Agilent
Wideband Waveform Center

81199A

User's Guide

Agilent Technologies

Notices

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For Assistance and Support

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Contents

1 Introduction

Introduction

The 81199A Wideband Waveform Center builds on

- the accuracy and wide bandwidth of 81180B and M8190A Arbitrary Waveform Generators (AWG),
- the high performance of 90000A/X Series Real-Time Oscilloscopes,
- and the flexibility of the 89601B Vector Signal Analysis (VSA) software,

to deliver an integrated stimulus / analysis test solution for the next generation of wideband vector modulated signals.

The 81199A software currently supports selected specifications addressing the 57 to 66 GHz unlicensed band; specifically IEEE 802.11ad and WirelessHD. These specifications were chosen, principally because they are important emerging technologies, but also because the 81199A software, in conjunction with the high performance of the associated hardware platform, makes it, for the first time, possible to accurately generate and analyze such wideband signals.

The 81199A software is not limited to the currently supported formats. It is a general purpose framework, and the associated hardware platform is similarly flexible. As well as the specified formats, the software has generic stimulus / analysis capabilities, such as multi-tone, and can be extended to support other wideband signals for which the associated hardware platform is an appropriate solution.

Users may also extend the 81199A software functionality by means of their own "plug in" DLLs, as described in Agilent Wideband Waveform Center 81199A – User Defined Plugins Guide (81199-91030).

Features and Benefits

- Integrated stimulus and analysis
- Unrivalled accuracy and wide bandwidth
- Fully featured and flexible signal generation
- Comprehensive signal analysis
- Unique support for important emerging technologies
- User extendable functionality
- SCPI remote control for test automation

What's inside this Manual

This manual provides detailed information about the following:

- 81199A software installation and configuration.
- Possible measurement hardware configurations.
- Using 81199A for wideband waveform generation and analysis.

Purpose of this Manual

The purpose of this manual is to enable you to install and use the 81199A Wideband Waveform Center software and to give some guidance on the configuration of the associated hardware platform.

Who should read this Manual

This manual is intended for;

- Anyone wishing to use the 81199A software to develop, debug or verify an implementation of any of the supported wideband modulation formats.
- Anyone wishing to use the 81199A software to exercise RF components or subsystems that have been designed to process any of the supported wideband modulation formats.
- Anyone wishing to generate or analyze very wide bandwidth vector modulated signals.

How this document is organized

This section provides information on the chapters, and their content.

Navigating this manual

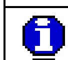
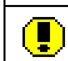
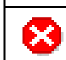
Chapter No.	Chapter Heading	This Chapter...
1	Introduction	Provides an overview of 81199A.
2	Installation	Describes the steps required to install 81199A software package.
3	Licensing	Describes Agilent software licensing and the licenses required to run the Agilent 81199A Wideband Waveform Center software.
4	Getting Started	Introduces to a typical 81199A workflow.
5	Hardware Configuration	Provides guidance on how to configure your measurement hardware.
6	Menu	Describes the functions available via the main 81199A menu.
7	Tool Bar	Describes the 81199A tool bar.
8	Status Bar	Describes the 81199A status bar.
9	Window Management and Manipulation	Describes the docking panel window system.
10	Working with Measurement Displays	Describes how to work with the various result displays available in the 81199A software.
11	Generate	Describes the general operation and layout of the waveform generation part of the 81199A software.
12	Pre-Correction	Describes how to compute and apply a pre-correction filter to compensate for signal path imperfections.
13	Supported Formats (Generate)	Describes the modulation and coding options supported by the waveform generation part of the 81199A software.
14	Measure	Describes the modulation analysis part of the 81199A software.

Chapter No.	Chapter Heading	This Chapter...
15	Supported Formats (Measure)	Describes the functionality of the measuring demodulators currently supported by 89601B VSA time-capture post-processing in the 81199A software.
16	FAQ	Provides answers to frequently asked questions about the 81199A software.
17	Release Notes	Directs you to a version-by-version list of the new features and known defects in the 81199A software.
18	Contacting Agilent	Provides contact information for support on the 81199A Wideband Waveform Center and the associated hardware platform.

Conventions used in this manual

The following table lists the icon conventions used in this manual:

Conventions

The icon...	Indicates...
	A note or important information.
	A tip
	A caution or warning

Acronyms used in this manual

The following table lists the acronyms used in this manual:

Acronyms used in this document

Acronym	Explanation
Ack	Short for Acknowledge
ADT	Antenna Direction Tracking
AGC	Automatic Gain Control
API	Application Programming Interface
AWG	Arbitrary Waveform Generator
BPSK	Binary Phase Shift Keying
BS	Beam Search
CD	Compact Disc
CSV	Comma Separated Value
DAC	Digital to Analog Converter
DLL	Dynamic Link Library
DVD	Digital Versatile/Video Disc
DUT	Device Under Test
EEP	Equal Error Protection
EVM	Error Vector Magnitude
FD	Frequency Domain
FEC	Forward Error Correction
FOE	Frequency Offset Estimation
GUI	Graphical User Interface
GB	Giga Byte
GPIB	General Purpose Interface Bus
HCS	Header Check Sum
HRP	High Rate PHY
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
IP	Internet Protocol
IQ	In-phase and Quadrature (the real and imaginary parts)
LRP	Low Rate PHY
OFDM	Orthogonal Frequency Division Multiplexing

PCS	Payload Check Sum
LAN	Local Area Network
LDPC	Low Density Parity Check
LO	Local Oscillator
LPSCPHY	Low Power Single Carrier PHY
MB	Mega Byte
OFDM	Orthogonal Frequency Division Multiplex
OQPSK	Offset QPSK
PCS	Payload Check Sum
PSG	Performance Signal Generator
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RTU	RF Test Unit
RUI	Remote-control User Interface
SCPHY	Single Carrier PHY
SCPI	Standard Commands for Programmable Instruments
SCS	Short Check Sum
SDF	Standard Data Format
TD	Time Domain
UEP	Unequal Error Protection
USB	Universal Serial Bus
VSA	Vector Signal Analyzer
WFA	Wi-Fi Alliance
WGA	Wireless Gigabit Alliance

2 Installation

2.1 Introduction

This chapter shows you the steps required to install 81199A software package.

2.1.1 Pre-Requisites

The following are the hardware pre-requisites for Agilent 81199A software:

Hardware	Operating System: (Preferred) Microsoft Windows® 7 Professional, Enterprise, or Ultimate	Operating System: (Optional) Microsoft® Windows® XP Professional SP3
CPU	1 GHz or faster 32-bit (x86) or 64-bit (x64) processor	1 GHz or faster 2 GHz recommended
RAM	2 GB recommended (32-bit) / 4 GB recommended (64-bit)	2 GB recommended
Video RAM	128 MB (512 MB recommended)	128 MB (512 MB recommended)
Hard Disk	1 GB available	1 GB available
Additional Drives	DVD to load software; license transfer requires network access, USB Flash drive, USB hard drive, or USB DVD drive	DVD to load software; license transfer requires network access, USB Flash drive, USB hard drive, or USB DVD drive
Interface Support	LAN, GPIB, USB or IEEE-1394 (only for VXI hardware and 1690 Series Logic Analyzer), AXIe, PXIe	LAN, GPIB, USB or IEEE-1394 (only for VXI hardware and 1690 Series Logic Analyzer), AXIe, PXIe
Network Bandwidth	10 Mbps	10 Mbps

Software Pre-Requisites

The following are the software pre-requisites for Agilent 81199A software:

1. Supported Operating System:
   - Windows XP SP3 (32 bit)
   - Windows 7 (32 bit)
   - Windows 7 (64 bit)

2. Ensure that you have Agilent IO Libraries Suite 16.1 Update 1 or higher installed on your system. The Agilent IO Libraries Suite can be found on the CD that is part of shipment content or at http://www.agilent.com/find/iosuite

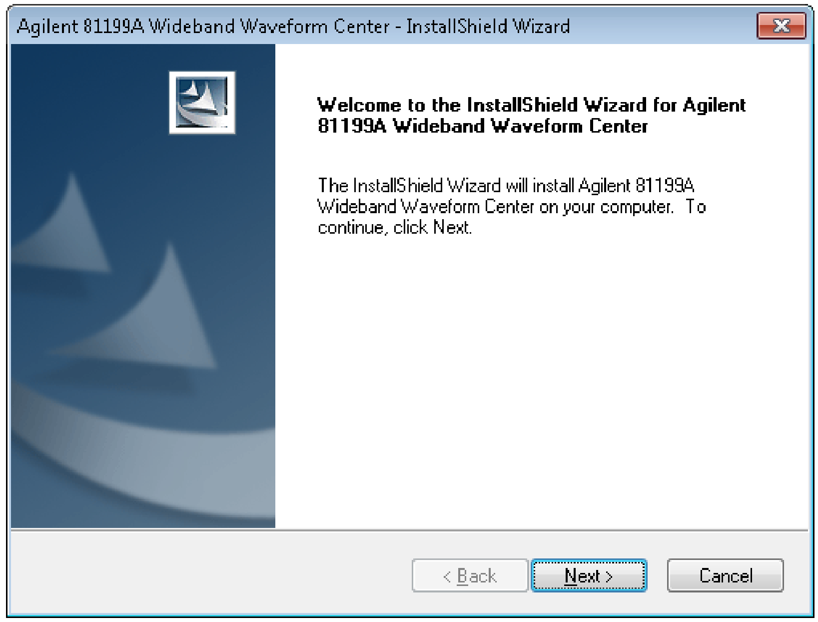
3. If you have a license for 81199A option 002 (analysis) and wish to use this capability, then you will also need Agilent 89601B VSA version 14 or higher installed on your system.

2.1.2 Installation Process

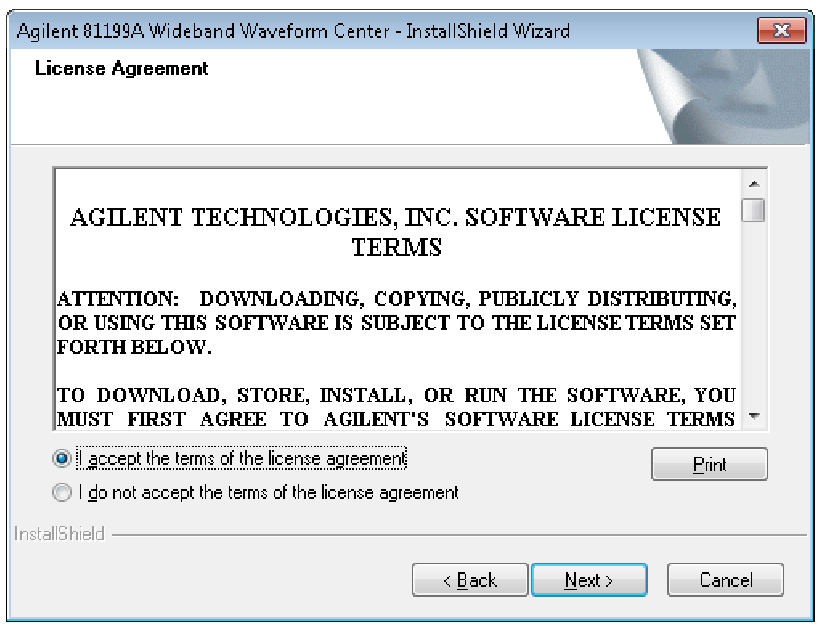
Follow the given steps to install Agilent 81199A software on your system.

1. Double-click the executable (*Agilent 81199A Setup.exe*) to run the 81199A setup. The 81199A setup will be available either on CD, USB drive or Web.

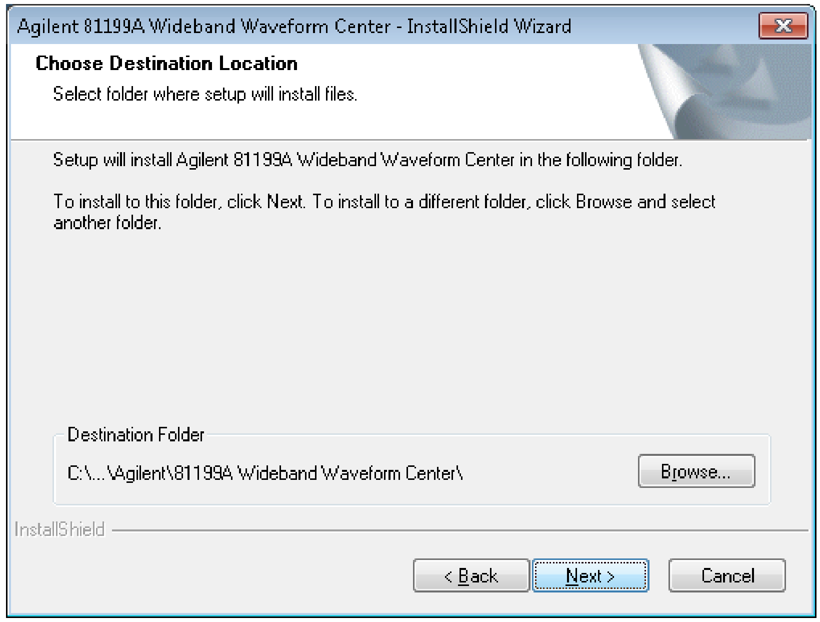
The following welcome screen will appear:



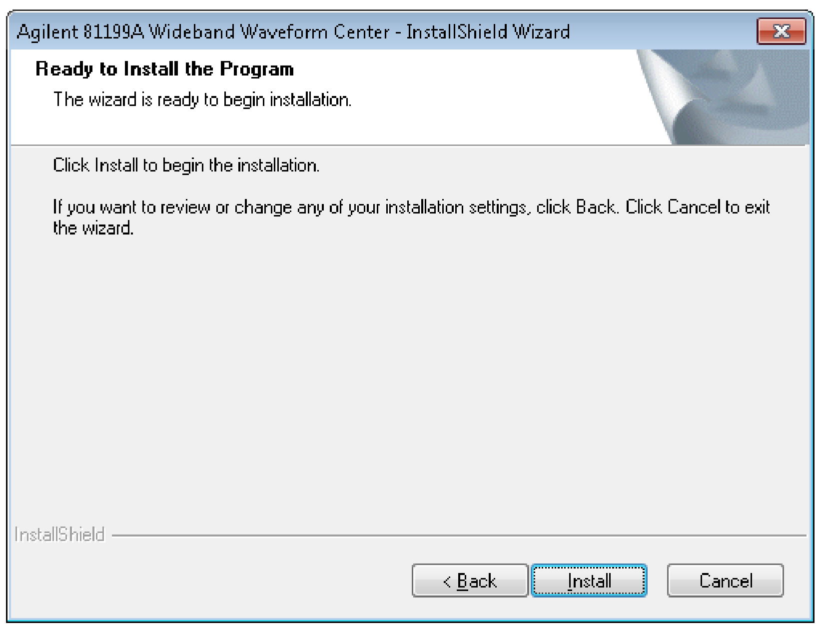
2. Click “Next” to continue. The license agreement window will appear.



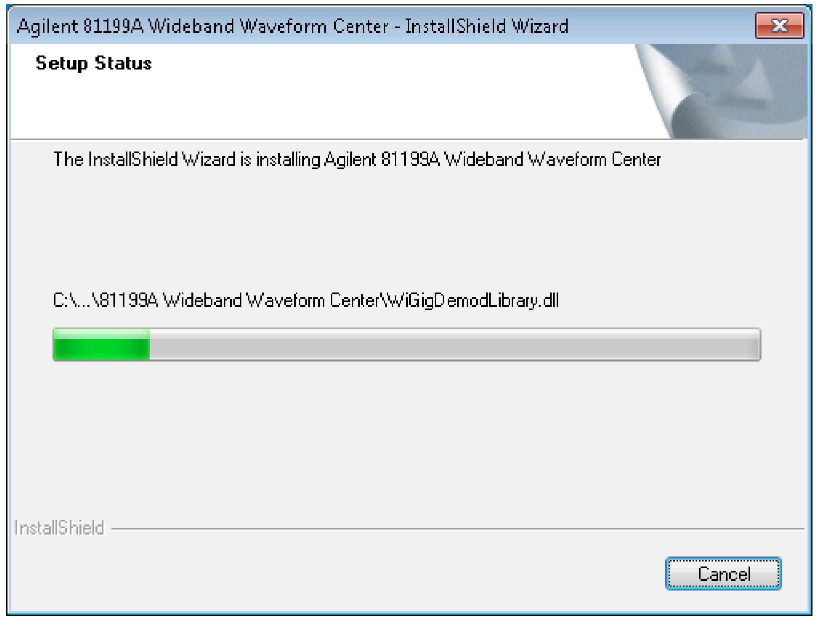
3. Select “I accept the terms of the license agreement” and click “Next” to continue. The following window will appear.



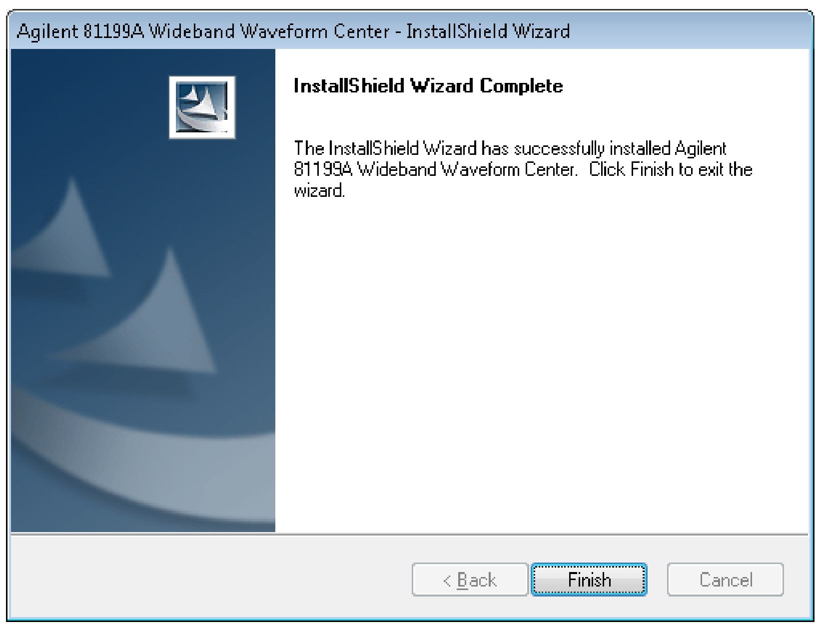
4. Click "Next" to install in the default folder. However, if you want to install to a different folder, click "Browse" and select another folder. The following screen will appear.



5. Click "Install" to begin the 81199A installation. The following screen will appear that displays the setup status of the 81199A installation.



6. The following screen will appear once the Agilent 81199A software is successfully installed on your system. Click “Finish” to exit 81199A setup.



This step completes the Agilent 81199A installation process.

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3 Licensing

3.1 Introduction

This chapter describes Agilent software licensing and the licenses you will need to run the Agilent 81199A Wideband Waveform Center software.

3.2 Agilent Software Licensing

The 81199A software can be installed on any PC that meets the pre-requisites specified in section 2.1.1. However, to run the software on a specific PC you must also obtain and install a PC-specific license key file.

When you purchase 81199A you will be provided with a License Redemption Entitlement Certificate that documents the options to which you are entitled.

You can redeem the certificate at

http://www.agilent.com/find/softwaremanager

using the purchase order number, entitlement certificate number and the licensing serial number for the PC on which you want to run the software.

To find the licensing serial number for your PC; once you have successfully installed the product, right-click on the Agilent License Manager icon in the status bar notification area and select "About Agilent License Notifier".

From the resulting dialog, note the hostid. The hostid has two parts, the fixed "model number", PCSERNO, and a "licensing serial number" unique to your PC. You will need the licensing serial number part.

The licensing serial number is not the manufacturer's serial number of your PC, is an identifier generated based on your PC hardware after installing the Agilent License Service.

The Agilent Software Licensing system will issue a license file for each purchased option, by email, to an address you specify. Each license file is a plain text file attachment with a filename in the form XXXXXX_YYYYYY.lic.

When you receive the email you should save the attached .lic file(s) to the Agilent license directory, which is, by default, located at

C:\Program Files\Agilent\licensing

The Agilent License Service on the PC constantly monitors the license directory and will install the license as soon as the new .lic file(s) appears in the license directory. The result of the license installation is reported by a status balloon in the notification area.

You can check the status of your software licenses by running the optional Agilent License Manager or by selecting Help > About... from the 81199A menu then selecting the Licenses tab in the About dialog.

If a license is not available or not valid, the corresponding feature will not be enabled by the Agilent 81199A Wideband Waveform Center.

The 89601B VSA software is not a part of the 81199A installation, but you will need a licensed installation of the 89601B VSA with at least options 200 (Basic VSA) and 300 (Hardware Connectivity) in order to use 81199A option 002 (analysis). You will also need 89601B option AYA (Vector Modulation Analysis) if you wish to analyze vector modulated signals other than those supported directly by 81199A.

3.3 81199A Licenses

Table 1. Agilent 81199A Software Options

Product / Feature	License Version	Option	Description
81199A-TRL	1.000	Trial	A 30-day free trial license that temporarily enables option 001, 002 and IAD functionality to permit product evaluation.
81199A-001	1.000	Generation	Generate waveforms and download to Agilent wideband AWGs. Generation options are subject to presence of options IAD and WHD.
81199A-002	1.000	Analysis	Acquire signal data from the 89601B VSA software. Measurement options are subject to presence of options IAD and WHD.
81199A-IAD	1.000	IEEE 802.11ad	Generate and measure waveforms compliant with the IEEE 802.11ad / WiGig MAC/PHY v1.2 specification.
81199A-WHD	1.000	WirelessHD	Generate and measure waveforms compliant with the WirelessHD 1.0b specification.
81199A-DFP	1.000	File Output	Save waveform data to an unencrypted file, in CSV, BIN or MAT format, on the host PC.
89601B-200 **89601B-300** **89601B-AYA (optional)**	YYYY.VVVV	VSA Licenses	The 81199A analysis capability is built upon the 89601B Vector Signal Analysis product. In addition to the 81199A license, you will need to have these 89601B features installed and licensed in order for 81199A-002 to function.

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4 Getting Started

4.1 Introduction

This chapter introduces you to a typical 81199A workflow, To do this, we will perform the following introductory activities,

- Configure the hardware
- Create a simple waveform
- Download the waveform
- Configure the VSA/oscilloscope to acquire the signal
- Look at time and spectrum results
- Enable pre-corrections
- Create an IEEE 802.11ad compliant waveform
- Download the waveform
- Enable demodulation and look at some measurement results

4.2 Configure the Hardware

Hardware configuration is described fully in Chapter 5. Here we will make a very simple baseband-to-baseband connection, which will be sufficient to get you familiar with the software workflow.

You are assumed to have the following equipment available,

- A computer with the 81199A and 89601B software correctly installed.
- An Agilent 81180B or M8190A AWG.
- An Agilent 90000A or 90000X Series oscilloscope.
- LAN connectivity between the computer, AWG and oscilloscope.

If you are only using 81199A for waveform generation (81199A option 001 only) then you do not require the 89601B software or the oscilloscope. (Unless you also plan to use the generator's Pre-Correction capability).

If you have 81199A option DFP, you can save waveforms to a file and recall them as "recordings" into the analysis part of the tool. This allows evaluation and demonstration of the software without any hardware.

4.2.1 Connect the AWG to the Oscilloscope

Agilent wideband AWGs have differential outputs; each channel has a normal and inverted output. To simplify the connection to the oscilloscope we shall only use the normal output and terminate the inverted output with a 50Ω load.

81180B

On the 81180B, the channel output connectors are labeled Out 1, /Out 1, Out 2, and /Out 2. These connectors are used for all output coupling modes.

- Connect 81180B Out 1 to 90000A/X Channel 1
- Connect 81180B Out 2 to 90000A/X Channel 3
- Connect a 50 ohm load to the unused 81180B /Out 1 connector
- Connect a 50 ohm load to the unused 81180B /Out 1 connector

M8190A

On the M8190A, there are two sets of output connectors for each channel, labeled Direct Out and Amp Out. We will use the Direct Out connectors which are used in the DAC output coupling mode.

- Connect M8190A Channel 1 Direct Out to 90000A/X Channel 1
- Connect M8190A Channel 2 Direct Out to 90000A/X Channel 3
- Connect a 50 ohm load to the unused M8190A Channel 1 /Direct Out connector
- Connect a 50 ohm load to the unused M8190A Channel 2 /Direct Out connector

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4.2.2 Connect the LAN

There are so many possible ways to achieve LAN connectivity that you will have to decide the best solution for your circumstances. However, we will suggest one possibility that is arguably the easiest way to achieve private test equipment LAN connectivity; especially if your organization's IT rules disallow connecting test equipment to the company LAN infrastructure.

Using a home router

You can use an inexpensive home networking (broadband) router to create a private LAN. The advantage of using a router intended for home use is that it will include a DHCP server which automates the allocation of IP addresses. If permissible, the router can also be connected to your company network for WAN connectivity.

81180B

If you have an 81180B AWG simply connect it, the computer, and the 90000A/X series oscilloscope to the router. Optionally, connect the router's WAN port to your company LAN.

M8190A

If you have an M8190A AWG that is connected to your computer using a PCIe cable then, assuming the M8190A firmware is also running on the computer, LAN connectivity is achieved via the localhost loopback.

If you have an M8190A AWG that is connected to another computer (such as an Agilent M9536A AXIe Embedded Controller) then connect that computer to the router.

Establishing the connections

The oscilloscope is not connected directly to the 81199A software; instead it is configured in the 89601B VSA software.

Setting up and using the Infiniium Oscilloscope with the VSA software is described in the application note Agilent Infiniium Oscilloscopes with 89600B VSA Software (P/N 5990-6819EN).

81180B

If you have an 81180B AWG you only need to know the IP address, which can be discovered from the 81180B front panel by pressing Utility > Remote Interface > LAN.

M8190A

If you have an M8190A AWG that is hosted on the same computer as the 81199A software then the IP address is 127.0.0.1, or you can enter the equivalent hostname "localhost".

If you have an M8190A AWG that is hosted on another computer then you can determine that computer's IP address by opening a command window (Start > Run... > cmd.exe) and executing the ipconfig command. Alternatively you can enter the computer's hostname.

Entering the AWG IP Address

To enter the AWG's IP address, select the appropriate output device using the menu selection Generate > Output Device > Agilent M8190A – Precision Mode (14 bit, 8 GHz), then, in the Current Output Device Settings window, enter the IP address or hostname in the Instrument Address setting.

The associated port number should normally be left at its default value of 5025.

It is only necessary to change the port number if the 81199A software and M8190A firmware are hosted on the same computer AND you want to remotely control the 81199A software.

4.3 Create a Simple Waveform

If you are hosting the M8190A on the same computer as the 81199A software, run the M8190A firmware before starting 81199A. This ensures that the M8190A firmware can claim ownership of port 5025 for remote control purposes.

1. Run the 81199A software.
2. Select the Multi-tone Segment Library window.
3. Drag and drop Segment 1 from the Segment Library window into the Waveform Layout window by clicking on the colored box numbered 1. This action will cause the Multi-tone Segment 1 Settings window to be selected in the docking panel on the left.

Change the segment 1 settings to,

- Tone Type: Multi Tone
- Multitone Number of Tones: 20
- Multitone Occupied Bandwidth: 1.800000 GHz
- Multitone Suppressed Tone: Tone at Fc
- Multitone Single-sided: True

4.4 Download the Waveform

If you have not already done so then, on the menu, select Generate > Output Device and select your output device.

In the Current Output Device Settings window enter the AWG IP address or hostname as the Instrument Address (you only need to do this once).

In the Final Waveform Settings window Set Sin(x)/x Correction On to True (because you are outputting to an AWG).

On the menu, select Generate > Generate and Output..., or click the Tool Bar Generate and Output... button.

4.5 Configure the VSA/Oscilloscope to Acquire the Signal

In the Acquisition Settings window, click the "Basic" button to select the simpler settings list, then change (if necessary) the settings to,

- Channel Config : I and Q Baseband Inputs (always change this setting first because it resets the center and span values)
- Center : 0.000 000 000 Hz
- Span : 2.500 000 000 GHz
- Points : 102,401
- Mirror Freq: False
- Main Length : 40.000000000 µs

You can then set the Range manually (400 mV is a good value for this configuration), or automatically by clicking the Auto-Range button in the Tool Bar. When in I and Q baseband mode, the channel 1 and 2 range settings are linked, you need only change the range value for channel 1.

4.6 Look at Time and Spectrum Results

If the analysis is not already running, click the Start button in the toolbar.

By default, Measurement Display window 1 should be mapped to the measurement result called Main Time and Measurement Display window 2 should be mapped to the measurement result called Spectrum.

The displays should be showing time and frequency traces similar to Figure 1 and Figure 2.

The individual Measurement Display windows can be brought out into a resizable floating window by double clicking on the window's tab, and can be returned to their original position by double clicking on the floating window's title bar.

Main Time

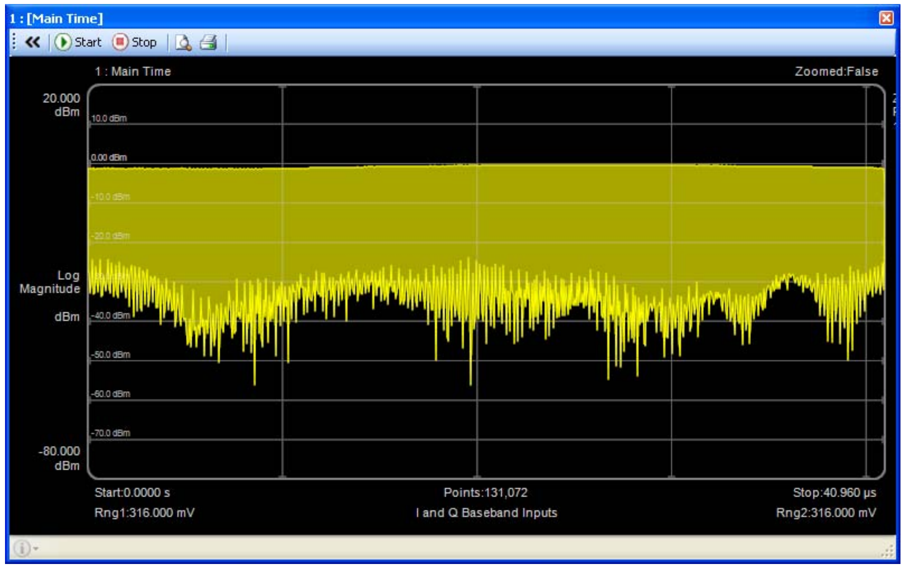

Figure 1. Main Time trace for a single-sided multi-tone signal.

