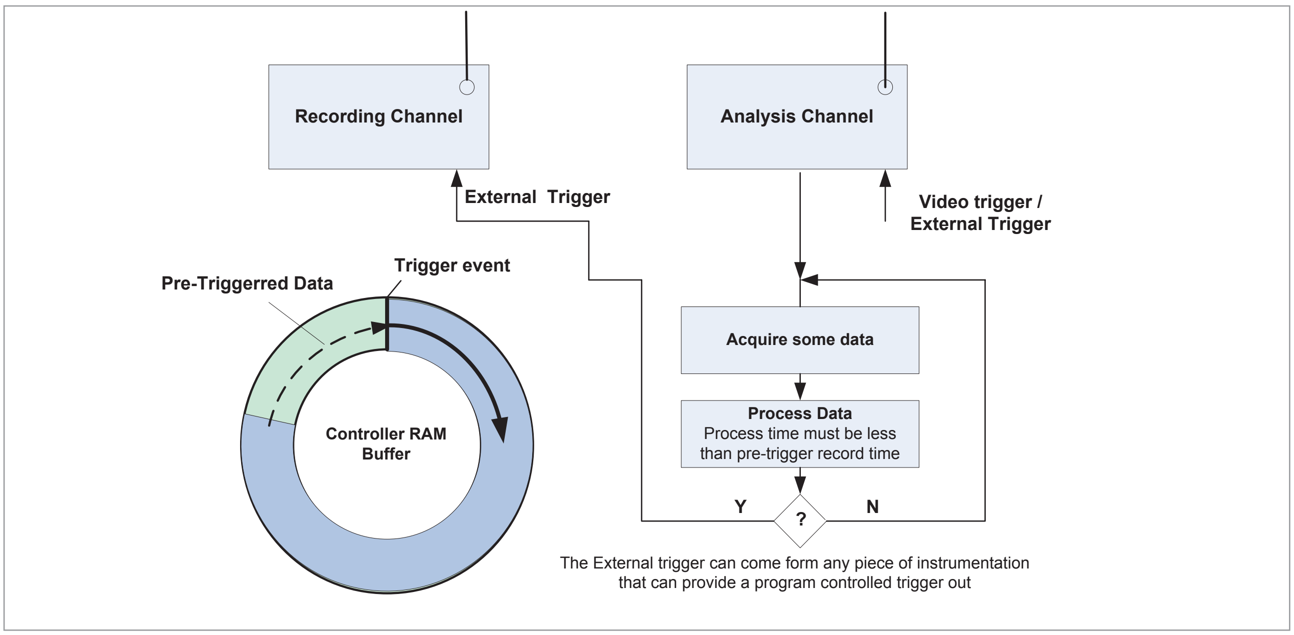


Figure 5. During triggered one-channel recording, using a pre-trigger buffer on the slave channel will help ensure capture of the actual beginning of the interference event.

4. In this example the "slave channel" can be thought of as the "recording channel".
5. In this example the "master channel" can be thought of as the "trigger channel".

Results

As noted earlier, the problem scenario centers on the development of an 802.11ac device. Its performance problems have been intermittent, but applying the system and process presented above suggest the interfering signal resides in the ISM band.

Setting up triggered measurements

After turning off all 802.11ac devices, data was captured on both channels for an extended period of time. The goal was to provide a baseline picture of the types of signals—stationary and intermittent—occurring between 5.490 and 5.815 GHz.

Agilent's free DataViewer was used to scan through the recorded data. Using the spectrogram display to view frequency and amplitude versus time, a variety of intermittent signals are clearly visible (Figure 6 only one channel is shown). Some resembled WLAN spectrum and time signatures while others were transient pulse sequences or spurious carrier signals.