Spectrum

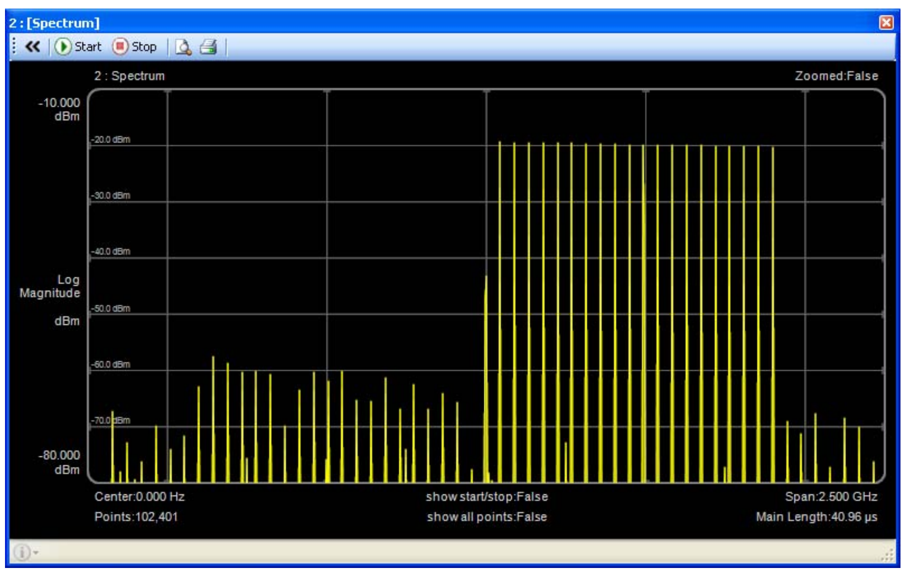

Figure 2. Spectrum trace for a single sided multi-tone signal with 5 ps IQ skew

Exploring the traces

Looking at Figure 2, the multi-tone spectrum is less than perfect at this stage.

This serves to illustrate an important point; small inaccuracies in IQ gain, timing, symbol clock etc., that you may have regarded as inconsequential when working at lower symbol rates can have a large impact on vector modulated signals at very high symbol rates.

In the example signal, the unexpected spurious tones in the lower half of the spectrum are largely due to a skew of just 5 ps between the I and Q signals. (5 ps skew equates to about 0.8 mm difference in the electrical length of the I and Q paths).

This skew can be manually compensated using the delay adjustment in the M8190A soft front panel, or the 81180B Ch1 / Ch2 Output | X-Channel controls, to give the improved spectrum shown in Figure 3.

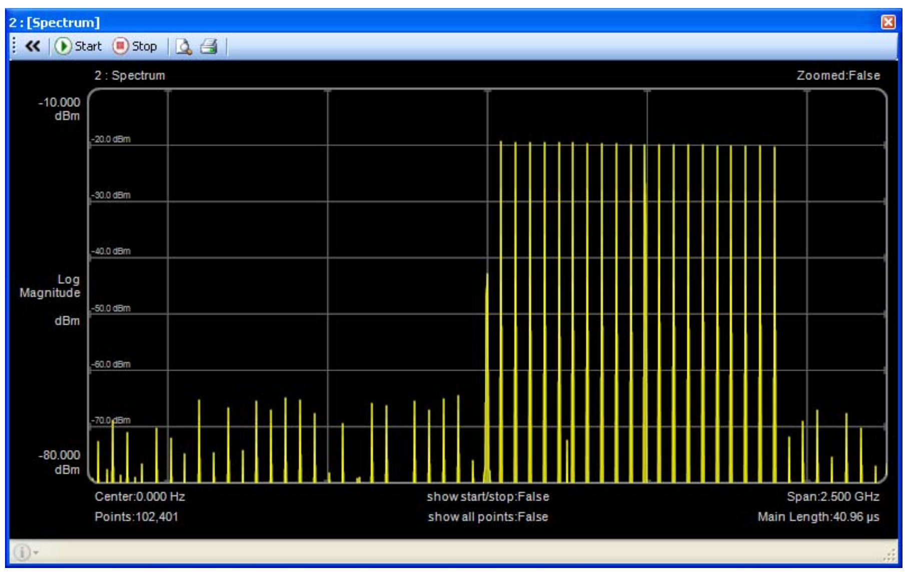

Figure 3. Multi-tone Spectrum with Manual Skew Correction.

In this simple hardware setup, we are mainly correcting for cable mismatch so a manually adjustment is practical, but for more realistic signal impairments, such as would be present in a fully modulated, up and down converted configuration, the necessary pre-corrections are complex and interactive, so the 81199A software provides an automated process.

Before we introduce the automatic pre-corrections capability, you should take some time to explore the display options.

Display Zoom

If you have a mouse with a wheel, a very useful display feature is Zooming, which enables you to quickly and easily zoom into interesting parts of the signal. Zooming is described in section 10.4.

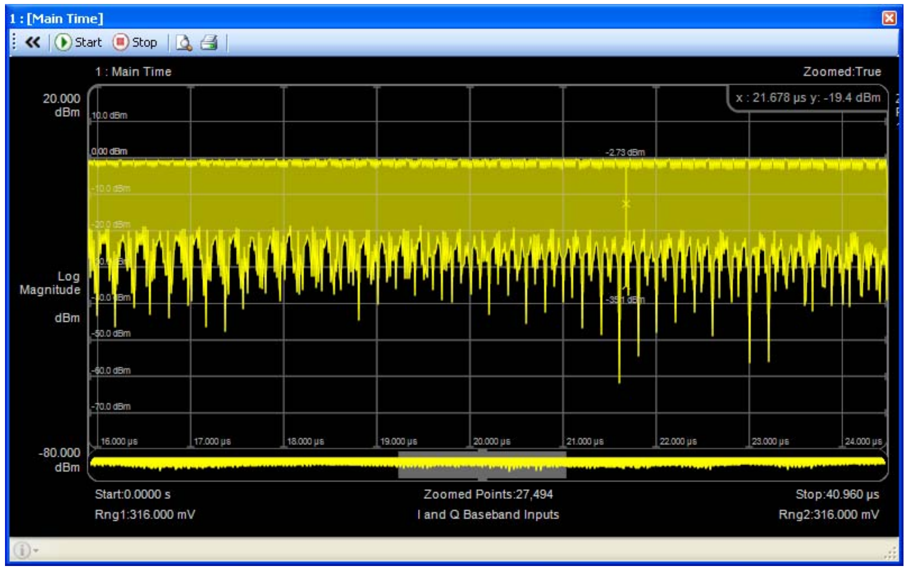

Figure 4. Main Time display with zoom active.

Display Settings

Most of the labeling on the display is active, meaning that you can double-click on the current value to select a different choice or a new value. For example in the Main Time trace you can double click on the default Y-axis Log Magnitude representation to change to, for example, Real, or Wrapped Phase. You can similarly change the units from dBm to, for example, Watts or Vrms, and you can change the ranges of both axes by double clicking on the current limits.

These features are described more fully in section 10.

4.7 Enable Pre-Corrections

In the Final Waveform Settings window, change the Calibration settings,

- Calibration Mode : Cal On Every Download
- Calibration Center Frequency : 0.000000 Hz

Then click the Generate and Output... button in the tool bar.

The software will automatically download and analyze a test signal to determine the mean channel response (magnitude and phase) and the IQ imbalance (magnitude and phase) of the end-to-end signal path from the AWG DAC outputs to the oscilloscope ADC inputs.

On completion of the calibration phase, graphs of the channel response and IQ imbalance are presented for inspection. The software offers an opinion as to whether the calibration was successful, but the outcome is so dependent on your particular hardware configuration that the final judgment is left to you.

Specific assessment criteria are discussed in section 12, but in general the old saying, "a smooth answer is a good answer" generally applies here.

The calibration algorithm also returns an estimate of the Frequency Offset and Quadrature error present in the signal path.

Figures Figure 5 and Figure 6 show measurements typical of the simple loopback setup we are using as an example.

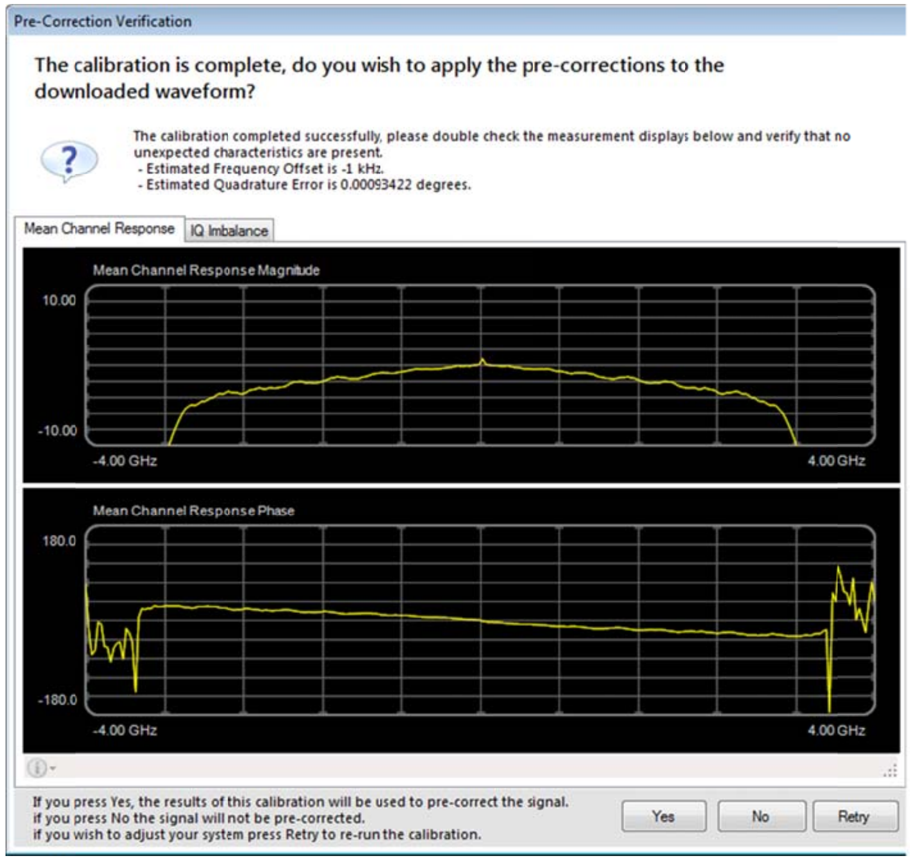

Figure 5. Measured Mean Channel Response

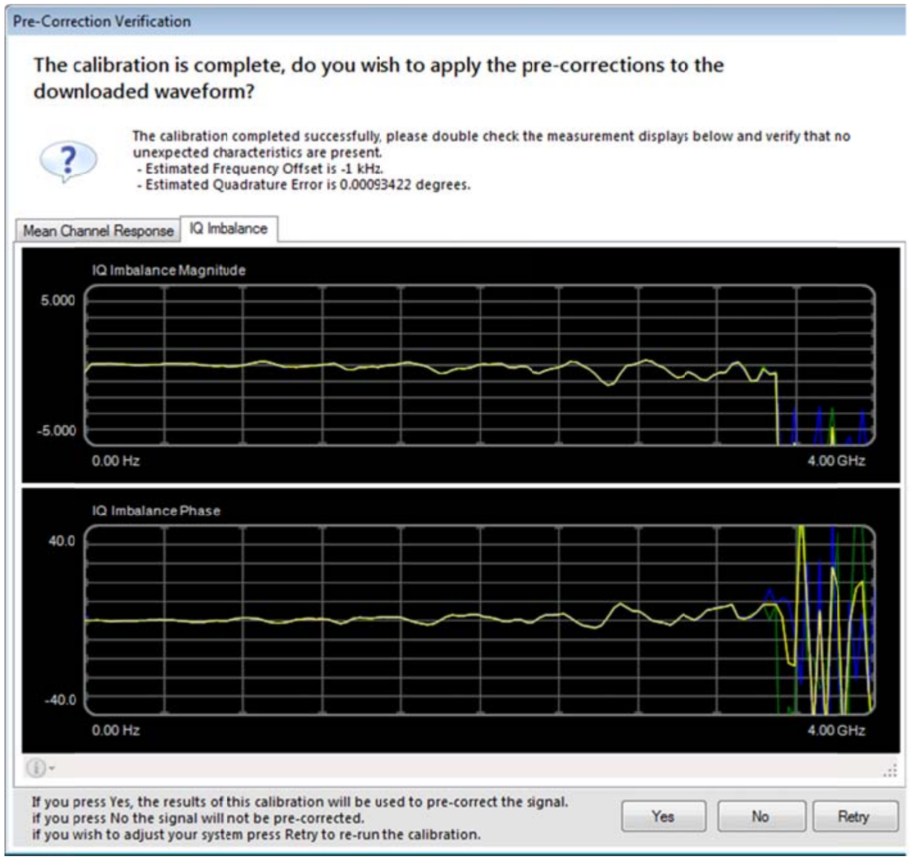

Figure 6. Measured IQ Imbalance

Assuming the calibration has been successful, click the Yes button. You can also abandon calibration by clicking No, or repeat the calibration (e.g. after making an adjustment) by clicking Retry.

When you click the Yes button, the software will calculate an appropriate pre-correction filter based on the measured responses, then apply the filter to the final waveform and download it to the M8190A.

This calibration procedure will be repeated every time you download a new waveform by clicking the Generate and Output... button.

If your hardware configuration and fundamental signal properties, such as sample rate, do not change from download to download, this represents unnecessary extra processing and time. For this situation the software provides a slightly smarter Calibration Mode setting, Cal On Settings Change, which only invokes a calibration when setting changes require it; see section 11.4.1 for details.

We have has only introduced the use of pre-correction here. See section 12 for a full description.

4.8 Create an IEEE 802.11ad Compliant Waveform

Once you can generate and receive a simple signal, such as the multi-tone, it is a relatively small step to do the same for more complex signals.

Delete the multi-tone segment from the Waveform Layout window by right-clicking on the segment label and selecting "Delete this segment instance" from the drop down menu.

Assuming that you have 81199A option IAD licensed, select the 802.11ad Segment Library window tab. If you have another waveform creation option licensed then you can likely follow a very similar procedure with that.

Drag and drop Segment 1 from the Segment Library into the Waveform Layout window by clicking on the colored box numbered 1. This action will cause the 802.11ad Segment 1 settings list to appear in the Settings Window on the left.

Leave the segment 1 settings at their default values.

4.9 Download the Waveform

Assuming that you have previously downloaded the multi-tone signal then then the output device will already have been selected and its IP address will have been set.

So that we can see later the improving effect of pre-corrections on a vector modulated signal, we turn them off initially. To do this, in the Final Waveform Settings window, set Calibration Mode to No Cal.

On the menu select Generate > Generate and Output, or click the Tool Bar Generate and Output button.

4.10 Enable Demodulation and Look at Analysis Results

Assuming that you have previously analyzed the example multi-tone signal then then the acquisition settings will already be correct for this 802.11ad signal.

To enable IEEE 802.11ad demodulation, set Demod On to True in the 802.11ad Demodulation Settings window.

To see the initial demodulation analysis results, select any of the Measurement Results windows, right mouse click on the window tab or on the title of the currently displayed measurement result, and select 802.11ad Error Summary from the drop-down menu.

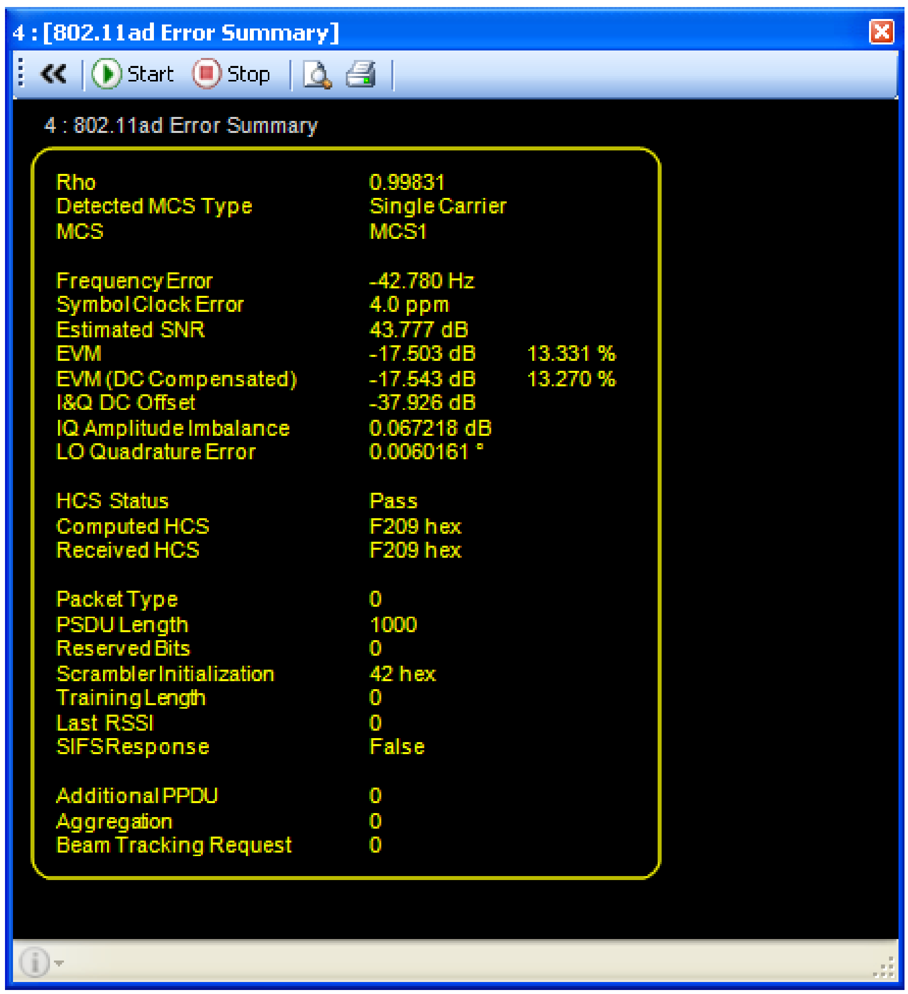

Figure 7. Initial 802.11ad Error Summary

We notice that the signal has been correctly identified as an MCS1 packet, but the EVM is surprisingly high at 13.3%.

If we right click on the result title and select 802.11ad IQ Data the reason becomes clear. The constellation points are very diffused. However, it is clearly a systematic problem rather than noise.

In fact we know from experience that this sort of constellation distortion is due to a symbol clock error. Another look at the Error Summary shows that the demodulator is reporting a Symbol Clock Error of 4.0 ppm.

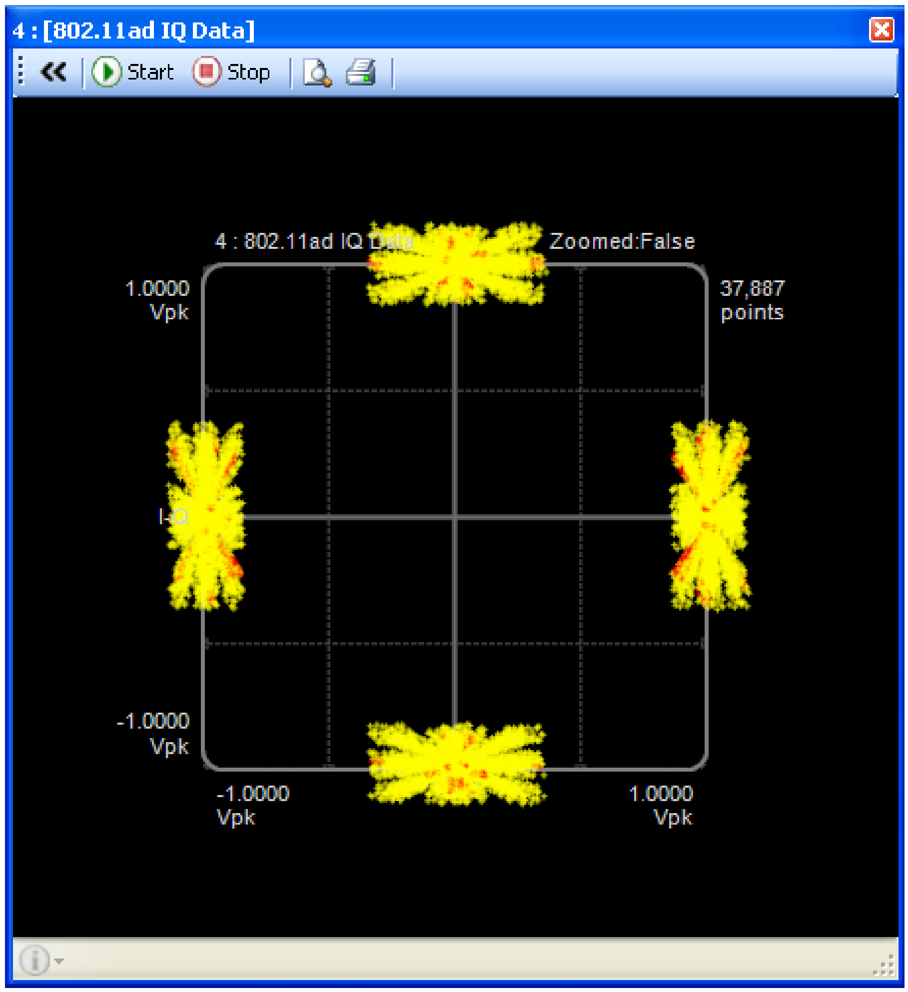

Figure 8. MCS1 Constellation with 4 ppm Symbol Clock Error

This error conveniently highlights an assumption about the test setup that you should be aware of. We are assuming that that transmitter's understanding of symbol clock frequency is exactly the same as the receiver's.

For an 802.11ad single carrier modulation they are both nominally 1.76 GHz, but the accuracy of that assumption is dependent upon the frequency references local to the transmitter (in this case the M8190A reference clock) and the receiver (in this case the 90000A/X reference clock).

If they are in fact slightly different, perhaps by just a few parts-per-million, then the receiver's understanding of symbol clock frequency will be similarly in error relative to the transmitter and this will result in a degraded EVM and constellation; as we see in Figure 7 and Figure 8.

As mentioned, the Error Summary shows that, in this case, there is a 4 ppm difference between the transmitter and the receiver's reference clocks.

Assuming that the acquisition hardware is locked to a traceable precision frequency reference, the Symbol Clock Error result provides a measure of the absolute transmitter symbol clock accuracy.

We want to measure this error (which is why it is displayed), but we would also like to correct for it (as the DUT would) so the 802.11ad demodulator has a setting in the Demodulator Settings window called Symbol Clock Offset which can be adjusted manually to match the source and destination symbol clocks Alternatively there is a similar adjustment in the Segment Settings window on the generate side.

On the test setup used to create the graphics for this guide, the demodulator Symbol Clock Offset was adjusted to -4 ppm to give a measured symbol clock error around 0.0 ppm and an EVM value of about 1.5 % EVM without further adjustment.

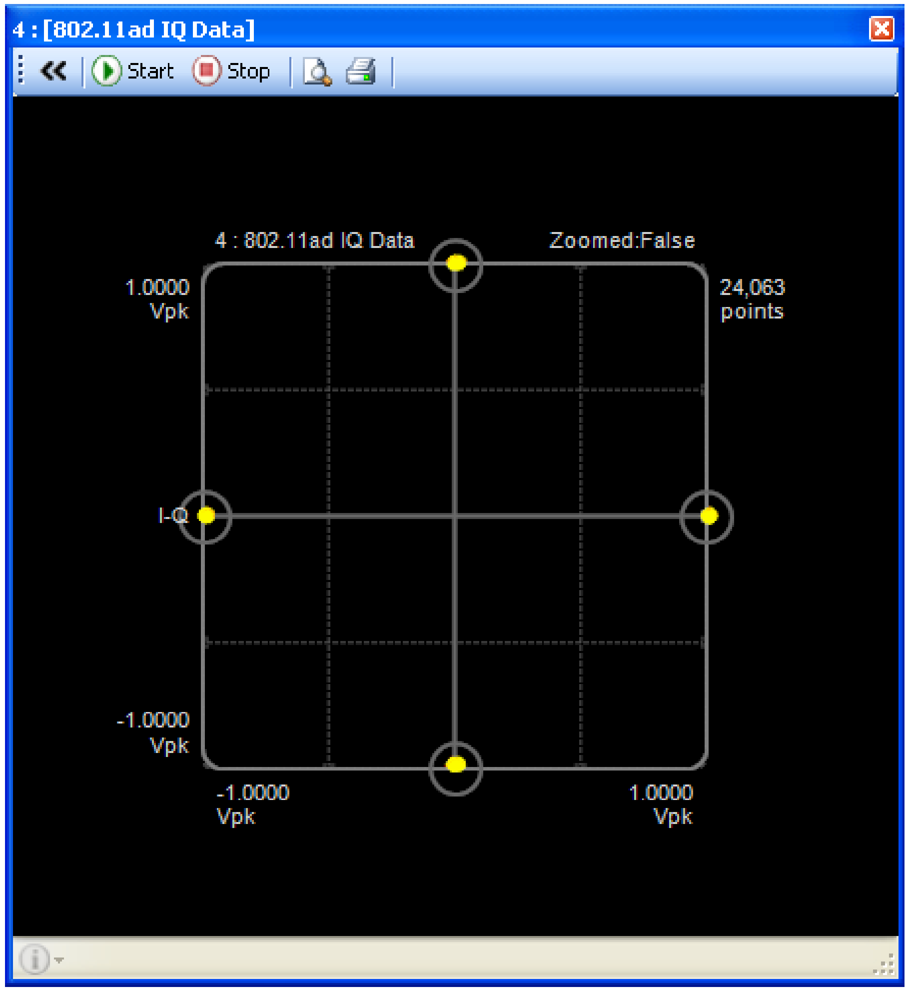

Figure 9. MCS1 Constellation after Symbol Clock Offset Adjustment

Now we can explore the benefit of pre-correcting the signal.

In the Final Waveform Settings window set Calibration Mode to Cal On Every Download and click the Generate and Output button. Once the calibration procedure has generated satisfactory channel response and IQ imbalance results, click the Yes button to compute and apply the corrections and download the waveform to the M8190A.

See section 12 for a full description of pre-correction.

On the test setup, pre-correction improved the measured EVM (DC Compensated) to less than 1.0%

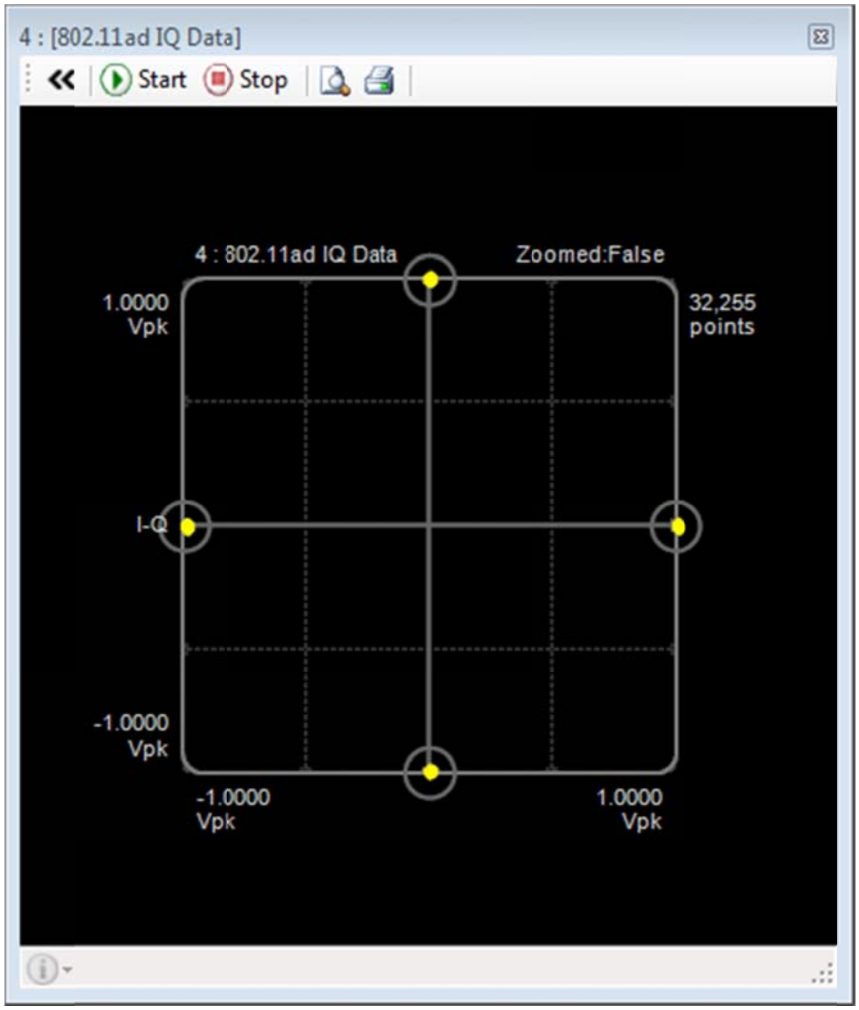

Figure 10. MCS1 Constellation with Pre-Corrections Applied

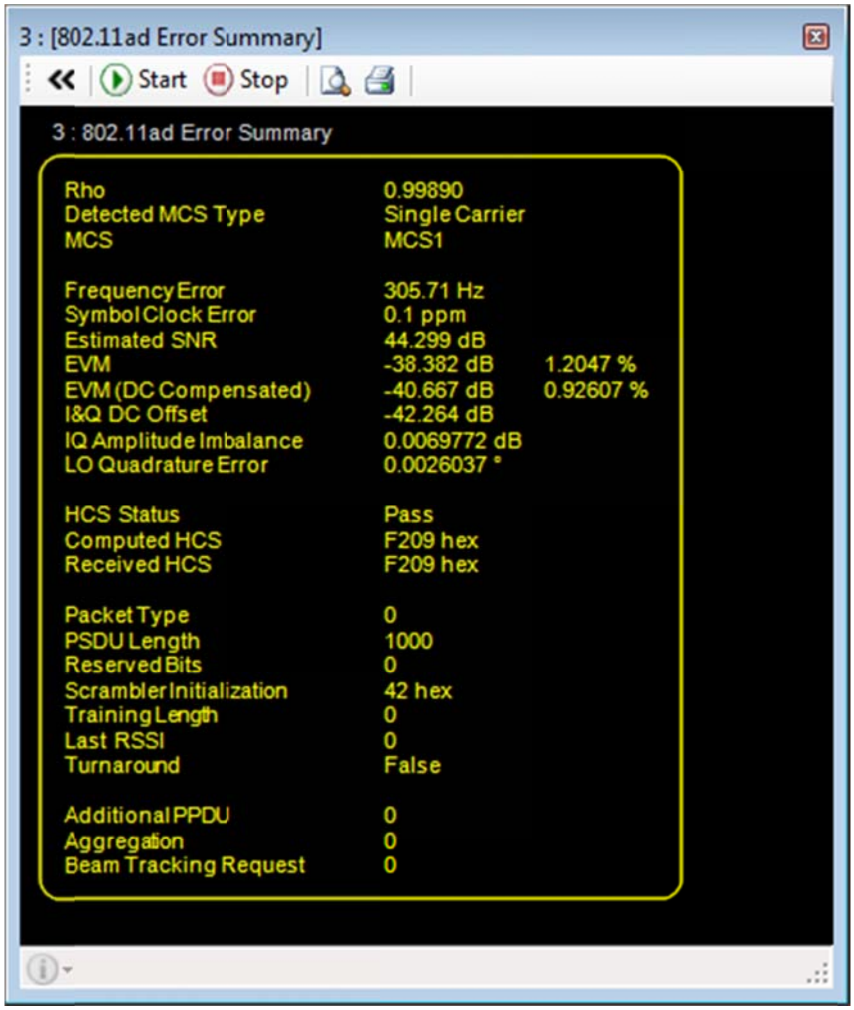

Figure 11. MCS1 Error Summary with Pre-Corrections Applied.

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5 Hardware Configuration

5.1 Introduction

This chapter provides guidance on how to configure your measurement hardware.

There are many possible test hardware configurations. The system can provide stimulus and / or analysis at the baseband IQ, IF or RF interfaces of the Device Under Test (DUT).

We will describe one possible complete hardware configuration here, and indicated where subsets and alternatives are possible. For further assistance please contact product support.

Figure 12 introduces the hardware aspects of the example test system.

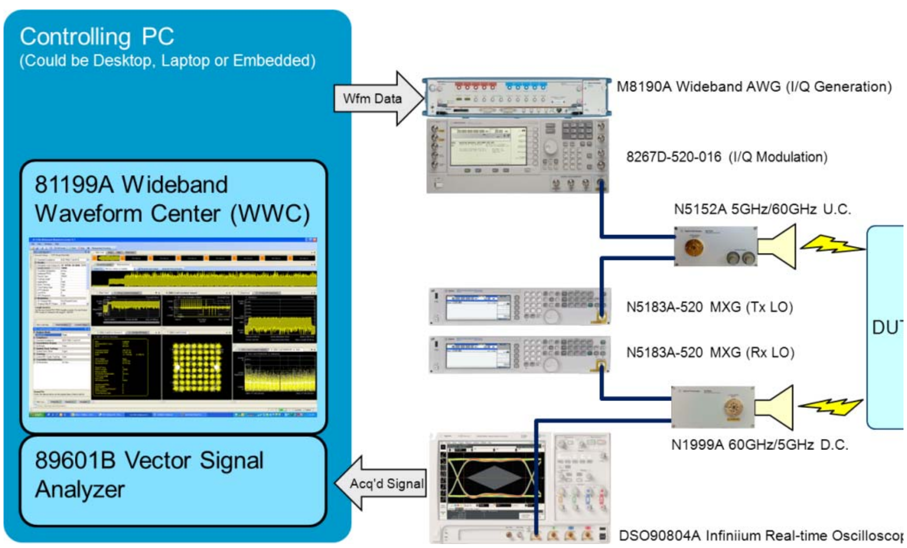

Figure 12. 81199A-based 60 GHz PHY test solution

Stimulus

Test waveforms are downloaded from the 81199A software to an M8190A or 81180B wideband AWG where they are "played" to produce differential or single-ended analog I and Q signals representing the signal as a baseband (zero IF) modulation.

The I and Q signals can be fed directly to a baseband DUT or to the wideband IQ inputs of an E8267D PSG Vector Signal Generator which can modulate the baseband signals onto an IF carrier in the range 4 to 44 GHz. If the DUT has an IF input in that range, then it can be driven by the PSG output.

If the PSG is set to generate a 5 GHz IF, then the signal can be fed to the IF input of an N5152A 5 GHz / 60 GHz Up-Converter to produce a 60 GHz RF stimulus.

Digital IF Generation

It is also possible to perform the first IF modulation in software and use a single channel M8190A to drive the N5152A directly, thus omitting the PSG. This alternative is discussed in sections 5.4.1 and 5.6.

In the example configuration, an N5183A MXG Microwave Signal Generator provides the local oscillator (LO) for the up-converter to determine which of the 4 RF channels the final modulation is delivered to.

The output of the N5152A Up-Converter is a WR-15 waveguide bulkhead to which a standard gain horn (SGH) can be attached for over-the-air stimulus of the DUT. Alternatively a V281A WR-15 to 1.85mm adapter can be used to implement a cabled connection to the DUT.

Analysis

For analysis at 60 GHz, an N1999A 60 GHz / 5 GHz Down-Converter can be tuned to the RF channel of interest by an LO. In the example configuration, an N5183A MXG Microwave Signal Generator is used to provide the LO.

The input of the N1999A Down-Converter is a WR-15 waveguide bulkhead so, as for the transmit side, either over-the-air or cabled connection to the DUT is possible.

The 5 GHz modulated IF output from the N1999A Down-Converter is digitized directly by the 90000A/X series Infiniium real-time oscilloscope. Depending on the chosen model of Infiniium oscilloscope, any IF up to 30 GHz can be acquired. Alternatively, the oscilloscope can be configured to accept differential or single-ended baseband IQ signals directly from a baseband DUT.

Digitized signal data from the oscilloscope is passed first to the 89601B VSA software and then on to the 81199A software for modulation analysis.

5.2 Waveform Generation

Test waveforms created in 81199A can be mathematically "perfect" or have quantified amounts of distortion, noise and other interferers added for test purposes.

Test waveforms can be "played" on Agilent hardware to generate a physical signal, or they can be saved to a file so that they can be, for example, streamed into a simulated DUT modeled in another software tool such as Agilent EESof SystemVue or MATLAB.

The Output Devices Tool Bar and the Current Output Device Settings window select the active output device and its settings respectively.

5.2.1 81180B

This section summarizes briefly how the 81180B can be used with the 81199A software. For a full description of the configuration and functionality of the 81180B Arbitrary Waveform Generator please refer to the 81180B User's Guide (P/N 81180-91020).

Sample Rate

The relatively limited sample rate of the 81180B (for this application) means that it can only be used to generate the baseband I and Q component signals. The complex modulation of these signals onto a first IF must be performed by an external hardware modulator such as the Agilent E8267D Performance Signal Generator with option 016 (Wideband I/Q inputs).

Connecting to the 81199A software

The 81199A software controls the 81180B by means of SCPI commands sent over LAN, therefore the computer hosting the 81199A software and the 81180B must both be connected to the same LAN.

The LAN can be anything from a corporate network to a simple cross-over cable connection. Refer to the LAN configuration section in the 81180A User's Guide for more information.

Connecting the DUT

The 81180B provides differential outputs. If the device to be connected has differential baseband I and Q inputs then connect the 81180B Out 1 and /Out 1 outputs to the device's I+ and I- inputs, and similarly connect the 81180B Out 2 and /Out 2 outputs to the device's Q+ and Q- inputs.

If the device to be connected has single-ended baseband I and Q inputs then connect the 81180B Out 1 output to the device's I input and terminate the 81180B /Out 1 output with a 50Ω load. Similarly connect the 81180B Out 2 output to the device's Q input and terminate the 81180B /Out 2 output with a 50Ω load.

The output signal quality will be degraded if the unused outputs are not terminated properly.

Settings

To select the output device; on the menu, select Generate > Output Device and choose "Agilent 81180B AWG".

If you have the older 81180A model, then you should choose "Agilent 81180A AWG". This will ensure that the maximum sample rate is set to 4.2 GHz for the 81180A rather than 4.6 GHz for the 81180B.

Once the output device has been selected, the Instrument Address and Socket Port Number should be set in the Current Output Device Settings window. Set the Instrument Address setting to the IP address of the 81180B and set the port number to 5025.

The 81199A software cannot control the 81180B over USB.

The Current Output Device Settings window also allows you to set the required output configuration (coupling, amplitude, DC offset, skew etc.). The 81180B will be set to these values every time a waveform is downloaded.

5.2.2 M8190A

This section summarizes briefly how the M8190A can be used with the 81199A software. For a full description of the configuration and functionality of the M8190A Arbitrary Waveform Generator product please refer to the M8190A User's Guide (P/N M8190-91030).

Sample Rate

The high sample rate of this product means that it is possible to generate a complex-modulated first IF directly.

The maximum possible IF depends upon the selected mode (Speed or Precision), the modulation bandwidth of the signal, and the 5 GHz analog bandwidth of the M8190A output amplifier.

So, for example, an IEEE 802.11ad signal could be modulated onto a 3.5 GHz IF in Speed Mode, or a 2.0 GHz IF in Precision Mode.

The relatively low frequencies of these IFs makes image free up conversion more challenging, but avoids the expense and imperfections of a hardware modulator. This is described more fully in sections 5.4.1 and 5.6.

Connecting to the 81199A software

The M8190A is a modular product, typically hosted in a 2 or 5-slot AXIe rack.

The M8190A must be controlled by a PC-based application that serves as the product's firmware to provide a remote control interface that translates SCPI commands to low-level hardware control. The M8190A firmware can reside on an embedded controller in the same AXIe rack as the M8190A module or on an external PC connected to the AXIe rack using a PCIe extender cable.

The 81199A software controls the M8190A by means of SCPI commands sent over LAN, therefore the computer hosting the 81199A software and the computer hosting the M8190A firmware must both be connected to the same LAN.

The LAN could be anything from a corporate network to a simple cross-over cable connection. It is also possible for the 81199A and M8190A software to reside on the same computer and communicate via the localhost (127.0.0.1) IP address. Refer to the M8190A User's Guide for more information.

Connecting the DUT

The M8190A provides differential outputs. If the device to be connected has differential baseband I and Q inputs then connect the M8190A Channel 1 DIRECT OUT and /DIRECT OUT outputs to the device's I+ and I- inputs, and similarly connect the M8190A Channel 2 DIRECT OUT and /DIRECT OUT outputs to the device's Q+ and Q- inputs.

If the device to be connected has single-ended baseband I and Q inputs then connect the M8190A Channel 1 DIRECT OUT output to the device's I input and terminate the M8190A Channel 1 /DIRECT OUT with a 50Ω load. Similarly connect the M8190A Channel 2 DIRECT OUT output to the device's I input and terminate the M8190A Channel 2 /DIRECT OUT with a 50Ω load.

Warning: The output signal quality will be degraded if the unused output is not terminated properly.

You may also (optionally) provide an external frequency reference to the REF CLK IN input.

Settings

A fully optioned M8190A (-12G, -14B and -DUC) has six distinct hardware modes of operation.

In 81199A, for simplicity, each M8190A mode is treated as a logically separate output device because the mode choice significantly alters the configuration of the M8190A in terms of valid sample clock range, data precision and data download format.

In addition, there is a mode in which the M8190A is configured to drive an N5152A 5 GHz / 60 GHz up-converter. This particular hardware combination is made considerably easier to configure and use by treating is as a special case composite device.

So there are seven M8190A output modes listed as separate "devices",

- Agilent M8190A AWG – Precision Mode (14 bit, 8 GHz)
- Agilent M8190A AWG – Speed Mode (12 bit, 12 GHz)
- Agilent M8190A/N5152A
- Agilent M8190A AWG – DUC Mode (x3 Interpolation)
- Agilent M8190A AWG – DUC Mode (x12 Interpolation)
- Agilent M8190A AWG – DUC Mode (x24 Interpolation)
- Agilent M8190A AWG – DUC Mode (x48 Interpolation)

If the M8190A does not have option DUC installed, only the first three modes will be listed.

The digital up-conversion (DUC) modes (and specifically the x3 interpolation mode) can support a maximum IQ sample rate of 2.4 GSa/s. This does not quite meet the requirements for 802.11ad signal generation, so digital up-conversion modes will not be considered further in this introduction.

The most appropriate mode for 802.11ad signal generation is the Precision mode, with up to 8 GHz sample rate and 14 bit sample resolution, so select this as the output device. On the menu, select Generate > Output Device and choose "Agilent M8190A AWG – Precision Mode (14 bit, 8 GHz)".

The special M8190A/N5152A mode is described separately in section 5.4.1.

Once the output device has been selected, the Instrument Address and Socket Port Number should be set in the Current Output Device Settings window. Set the Instrument Address setting to the IP address of the computer hosting the M8190A firmware and set the port number to 5025.

The 81199A software cannot control the M8190A over USB.

The Current Output Device Settings window also allows you to set the required output configuration (coupling, amplitude, DC offset, skew etc.). The M8190A will be set to these values every time a waveform is downloaded.

M8190A and 81199A on the same PC

As mentioned above (Connecting to the 81199A software) the 81199A and M8190A software may reside on the same computer and communicate via the localhost (127.0.0.1) IP address.

In this configuration, where two applications are sharing the same computer and hence the same LAN interface, it is important to understand the role of LAN socket ports, especially if you wish to programmatically control the 81199A software using SCPI commands.

Agilent instruments and remotely controllable applications, by default, listen on LAN socket port 5025 for SCPI commands.

When the M8190A firmware is started it will take ownership of LAN port 5025 unless another application has already claimed the port.

If another application has possession of port 5025, then the M8190A software will have no SCPI access via sockets, and consequently the 81199A software (or any other application that uses SCPI over sockets) will not be able to connect to the M8190A.

Ironically, the most likely application to prevent the M8190A from using port 5025 is the 81199A software itself.

In anticipation of being remotely controlled the 81199A will also, by default, take ownership of LAN socket port 5025 for SCPI commands, if the port is available.

This is why, in this shared computer configuration, the M8190A firmware must be started before the 81199A software. This sequence ensures that the M8190A firmware gets port 5025 and hence is controllable by 81199A.

81199A Remote Control

If you wish to remotely control the 81199A software in a shared computer configuration, then you must move the M8190A to a different socket port so that the 81199A can claim port 5025 for SCPI control. This is achieved by means of an M8190A command line switch. For example, to change to socket port 5022, run the M8190A firmware using the command line,

AgM8190Firmware.exe /s 5022 /t -1 /i -1

The full list of M8190A firmware command line switches is given on page 92 of the M8190A User's Guide (P/N M8190-91030).

You must also configure the alternative socket port number into the 81199A software by entering the new value as the Socket Port Number setting in the M8190AP and/or M8190AS Current Output Device Settings windows.

5.2.3 File Output

If the current output device is set to "File (csv, binary or matlab)" then the generated waveform data can be saved to a file on the host computer.

For file data, the maximum sample rate is not limited by hardware, so for internal coding purposes a nominal limit of 5 GHz is set. Within this limit, the auto sample rate algorithm will choose the most appropriate sample rate for the generated waveform. If a higher sample rate is needed, then this nominal limit can be over-ruled by using the manual sample rate setting.

The output files are unencrypted and can be formatted in various ways to facilitate their import into other Agilent and non-Agilent tools.

Output to all supported Agilent AWGs is standard as part of 81199A option 001 functionality but file output is separately licensed as 81199A option DFP.

5.3 Waveform Acquisition

When underpinned by Agilent's 89601B Vector Signal Analyzer application, the 81199A application also provides comprehensive standards compliant modulation and coding analysis of physical signals acquired at baseband, IF or RF. It can also analyze synthesized or pre-recorded signals read from file, to permit use in a simulation environment.

The 81199A software always takes its data for analysis from the subordinate instance of the 89601B Vector Signal Analyzer software in order to immediately take advantage of the wide range of acquisition platforms already supported by that tool.

So the waveform acquisition mechanism is configured in the 89601B, the acquired calibrated time records are extracted from the 89601B into 81199A using the 89601B's COM-based API.

Currently the only Agilent products with sufficient acquisition bandwidth to capture a very wideband modulated signal in real time are members of the Agilent range of Real-Time Oscilloscopes.

5.3.1 90000A Series Oscilloscope

The Agilent Infiniium 90000A Series real time oscilloscopes can be used to acquire complex baseband (I + jQ) or modulated IF signals.

The 90000A Series oscilloscope range offers a variety of bandwidths and the right choice depends on the DUT configuration.

For complex baseband acquisition only, an entry level model (2.5 GHz) is sufficient. If you also want to acquire the 5 GHz IF from the N1999A 60 GHz / 5 GHz block down-converter, then the DSO 90804A is recommended.

To acquire IF signals at higher frequencies then the carrier frequency and modulation bandwidth will determine the appropriate model.

Connecting the DUT

If the device to be connected has single ended baseband I and Q outputs then connect the device I output to the 90000A series Channel 1, and connect the device Q output to Channel 3. In the 81199A Acquisition Settings window set Channel Config to I and Q Baseband Inputs.

If the device to be connected has differential baseband I and Q inputs then you have two choices.

Differential connection using probes

You can use probe amplifiers fitted with differential probe heads such as the 1169A / N5380A combination, in which case the 81199A configuration is the same as for single ended operation because the probes convert the differential signals to single ended signals into the oscilloscope.

Differential connection using cables

Or you can use the differential input capability of the oscilloscope. The configuration of the equipment is a little more complicated and has some documented limitations, but it permits a simpler connection to the DUT.

First connect the device to the 90000A series oscilloscope as follows,

- Device I+ output to oscilloscope Channel 1,
- Device I- output to oscilloscope Channel 3,
- Device Q+ output to oscilloscope Channel 2,
- Device Q- output to oscilloscope Channel 4.

In the 81199A Acquisition Settings window, select the Advanced tab to reveal the 89600 State setting and set it to Visible. This will make the GUI of the underlying 89601B VSA instance visible.

The 89601B VSA GUI is usually hidden because, in general, making changes to the 89601B settings directly will create conflicts with the 81199A state; however, there are some advanced settings which can safely be changed.

On the 89601B VSA GUI, select Input > Channels > Custom. The dialog box should show that VSA Logical Channel 1 is enabled, the operator should be I+jQ and Inputs 1 and 2 sources should be shown as Ch1 and Ch3 respectively. This is the default setting for the I+jQ channel configuration.

Use the drop-down list to change Input 2 to come from Ch2. (rather than Ch3) and click OK.

On the 89601B VSA GUI, select Input > Extensions and double-click on the UserSCPIPreset text field. In the dialog box, enter

:CHAN1:DIFF ON;:CHAN2:DIFF ON

and click OK.

This will sent the SCPI command string to the oscilloscope, which will have the effect of putting channels 1 and 2 into differential mode so that Ch1 = Ch1-Ch3 and Ch2 = Ch2-Ch4. You can confirm that the oscilloscope is in the correct mode by noting that channels 1 and 2 are active and are labeled on screen as [1-3] and [2-4] (rather than [1] and [2]).

These settings will be retained by an 81199A setup save/recall and will not be reset unless you change the Channel Config setting in the 81199A software.

There are known limitations with this configuration,

1. The overload indicator in the 81199A / 89601B will not be accurate.
2. The input ranges on the scope channels used to form the differential channel are coupled and cannot be set independently.
3. The differential hardware channel from the scope cannot be explicitly assigned to a particular VSA channel.
4. Channel triggering occurs on a non-differential scope channel and not on the differential channel.

Connecting to the 81199A software

The oscilloscope is not connected directly to the 81199A software; instead it is configured in the 89601B VSA software.

Setting up and using the Infiniium Oscilloscope is described in the application note Agilent Infiniium Oscilloscopes with 89600B VSA Software (P/N 5990-6819EN).

The 81199A software will look for and run an instance of the 89601B VSA software, which, in turn, will connect to the configured hardware (which may be any device of sufficient bandwidth that is supported by the 89601B VSA software, not just oscilloscopes).

If you recall an 81199A setup file, then a matching 89601B setup file will be recalled at the same time.

5.3.2 90000X Series Oscilloscope

The Agilent Infiniium 90000X Series real time oscilloscopes can be used to acquire complex baseband (I + jQ) or modulated IF signals. In particular, to acquire IF signals at frequencies beyond the range of the 90000A series oscilloscopes.

The IF carrier frequency and modulation bandwidth will determine the appropriate model.

Connecting the DUT

The options for connecting to the DUT are the same in principle as for the 90000A series oscilloscopes.

Because of the frequency range of the 90000X series oscilloscopes, the probe connectors on the front panel are 3.5mm threaded RF connectors instead of the precision BNC connectors on the 90000A series and consequently the probe accessories are also different.

However, for lower frequencies, the N5442A BNC adapter can be used to simplify the connection of BNC probes and cables.

Connecting to the 81199A software

The oscilloscope is not connected directly to the 81199A software; instead it is configured in the 89601B VSA software.

Setting up and using the Infiniium Oscilloscope is described in the application note Agilent Infiniium Oscilloscopes with 89600B VSA Software (P/N 5990-6819EN).

5.3.3 File Input

The 89601B VSA software can read data from "recordings", which are simply data files containing sampled baseband or IF waveforms.

As a consequence, the 81199A can also analyze data from a file.

These signal data could have come from alternative acquisition hardware, or a previous recording taken with Agilent hardware. They could also be the output of a device simulation in Agilent EESof SystemVue or MATLAB, or from an 81199A generated waveform file.

5.4 RF Modulation and Up-Conversion

vector modulation

In the example hardware configuration we have used the E8267D PSG Vector Signal Generator fitted with option 016 (Wideband External I/Q Inputs) to modulate the complex I + jQ signals from the M8190A onto a first IF.

Depending on the chosen frequency range option of the E8267D, this first IF can be at any frequency from 3.2 GHz to 44 GHz.

The recommended drive level for the E8267D wideband I/Q inputs is 0 dBm.

For an IEEE 802.11ad single carrier modulation this level can be achieved by selecting the M8190A DC amplifier output, driving the E8267D differentially, and setting the M8190A output amplitude to 820mV.

For further information about the E8267D PSG please consult the data sheet (P/N 5989-0697EN).

up-conversion

If the E8267D PSG or an equivalent vector modulator is set to produce a first IF at 5.0 GHz then the N5152A 5 GHz / 60 GHz Up-Converter can be used to translate the signal to the 60 GHz band.

To deliver the best CW performance, the PSG employs band filtering, which unfortunately introduces a gain slope when modulating a very wideband signal onto a 5 GHz carrier. However, you can easily force the PSG firmware to select the next overlapping filter band (which has a much flatter response) by incrementing the RF frequency by 1 Hz to 5.000000001 GHz.

The center frequency of the up-converter output is determined by the local oscillator frequency according to the equation

$$F_{LO} = (F_{CHAN} - 17.5\ \text{GHz}) / 4.0$$

For the ITU approved 60 GHz channelization, the LO frequencies are as listed here,

- Channel 1 : FC = 58.32GHz, FLO = 10.205 GHz
- Channel 2 : FC = 60.48GHz, FLO = 10.745 GHz
- Channel 3 : FC = 62.64GHz, FLO = 11.285 GHz
- Channel 4 : F_C = 64.80GHz, F_{LO} = 11.825 GHz

In the example configuration, for maximum flexibility, the LO is provided by an N5183A MXG Analog Signal Generator, however any low phase noise 10 GHz to 12 GHz source will serve this purpose.

A procedure for configuring the operating point of the N5152A to maximize signal to noise ratio and minimize signal distortion is described in the N5152A manual (P/N N5152-90001).

5.4.1 The M8190A/N5152A Special Mode

For reasons explained in section 5.6, the M8190A output driver provides a special mode which configures the 81199A software and M8190A to produce a digitally modulated first IF at 5 GHz that is suitable for direct connection to an N5152A 5 GHz / 60 GHz wideband up-converter.

We will describe here only how to test this special mode in loopback for verification purposes. To use the mode in practice, you should use the same up-converter / down-converter setup as is described in the preceding sections.

Configure the Hardware

The M8190A provides differential outputs. In this mode we are using the Direct output single ended so connect the M8190A Channel 1 DIRECT OUT to oscilloscope channel 1. Terminate the M8190A Channel 1 /DIRECT OUT with a 50Ω load.

Configure the Software

Drag and drop Segment 1 from the Segment Library into the Waveform Layout window by clicking on the colored box numbered 1. This action will cause the 802.11ad Segment 1 settings list to appear in the Settings Window on the left.

Accept the segment 1 default settings.

On the menu select Generate > Generate and Output, or click the Tool Bar Generate and Output button.

In the Acquisition Settings window, click the "Basic" button to select the simpler settings list, then change (if necessary) the settings to,

- Channel Config : 1 Channel (always change this setting first because it resets the center and span values)
- Center : 5.000 000 000 GHz
- Span : 2.500 000 000 GHz
- Points : 102,401
- Mirror Freq: True
- Main Length : 40.000000000 μs

Mirror frequency is set to True because the signal we are receiving in this special mode is the lower side-band modulation image around the sampling clock, which is spectrally inverted.

Evaluate the Signal

To enable IEEE 802.11ad demodulation, set Demod On to True in the 802.11ad Demodulation Settings window.

To see the initial demodulation analysis results, select any of the Measurement Results windows, right mouse click on the window tab or on the title of the currently displayed measurement result, and select 802.11ad Error Summary from the drop-down menu.

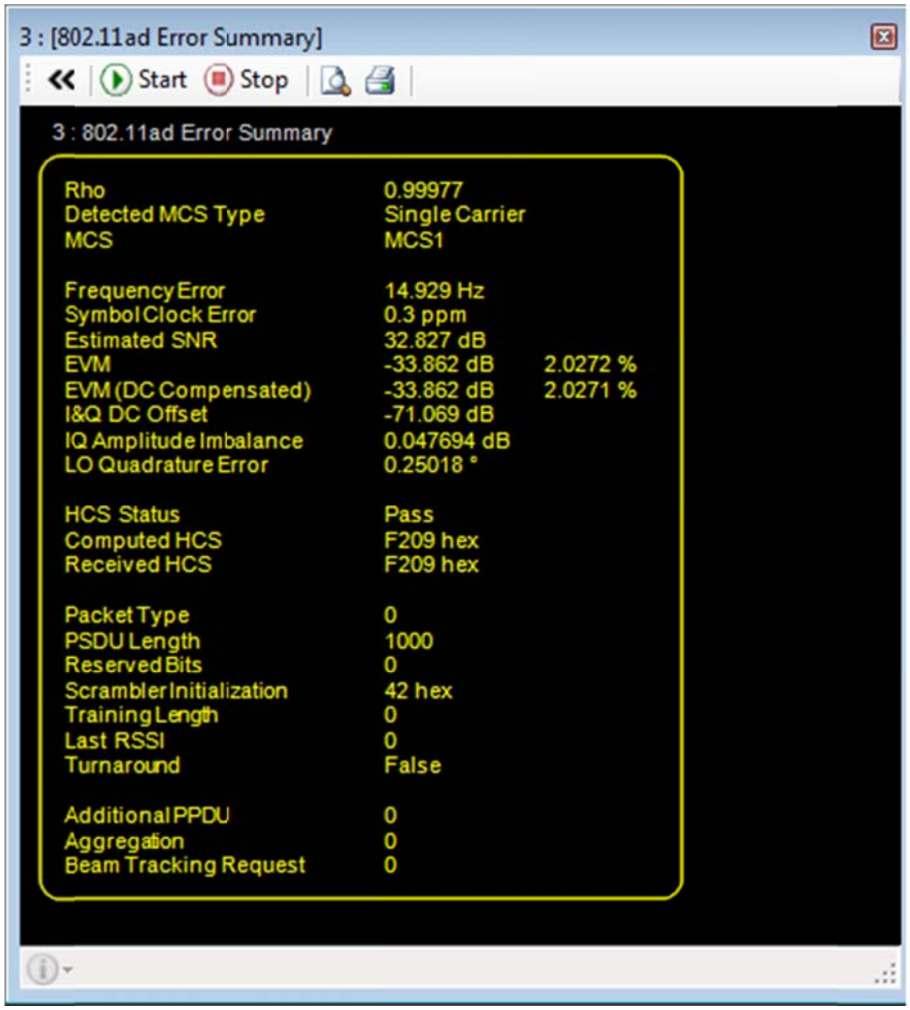

Figure 13. Initial 802.11ad Error Summary for M8190A/N5152A Mode

The signal has been correctly identified as an MCS1 packet and the EVM is reported as 2.03%. As was discussed in section 4.10, if the EVM is worse than expected examine the IQ constellation for clues. A common cause of poor EVM is symbol clock error.

If we look at the 802.11ad channel frequency response we see that the generated signal is not quite flat. This can be addressed by using pre-corrections.

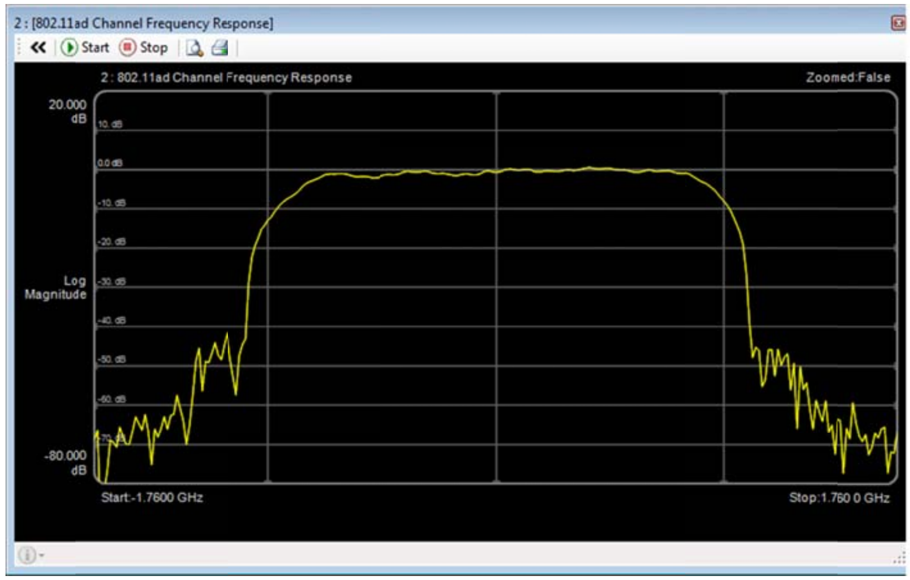

Figure 14. Raw Channel Response in M8190A/N5152A Special Mode

To pre-correct the non-flatness, in the Final Waveform Settings window configure the following settings

- Calibration Mode : Cal On Every Download
- Calibration Center Frequency : 5.000000 GHz

and click the Generate and Output button. Once the calibration procedure has generated satisfactory channel response and IQ imbalance results, click the Yes button to compute and apply the corrections and download the waveform to the M8190A.