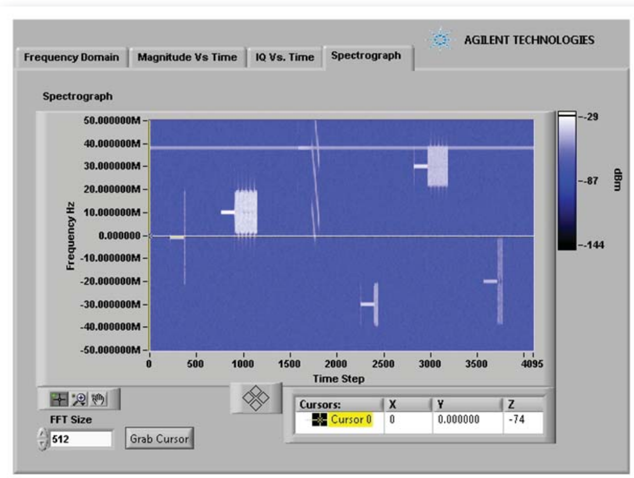


Figure 6. A spectrogram display in DataViewer shows a variety of possible interference signals in one of the 802.11ac channels.

DataViewer was then used to snip out a section of the recorded data for analysis with X-COM's Spectro-X signal analysis toolkit. Figure 7 is a persistence spectrum display of the same data shown in Figure 4. This type of "big picture" view makes it easier to start tracking down possible external sources of the performance problem.

Among the in-band signals, several were at frequencies and magnitudes capable of interfering with 802.11ac transmissions. For example, there were WLAN signals with 20-MHz bandwidth on channels 149, 157 and 161; there may also have been an 802.11n signal with 40-MHz bandwidth across channels 149 and 153.

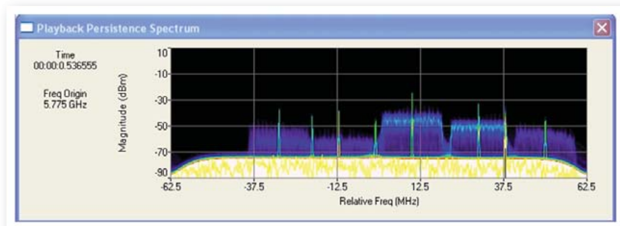


Figure 7. Using the Spectro-X software to analyze the captured data revealed problems such as the presence of other WLAN signals.

Because 802.11ac devices are designed to manage possible collisions with other WLAN signals, the next possible sources of interference were non-WLAN signals with lower magnitudes. The Spectro-X tools allow the user to control how much data is displayed or processed during each update. Varying settings such as data size, update rate and persistence value make it relatively easy to find transient or low-level signals that are being masked by stronger signals. An example is shown in Figure 8: Although the magnitude of the in-band transient waveform was relatively low, it was still large enough to cause degradation of transmissions to and from the 802.11ac device.

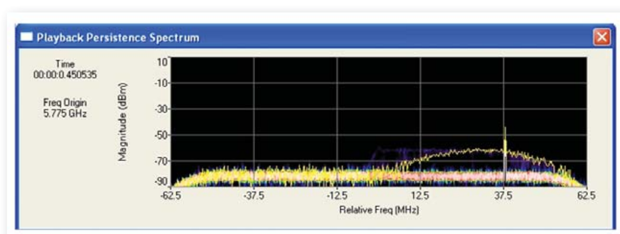


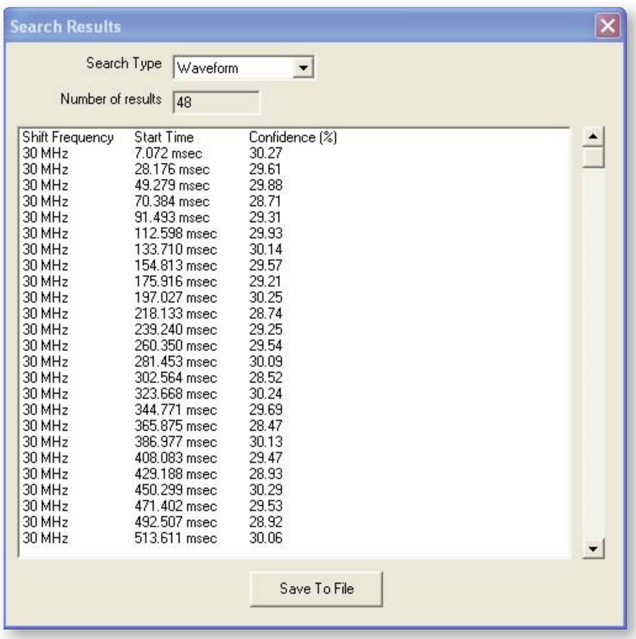
Figure 8. A persistence display clearly reveals a transient signal capable of interfering with 802.11ac transmissions.