You may find that applying pre-corrections appears to slightly degrade the EVM (on the test setup, the EVM grew from 2.03% to 2.16%). This can happen if the pre-corrections filter has had to alter the overall transmitted power in order to correct the non-flatness. In this case you should re-autorange the receiver by clicking the autorange button in the top right of the toolbar.

On the test setup, this improved the measured EVM to 1.93% and the channel response is now flat to within a few tenths of a dB.

Another point of note is that in this mode, you can see from Figure 15 that the estimated SNR and the EVM have almost the same magnitude (ignoring the sign difference) which suggests that in this mode the EVM performance is noise limited to around 2%.

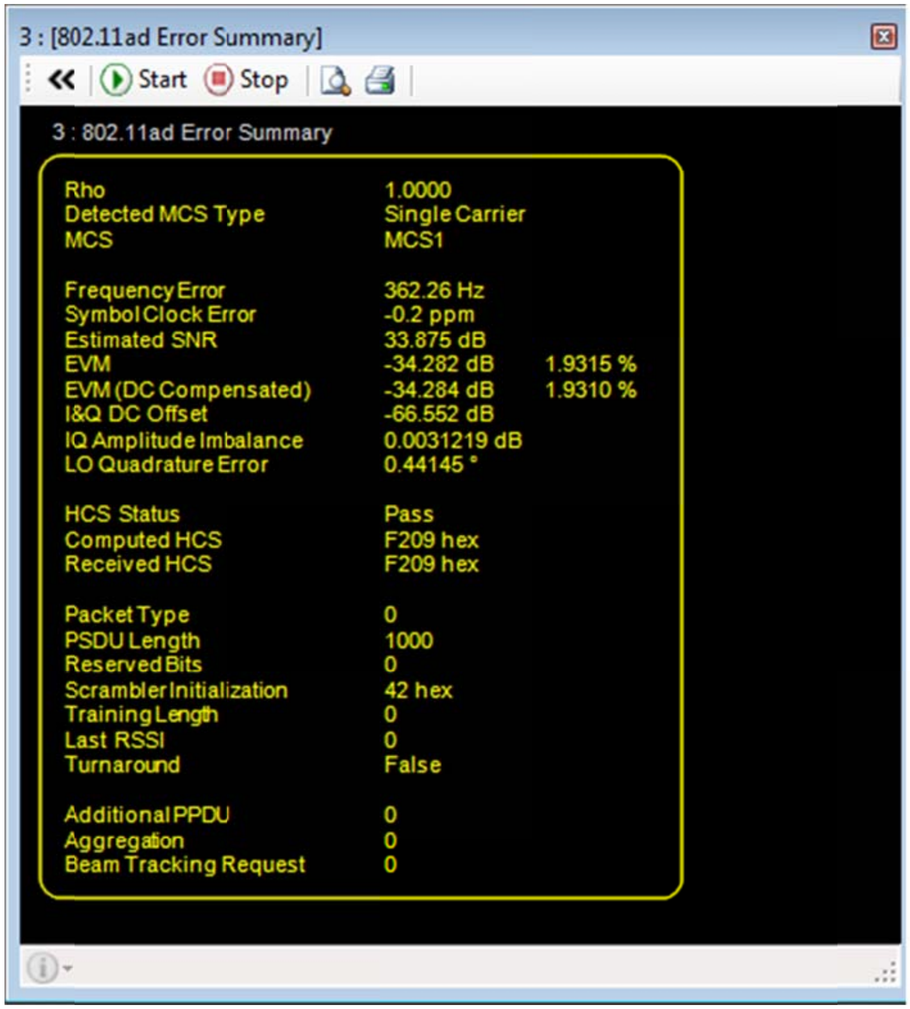

Figure 15. Final 802.11ad Error Summary for M8190A/N5152A Mode

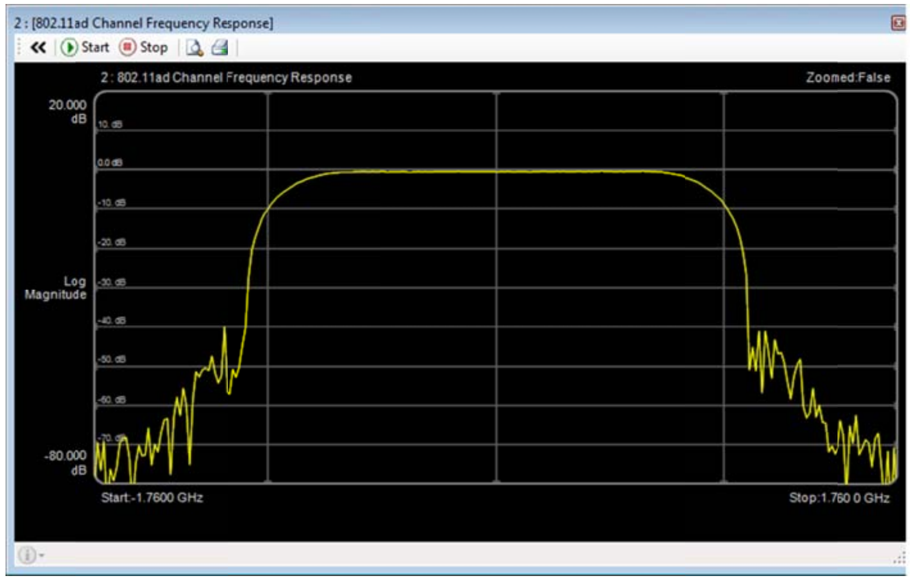

Figure 16. Corrected Channel Response in M8190A/N5152A Special Mode

5.5 Down-Conversion

For intermediate frequencies up to 30 GHz, the signal can be digitized directly by the appropriate choice of Infiniium oscilloscope.

For signals in the 60 GHz band, the N1999A 60 GHz / 5GHz down-converter can be used to translate the signal down to a common IF of 5 GHz, which can be digitized by, for example, a DSO90804A oscilloscope.

The local oscillator frequency is determined by the desired center frequency of the down-converter input according to the equation

$F_{LO} = (F_{CHAN} – 5\ GHz) / 4.0.$

For the standard 60 GHz channelization, the LO frequencies are as listed here,

- Channel 1 : F_{CHAN} = 58.32GHz, F_{LO} = 13.33 GHz
- Channel 2 : F_{CHAN} = 60.48GHz, F_{LO} = 13.87 GHz
- Channel 3 : F_{CHAN} = 62.64GHz, F_{LO} = 14.41 GHz
- Channel 4 : F_{CHAN} = 64.80GHz, F_{LO} = 14.95 GHz

In the example configuration, for maximum flexibility, the LO is provided by an N5183A MXG Analog Signal Generator, however any low phase noise 13 GHz to 15 GHz source will serve this purpose.

A procedure for configuring the operating point of the N1999A to maximize signal to noise ratio and minimize signal distortion is described in the N1999A manual (P/N N1999-90001).

5.6 Digital IF Generation

Hardware generation

If your M8190A includes the digital up-conversion (DUC) option then you can configure the M8190A to modulate the complex baseband (IQ) waveform data from 81199A onto an arbitrary IF carrier.

This capability has two key advantages.

1. The modulation is performed digitally in hardware using carrier values generated by a highly agile hardware synthesizer. The resulting modulated signal is not only free of the many impairments typically associated with analog vector modulation, but its amplitude, phase and frequency can be switched with great precision in real time.
2. The 81199A need only generate waveform samples at the modulation symbol rate, leaving the M8190A to interpolate the data in hardware (by the selected factor) prior to digital modulation. This can significantly reduce the amount of waveform data that needs to be downloaded, and makes more efficient use of the sample memory.

However, in DUC mode, the DAC rate is limited to a maximum of 7.2 GSa/s and the minimum interpolation factor (which necessary to avoid aliasing) is 3. This means that the maximum modulation sample rate supported is 7.2 / 3 = 2.4 GSa/s.

For modulations with sample rates up to 2.4 GSa/s, DUC mode is the best solution.

When the 81199A software is in Precision or Speed mode, the real part of the complex waveform is downloaded to M8190A channel 1, and the imaginary part is downloaded to M8190A channel 2.

When the 81199A software is in one of the DUC modes, the real and imaginary parts of the complex waveform are time interleaved and downloaded to M8190A channel 1. The same interleaved data is then also downloaded to M8190A channel 2 (if it is installed). Since the digitally generated IF can have a different frequency in each channel it is possible to output the same signal on two different IFs.

These default behaviours can be modified by altering the Download to... settings in the Current Output Device Settings window.

Software Generation

The 81199A software can be configured to offset (from zero) the center frequency of each track by software modulating the track waveform data.

This capability is intended to permit the creation of a single baseband waveform that contains multiple narrower-band modulations at different offset frequencies within the composite waveform's bandwidth

.

Software modulation is achieved by setting the Track <n> Offset Frequency in the Final Waveform Settings window to a non-zero value, subject to the limitation,

Maximum Offset = (Max Sample Rate / 2.56) – (0.5 x Occupied Bandwidth)

Using an M8190A, even in 12 GHz sampling "Speed Mode", the maximum recommended offset for a 2 GHz occupied bandwidth modulated signal is about 3.69 GHz.

Maximum Offset = (12 GHz / 2.56) – (0.5 x 2 GHz) = 3.69 GHz

Also, remember that, signal energy is not only present at $F_{OFF.}$ Due to sampling, there is also signal energy at ($F_S \pm F_{OFF}$, $2F_S \pm F_{OFF}$, and so on). Normally these sampling images are removed by a low-pass reconstruction filter but they must be considered when setting offset frequencies to ensure that no aliasing occurs.

The track frequency offset capability is not intended to permit the creation of a modulated signal that has no spectral content near DC (e.g. so that the I channel output only could be used directly as an IF signal).

This is because the pre-corrections calibration procedure, which is applied to the final composite waveform, always corrects the entire baseband bandwidth. Hence the pre-corrections calibration signal always extends from $-F_S/2$ to $+F_S/2$ and must be applied prior to any conversion to an IF or aliasing will occur.

We have already noted that the M8190A hardware DUC modes are unsuitable for 802.11ad up-conversion, and here we have also determined that track offsets cannot be used to modulate an 802.11ad signal on to a first IF in software if pre-corrections are required.

Fortunately, the M8190A output driver provides a special mode which addresses these concern by forcing a waveform generation sample rate of 3 GHz, applying software up-conversion (after pre-correction filtering) to a fixed IF of 1.67 GHz then using the M8190A in doublet mode at a sample rate of 6.67 GHz to produce a first IF at 5 GHz (the lower sideband of the 1.67 GHz images around Fs)

This signal is spectrum inverted and is not image free, however, the N5152A also contains a spectrum inversion due to a high-side mix and a band-pass filter which will remove the unwanted images, thus giving the desired signal in the 60 GHz band

6 Menu

6.1 Introduction

This chapter describes the functions available via the main 81199A menu.

6.2 File

The file menu allows you to save and open configuration setups, load recordings, and print measurement result screens.

6.2.1 Save Setup

To save the current 81199A setup select File > Save Setup and enter a name for the setup save files.

The save setup process creates three files which together constitute the saved state of the application,

- <filename>.wwcsetup
- <filename>.wwcsetup.89600.settings
- <filename>.wwcsetup.window.settings

In the file dialog you only name the <filename>.wwcsetup file, the other two are automatically named and created.

6.2.2 Open Setup

To open and restore a saved 81199A setup, select File > Open Setup and select the required .wwcsetup file.

The saved setup comprises three files which together constitute the saved state of the application,

- <filename>.wwcsetup
- <filename>.wwcsetup.89600.settings
- <filename>.wwcsetup.window.settings

In the file dialog you only select the <filename>.wwcsetup file; the other two are automatically identified.

6.2.3 Preset Setup

To load the preset setup, which returns all the 81199A settings to their default state, select File > Preset Setup.

6.2.4 Auto-Load Last State

If this menu item has a check mark beside it, then the 81199A software will save its state when it is closed and will use this saved state when it is next run, to automatically resume with the same settings.

The check mark can be toggled on and off by selecting File > Auto Load Last State.

In general, this feature should not be used if you intend to make hardware configuration changes between runs, as the recalled state may no longer be appropriate.

6.2.5 Open Recording

When the 81199A analysis option is enabled (option 002) it is possible to use the underlying 89601B VSA software to read data from recording files and analyze them as if they were a live signal.

Recordings are files containing sampled baseband or IF waveform data.

They can be data captured by the same or alternative acquisition hardware, at an earlier time or different location.

They can be the output of a device simulation in Agilent EESof SystemVue or MATLAB, or from an 81199A generated waveform file.

Recordings are useful for many purposes. For signal archiving, regression testing, and in providing debug assistance by permitting remotely located experts to analyze recordings of problem signals.

To open a recording select File > Open Recording and select the recording file.

The supported file types are defined by the 89601B VSA software, Currently the following types are supported,

- CSV (comma delimited ASCII), *.csv
- E3238S Time Snapshot , *.cap
- MAT-file (MATLAB), *.mat
- MAT-file (MATLAB Version 4), *.mat
- MATLAB HDF5, *.mat , *.hdf, *.h5
- N5106A Waveform (streaming data), *.bin
- N5110A Waveform, *.bin
- SDF (Fast or Export), *.sdf, *.dat
- Text (Tab delimited ASCII), *.txt types of file

Please refer to the topic "Supported File Formats" in the 89601B online help documentation for more information.

6.2.6 Print

The printing related menu items are only enabled when the user selects one of the Measurement Display windows.

Having selected a Measurement Display window the contents can be printed by selecting File > Print.

Only the contents of the selected Measurement Display window will be printed.

Settings windows and Waveform Generation windows cannot be printed.

6.2.7 Print Preview

Having selected a results window, the image that will be sent to the printer can be previewed by selecting File > Print Preview.

6.2.8 Page Setup

Select File > Page Setup to configure the paper size, orientation and margins of the printed image.

6.2.9 Print Setup

Select File > Print Setup to configure the printer settings.

6.2.10 Exit

Select **File** > **Exit** to close the 81199A application. This will also terminate the associated instance of the 89601B VSA software if it is running.

6.3 View

The View menu allows you to choose whether certain tool and status information is visible on the 81199A GUI.

6.3.1 Tool Bar

The Tool Bar, if visible, appears at the top of the window, just under the menu bar. It contains icon buttons to access the most commonly used 81199A functions.

If this view menu item has a check mark beside it, the main Tool Bar will be visible.

The check mark can be toggled on and off by selecting View > Tool Bar.

6.3.2 Status Bar

The Status Bar, if visible, appears at the bottom of the window and reports the status of the remote control ports that the 81199A software can support.

If this menu item has a check mark beside it, then the status bar will be visible.

The check mark can be toggled on and off by selecting View > Status Bar.

6.3.3 Performance Information

If this menu item has a check mark beside it, then additional performance diagnostic information will be visible in the Tool Bar.

The check mark can be toggled on and off by selecting View > Performance Information.

6.4 Generate

The Generate menu allows you to specify the output device, generate waveforms and output them to the selected device, and to compute pre-corrections to compensate for hardware imperfections.

6.4.1 Output Device

Select Generate > Output Device to choose the output device. The supported output devices are,

- Agilent M8190A AWG – Speed Mode (12 bit, 12 GHz)
- Agilent M8190A AWG – Precision Mode (14 bit, 8 GHz)
- Agilent M8190A/N5152A
- Agilent M8190A AWG – DUC Mode (x3 Interpolation)
- Agilent M8190A AWG – DUC Mode (x12 Interpolation)
- Agilent M8190A AWG – DUC Mode (x24 Interpolation)
- Agilent M8190A AWG – DUC Mode (x48 Interpolation)
- Agilent 81180A AWG
- Agilent 81180B AWG
- File (csv, binary or matlab)   (requires 81199A option DFP)

If the software is preset then the default device will be the one that supports the highest sample rate.

6.4.2 Generate and Output

Select Generate > Generate and Output to download the waveform to the selected output device.

For AWG output devices, the download is executed immediately, subject to the 81199A software being able to communicate with the selected AWG. If the software is unable to find the AWG, then, after a timeout period, it will report an error.

For file output, the waveform will be saved to the file specified on the Current Output Device window under Waveform File Name (overwriting any previous content). If no filename has been specified in this setting, then a File Save dialog will open for you to enter a file name.

6.4.3 Generate and Output As...

This menu item is only relevant to file output.

Select Generate > Generate and Output As... to save the waveform using the File Save dialog so that you have the opportunity to rename the waveform data rather than simply overwriting the previously named file.

6.4.4 Generate User Defined Pre-Corrections

This menu item is intended for expert users who wish to pre-compute calibration data using the fully configurable version of the pre-corrections algorithm that is more typically enabled and used via the Calibration Mode setting in the Final Waveform Settings window.

The user-defined pre-corrections generation procedure is described in section 12.8

6.5 Measure

The Measure menu controls the 81199A measurement functions.

6.5.1 Start Measurement

Select Measure > Start Measurement to start the measurement processes.

The 81199A software will acquire a time record from the 89601B VSA software and pass it to each of the active demodulators (there can be more than one active at the same time) for analysis. Then it will gather the demodulation results from each of the active demodulators, perform any post processing required for presentation (such as units conversion) and display the results.

If measurement is configured for continuous operation, then the software will repeat this process until instructed to stop.

6.5.2 Stop Measurement

Select Measure > Stop Measurement to stop the measurement processes.

6.5.3 Continuous / Single Measurement

Measurement can be configured for continuous operation (started by Measure > Start Measurement and stopped by Measure > Stop Measurement), or for single-shot operation (started by Measure > Start Measurement and stopping automatically after a single acquisition, demodulation, post-processing and display cycle).

6.5.4 Auto-Range

Select Measure > Auto-Range to automatically adjust the oscilloscope input range setting for maximum sensitivity.

6.6 Windows

The Windows menu allows you to select which tool and document windows are visible and which window has focus.

The default windows layout can be recovered by selecting File > Preset Setup, but beware that this will reset everything else as well.

6.6.1 Close All Document Windows

The 81199A Graphical User Interface (GUI) contains two distinct types of window; tool windows and document windows.

Tool windows cannot be closed because, in general, they contain important information such as settings (they can, however, be auto-hidden).

Document windows can be closed because, in general, they are used to present results and you may wish to remove unused result windows. (They can always be re-instated from this menu).

Select Windows > Close All Document Windows to close all the Document windows.

Any docking panel containing a tool or document window can be made permanently visible by clicking on the push-pin icon (on the right of the title bar) so that it is vertical, or made to auto hide by clicking the push-pin icon so it is horizontal. Any docking panel containing only document windows can also be closed, however if the panel contains one or more tool windows it can only be put into auto-hide mode, it cannot be closed.

6.6.2 Windows List

The exact list of windows depends on the installed options.

6.7 Help

The Help menu allows you to access various forms of assistance.

6.7.1 User's Guide

Select Help > User Guide to access a PDF version of this User Guide.

6.7.2 SCPI Command Reference

Select Help > SCPI Command Reference to access an HTML format listing of the programming syntax for all the SCPI remote control commands recognized by the 81199A software.

All functions of the 81199A are remotely controllable so that the operation of this software can be fully automated.

Any programming environment that permits the user to send ASCII strings to a LAN or USB destination can be used.

Here is a very simple MATLAB script to illustrate the idea,

```
t = tcpip('localhost', 5025);
fopen(t);
fprintf(t,'*RST');
fprintf(t,'*IDN?');
reply = fscanf(t);
sprintf('You are talking to: %s', reply);
fprintf(t,'SOUR:TRACK1:SLIS:ADD AD,1');
fprintf(t,'SOUR:RAD:AD1:MCS 6');
fprintf(t,'SOUR:RAD:AD1:LEN:NCPH 2000');
fprintf(t,'SOUR:RAD:AD1:CONT PN23');
fprintf(t,'OUTP:NOIS:CNR 30DB');
fprintf(t,'OUTP:NOIS:STAT ON');
fprintf(t,'OUTP:DEV:SEL M8190AP');
fprintf(t,'OUTP:M8190AP:ADDR "192.168.1.101"');
fprintf(t,'OUTP:DEV:RUN');
fclose(t);
```

6.7.3 Show Startup Warnings

If this menu item has a check mark beside it, then startup warnings (if any) will be shown.

The check mark can be toggled on and off by selecting Help > Show Startup Warnings.

When 81199A starts up it checks whether certain software is installed correctly and it will warn you if they are not. If you disable this menu item these warnings will not be shown.

6.7.4 About

Select Help > About to access the About box. This dialog box has four tabs,

- Detailed Version Information : This tab lists the full version number, location, date and source of every software module used by the application. This is mainly intended for support purposes.
- Startup Messages : This tab lists the messages that were posted by the software during system startup. This is the same list of messages as appears in the scrolling status window of this splash screen.
- System Information : This tab lists the current value of the system properties that are important to the software. This is mainly intended for support purposes.
- Licenses : This tab lists all of the currently valid Agilent software licenses present on the host computer and their expiry dates. This will also include licenses for other Agilent products, if present.

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7 Tool Bar

7.1 Introduction

This chapter describes the 81199A Tool Bar.

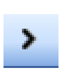
The Tool Bar contains icon buttons to access the most commonly used 81199A functions. It also provides status information relevant to the measurement processes.

7.1.1 Action Buttons

This button is equivalent to selecting Generate > Generate and Output on the menu.

This button is equivalent to selecting Measure > Start Measurement on the menu.

This button is equivalent to selecting Measure > Stop Measurement on the menu.

 or 

The two states of this toggle button are equivalent to selecting Measure > Continuous Measurement or Measurement > Single Measurement menu on the menu.

7.1.2 Measurement Status

The measurement status display reports the current status and, where appropriate, the sub-status, of the analysis cycle. The possible status messages are tabulated below,

Measurement Running...
Measurement Running : waiting for trigger...
Measurement Running : acquiring data...
Measurement Running : acquisition done.
Measurement Running : reading data...
Measurement Running : no data, reacquiring...
Measurement Running : demodulating...
Measurement Stopping...
Measurement Stopped
Loading Recording...
Recording Loaded

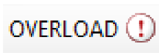
7.1.3 Performance Information

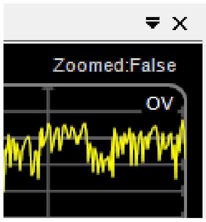
The 81199A analysis software cycles through up to four states; acquisition, demodulation, post-processing and display.

The performance information indicators illustrate subjectively how much time the software is spending in each activity as well as giving an overall measurement update rate. The indicators are optional and controlled by the View > Performance Information menu toggle.

The 81199A software will use multiple-CPU cores where they are available so it is possible for more than one of the state indicators to be active simultaneously.

7.1.4 Overload Indicator





This indicator normally shows as a hyphen at the right end of the status display part of the Tool Bar and changes to the word OVERLOAD! if the 89601B VSA software reports a signal overload condition.

The mnemonic OV also appears in the top-right corners of the Main Time and Spectrum displays to mimic the similar indicator in the underlying 89601B VSA instance.

To manually adjust the acquisition device for maximum sensitivity, adjust the input range until the overload indicator comes on and then increase the range by one or two setting positions from there (so that the indicator remains off). This is essentially the procedure that the Auto-Range button automates.

The overload indicator will only indicate an overload on the acquisition device. It will not detect overload conditions in the RF or IF stages of any down conversion hardware that is being used.

7.1.5 Auto-Range Button

This button automatically adjusts the acquisition device (oscilloscope) input range setting for maximum sensitivity.

7.1.6 Full Screen Button

This is a toggle button that maximizes the available screen space by expanding the main window content to occupy the full screen. This has the effect of temporarily hiding the menu bar, which is why this function is only available on the Tool Bar and not in the menus.

7.1.7 Help Button

This button is equivalent to selecting Help > User's Guide... on the menu.

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8 Status Bar

8.1 Introduction

This chapter describes the 81199A Status Bar.

The Status Bar reports the status of the remote control ports that the 81199A software can support.

8.1.1 Remote Interface States

81199A software can be remotely controlled over GPIB, LAN, or USB interfaces and the LAN interface can support sockets and telnet sessions.

There is an icon for each of these possibilities in the status bar.
If an icon is greyed out then that interface is not available. If it is not greyed out then that interface is available. If it is highlighted with a green background, then that interface is ready and can accept remote control commands.

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9 Window Management and Manipulation

9.1 Introduction

This chapter describes the docking panel window system that is used in the 81199A software to provide considerable flexibility in configuring the user interface and, in particular, organizing the display of measurement results.

9.2 Overview

The 81199A docking panel system allows windows to be arranged in arbitrary positions within the main window and to be un-docked from the main window and shown as separate floating windows.

The following description describes the default screen layout for a fully optioned installation of the 81199A software.

Certain docking panels and windows will be automatically omitted from the layout if the necessary software option licenses are not available. Also, screen layouts are remembered as part of a saved setup, so your screen might look quite different to the defaults described here.

When the software first starts up you should see a window that looks something like Figure 17.

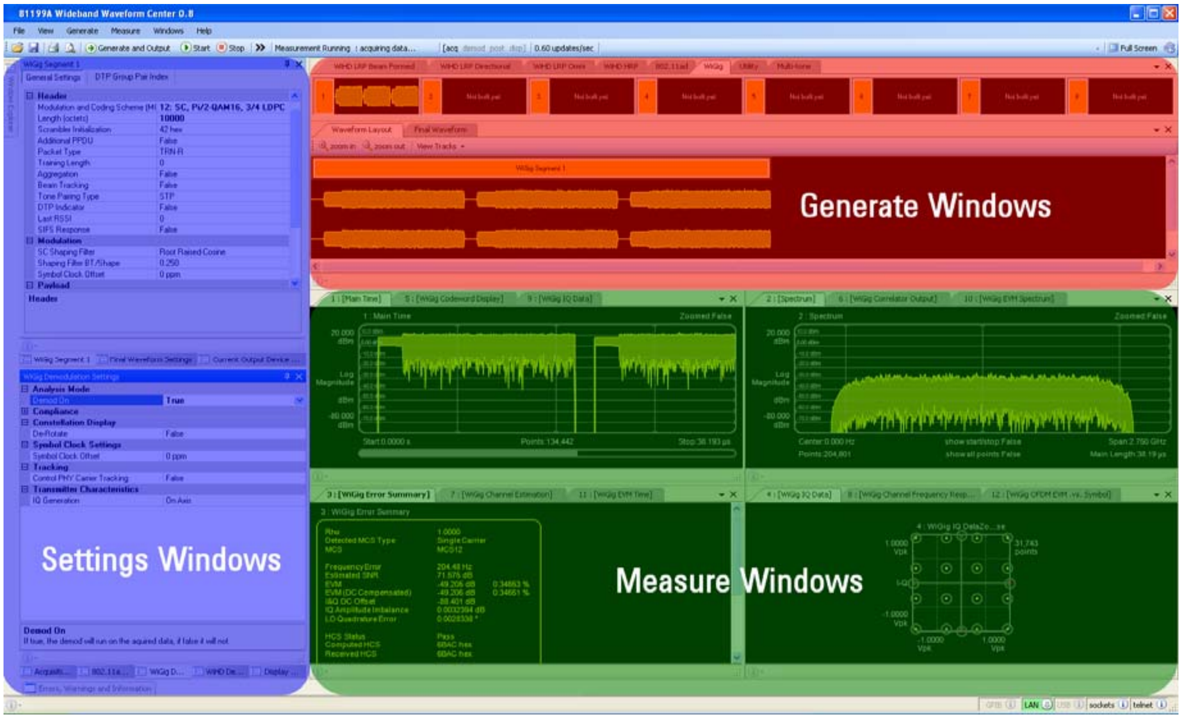

Figure 17. Default screen layout for a fully optioned installation.

In the default layout (for a fully optioned installation), the main window is divided into three zones; settings, generate and measure.

Each of these zones contains a number of docking panels.

Docking Panels

Docking panels provide a hierarchical mechanism for arranging the content of the main application window. They are essentially containers for a collection of windows.

Within a docking panel, windows may be arranged in a stack (with tabs) or tiled, whichever is more appropriate for the window content.

Individual windows may be dragged and dropped from one docking panel to another.

Docking panels and individual windows may be switched into floating windows, separate from the main application window.

9.3 Settings Values

The Settings Windows contain grouped lists of settings fields.

There are a number of ways to enter a specific numeric value in a settings field.

Explicit value and units

The value and units can be entered explicitly. For example, if you want to enter a frequency of 9.2 GHz, you can enter “9.2 GHz”. If you enter units this way, they are expected to be correctly cased SI units. So, for this example, the units would have to be “GHz” not “gHz” or “ghz”.

Abbreviated units

If you want to enter engineering values quickly, you can abbreviate the unit multiplier. For example, entering “9.2g” will be converted to “9.2 GHz” (assuming the setting is a frequency), and “1.2m” will be converted to “1.2 mV” if the setting is a voltage.

81199A settings fields understand the following abbreviations,

“p” for pico (10-12)
"n” for nano (10-9)
“u” for micro (10-6)
“m” for milli (10-3) – this must be a lower case m.
“k” for kilo (103)
“M” for Mega (106) – this must be an upper case M.
“G” or “g” for Giga (10^9)

Default units

If you enter a value without any units, it is assumed to be in the “base” unit, for example, if you are entering a frequency and you simply enter “20”, this is interpreted as “20 Hz” even if the current value is something like “10 MHz”.

You can also step most values up and down using the mouse wheel. You can also reset a value, or set it to its min or max value by right clicking over the setting name.

9.4 Settings Windows

In the Settings Windows area, there are four docking panels, two of which are "pinned" and therefore permanently visible, and two are in Auto Hide mode so they normally only show as tabs at the edge of the main window.

When you move your cursor over the tab of an auto-hidden window it un-hides and pops out.

 fixed

 auto hide

Any docking panel can be made permanently visible by clicking on the push-pin icon (on the right of the title bar) so that the pin is vertical, or made to auto hide by clicking the push-pin icon so it is horizontal.

The normally auto-hidden docking panels in the Settings Windows zone are the Window Explorer and the Errors, Warnings and Information panels. We will focus here on the two visible docking panels.

Of the two visible docking panels one, in the upper half of the zone, is intended as a container for waveform generation related settings windows, and contains three dockable windows,

- <currently selected> Segment Settings,
- Final Waveform Settings,
- Current Output Device Settings.

The other docking panel, in the lower half of the zone, is intended as a container for measurement related settings windows and contains two or more dockable windows from the following list,

- Acquisition Settings,
- 802.11ad Demodulation Settings,
- WiHD Demodulation Settings,
- Display Settings.

When re-arranging the 81199A user interface, it is useful to know that windows used for configuration and control (tool windows) cannot be removed from the user interface, whereas windows used for waveform generation and measurement results (document windows) can be closed.

The settings windows are tool windows and cannot be closed. They can, however, be auto-hidden (by clicking the push-pin) so as to maximize the screen area available for measurement results.

More About Docking Panels

A docking panel has 5 docking positions; top, bottom, left, right or "document".

The first four of these positions enable windows to be tiled within the docking panel; as we will describe shortly. However, for the settings windows, the document docking position is more appropriate.

When windows are docked in the document position the windows contained in the docking panel are conceptually laid on top of each other and accessed by a row of tabs at the bottom (or top) of the dock pane area. Clicking on a tab brings the corresponding window to the top of the stack.

Any window in a docking panel can be displayed as a floating window.

To convert a docked window to a floating window, double click on the window tab in the docking panel. To return the window to its original position in the docking panel, double click on the title bar of the floating window.

Any window can be moved from one docking panel to another. Click the window tab in one docking panel and drag it. A transparent blue overlay will show you the position of the corresponding floating window and will move with your cursor.

To float or drag a window it must first be pinned (not in Auto-Hide mode.)

As your cursor moves over each docking panel a docking position selector will appear for that docking panel.

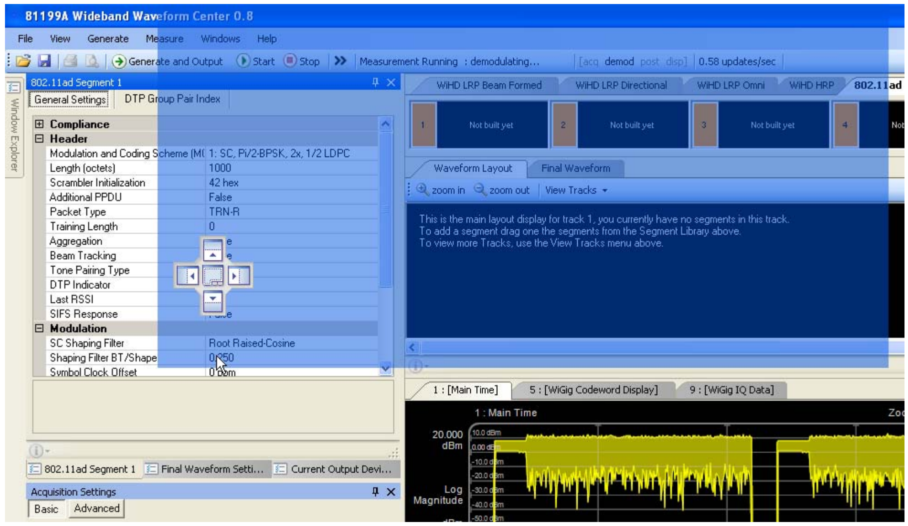

Figure 18. Dragging a Window

Move your cursor over the intended destination docking panel to get the correct destination selector, and then move the cursor to the desired docking position selector hotspot. When you release the mouse button, the window will be tiled as illustrated by the blue overlay, as shown in Figure 19.

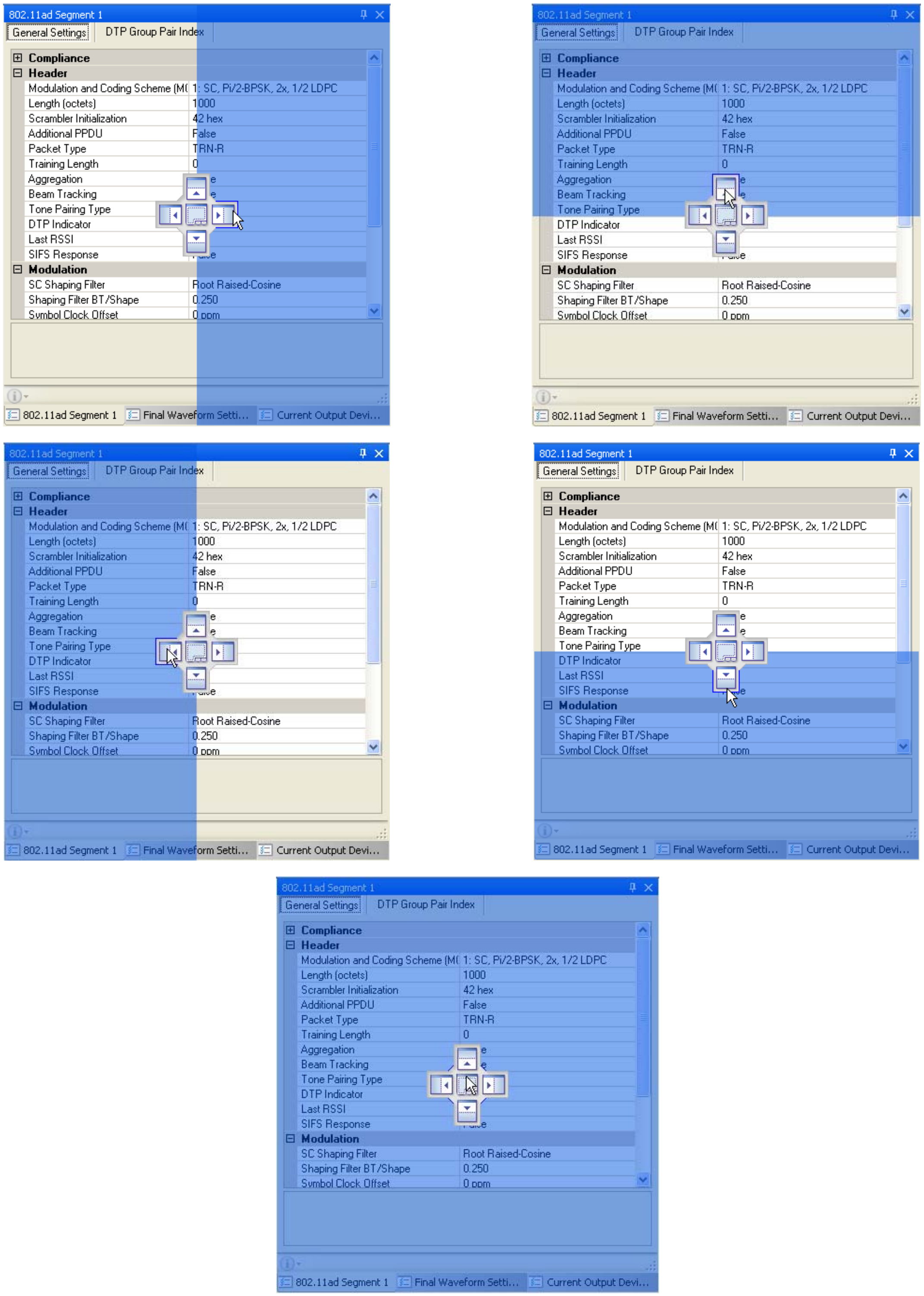

Figure 19. Possible Docking Panel Window Docking Positions

9.4.1 Purpose of Each Window

The 81199A software has 10 tool windows in the Settings Windows zone, some of which will only be added to the user interface if the corresponding license is valid.

<current> Segment Settings	Configure the settings of the waveform segment that is currently selected in the Waveform Layout window, or the active Segment Library window.
Final Waveform Settings	Configure the settings of the final waveform that will be generated.
Current Output Device Settings	Configure the settings of the current output device which may be an Arbitrary Waveform Generator or a File.
Acquisition Settings	Configure the settings of the underlying 89601B VSA software.
802.11ad Demodulation Settings	Configure the settings of the 802.11ad demodulator. Note: This window will only be present if you have a valid 81199A option IAD license installed.
WiHD Demodulation Settings	Configure the settings of the WiHD demodulator. Note: This window will only be present if you have a valid 81199A option WHD license installed.
Display Settings	Configure the properties of the measurement result displays.
Window Explorer	This window provides an overview of all the windows in the application's user interface. It also allows you to quickly bring a particular window into focus by clicking on the name.
Errors, Warnings and Information	This tool window collects and displays any error, warning or information messages issued by the software, either since start up, or since the Clear List button (in the top right corner of this window) was last clicked. The information can optionally be grouped by type.

9.5 Waveform Generation Windows

In the Generate Windows zone, there are two docking panels. One, in the upper half, contains a Segment Library window for each currently licensed format, as well as for the standard segment libraries; Utility and Multi-tone.

A fully optioned 81199A will have tabs for all of the following,

- WiHD LRP Beam Formed
- WiHD LRP Directional
- WiHD LRP Omni
- WiHD HRP
- 802.11ad
- Utility
- Multi-tone

If Utility and Multi-tone are unexpectedly the only tabs present then there may be a problem with your software licenses. Check your license status using the Licenses tab in the Help > About... dialog box.

If you have created your own plug-in waveform class as described in the Agilent Wideband Waveform Center 81199A – Development Option Guide (P/N 81199-91030), and correctly installed the DLL in the plug-ins directory prior to starting the application, then there will also be Segment Library window tab(s) named according to your class definition(s).

The other docking panel, in the lower half of the Generate Windows zone contains,

- Waveform Layout window,
- Final Waveform window

These docking panels and windows can be manipulated in exactly the same way as was described for Settings Windows in section 9.3 However; their default layout is likely to be the most useful.

9.5.1 Purpose of Each Window

The 81199A software can have 10 or more document windows in the Generate Windows zone, some of which will only be added to the user interface if the corresponding license is valid.

WiHD LRP Beam Formed WiHD LRP Directional WiHD LRP Omni WiHD HRP 802.11ad Utility Multi-tone	If present, each window provides a library of 8 independently configurable waveform segments, compliant with the relevant specification, which can be dragged and dropped into the Waveform Layout window to construct arbitrarily complex waveform sequences.
Waveform Layout	This window provides a workspace where segments from the Segment Library can be sequenced in time, and across up to 4 concurrent tracks (in the style of an audio mixer) , and where (optionally) a range of impairments and other post processing can be specified to be applied before being downloaded to the output device.
Final Waveform	This window provides a viewer for the final waveform data, including any impairments and other post processing, before it is downloaded to the output device.

9.1 Measurement Result Windows

In the Measurement Windows zone, there are four docking panels arranged in a 2 x 2 grid which, together, contain 12 Measurement Result windows (3 in each docking panel).

Each of the Measurement Result windows (numbered 1 to 12), can contain any measurement result for which the 81199A software has a valid license.

As well as the two primary measurement displays taken directly from the underlying 89601B VSA software (Main Time and Spectrum), a fully optioned 81199A has a further 40 measurement displays aggregated across the 3 currently available wideband demodulators.

The software will provide a default mapping of measurement displays to Measurement Result windows depending on the installed options, but it is important to realize that you can easily re-configure the 12 Measurement Results windows to show any combination of the available measurement displays.

As an example, if you only have option IAD (802.11ad) installed the default mapping is as follows, Top left docking panel

Measurement Result window 1 : Main Time

Measurement Result window 5 : 802.11ad Codeword Display

Measurement Result window 9 : 802.11ad IQ Data

Top right docking panel

Measurement Result window 2 : Spectrum

Measurement Result window 6 : 802.11ad Correlator Output

Measurement Result window 10 802.11ad EVM Spectrum

Bottom left docking panel

Measurement Result window 3 : 802.11ad Error Summary

Measurement Result window 7 : 802.11ad Channel Estimation

Measurement Result window 11 802.11ad EVM Spectrum

Bottom right docking panel

Measurement Result window 4 : 802.11ad Decoded Data

Measurement Result window 8 : 802.11ad Channel Frequency Response

Measurement Result window 12 802.11ad OFDM EVM .vs. Symbol

You can change the displayed result by right mouse clicking either on the Measurement Result window tab or on the title in the measurement display and choosing another result from the drop down menu.

Each set of three Measurement Result windows is, by default, docked in their respective docking panels as a stack. However, you can rearrange this to your preference by dragging and dropping the windows in exactly the same way as was described for Settings Windows in section 9.3.

For measurement displays, the tiling option is often particularly useful. For example to tile the magnitude and phase presentations of channel response in the same panel.

9.1.1 Purpose of Each Window

The 81199A software has up to 12 document windows in the Measure Windows zone; they are all Measurement Result windows.

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10 Working with Measurement Displays

10.1 Introduction

This chapter describes how to work with the various result displays available in the 81199A software.

10.2 Selecting Measurements

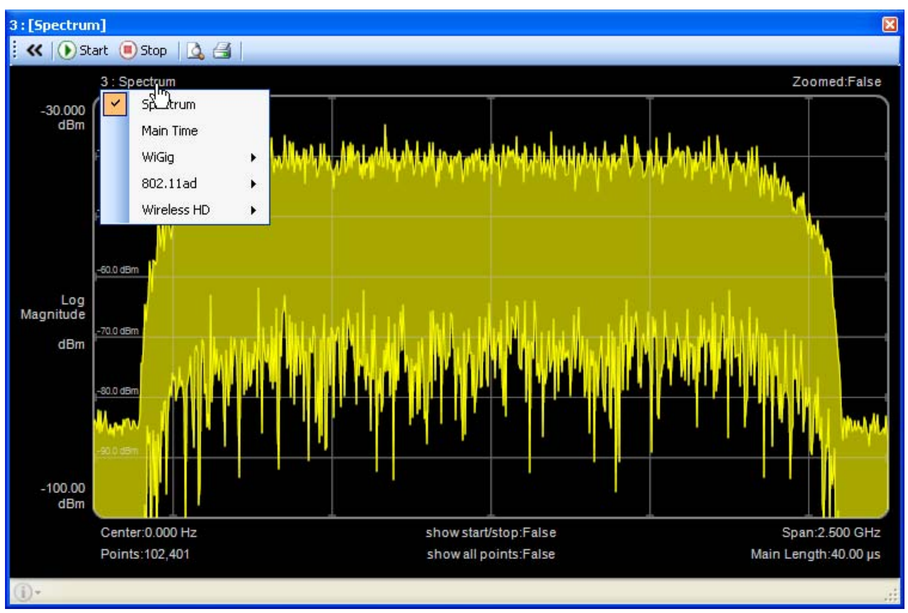

Figure 20. Selecting a Measurement Result

You can select which measurement result is displayed in a particular Measurement Display window by right-clicking on the title of the currently displayed measurement result and choosing the measurement you want from the drop-down menu.

The same menu will appear of you left-double-click or right-click on the tab of a docked Measurement Display window.

It is possible to have the same result displayed in multiple Measurement Display Windows, for example, if you want to concurrently display the magnitude and phase parts of a result.

10.3 Altering Coordinate Ranges, Units Etc.

Mouse over

If you hover your mouse over an annotation in a measurement result display and a dark grey box appears around it, this means that it is adjustable.

If the value is numeric, the easiest way to adjust it is to single click it (the box should turn a brighter yellow), and you can use your mouse wheel to scroll the value up and down.

Mouse click on numeric

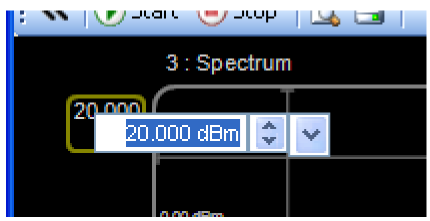

Figure 21 Changing a limit.

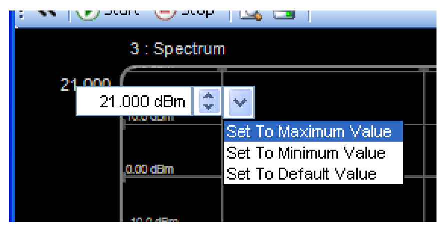

Figure 22 Selecting a limit default.

If you want to type in a specific value, double left click or right click the annotation to open a compound control that allows you to enter a new value, increment or decrement the current value, or pick a default value as shown in Figure 21 and Figure 22.

Mouse click on list item

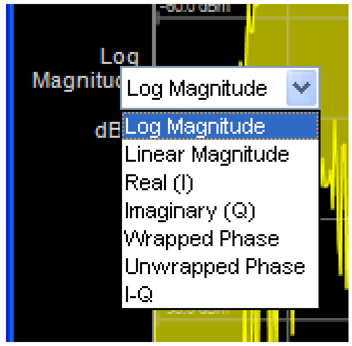

Figure 23. Changing Data Representation

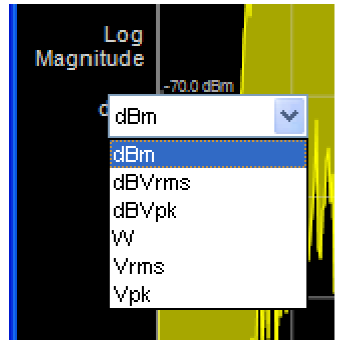

Figure 24. Changing Displayed Units.

A double left click or right click on a list item, for example, the Y-axis limit will open a drop-down menu that allows you to select a different data representation of the result data. Similarly, clicking on the units opens another drop-down menu that allows you to select different units, as shown in Figure 23 and Figure 24.

10.4 Zooming

Zooming is enabled by double clicking on the Zoomed status indicator in the top right of the display. When the Zoomed status is True, a secondary bar appears at the bottom of the trace with a grey overlay showing how much of the time record is currently being displayed. Initially the overlay will cover the entire extent of the time record, but this can be reduced or enlarged using the mouse wheel and the display will be updated correspondingly.

The position of the partial time record being displayed can be changed in large time steps by clicking and dragging the grey overlay cursor, or in fine time steps by clicking and dragging the display itself.

Quick Zoom

Alternatively, even if your mouse does not have a wheel, you can use the "Quick Zoom" capability by holding the Control key down then clicking and holding the left mouse button. Moving the mouse left and right pans the zoomed display, while moving the mouse up and down zooms in and out. Releasing the left mouse button returns you to non-zoomed operation.

Markers while zooming

When a display is zoomed, an information panel appears in the top right of the display that gives a readout of the X and Y coordinates of the cursor. The coordinated are expressed in the current X and Y units.

10.5 Right-Click Menu in the Display Area

All measurement result displays support a right-mouse-click menu providing the functions described in this section. Some result displays add result specific entries to this menu as well. Those are introduced in the relevant result descriptions.

10.5.1 Copy Data as Text

Selecting this menu item copies the displayed measurement's X and Y-axis values to the clipboard as text. Only values within the displayed X-axis range are saved.

The X-axis range is most easily positioned and adjusted using the zoom function, permitting you to quickly and visually select just the data of interest from the full measurement, which can have many thousands of data points.

10.5.2 Copy Image

Selecting this menu item copies the measurement result display to the clipboard as a graphic that can be pasted into other applications.

10.5.3 Auto-Scale Y-Axis

Selecting this menu item sets the measurement result display Y-axis limits to match the minimum and maximum Y-axis values of the displayed data.

The Y-axis limits can be returned to their default values as described in section 10.3.

10.6 Display Settings

The Display Settings window provides considerable control over the appearance of various elements in the measurement result displays.

10.6.1 Constellation Displays

The Constellation Displays settings apply to the IQ Data (constellation) measurement result display.

Symbol Shape

Set how the measured symbol positions are represented in the IQ Data (constellation) display. The choices are,

- Open Circles
- Filled Circles
- Crosses
- Diagonal Crosses
- Vertical Lines
- Horizontal Lines
- Boxes
- Filled Boxes
- Open Diamonds
- Filled Diamonds
- Dots
- None

Dots are the most precise representation, but, subjectively, Crosses (the default) make the constellation display easier to see, especially if there are relatively few points mapped.

Symbol Size	Set the size of the measured symbol representation. The graticule size is always ±1V pk in both axes. Expressing the symbol size in mV ensures that it maintains the same size relative to the graticule even if the display window is re-sized so that the constellation's appearance does not change.
Show Graticule	If set to True the IQ Display will include a graticule.
Show Ideal Symbols	If set to True the IQ Display will include markers showing the idea symbol positions for the detected constellation type.
Ideal Symbols Shape	Set how the ideal symbol positions are marked in the IQ Data (constellation) display. The choices are the same as for Symbol Shape. Crosses most precisely mark the target position, but can be obscured by the measured symbols in a dense constellation. Open circles provide a boundary around the ideal position and can give a better subjective reference for evaluating distortions.
Ideal Symbols Size	Set the size of the ideal symbol marker. The graticule size is always ±1V pk in both axes. Expressing the symbol size in mV ensures that it maintains the same size relative to the graticule even if the display window is re-sized so that the constellation's appearance does not change. When using open circles as a marker, the circle can serve as a visual limit line for subjective assessment of the constellation.

10.6.2 EVM Displays

The EVM Displays settings apply to the OFDM EVM .vs. Symbol and EVM .vs. Carrier measurement result display.

Symbol Shape — Set how the measured EVM values are marked in the OFDM EVM displays. The choices are the same as for IQ Data Symbol Shape.

Symbol Size — In the EVM displays the symbol is just a marker, so its size is expressed in pixels. The default value of 2 is a balance between visibility and clutter.

RMS Plot Only — If this is set to True, only the white RMS value trace is included in the display.

10.6.3 General Display Settings

The Constellation Displays settings apply to the IQ Data (constellation) measurement result display.

Display Quality — Set the level of display quality. On slower computers switching to a lower quality may improve graphics update performance.

10.6.4 Spectrum/Main Time Displays

The Spectrum / Main Time Displays settings apply to the Spectrum, Main Time, and other time / frequency domain measurement result displays.

Draw Min/Max Lines — If this is set to True, a solid line is drawn that shows the minimum and maximum values in the trace data.

Fill Min/Max — If this is set to True, the region bounded by the maximum and minimum values is shaded.

Draw All Points — If this is set to True, every data point in the trace is shown. This can reveal subtle behaviors in the data, but will lower the graphics update performance.

10.6.5 Sub-Carrier Displays

The Sub-Carrier Displays settings apply to measurement displays that have sub-carriers as the X-ordinate, for example, OFDM EVM .vs. Subcarrier.

Reverse Sub-Carrier Axis — Set this to True when displaying results from demodulating a spectrum reversed signal that have sub-carriers as the X-ordinate.

10.6.6 Text Displays

The Text Displays settings apply to the Error Summary measurement result display.

Auto Grow Text Displays — If set to True then the font size of the text in the Error Summary result display will increase to fill the available space if you stretch the window. This is particularly useful if you need to read the results from a distance.

Auto Shrink Text Displays — If set to True then the font size of the text in the Error Summary result display will reduce to fit the available space if you shrink the window. This is particularly useful if you want to maximize the information visible on a small screen.

11 Generate

11.1 Introduction

This chapter describes the general operation and layout of the waveform generation part of the 81199A software.

Waveforms are created by dragging and dropping waveform segments from the active Segment Library window into the Waveform Layout window.

Once the desired sequence of waveform segments is achieved, the composite waveform, including any added noise or other impairments, can be reviewed in the Final Waveform window.

The waveform can then be downloaded to the selected output device by clicking the Generate and Output button on the Tool Bar or selecting **Generate** > **Generate and Output** on the menu.

11.2 Segment Library

In the Generate zone of the user interface (see Figure 17) there is a Segment Library window for each currently licensed format, as well as for the standard segment libraries; Utility and Multi-tone.

To create a waveform, first select the tab representing the format of interest.

You will see eight numbered containers; each will contain either a small graphic of the segment currently occupying that position, or the words "Not built yet" if that segment has not yet been used.

To use a segment, simply click on the colored numbered box on the left of the segment container, drag and drop it into the Waveform Layout window.

If the segment had not previously been built, it will immediately build, based on the default settings for that waveform type. If it has previously been built it will be re-built based on the most recent setting values.

Each of the eight segments available from the library is independently configurable.

11.3 Waveform Layout

The Waveform Layout window is similar in concept to an audio track editor.

Start by selecting a segment type in the Segment Library and selecting the Waveform Layout Window. The Waveform Layout window is initially blank.

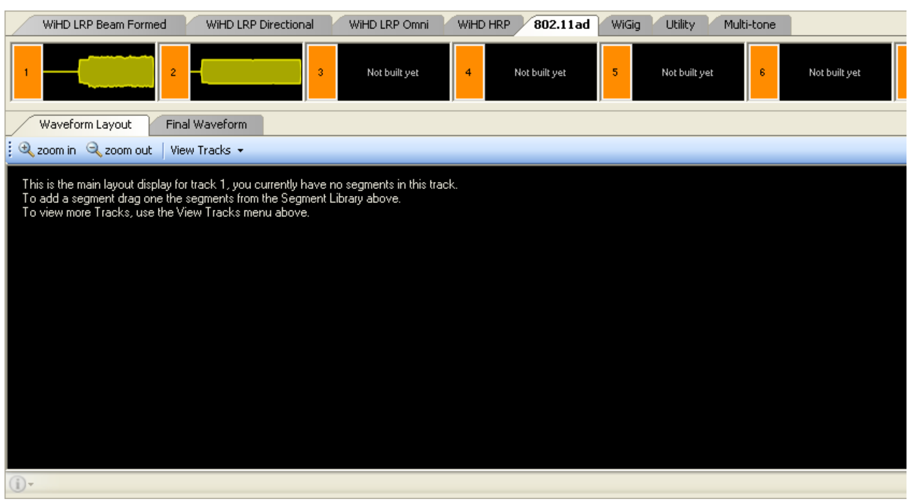

Figure 25. Segment Library and Waveform Layout Windows Ready to Build a Waveform

Drag and drop segment 1 from the selected 802.11ad library into the layout window, by clicking and dragging the numbered, colored box at the left side of the wanted segment in the library.

When dragging a segment, the cursor changes to the form shown in the Figure 26.

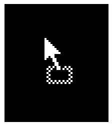

Figure 26. Cursor Shape When Dragging a Segment

When the mouse button is released a copy instance of 802.11ad segment 1 is drawn in the Waveform Layout window.

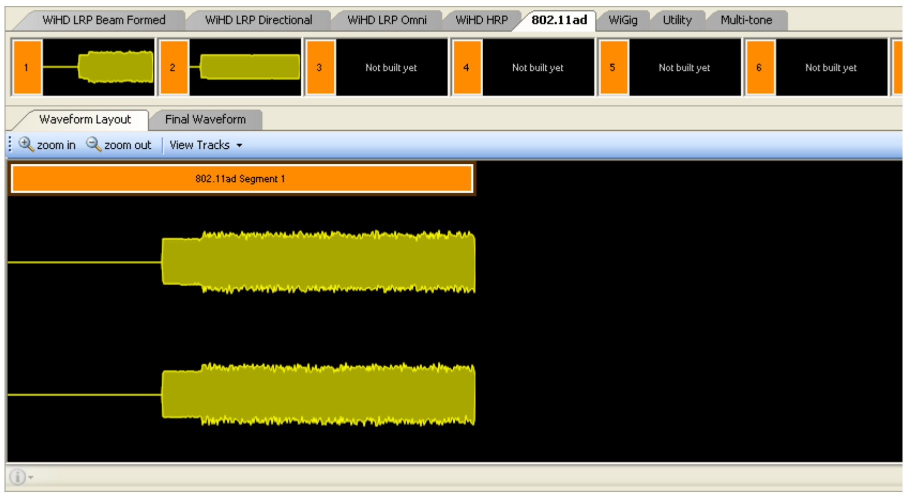

Figure 27. First Segment Dropped onto the Time Line

Repeat the process to drag a copy instance of 802.11ad segment 2 into the Waveform Layout window, dropping it to the right of the first segment.

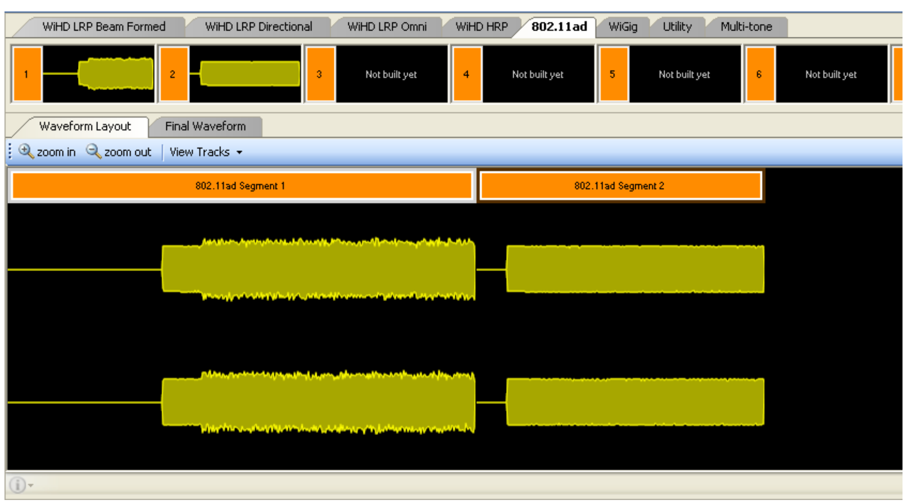

Figure 28. Second Segment Added to the Time Line

In this way, one or more segments of waveform can be concatenated to compose a complete waveform.

Each copy you drop into the Waveform Layout window is really just a reference back to the library segment, if you select and edit the settings of one copy, all the other copies will take on the same values.

A segment can be dropped into the Waveform Layout window multiple times to create heterogeneous segment sequences with relatively few unique segments.

You can create multiple contiguous repetitions of the same packet by drag/dropping multiple copies from the segment library, but it is better to use a single segment and change its Packets in Segment property.

You can re-order segments that have already been placed on the time line by dragging and dropping them again.