Results (continued)

Tagging additional occurrences

To enable detailed analysis, the I/Q signature that represents the data shown above was copied to a reference file. The signature was then used as a reference to search for other similar instances within the full data record.

Sifting through gigabytes or terabytes of recorded data is best done with an automated tool. Fortunately, the Spectro-X toolkit includes a search function designed for this purpose. A search for signals similar to the I/Q signature (with a 20% confidence threshold) produced 48 occurrences (Figure 9).



Search Results

Search Type: Waveform

Number of results: 48

Shift Frequency	Start Time	Confidence (%)
30 MHz	7.072 msec	30.27
30 MHz	28.176 msec	29.61
30 MHz	49.279 msec	29.88
30 MHz	70.384 msec	28.71
30 MHz	91.493 msec	29.31
30 MHz	112.598 msec	29.93
30 MHz	133.710 msec	30.14
30 MHz	154.813 msec	29.57
30 MHz	175.916 msec	29.21
30 MHz	197.027 msec	30.25
30 MHz	218.133 msec	28.74
30 MHz	239.240 msec	29.25
30 MHz	260.350 msec	29.54
30 MHz	281.453 msec	30.09
30 MHz	302.564 msec	28.52
30 MHz	323.668 msec	30.24
30 MHz	344.771 msec	29.69
30 MHz	365.875 msec	28.47
30 MHz	386.977 msec	30.13
30 MHz	408.083 msec	29.47
30 MHz	429.188 msec	28.93
30 MHz	450.299 msec	30.29
30 MHz	471.402 msec	29.53
30 MHz	492.507 msec	28.92
30 MHz	513.611 msec	30.06

Save To File

Figure 9. The listing of search results shows the start time and confidence level for every instance of signal correlation.

Within the search results, individual instances can be selected and displayed in a variety of formats. For example, the data associated with the correlation match at 133.710 ms was viewed as a spectrogram (Figure 10).

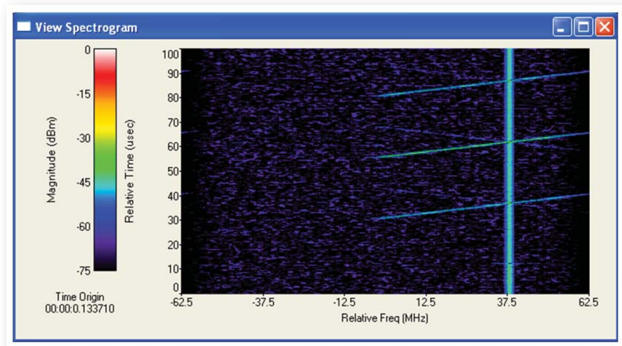


Figure 9. The listing of search results shows the start time and confidence level for every instance of signal correlation.

Results (continued)

Observing the effects of interference

After characterizing the ambient sources of noise and interference in the channels, the next step was to perform a two-channel recording while the 802.11ac device was operating within the RF environment. A search through the recorded data revealed several periods of activity by a few specific interference signals. These sections were snipped out and then analyzed using the 89600 VSA software and its advanced demodulation capabilities.

The results are shown in Figures 11, 12 and 13. For all three measurements, the 89600 VSA software was used to demodulate and analyze the 802.11ac waveforms. In Figure 11, minimal noise is present and the 64QAM constellation (upper left) is stable, a condition that should ensure a high average throughput.

In Figure 12, the channel was noisier than expected and a continuous-wave carrier was present in the OFDM trace (upper middle). Note that the carrier level was so low that it did not appear in the spectrum trace (lower left). Under these conditions, the 802.11ac device did not stop transmitting but had problems maintaining high-order modulation coding scheme. As a result, average data throughput suffered.

Finally, Figure 13 shows the presence of a broadband interference signal. This caused a tremendous amount of distortion in the OFDM constellation (upper left) and extra frequency content in the OFDM vector spectrum (upper middle). These may be signs that the 802.11ac transmitter is near the point of turning off.