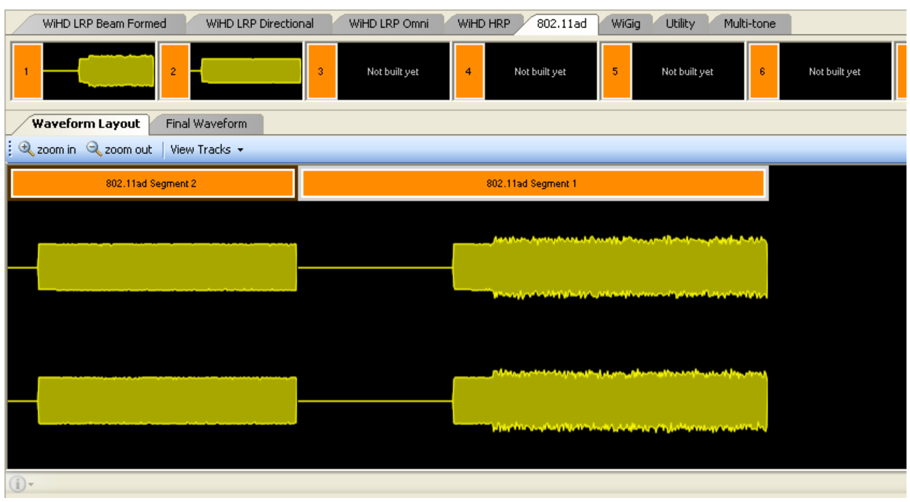

Figure 29. Segments Re-Ordered on the Time Line by Drag / Drop

You can delete unwanted segments by right-clicking on the segment title bar and selecting the menu item Delete the segment instance.

This does not delete the segment from the library, or reset the most recent settings (because those are actually properties of the library segment).

If you want to re-instate the segment, simply drag and drop another copy from the Segment Library.

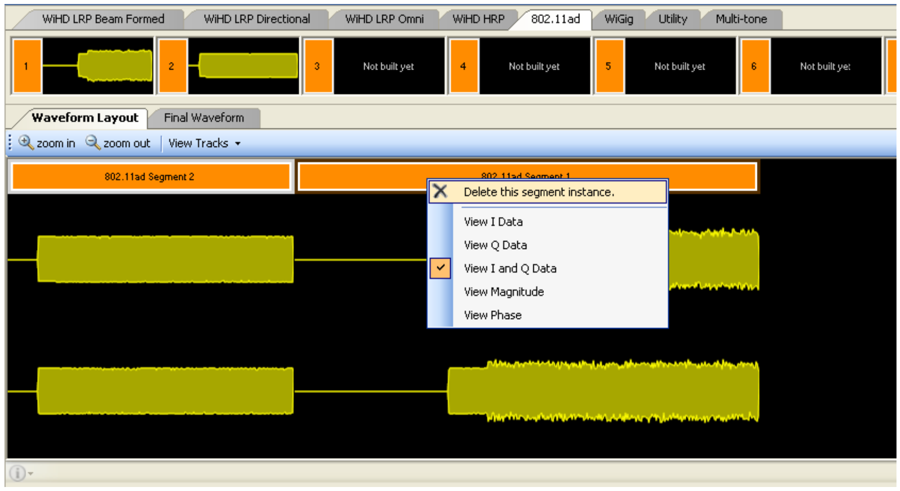

Figure 30. Waveform Layout Right-Click Menu

The Waveform Layout window also extends the audio editor metaphor by providing up to 4 concurrent tracks, so that segments from the Segment Library can be sequenced in time along multiple tracks to create composite waveforms.

Section 11.3.1 explains how to enable multiple tracks and sections 11.3.3, 11.3.4, and 11.3.5 illustrate some of the possible uses.

11.3.1 Waveform Layout Tool Bar

At the top of the Waveform Layout window there is a tool bar.

Zoom In and Zoom Out

As you build your waveform you many need to zoom in or out on the timeline displayed in the window.

A good example is given in the example of section 11.3.4, where it is necessary to zoom in quite far to see the delay segments because they are so much shorter duration than the 802.11ad segment.

As well as the Zoom In and Zoom Out buttons, you can also use the mouse wheel to adjust the zoom, and the slider bar to adjust your position in the time record.

View Tracks — Clicking this button activates a menu which allows you show or hide additional waveform layout "tracks".

The Waveform Layout window provides up to 4 concurrent tracks (in the style of an audio mixer). Segments from the Segment Library can be sequenced in time along any track, and the tracks are summed together to create the final waveform.

The amplitude, phase, and Intermediate Frequency of each track can be individually configured prior to summation, which allows considerable flexibility in the creation of composite waveforms.

The examples given in Sections 11.3.3, 11.3.4, and 11.3.5 illustrate some of the possibilities.

The purpose of the View Tracks menu is to save display space by having visible, only the tracks you are using. If the menu item has a check mark next to it then the track is visible.

11.3.2 Right-Click Menu

As shown in Figure 30, the Waveform Layout window has a right click menu.

Delete Current Segment — This menu selection will delete only the segment copy instance on which the right-click was performed. It does not delete any other copy instances of the same library segment (even though all the copy instances of that segment will be highlighted by a brown frame on the Segment Label(s)).

Nor does it delete the segment from the library, or reset the most recent settings (because those are actually properties of the library segment).

View I, Q or I and Q Data — These menu selections control how the I and Q components of the waveform data are plotted. The default setting is I and Q so each waveform track has two traces.

View Magnitude or Phase	These menu selections plot the waveform data in magnitude or phase representation.

11.3.3 Using Tracks to Add a Modulated Interferer

This section describes how the multi-track capability of the 81199A software can be used to create a signal containing a modulated co-channel interferer.

As an example, we will create a waveform containing an 802.11ad modulated signal, with a second 802.11ad modulated signal at -30 dBr.

First we configure two 802.11ad segments as follows (only the non-default values are specified),

802.11ad segments

802.11ad Segment 1

- Modulation and Coding Scheme: 12: SC, Pi/2-QAM16 3/4 LDPC
- Length (octets): 10000
- Payload Content: PN23
- Interpacket Gap: 10 µs
- Packets in Waveform : 2

802.11ad Segment 2

- Modulation and Coding Scheme: 4: SC, Pi/2-BPSK, 3/4 LDPC
- Length (octets): 2000
- Payload Content: PN23
- Interpacket Gap: 5 µs
- Packets in Waveform : 3

Enable tracks 1 and 2, then drag and drop instances of the configured segments onto the tracks as follows,

Track 1

- 802.11ad Segment 1

Track 2

- 802.11ad Segment 2

The resulting waveform should look like

Figure 31. Waveform Layout for Modulated Interferer

In the Final Waveform Settings window, set the track Amplitudes to

Track 1

Amplitude : 100.0%,

Track 2

Amplitude : 3.2% (= -30 dBr, computed as 100 x $10^{(-30/20)}$)

Measuring the result

In this case, the MCS 12 signal in track 1 is easily receivable with a reported EVM of 3.18% and SNR of around 28.7 dB, suggesting that there is some noise or interference present.

Looking at the EVM Time result shows that the EVM steps up and down over time suggesting that the interferer is a bursty signal rather than noise.

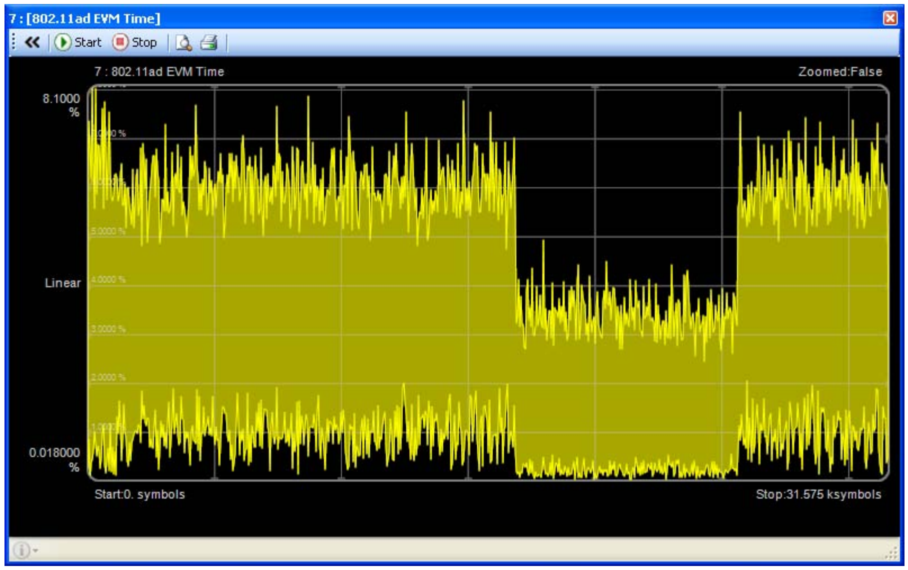

Figure 32. EVM Time Display Showing the Effect of a Bursty Interferer

Looking at the Ga128 Correlator Output result we see the correlator spike "signature" of another 802.11ad signal at a very low level.

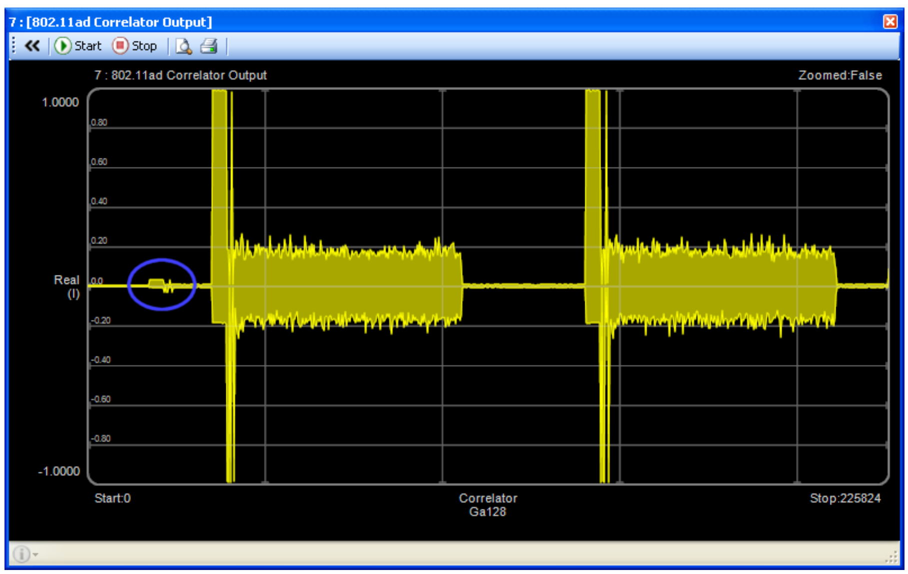

Figure 33. Ga128 Correlator Output Showing Correlation "Signature" of an 802.11ad Interferer.

11.3.4 Using Tracks to Create a Multipath Signal

This section describes how the multi-track capability of the 81199A software can be used to create a multi-path signal.

As an example, we will create a waveform containing an 802.11ad signal as it would appear at a receiver if there were three unequal transmit paths.

First we configure one 802.11ad segment and two Utility "Silence" segments as follows (only the non-default values are specified),

802.11ad segment

802.11ad Segment 1

- Modulation and Coding Scheme: 12: SC, Pi/2-QAM16 3/4 LDPC
- Length (octets): 10000
- Payload Content: PN23
- Interpacket Gap: 10 μs
- Packets in Waveform : 2

Utility Silence segments

Utility Segment 1

- Length : 10 ns

Utility Segment 2

- Length : 14 ns

Enable tracks 1, 2 and 3, then drag and drop instances of the configured segments onto the tracks as follows,

Track 1

- 802.11ad Segment 1

Track 2

- Utility Segment 1
- 802.11ad Segment 1

Track 3

- Utility Segment 2
- 802.11ad Segment 1

The resulting waveform (very zoomed in to show the silences) should look like Figure 34.

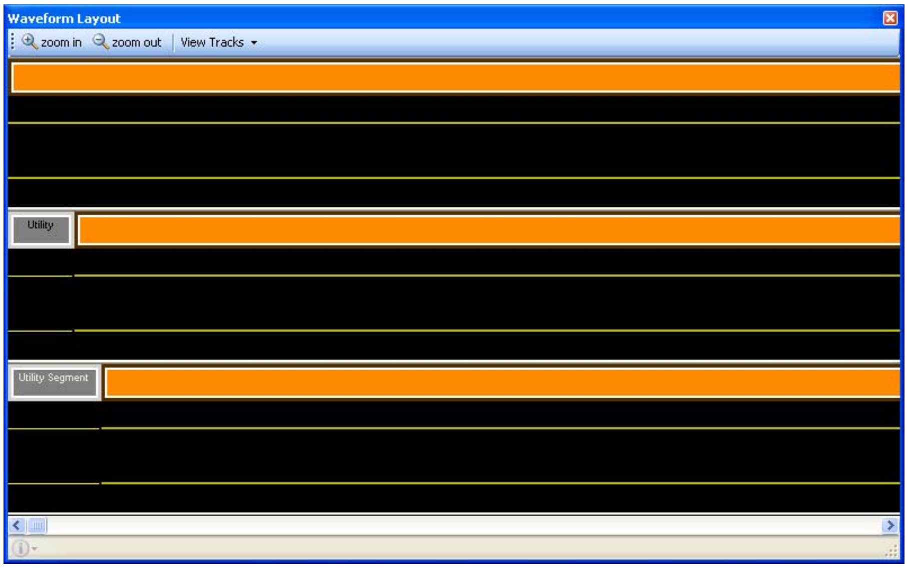

Figure 34. Zoomed in Waveform Layout Showing How Silences Provide Time Delays.

A multi-path waveform should be constructed in this way (with the same segment in each track) so that only one segment needs be edited to ensure that there is always the same signal on all three paths.

In the Final Waveform Settings window, set the track Amplitudes and Phases to,

Track 1

Amplitude : 31.62% (= -10 dBr, computed as 100 x $10^{(-30/20)}$)

Phase : -58°

Track 2

Amplitude : 100%

Phase : 0°

Track 3

Amplitude : 17.78%,(= -15 dBr, computed as 100 x 10(-30/20))

Phase : -123°

Looking at the Channel Estimation of this simulated multi-path signal we can see the peaks due to a -10 dBr path, 10 ns before the main path (at 0 dBr, 0 ns), then a delayed path at -15 dBr, 4 ns after the main path.

The Channel Estimation display has been zoomed so we can use the cursor to get numerical results. The cursor is sitting on the pre-echo peak in Figure 35.

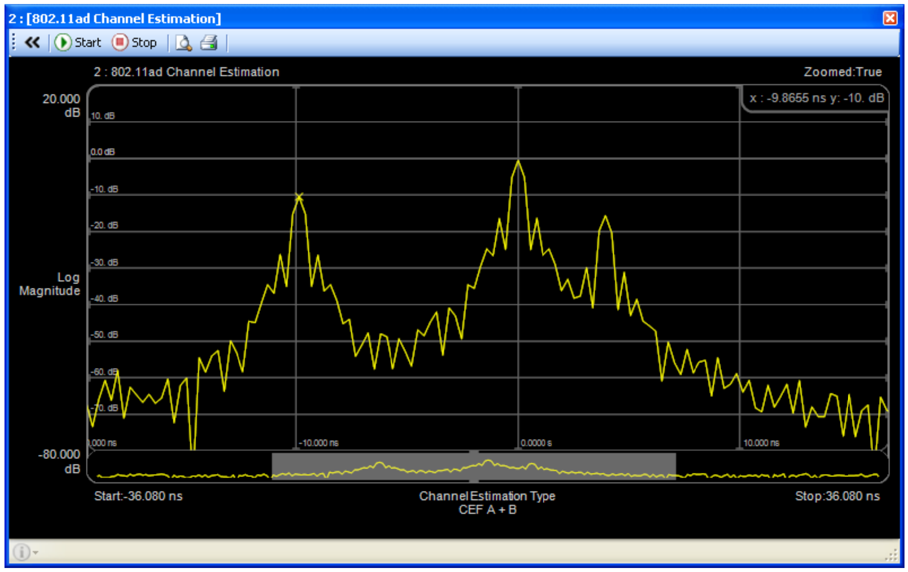

Figure 35. 802.11ad Channel Estimation (Zoomed)

11.3.5 Using Tracks to Create a Multi-Channel Signal

This section describes how the multi-track capability of the 81199A software can be used to create a signal containing multiple RF channels.

As an example, we will create a waveform containing a mixture of WirelessHD and 802.11ad modulated channels.

First we configure five 802.11ad segments and two WirelessHD segments as follows (only the non-default values are specified), 802.11ad segments

802.11ad Segment 1
- Modulation and Coding Scheme: 0: Control, DBPSK, 1/2 LDPC
- Payload Content: PN23

802.11ad Segment 2
- Modulation and Coding Scheme: 6: SC, Pi/2-QPSK, 1/2 LDPC
- Length (octets): 2000
- Interpacket Gap: 10 µs

802.11ad Segment 3
- Modulation and Coding Scheme: 12: SC, Pi/2-QPSK, 1/2 LDPC
- Length (octets): 10000
- Payload Content: PN23
- Packets in Waveform: 2

802.11ad Segment 4
- Modulation and Coding Scheme: 0: Control, DBPSK, 1/2 LDPC
- Length (octets): 80

802.11ad Segment 5
- Modulation and Coding Scheme: 24: SC, Pi/2-QPSK, 1/2 LDPC
- Length (octets): 10000
- Payload Content: PN23
- Packets in Waveform: 5

WiHD segments

WiHD LRP Directional Segment 1
- Header Type: Data

WiHD HRP Segment 1
- Packets in Waveform: 3
- SP1 Payload: 12000

Enable tracks 1 to 4, then drag and drop instances of the configured segments onto the tracks as follows,

Track 1

802.11ad Segment 2

802.11ad Segment 1

802.11ad Segment 2

Track 2

802.11ad Segment 4

802.11ad Segment 5;

Track 3

WiHD HRP Segment 1

WiHD LRP Directional Segment 1

Track 4

802.11ad Segment 3;

802.11ad Segment 1

The resulting waveform layout should look like Figure 36.

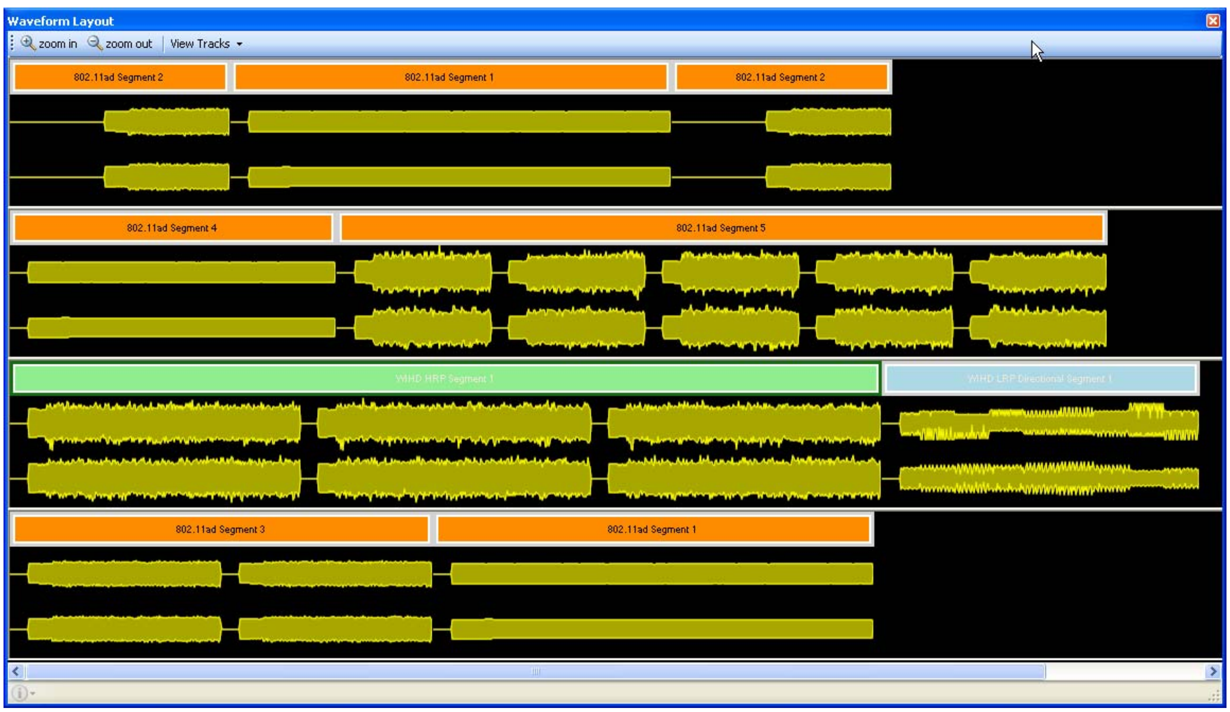

Figure 36. Waveform Layout for 4 RF Channel Mixed Signal Scenario.

To create an IQ baseband signal containing the four channel RF scenario, set the channel offset frequencies to distribute the channels across the available AWG bandwidth.

In the Final Waveform Settings window, set the track Offset Frequencies to

Track 1
  Offset Frequency : -3.24 GHz,
Track 2
  Offset Frequency : -1.08 GHz
Track 3
  Offset Frequency : 1.08 GHz
Track 4
  Offset Frequency : 3.24 GHz

If the resulting IQ baseband signal is vector modulated onto a nominal carrier frequency of 61.56 GHz then the four channels will be centered on 58.32 GHz, 60.48 GHz, 62.64 GHz and 64.80 GHz, which are the center frequencies of Channels 1 through 4 in the ITU approved 60 GHz channel plan.

Of course, this requires vector modulation and up-conversion hardware that is capable of processing a signal with approximately 8.25 GHz modulation bandwidth.

However, for demonstration purposes we can simply feed the baseband I and Q signals into, for example, a DSO90804A oscilloscope.

Computing the required sample rate

Before generating the signal we must also check that the final sample rate is sufficiently high.

- The highest offset present is 3.24 GHz.
- The occupied bandwidth of the 802.11ad signals at those offsets is 2.4 GHz. (Based on the specification -20dB mask points.)
- Multiply by 2.56 to avoid aliasing effects.

Therefore the minimum sampling rate is,

Required Sample Rate = (Highest Offset + (0.5 x Occupied Bandwidth)) x 2.56
= (3.24 + (0.5 x 2.4)) x 2.56 = 11.3664 GHz

The M8190A defaults to its maximum sample rate of 12 GHz in Speed Mode, so this is sufficient.

Computing the maximum IF from the available sample rate

The calculation can, of course, also be worked in the other direction. If, for example, you wanted to use the M8190A Precision Mode then the maximum available sampling rate is 8 GHz and so the maximum un-aliased offset achievable with 802.11ad modulated signals is,

Maximum Offset = (Max Sample Rate / 2.56) – (0.5 x Occupied Bandwidth)
(8.0 / 2.56) – (0.5 x 2.4) = 1.925 GHz

So it would be possible to simulate a 2 channel signal (at ±1.08 GHz) in Precision Mode.

Measuring the Result

By setting the span to 12 GHz / 1.28 = 9.375 GHz we can see the spectrum of all four channels.

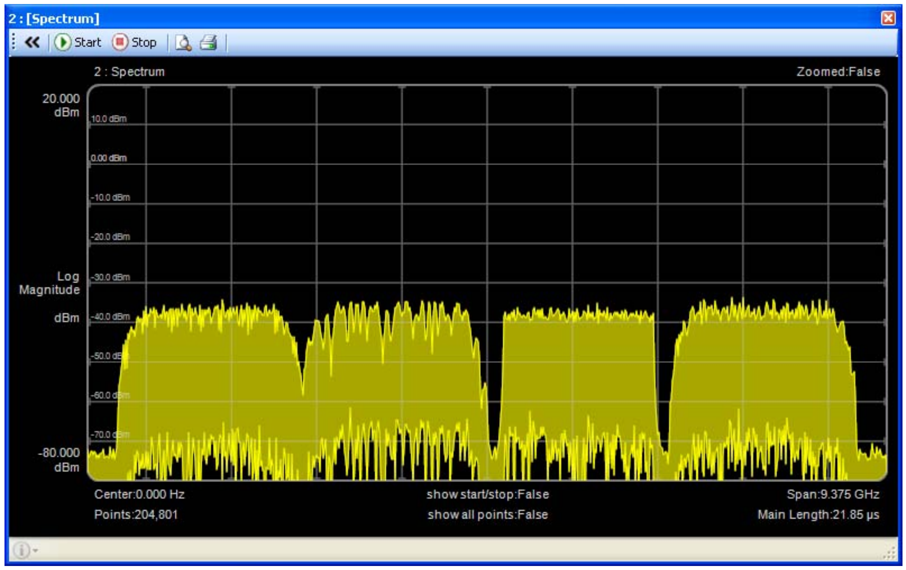

Figure 37 Baseband IQ waveform with 4 x 2.16 GHz Channels with 802.11ad in channels 1, 2 and 4, and WirelessHD in channel 3.

By setting the span to 2.5 GHz and the center frequency to, for example, -1.08 GHz we can demodulate and measure individual channels as shown in Figure 38, Figure 39, and Figure 40.

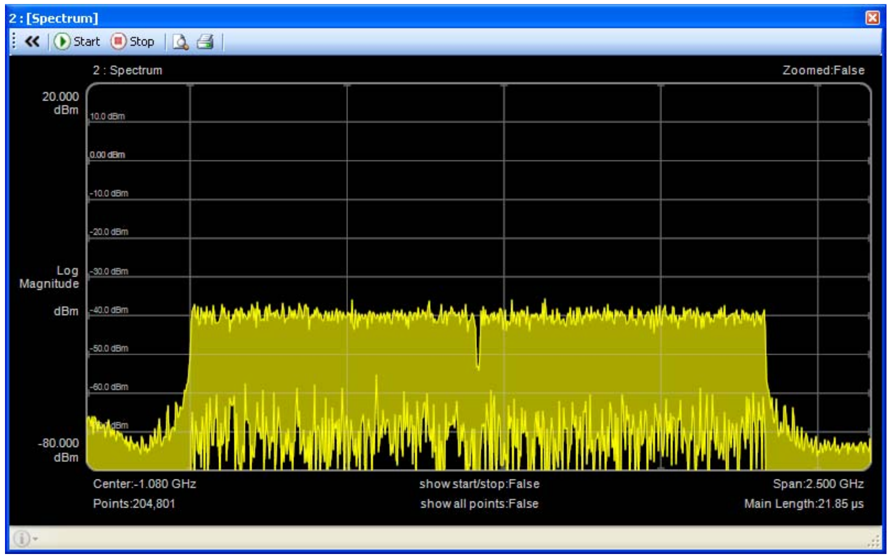

Figure 38. Center Frequency at -1.08 GHz (Channel 2)

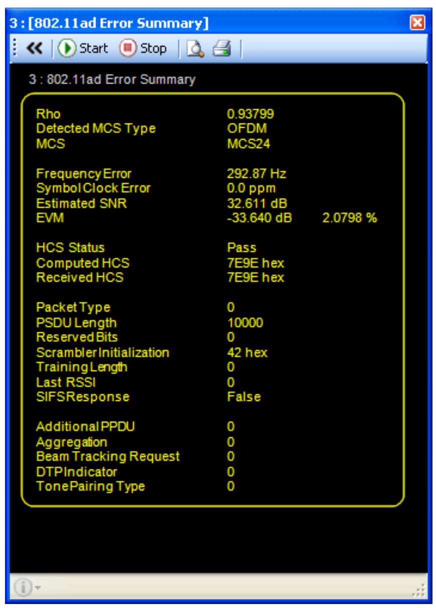

Figure 39. Channel 2 Error Summary

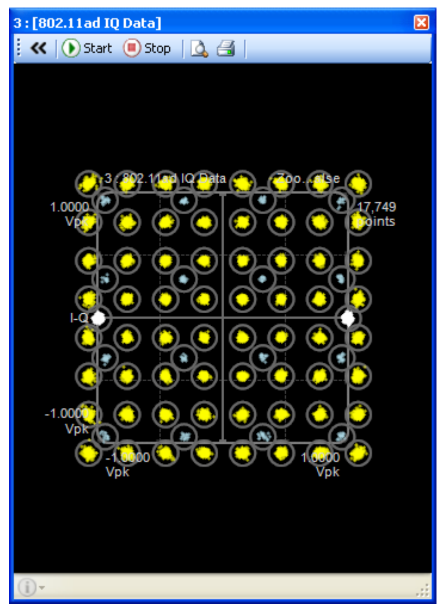

Figure 40. Channel 2 IQ Data

11.4 Final Waveform Settings

The Final Waveform Settings window lists all the settings relating to the processing and conditioning of the mathematically perfect waveforms in the Layout Window to create the final composite waveform prior to download to the output device.

11.4.1 Calibration

Calibration Mode

This setting determines how the downloaded signal is pre-corrected for any impairments present in the signal path. It has four possible values,

- **No Cal:** No pre-correction filter is applied. This is the setting default.

- **Cal On Every Download:** Every time you request a waveform download (by selecting **Generate** > **Generate and Output** on the menu, or by clicking the Generate and Output button on the Tool Bar.), the software will automatically perform a calibration, then calculate and apply the resulting pre-correction filter before downloading the signal.

  This is the simplest mode of operation. It is intended for use where the characteristics of the signal path are unknown or known to vary significantly over time, but it requires that the 89601B VSA software and associated oscilloscope remain correctly configured for every calibrate and download sequence.

In this mode the calibration signal always occupies approximately 80% of the bandwidth implied by the sampling rate and hence may not be appropriate for all signal path configurations.

Ideally the signal path should be able to accommodate the full bandwidth of the calibration signal, but if the cumulative signal path bandwidth is significantly restricted relative to that of the calibration signal then the pre-correction computation may over-compensate the band edges. In this case you should consider using the User Defined mode to tailor the calibration signal to the available path bandwidth.

- **Cal On Settings Change:** This setting is a slightly smarter version of the On Every Download setting that is intended to shorten download times by avoiding potentially unnecessary calibration sequences.

  When you request a waveform download the software will apply a pre-correction filter prior to downloading the signal.

  If you have changed any of the following settings since the last calibration,

  - Waveform final sample rate
  - Calibration signal center frequency
  - Receiver mirror spectrum state
  - Receiver channel configuration

then the software will automatically perform a new calibration, then calculate and apply the resulting pre-correction filter before downloading the signal.

The pre-correction filter definition will be retained and used to pre-correct any further waveform downloads with the same key settings until the filter definition is updated by another calibration.