In the noisy conditions, the 802.11ac device was transmitting properly; however, the low-level interference signal was preventing the device from achieving maximum throughput performance. Ultimately, this analysis provided two key insights: the device was operating properly and source of the performance problem was not in the design—it was external.

Finding the problem was more difficult than expected, even with these tools. In contrast it would have been extremely difficult—and more time-consuming—to resolve this issue using traditional methods.

Figure 11. This segment of the recorded spectrum contained minimal noise and the demodulated 802.11ac signal was in good condition.

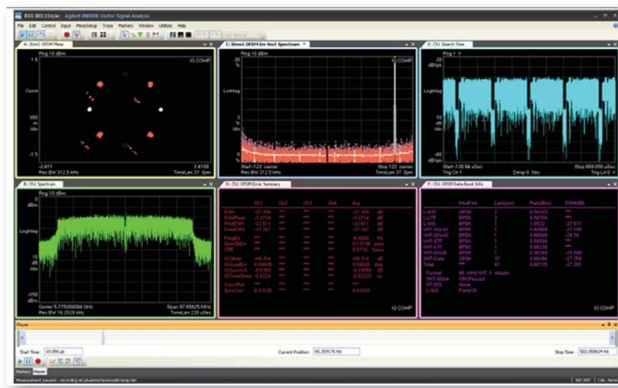


Figure 12. This section of the recorded spectrum was noisier than expected and the demodulated 802.11ac signal exhibits several problems.

Figure 13. This portion of the recorded spectrum shows the presence and effects of a broadband interference signal.

Conclusion

The methods described here overcome two of the key challenges in the analysis of intermittent problems: gaps in the data and tools for efficient post-processing and analysis of large data sets. By enabling the capture and analysis of intermittent problems at high frequencies and wide bandwidths, the two-channel system can help engineers troubleshoot a wide range of problems in the development of new RF and microwave devices.

Taking a broader view, this system is generally applicable to test scenarios that require continuous recording of data for extended periods of time and detailed analysis of cross-channel relationships. Expanding the system to include three or more digitizers opens the door to applications such as MIMO and geolocation. In this case, simultaneous recording on one or two additional 100-MHz bandwidth channels would require a second two-channel PXI vector analysis system.

For more details on configuration of a multichannel wideband streaming solution, please see literature no. 5991-0221EN.

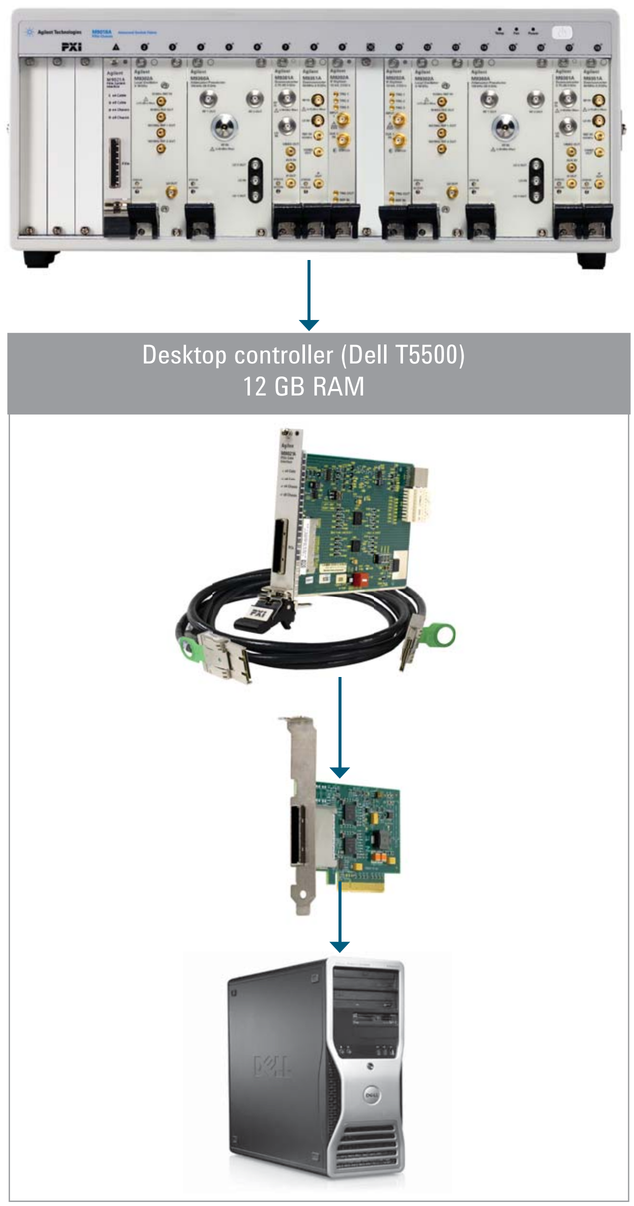


Figure 14. Connection Diagram with M9018A 18 slot chassis, M9392A vector signal analyzer, M9021A PCIe cable interface, Y1202A PCIe interface cable and Dell T5500 Desktop (with M9047A PCIe Interface card placed inside).

Configuration and Ordering Information

Software Information

Chassis slot compatibility: PXIe system slot	
Supported operating systems	Microsoft Windows® XP Microsoft Windows® 7 (32/64-bit)
Agilent IO Libraries	Includes: VISA Libraries, Agilent Connection Expert, IO Monitor

Related Information

- White Paper: *Multichannel Wideband Streaming with the M9392A PXI Vector Signal Analyzer*, publication 5991-0221EN
- Application Note: *Capturing Events of Long Duration or High Volume*, publication 5990-7734EN
- Application Note: *How to get the most from the M9392A vector signal analyzer with 100 MHz streaming option*, publication 5990-8872EN
- White Paper: *Connecting and Configuring JMR RAID to Work with the M9392A VECTOR SIGNAL ANALYSIS System*, publication 5990-9483EN
- Brochure: *M9392A PXI vector signal analyzer*, publication 5990-6049EN
- Data sheet: *M9392A PXI vector signal analyzer*, publication 5990-6050EN
- Flyer: *M9392A PXI vector signal analyzer*, publication 5990-6051EN
- Application Note: *X-COM Interference test solution*, publication 5990-9243EN
- Symmetricom IRIG/GPS PCI Module www.symmetricom.com/products/bus-leveltiming/pci-express/

	Model	Description
☑	M9392A[1]	PXI Vector Signal Analyzer: 50 MHz to 26.5 GHz (for the 2-channel solution order 2 systems)
	☑ M9302A[2]	PXI Local Oscillator: 3 GHz to 10 GHz
	☑ M9360A[2]	PXI Attenuator/Preselector: 100 kHz to 26.5 GHz
	☑ M9202A[2]	PXIe IF Digitizer: 2GS/s 1GHz, 50 MHz BW streaming
	☐ M9202A-V10	PXIe IF Digitizer: 100 MHz BW streaming option
	☑ M9361A[2]	PXI Downconverter: 2.75 GHz to 26.5 GHz
	☑ M9351A	PXI Downconverter: 50 MHz to 2.9 GHz
☑	M9300A	PXIe Frequency Reference.
☑	89601B	VSA software
☑	89601B-200	Basic Vector Signal Analyzer
☑	89601A-300	Connectivity option
☑	89601A-AYA	Vector modulation analysis
☑	M9048A	PCIe desktop adapter
☑	M9021A	PCIe Cable Interface
☑	M9018A	18-slot PXIe Chassis
☑	Y1202A	PCIe x8 gen2 Interface Cable
☐	Spectro-X	X-COM Signal Search Software
☐	Dell T5500[2]	PC Workstation with 12 GB RAM
☐	JMR RAID Storage system option	1. AGIL-G4-DC-16T or AGIL-G4-DC-32T 2. Two of each Y1202A Interface Cable
☑	*Recommended configuration*	

1. For multichannel streaming at 100 MHz bandwidth the Dell T5500 Workstation with 12 GB RAM is recommended.

The Modular Tangram

The four-sided geometric symbol that appears in this document is called a tangram. The goal of this seven-piece puzzle is to create identifiable shapes—from simple to complex. As with a tangram, the possibilities may seem infinite as you begin to create a new test system. With a set of clearly defined elements—hardware, software—Agilent can help you create the system you need, from simple to complex.

Challenge the Boundaries of Test

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