For example, if you download a signal at 8 GHz sample rate for the first time, an 8 GHz pre-correction filter will be computed and will be applied to all subsequent 8 GHz sampled waveforms until you download at a different rate, say, 7 GHz at which time a 7 GHz pre-correction filter will be computed and the 8 GHz filter definition will be discarded. If you return to 8 GHz sampling a new 8 GHz filter will be computed.

Note that the settings listed above can be often changed in more than one way, depending on the precise configuration of the software.

For example, the receiver channel configuration can be changed by the Calibration Channel Config. Setting in the Final Waveform Settings window (when option 002 is **not** present) or by the Channel Config setting in the Acquisition Settings Window (when option 002 is present).

- **User Defined Cal:** Every time the user requests a waveform download, the 81199A will apply a pre-correction filter prior to downloading the signal. The pre-correction filter is user-defined by the filename in the Pre-Correction Filename setting.

  This option is intended for expert users who wish to pre-compute calibration data using the fully configurable version of the pre-corrections algorithm available through the **Generate > User Defined Pre-Corrections** menu pick.

  This can be useful if the user wishes to pre-compute corrections for a variety of signal path configurations, or where the cumulative signal path bandwidth is significantly restricted relative to the bandwidth implied by the source sample rate, or any other hardware configuration that cannot be satisfactorily pre-corrected by the simpler modes.

  Section 6.4.4 describes the process of generating pre-correction files.

Calibration Center Frequency.	This setting is not available in the User Defined Cal mode. To perform the pre-corrections calibration, the software transmits a specially designed calibration signal. To complete the calibration the 89601B VSA must be told the center frequency of the calibration signal at the other end of the signal path. This would be 0 Hz (the setting default) for a baseband to baseband calibration, but could, in principle, be any frequency as a result of frequency conversion in the signal path. This setting is not available in the User Defined Cal mode because, in that mode, it is not needed as no calibration is performed prior to download. In User Defined Cal mode, pre-correction is achieved by applying a previously computed filter defined by the named pre-corrections filter coefficients file.

Calibration Receiver Mirror Spectrum.	This setting is only available if 81199A option 002 is **not** installed **and** the Calibration Mode is set to Cal On Every Download or Cal On Settings. The signal path to be calibrated may invert or "mirror" the signal spectrum (due to IQ reversal, high-side mixing etc.). This setting allows the calibration routine to take this into account when characterizing the signal path by conjugating the received signal. If 81199A option 002 is not installed then there is no Acquisition Settings menu by which to control the receiver configuration. This setting is therefore added to permit control of this key configuration point during calibration.
Calibration Channel Config.	This setting is only available if 81199A option 002 is **not** installed **and** the Calibration Mode is set to Cal On Every Download or Cal On Settings. The calibration test signal as it appears at the end of the signal path to be calibrated may be an IQ signal (I and Q baseband inputs) or an IF/RF (1 channel) signal. This setting allows the calibration routine to take this into account by setting the 89601B / VSA input configuration appropriately. If 81199A option 002 is not installed then there is no Acquisition Settings menu by which to control the receiver configuration. This setting is therefore added to permit control of this key configuration point during calibration.
Apply:	This setting is only available in the User Defined Cal mode. The calibration procedure generates corrections for both IQ impairments and the complex channel response. It can be useful to be able to apply these in full or to only correct the channel response (e.g. when the IQ modulation is performed digitally) so this setting offers the following choice, • All corrections • Channel Response corrections only

Pre-Corrections Filename.	This setting is only available in the User Defined Cal mode. It identifies the path and name of the pre-correction filter that will be applied to the final waveform every time the user requests a download.

11.4.2 IQ Distortions

I/Q Exponent	The I and Q values are raised to this power before being subject to the other distortions. (Sign is preserved).
Gain on I/Q	Set the linear gain on I and Q.
DC Offset on I/Q	Set the DC offset present on the real and imaginary axes. Expressed as a fraction of 1.0 = constellation axis magnitude.
LO Quadrature Error	Set the deviation from perfect quadrature in the I and Q axis.
IQ Conjugation	Set whether I and Q will be output normally, or whether the Q values will be inverted or whether the I and Q values will be swapped.

11.4.3 Noise Settings

Noise On	If true, noise is added to the generated waveform file at the specified C/N ratio as measured in the specified measurement bandwidth.

Noise Only

When noise generation is enabled and this is true, the waveform file will contain noise only; at the same power level it would have were the signal also present.

This allows the user to measure the in-band power level directly.

If "Normalize data" is set true then the noise power level of the "noise only" waveform file will be increased by normalization. In this case the power level will not be at the same power level as it would have were the signal also present.

C/N Ratio

Set the carrier to noise ratio that will be applied to the signal in the specified measurement bandwidth.

Measurement Bandwidth

Set the bandwidth in which the carrier to noise ratio is measured. Normally, this should be set to match the occupied bandwidth of the signal.

11.4.4 Phase Modulation

Peak Amplitude	This impairment applies sinusoidal phase modulation to the waveform. This sets the peak phase rotation. So, for example, with the value set to 20°, a constellation point at 0° will oscillate sinusoidally between +20° and -20°.
Modulation Frequency	Set the frequency of the sinusoidal phase modulation.

11.4.5 Post Processing

The Post Processor settings are only visible in the window if you have the 81199A option DEV installed.

Custom post processing is explained in the 81199A Development Option Guide (P/N 81199-91030)

Post Processor Library	This specifies the post processor library (DLL) that will be used to post process the generated waveform data. The DLL file is selected using a File Open dialog that is activated by clicking the button labeled "...", which appears in the right of field when the setting is selected.
Post Processor Class Name	This setting selects the class of post processing object that will be used to post process the waveform data. When you next generate and output a waveform, the samples will be passed through an instance of your post processor class. All the valid post processing object classes found in the library DLL are presented as a drop-down list. The DLL can contain one or more post processing classes, but only classes that implement the 81199A post processor interface will be listed.

11.4.6 Sample Rate

Sample Rate Mode

This sets how the final output sample rate is determined.

Any band-limited waveform has a lower bound for alias-free signal sampling and this is often used as the default sample rate for signal generation. For example IEEE 802.11ad defines a reference sample rate of 2.64 GHz for its OFDM modulation modes.

The 81199A will initially generate signals at an appropriate, format specific, minimum sample rate; however the output sample rate will usually be higher than this. This may be because the signal has been shifted to an offset frequency, or because it has been mixed with other higher bandwidth signals, or simply to match output device capabilities. The necessary fractional sample rate conversions are achieved by arbitrary resampling.

If this setting is set to auto, the final sample rate is primarily determined by the selected output device's maximum available sample rate, This is done mainly to move the sampling image as far away from the desired signal as possible (within the capabilities of the output device), but also to simplify the generation and application of pre-corrections.

When the output "device" is a data file, the appropriate final sample rate is determined by the type of signal being generated,

If the mode is set to manual, then the sample rate can be set to any value that is valid for the chosen output device. For data files, this means the sample rate can be set to any value, though, of course, excessive oversampling can result in very large data files.

Sample Rate

This sets the sample rate for the final waveform. If you are specifying the sample rate manually, the sample rate should be at least,

sample rate = 2.56 * (|max track offset| + 0.5 * max signal bandwidth).

Please see the example in section 11.3.5 for more detail on working with track frequency offsets.

11.4.7 Skew

Skew

If set to a non-zero value, the real and imaginary parts of the waveform are generated with a time skew between them. If the skew value is positive, the real component will lead the imaginary, while a negative value will cause the real component to lag the imaginary.

Skew is applied on a per-segment basis so if there are discontinuities between segments, skew can make this more pronounced.

11.4.8 Track 1...4 Settings

Amplitude

Set the amplitude scale factor for the track.

Phase

Set the phase angle for the track. A phase angle of 180° will cause the complex value to be negated, that is A + jB will become -A - jB.

Offset Frequency

Set the offset frequency (F_{OFF}) of the track. A value of zero means that the signal is a "zero IF" or baseband IQ signal and no further conversion is done. If the value is non-zero, then the signal is re-modulated digitally to the specified frequency offset from zero.

The ability to generate a digital IF in this way is limited by the maximum sample rate available from the output device.

For a given sample rate, the maximum valid offset will be equal to,

max track offset = ±((sample rate / 2.56) – (0.5 * occupied bandwidth))

For example, with a 12 GSa M8190A playing an 802.11ad OFDM waveform, the maximum track offset is limited to

max track offset = ±((12.0 / 2.56) – (0.5 * 2.4)) = ±3.4875 GHz.

It is possible to create a multi-channel signal by specifying different offsets for different tracks.

The 12 GSa M8190A can directly generate RF "scenarios" up to 5 GHz wide in this way (and up to 10 GHz if the complex signal can be re-modulated to a higher IF), as described in section 11.3.5., however in both cases is important to check that the hardware being driven by such a signal can also handle such wide bandwidths.

11.4.9 Waveform Generator Corrections

Sin(x)/x Correction On

Inside the 81199A software, waveforms are represented by a sequence of instantaneous values, implicitly spaced out in time at the sample rate with zero signal between each sample. When these instantaneous values are played out using an AWG, the sample value is held at the AWG output for the sample period, effectively turning each zero width sample impulse into a finite width pulse.

This has the effect of multiplying the signal spectrum by the spectrum of a sample-period wide pulse. The frequency spectrum of such a pulse has a sin(x)/x shape with the first zero crossing at the sampling frequency. For signals where the sampling frequency is a relatively low multiple of the signal bandwidth the resulting sin(x)/x shaped attenuation of the signal in the frequency domain can be significant (perhaps 1 or 2 dB at the band edge).

81199A can compensate for this droop by applying an appropriate frequency domain pre-emphasis to the signal before it is downloaded to the AWG.

The sin(x)/x pre-emphasis is optional because it is not appropriate to apply it when the signal data is being saved to a file.

Sin(x)/x Filter Boost

The sin(x)/x compensation filter can be used to apply more than normal high-frequency lift as a quick and approximate compensation for real droop in the baseband response.

A value of 1 gives normal sin(x)/x compensation. A value of n will give n times the amount of high frequency lift.

11.5 Current Output Device Settings

This window is where you configure all settings relating to the currently selected output device.

11.5.1 Agilent AWG (81180B and M8190A)

The 81199A supports output to two models of Agilent AWG, the 81180B and the M8190A.

Instrument Address

Sets the IP address of the connected output device. The computer hosting the 81199A software and the output device must both be connected to the same LAN.

In the case of the M8190A, the IP address will be that of the computer hosting the M8190A firmware. If the M8190A software resides on the same computer as the 81199A then the IP address will be 127.0.0.1 (localhost).

Socket Port Number

Sets the port number on the output device to which SCPI commands are sent.

In Agilent products, the default port for SCPI commands is port 5025, however when multiple instances of a device exist at the same IP address (for example, multiple copies of the M8190A firmware running on a single PC) it can be necessary to configure a non-standard port number in order to communicate with the second and subsequent devices.

Time Out

Sets the receive timeout for the connection. If the AWG does not respond in the specified time a download may fail.

Offset (81180B only)	Set the coarse time offset between the two AWG channels. The offset is expressed in sample points (which translate to time, subject to the prevailing sample period). This setting is only available when the 81180B AWG is the current device.
Skew (81180B only)	Set the fine time skew between the two AWG channels. The skew is expressed in seconds.

Auto Scaling

Depending on modulation type, filtering, added noise, track summation etc., a final waveform may end up with a numerical range significantly larger than the nominal ±1.00 of the IQ constellation dimensions.

Set Auto Scaling True to ensure that under all circumstances, the AWG is not sent data values that would over-range the DAC and cause distortion due to clipping or wrapping. If enabled, the waveform will be scaled so as to fit the maximum AWG output range.

The auto-scaling procedure is,

1. The absolute maximum value across both the I and Q component is found. So, for example, if the I component ranged from -1.32 to + 1.29 and the Q component ranged from -1.34 to +1.31 then 1.34 would be taken as the absolute maximum value.
2. The found maximum value prior to scaling is reported in the Maximum Value setting.
3. All values in the waveform are divided by the found maximum value so that they will be less than or equal to 1.00.
4. The normalized values are converted to AWG-safe data values by multiplying them with the AWG range maximum.

This has the side-effect that every waveform is potentially scaled differently depending on the maximum value present. While this is the safe default, it may not be what you want because, for given AWG output gain settings, waveforms with different peak values would be generated with different average powers due to the auto-scaling.

If you want all waveforms to have the same average power level then you should set Auto Scale to False and use fixed scaling.

Maximum Value

When Auto Scaling is set to True, this setting reports the found maximum value prior to auto scaling. When Auto Scaling is set to False, this setting determines the maximum value that will be used to scale all waveforms.

This ensures that all waveforms will have the same average power level for a given AWG output gain setting, but you must ensure that the set maximum value is not exceeded by any waveform (otherwise distortion due to clipping or wrapping will occur).

If Maximum Value is set too high, the average signal power will be unnecessarily reduced and low crest factor signals will only use a small part of the AWG DAC range, which will compromise their accuracy and SNR.

You can get a good idea of an appropriate fixed Maximum Value by looking at the Maximum Values reported for various waveforms in Auto Scale mode.

AWG Granularity Options

Some of Agilent's wideband AWGs have memory granularity. That is, the waveform length has to be an integer multiple of a minimum sample chunk size. The chunk sizes for some current AWGs are,

- 81180B – 32 samples
- M8190A Speed Mode – 64 samples
- M8190A Precision Mode – 48 samples
- M8190A/N5152A Mode – 48 samples
- M8190A DUC Modes – 24 samples

If the waveform generation process has resulted in a sample count that is not a whole number of memory chunks long, then this setting determines how the AWG granularity requirement is met. The options are,

Repeat: Multiple repetitions of the waveform are downloaded to the AWG memory until it occupies a whole number of memory chunks. This can increase download times and AWG memory usage considerably but will ensure that the best possible signal quality.

Truncate: A few samples are removed from the waveform. This is not appropriate for signals that are computed to be phase continuous when played repetitively.

Append Silence : This is the least intrusive for a burst mode signal. A few extra zero samples are added to the waveform. This has the effect of slightly increasing the inter-packet gap so it is not appropriate if you want a precise time between bursts. It is also not appropriate for signals that are computed to be phase continuous when played repetitively.

Reference Clock Source

The M8190A can be configured to take its reference clock either from the 100 MHz clock provided by the AXIe card cage backplane or from the REF CLK IN connector on the front panel.

The AXIe card cage backplane 100 MHz clock can be phase locked to the 10 MHz CLOCK IN connector on the card cage Embedded System Module (ESM).

Reference Clock Frequency

When the M8190A is configured to take its reference clock from the REF CLK IN connector on the front panel it, by default, assumes that the reference clock frequency is 100 MHz, but it can be configured to accept other frequencies in the range 1 MHz to 200 MHz so that it can use, for example, the 10 MHz reference clock that is commonly available from other equipment, such as Agilent signal generators.

It is common for specifications to mandate that the center frequency and symbol clock frequency of a modulated signal are locked to the same frequency reference. You can ensure you meet this requirement by connecting a suitable reference clock output from your modulation and up-conversion hardware to the M8190A or AXIe card cage reference clock input.

Play On Download

If this is set true then the AWG will be instructed to play the waveform once it is downloaded.

11.5.2 Channel 1/2 Settings

Download to Channel

If this is set true, waveform data will be downloaded to this channel.

Normally, the real part of a complex signal will be downloaded to channel 1 and the imaginary part of a complex signal will be downloaded to channel 2.

If the final waveform happens to be real valued then the signal can be played out on a single channel AWG by setting Download to Channel false for channel 2.

This prevents the 81199A software from trying to download the un-needed (zero valued) complex part to a non-existent channel.

Output Coupling	Set the output coupling for the AWG. The choices are, • DAC – the AWG DAC outputs are brought directly to the front panel with no amplification or filtering. • DC – the AWG DAC outputs are passed through a DC-coupled amplifier. • AC – the AWG DAC outputs are passed through an AC coupled amplifier.
DAC Amplitude	When the Output Coupling is set to DAC, this sets the AWG channel maximum amplitude Typically, the DAC amplitude has limited range because there is no output amplifier in circuit.
DAC Offset	When the Output Coupling is set to DAC, this sets the AWG channel DC offset. Typically, the DAC DC offset has limited range because there is no output amplifier in circuit.
DC Amplitude	When the Output Coupling is set to DC, this sets the AWG channel maximum amplitude.
DC Offset	When the Output Coupling is set to DC, this sets the AWG channel DC offset.
AC Amplitude	When the Output Coupling is set to AC, this sets the AWG channel maximum amplitude.

Delay (M8190A Only)	Set the delay for this channel. Positive and negative skew between the two AWG channels is achieved by setting a positive delay on channel 1 (1 lags 2) or channel 2. (2 lags 1) This setting is only available when the M8190A is the current device.

11.5.3 Save File Settings

When the current output device is set to File, the Current Output Device Settings reduces to a set of Save File settings.

Waveform Filename

Specify the name of the file that the waveform will be saved to.

The file is selected using the Open File dialog that is activated by selecting the setting field and then clicking the button with the ellipsis that appears on the right of the setting field.

The following file types are supported,

- Comma Separated Value (CSV file) : These are plain text files suitable for general importing to other applications, particularly spreadsheets such as Microsoft Excel. If the optional 89601B header is present, then it can also be read back into the 81199A or 89601B VSA software as a "recording".

- N5110A Waveforms (BIN file) : These are binary files that store waveform data as scaled 16-bit integers without any embedded information about, for example, center frequency or sampling rate. However, an optional header file containing this information will be written if the Include 89600 Header setting is set True.

- MATLAB (MAT file): These are MATLAB Level 5 files containing a 1 x N matrix called Y1 that contains the complex valued waveform data, and a 1 x 1 matrix called XDelta that contains the sample period in units of seconds.

The waveform data in the file is not encrypted.

The option to output to a file is only available with 81199A option DFP.

Include 89600 Header	When this is set true and the user generates a CSV or BIN file, the header information for the 89600 VSA will be saved. When saving BIN header files the header is saved in a separate file with a .txt extension. This allows CSV and BIN files to be immediately read back into the 81199A or 89601B software as a "recording", which can be very useful for tutorial or demonstration purposes.
CSV File Style	This determines how the data is organized in the CSV file. The options are, • One Channel : The data is written with one Y channel that has a single column of complex values. • Two Channel : The data is written with two Y channels, Y1 contains the real data, while Y2 contains the imaginary data. • Interleave : The data is written in a single column of interleaved real then imaginary part values. This format is intended to facilitate waveform input to Agilent EESof ADS and SystemVue tools. The waveform data can be read and converted to complex data using the block sequence, ReadFile > Distributor2 > RectToCx.
Normalize Data	When this is set to true, the complex data in CSV and MAT files is scaled so that both the real and imaginary parts lie strictly in the range ±1. The data in BIN files is always normalized to be in the range ±32767 but the scaling factor in the header file is set to scale the data to ±1. If noise has been added to the waveform, the data will be scaled to preserve the specified C/N ratio, but this will inevitably mean that the signal power is reduced accordingly.

12 Pre-Correction

12.1 Introduction

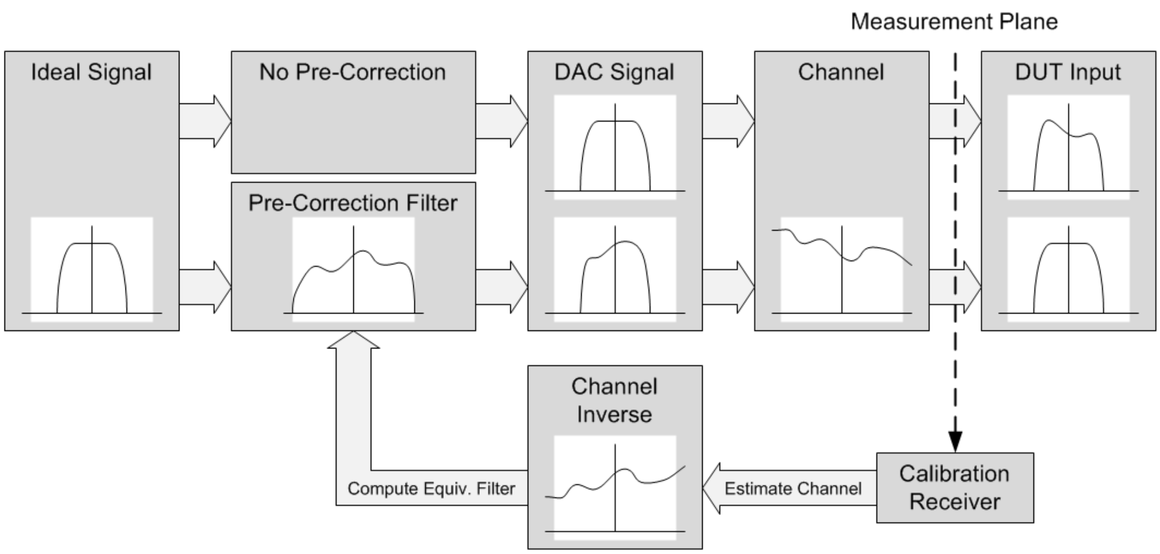

Figure 41. Principle of Pre-Correction

The ideal signal on the left of Figure 41 represents the final composite waveform at the output of the waveform mixer in the 81199A core.

In this context, ideal means that the signal is, mathematically speaking, exactly the signal that you want to transmit; it does not necessarily mean that the signal is perfect. For example, you may have deliberately included specified levels of impairment such as quadrature error, skew or Gaussian noise, or perhaps summed in an interfering tone.

In normal operation, illustrated by the upper signal flow in Figure 41, the ideal signal will be downloaded to the AWG waveform memory and transmitted. It will then be subject to any imperfections in the channel before arriving at the DUT input.

Since the "channel" (analog signal path) starts at the digital inputs of the D/A converters in the AWG, the channel will include the AWG output paths (amplifiers, filters etc.) and any subsequent vector modulation or up-conversion necessary to create the test signal required by the DUT.

We would like the signal delivered to the DUT input to be the ideal signal, but in practice the signal path will be imperfect and the delivered signal will be distorted as a result. We cannot know in advance what these imperfections will be because they are entirely dependent on the specific hardware and its configuration, and this is determined by the user.

We can, however, measure the test setup to determine its channel response and vector modulation impairments, then use that information to develop a filter that will pre-compensate the waveform data so that the delivered signal is as near to the ideal signal as possible.

The signal flow with pre-corrections applied is illustrated by the lower flow in Figure 41. The ideal waveform data is pre-corrected by applying a filter. As a result, the signal at the DAC will be non-ideal, but the channel imperfections will then cancel those of the signal, resulting in the intended signal at the DUT input.

The channel imperfections are estimated by transmitting a specially designed test signal, which is then acquired by a calibration receiver at the point in the diagram labeled as the measurement plane. This should be as close to the DUT input as possible because this is the point where the signal will be nominally ideal after pre-correction.

In this simple model, the calibration receiver is assumed to be perfect and to not add any further impairment to the signal before it is digitized at the calibration receiver's A/D converters. In practice the calibration receiver should be independently calibrated to the desired measurement plane.

Based on the signal data from the calibration receiver, the 81199A pre-correction algorithm makes an estimate of the complex channel response and IQ impairments, then designs a corresponding pre-correction filter. The next time generation is requested (with pre-correction enabled) the filter is applied to the ideal waveform data before the signal is downloaded to the AWG.

12.2 Enabling Pre-Correction

The configuration and application of pre-corrections is controlled by the Calibration settings in the Final Waveform Settings window. All the possible settings values are documented in section11.4.1, but essentially there are four calibration modes,

- No Cal
- Cal on Every Download
- Cal on Settings Change
- User Defined Cal

Each of the above modes applies the same pre-correction calibration algorithm; the difference is only in when the correction is computed and when it is applied. The right mode to use depends on your particular hardware configuration.

12.3 What Can Go Wrong?

The specially designed calibration test signal mentioned earlier always occupies approximately 80% of the IQ bandwidth that is implied by the sampling rate. This may not be appropriate for all signal path configurations without adjustment.

Ideally the signal path should be able to accommodate the full bandwidth of the calibration signal, but if it is severely attenuated by a bandwidth constricted signal path, then there will be very little higher frequency test signal energy present at the calibration receiver and as a result the pre-correction algorithm will not be able to estimate the channel response or determine IQ impairments accurately.

If the algorithm estimates are noisy, then the derived filters can be noisy and actually degrade rather than improve the signal quality. This effect is illustrated in Figure 42.

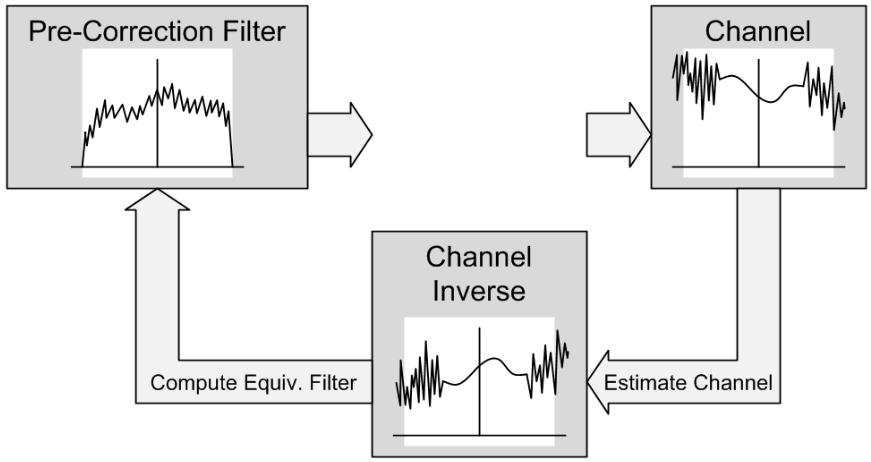

Figure 42. Noisy Pre-Correction Due to Band-Limited Test Signal.

If this is the case for your setup, and it is usually easy to identify by the presence of excessive band-edge noise in the channel response and IQ impairment graphs, then you should reduce the waveform sample rate by manually setting a sample rate more tailored to the bandwidth of the signal you are generating.

We consider an example of this situation in section 12.5.

If you a have been using a high sample rate for waveform generation because you are concerned about the proximity of sampling images in the generated signal, then you can use the User Defined Cal mode to perform the calibration at the reduced (tailored) sample rate, save the pre-corrections filter to a named file, then return to the higher sample rate for subsequent generation, with the named pre-corrections file identified in the settings. In this case, the software will re-sample the pre-corrections filter to the higher rate.

There is more detail in section 12.8.

12.4 Pre-Correcting a Baseband Connection

Figure 43 illustrates the essential hardware configuration that we are assuming in this section. We also assume here that you have already established correct operation with un-corrected signals. See sections 4 and 5 if you need assistance with basic connectivity.

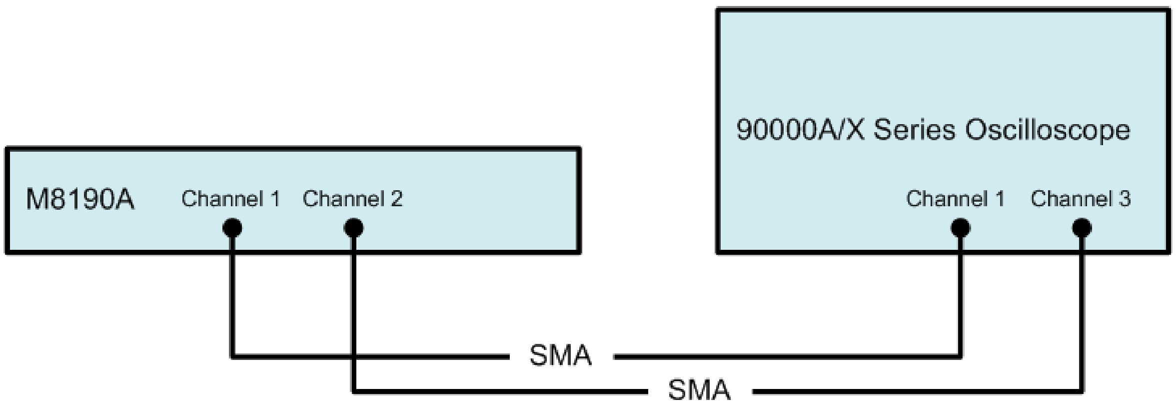

Figure 43. Essentials of Pre-Correcting at Baseband IQ

Select the M8190A as the output device using the menu selection Generate > Output Device > Agilent M8190A – Precision Mode (14 bit, 8 GHz), then configure its settings using the Output Device Settings window.

Compose the waveform you wish to transmit in the Waveform Layout window.

In the Final Waveform Settings window, change the Calibration settings,

- Calibration Mode : Cal On Every Download
- Calibration Center Frequency : 0.000000 Hz

In the Acquisition Settings window, click the "Basic" button to select the simpler settings list, then change (if necessary) the settings to,

- Channel Config : I and Q Baseband Inputs (always change this setting first because it resets the center and span values)
- Center : 0.000 000 000 Hz
- Span : 2.500 000 000 GHz
- Points : 102,401
- Mirror Freq: False
- Range : 400 mV (or use autorange)
- Main Length : 40.000000000 µs

Then click the Generate and Output... button in the tool bar.

The software will automatically download and analyze a test signal. On completion of the calibration phase, graphs of the channel response and IQ imbalance are presented for inspection.

Figure 44 and Figure 45 show measurements typical of the baseband IQ setup illustrated in Figure 43.

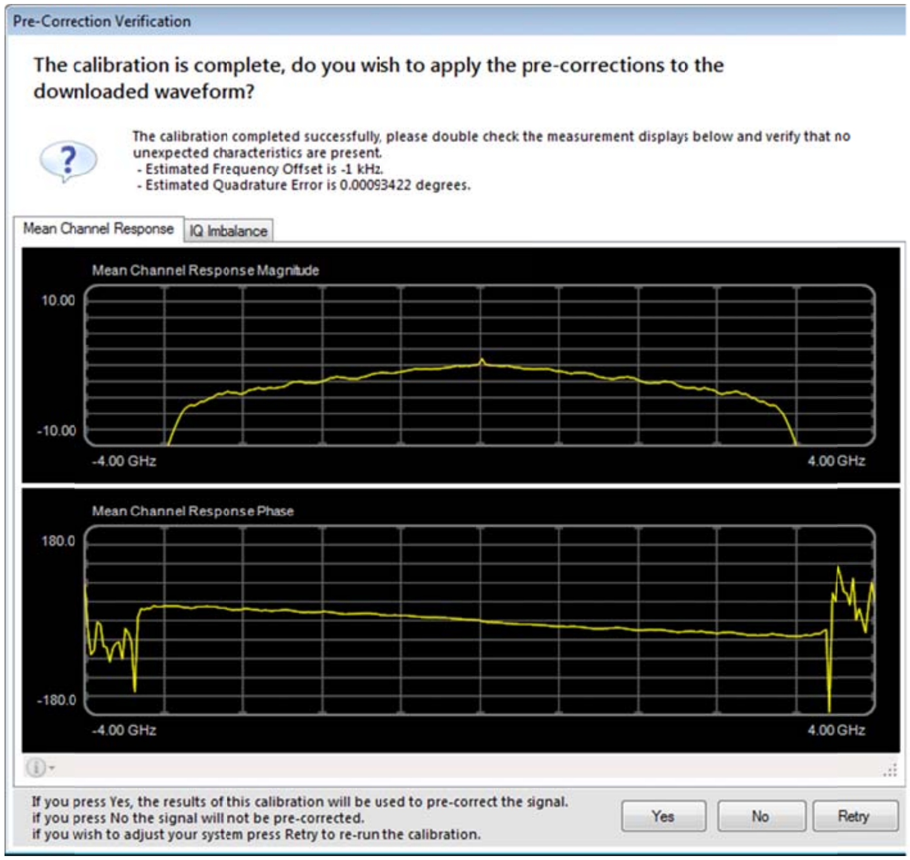

Figure 44. Typical Mean Channel Response for a BBIQ Connection

Features to note that are indicative of a good measurement:

- Both graphs are well behaved across the middle 80% (approximately). Some attenuation and noise at the graph edges is to be expected as the calibration test signal is shaped to avoid aliasing errors, so there is no test stimulus to analyze in this area.

- The graphs indicate physically probable properties. In this example the magnitude graph reveals credible high-frequency / band-edge roll-off, and the phase graph reveals broadly linear phase with no significant discontinuities in the phase progression.

Note, however, that if the phase values are close to the 180° / -180° point then phase wrapping may produce top to bottom jumps in the graph.

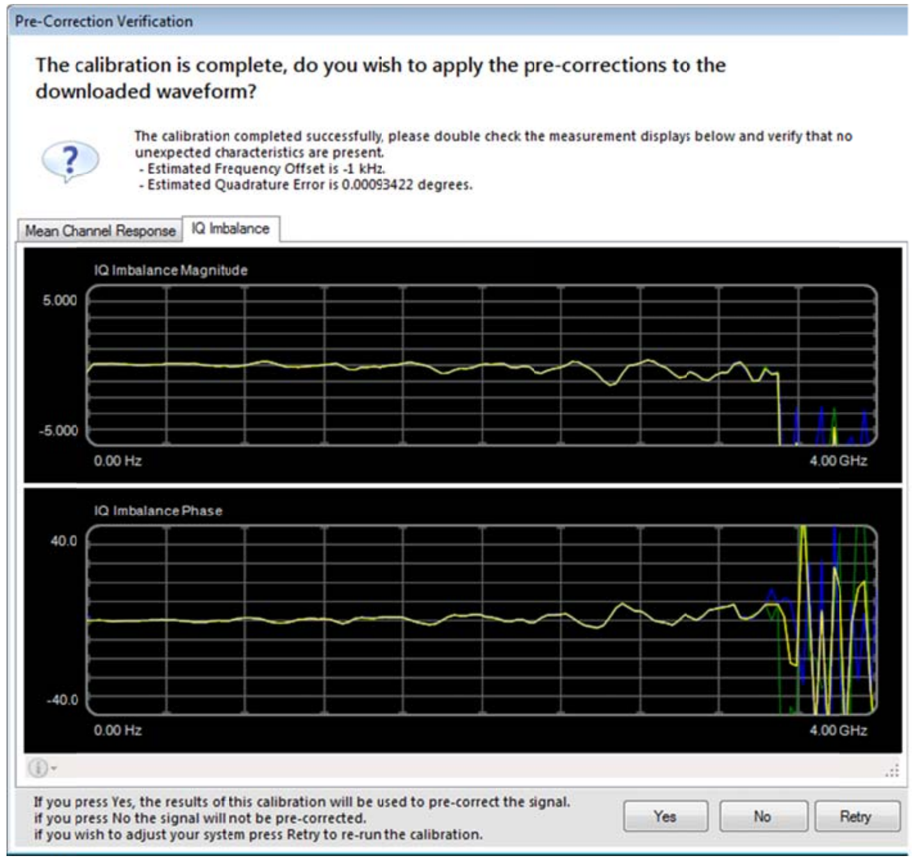

Figure 45. Typical IQ Imbalance for a BBIQ Connection

The IQ Imbalance graphs each contain three traces. The Dark Blue and Dark Green traces are separate estimates which are averaged to provide the final IQ imbalance estimate, traced in Yellow.

Similar goodness criteria apply to the IQ imbalance graph as to the Channel Response (you should always check both to confirm that the calibration is good).

Here we see that the I and Q channels are very well matched in magnitude and phase at lower frequencies, degrading slightly at higher frequencies. Again the graphs are well behaved, and only become noisy at the highest frequencies where there is no test signal energy.

Assuming the calibration has been successful, and you click the Yes button, the software will calculate an appropriate pre-correction filter based on the measured responses, then apply the filter to the final waveform and download it to the M8190A.

The signal present at the oscilloscope inputs should now be a corrected baseband IQ signal.

12.5 Pre-Correcting a Digital IF (M8190A) Connection

Figure 46 illustrates the essential hardware configuration that we are assuming in this section. We also assume here that you have already established correct operation with un-corrected signals. See sections 4 and 5 if you need assistance with basic connectivity.

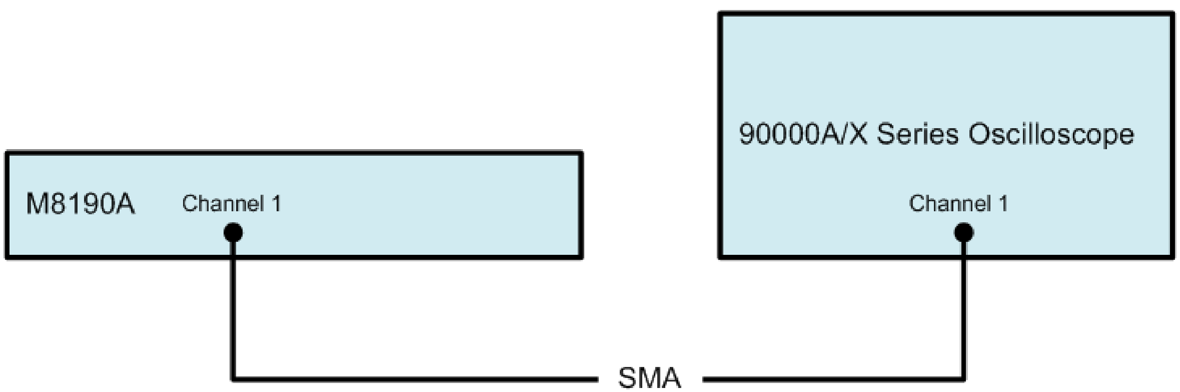

Figure 46. Essentials of Pre-Correcting a 5 GHz Digital IF

Select the M8190A/N5152A as the output device using the menu selection Generate > Output Device > Agilent M8190A/N5152A, then configure its settings using the Output Device Settings window.

Compose the waveform you wish to transmit in the Waveform Layout window.

In the Final Waveform Settings window, change the Calibration settings,

- Calibration Mode : Cal On Every Download
- Calibration Center Frequency : 5.000000 GHz

In the Acquisition Settings window, click the "Basic" button to select the simpler settings list, then change the settings to,

- Channel Config : 1 Channel (always change this setting first because it resets the center and span values)
- Center : 5.000 000 000 GHz
- Span : 2.500 000 000 GHz
- Points : 102,401
- Mirror Freq: True
- Range : 316 mV (or use autorange)
- Main Length : 40.000000000 µs

Then click the Generate and Output... button in the tool bar.

Note that the Mirror Freq setting is True because the M8190A / N5152A mode introduces a spectrum inversion in the 5 GHz output signal.

The software will automatically download and analyze a test signal. On completion of the calibration phase, graphs of the channel response and IQ imbalance are presented for inspection.

Figure 47 and Figure 48 show measurements typical of the digital IF setup illustrated in Figure 46.

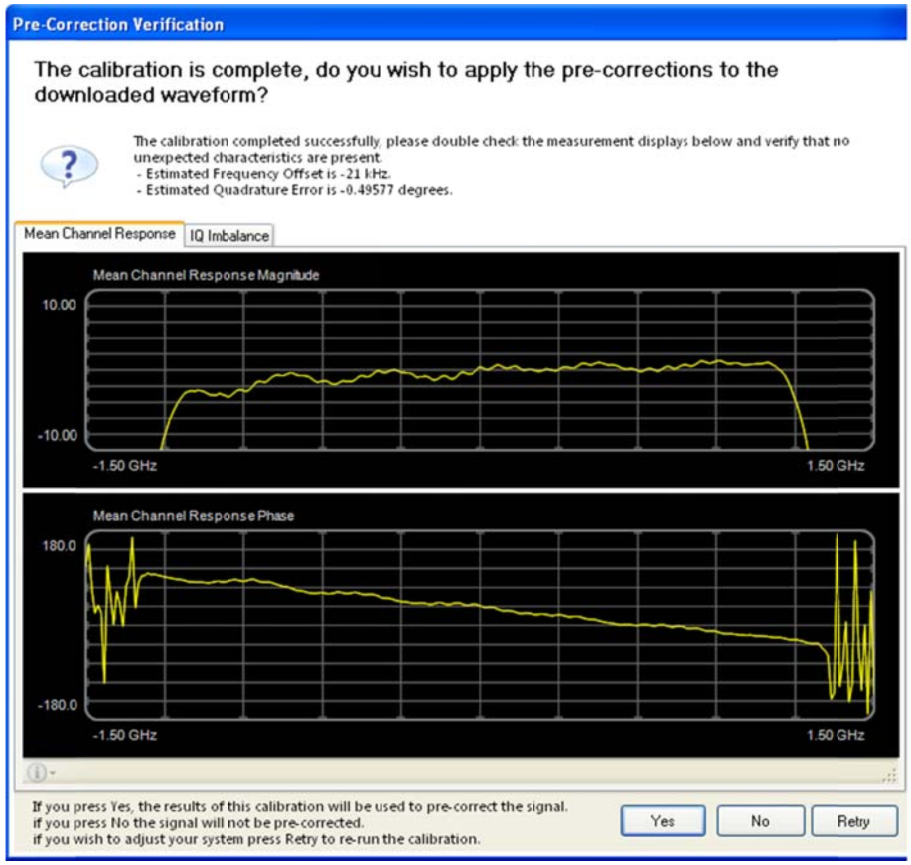

Figure 47. Typical Mean Channel Response for a Digital IF Connection

Features to note that are indicative of a good measurement:

- Both graphs are well behaved across the middle 80% (approximately). Some attenuation and noise at the graph edges is to be expected as the calibration test signal is band-limited to avoid aliasing errors, so there is no test stimulus to analyze in this area.

- The graphs display physically probable properties. In this example the magnitude graph reveals an asymmetric slope across the passband (suggesting that this non-flatness is imposed after modulation) and the phase graph reveals broadly linear phase with no significant discontinuities in the phase progression.

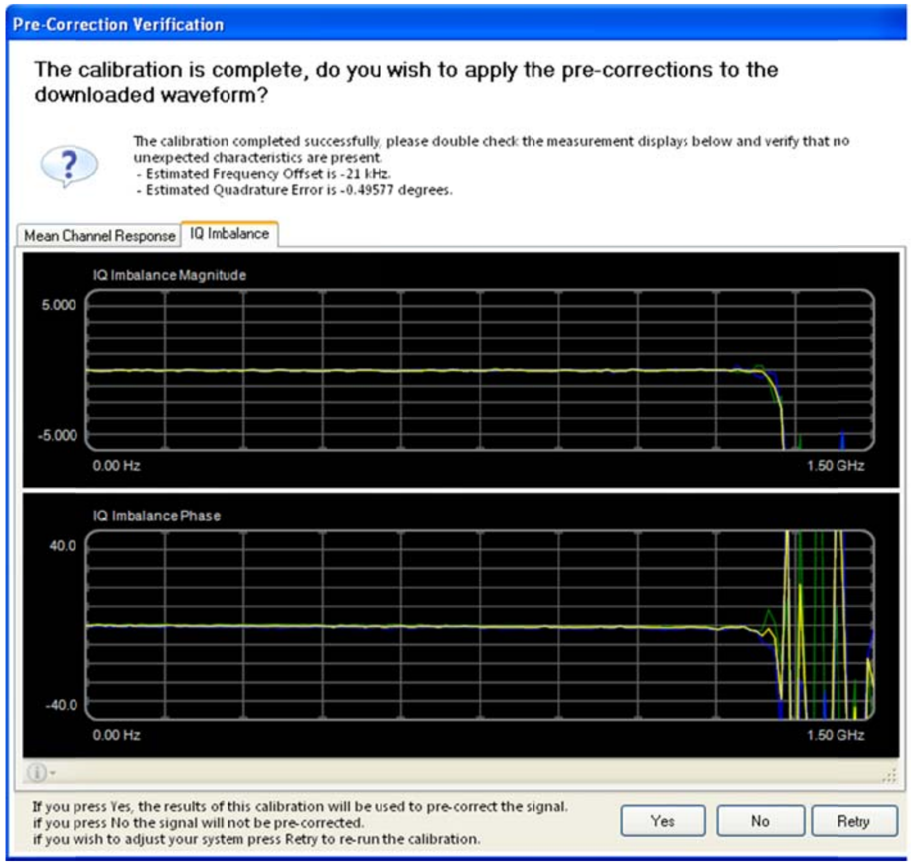

Figure 48. Typical IQ Imbalance for a Digital IF Connection

Similar goodness criteria apply to the IQ imbalance graph as to the Channel Response (you should always check both to confirm that the calibration is good).

Here we see that the IQ magnitude and phase are extremely well matched, as you might expect because, in this case, the I and Q signals are never in analog form; the IQ modulation is performed digitally before D/A conversion. Again the graphs are well behaved, and only become noisy at the highest frequencies where there is no test signal energy.

Assuming the calibration has been successful, and you click the Yes button, the software will calculate an appropriate pre-correction filter based on the measured responses, then apply the filter to the final waveform and download it to the M8190A.

The signal present at the oscilloscope inputs should now be a corrected (spectrally inverted) first IF signal at 5 GHz.

12.6 Pre-Correcting an Analog IF (E8267D) Connection

Figure 49 illustrates the essential hardware configuration that we are assuming in this section. We also assume here that you have already established correct operation with un-corrected signals. See sections 4 and 5 if you need assistance with basic connectivity.

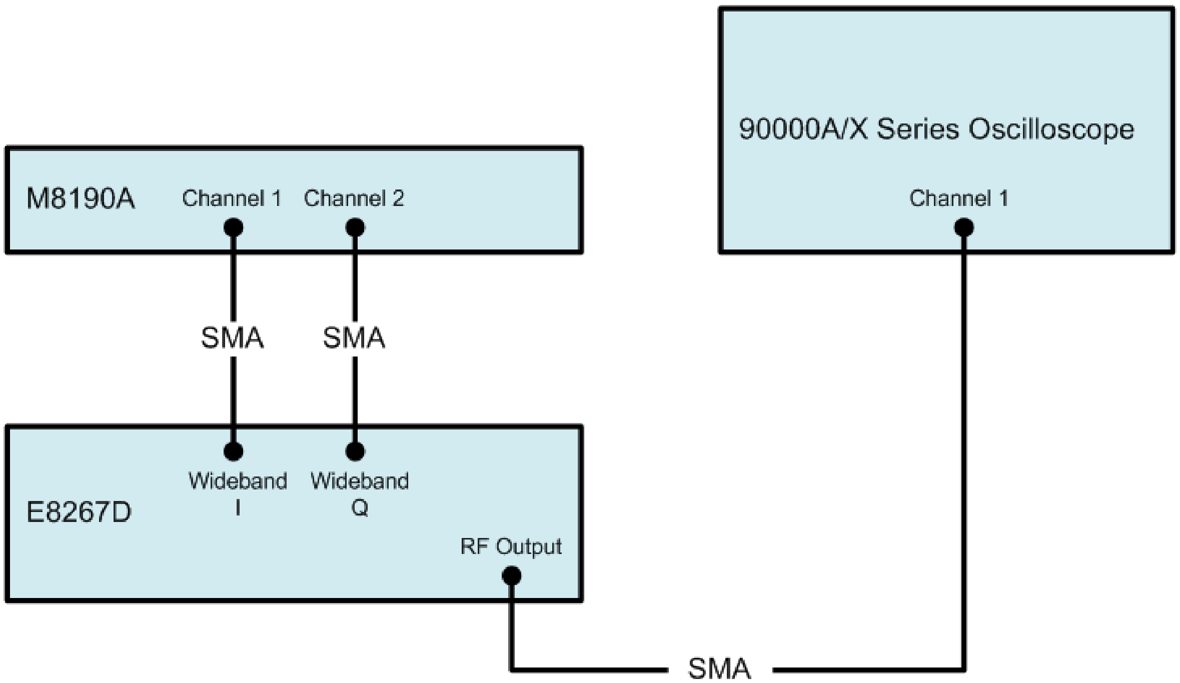

Figure 49. Essentials of Pre-Correcting an Analog IF

Select the M8190A as the output device using the menu selection Generate > Output Device > Agilent M8190A – Precision Mode (14 bit, 8 GHz), then configure its settings using the Output Device Settings window.

Compose the waveform you wish to transmit in the Waveform Layout window.

In the Final Waveform Settings window, change the Calibration settings,

- Calibration Mode : Cal On Every Download
- Calibration Center Frequency : 5.000000 GHz <see note>

In the Acquisition Settings window, click the "Basic" button to select the simpler settings list, then change (if necessary) the settings to,

- Channel Config : 1 Channel (always change this setting first because it resets the center and span values)
- Center : 5.000 000 000 GHz <see note>
- Span : 2.500 000 000 GHz
- Points : 102,401
- Mirror Freq: False
- Range : 316 mV (or use autorange)
- Main Length : 40.000000000 µs

Then click the Generate and Output... button in the tool bar.

Because of the test equipment's flexibility, the center frequency, can, in principle, be any frequency supported by both the E8267D and the 90000A/X series oscilloscope. For test purposes we suggest you use 5.0 GHz.

When using the E8267D PSG at 5 GHz, remember to increment the PSG RF frequency by 1 Hz to 5.000000001 GHz. This causes the PSG firmware to select the filter band for frequencies > 5 GHz, which has a much flatter response than the default choice for exactly 5 GHz.

The software will automatically download and analyze a test signal. On completion of the calibration phase, graphs of the channel response and IQ imbalance are presented for inspection.

If you see an extremely noisy channel response such as that illustrated in Figure 50, you have most likely not set the calibration center frequency correctly. The calibration center frequency setting is in the Calibration settings group in the Final Waveform Settings window.

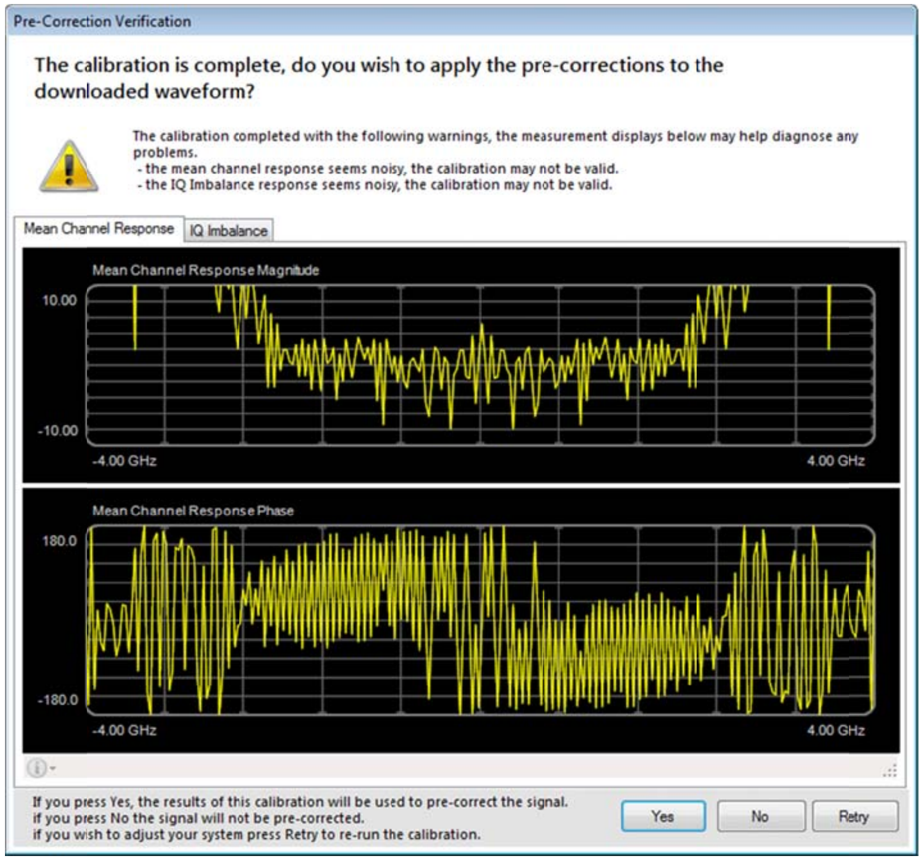

Figure 50. The Calibration center frequency has not been set correctly.

However, assuming that calibration center frequency has been set correctly, then Figure 51 shows a typical initial channel response result when calibration is executed on the analog IF setup illustrated in Figure 49 using the default sample rate of 8 GHz.

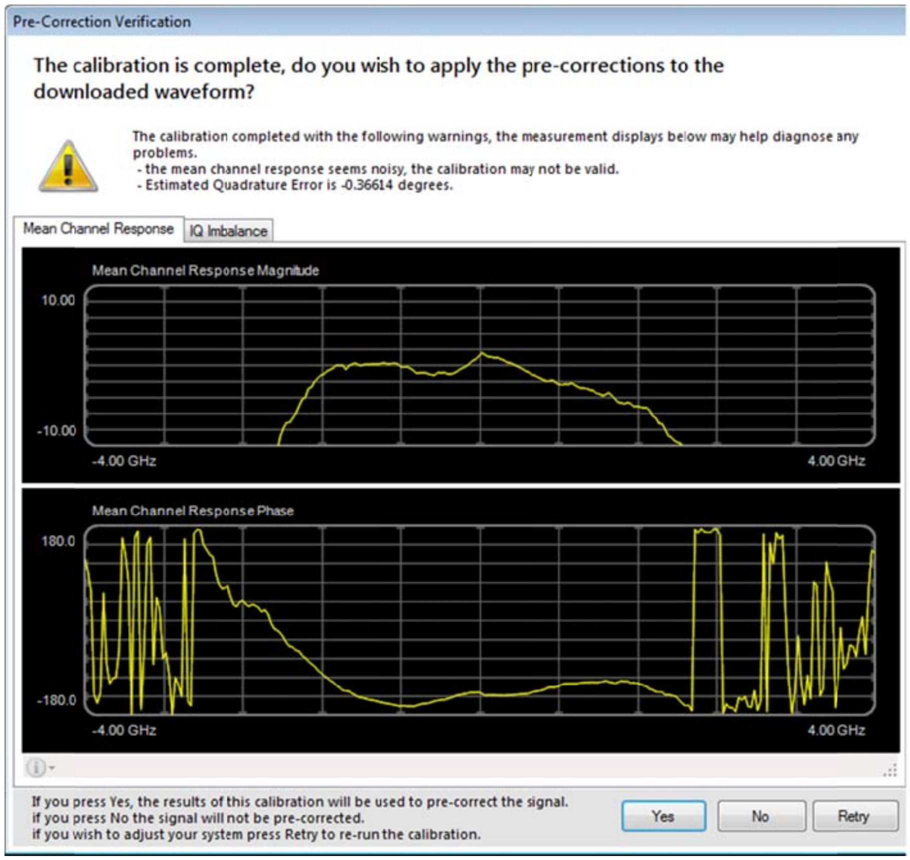

Figure 51. Mean Channel Response for an Analog IF Connection with Default 8 GHz Sample Rate.

In this case, with default settings, the measurement is still problematic, as indicated by the guidance at the top of the dialog.

Both graphs are still well behaved across the middle 50%, but the response falls below -10 dB relative to the band center beyond that. It appears that the test signal has been significantly attenuated by a bandwidth constricted channel.

An undesirable consequence of this is that a significant portion of the estimated amplitude and phase response will be noisy (as can be seen immediately on the phase graph, and can also be seen on the amplitude graph if you adjust the scale).

If we were to go ahead and perform the pre-correction computation based on this noisy estimate of the channel response and IQ impairments it would result in a poor (noise impaired) filter design. Figure 52 illustrates the undesirable effect of applying a noise impaired filter.

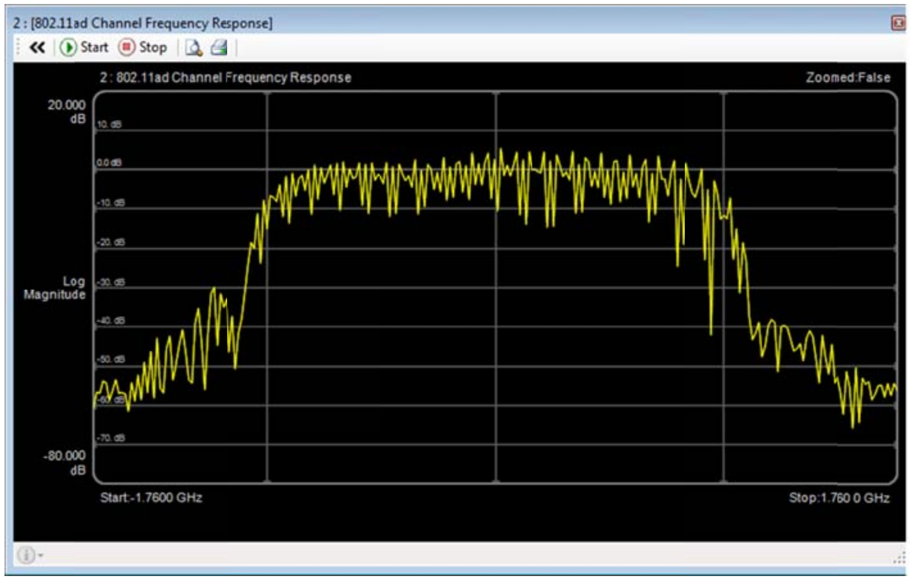

Figure 52. Result of applying a poor pre-correction filter.

Looking again at the received signal we see that, in this case, the original, approximately 6.4 GHz wide, test signal has been filtered down to less than 4 GHz wide by the limited analog bandwidth of the wideband IQ inputs in the E8267D PSG.

To achieve an accurate calibration, we must adjust the calibration bandwidth to better match the available channel bandwidth.

By default, the calibration bandwidth is equal to the waveform sample rate and here it is set to 8 GHz (the auto setting for an M8190A in precision mode).

This is significantly larger than both the available channel bandwidth and the signal bandwidth, and so can safely be reduced (in this case) to 4 GHz, to better match the available channel bandwidth.

To set the waveform sample rate manually, select the Final Waveform Settings tab, change the Sample Rate Mode setting from Auto to Manual, then change the Sample Rate setting to 4 GHz.

Re-run the calibration with the new sample rate.

Figure 53 and Figure 54 show typical improved measurements resulting from calibrating the analog IF setup illustrated in Figure 49 at a tailored sample rate of 4 GHz.

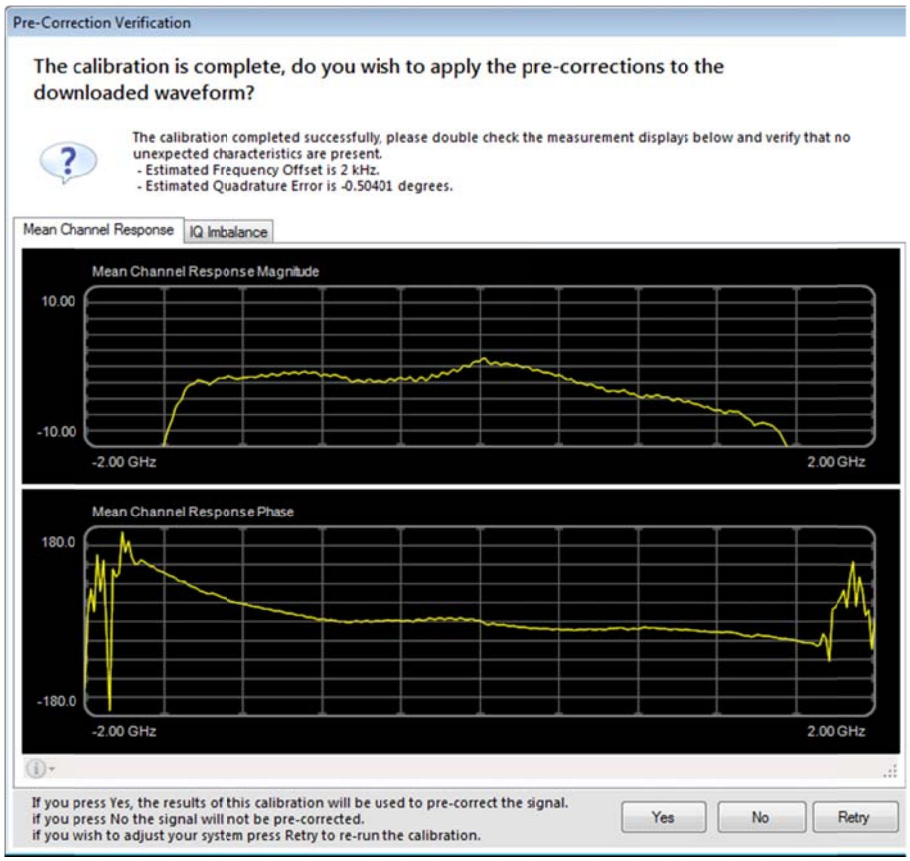

Figure 53. Typical Mean Channel Response for an Analog IF Connection with Tailored 4 GHz Sample Rate.

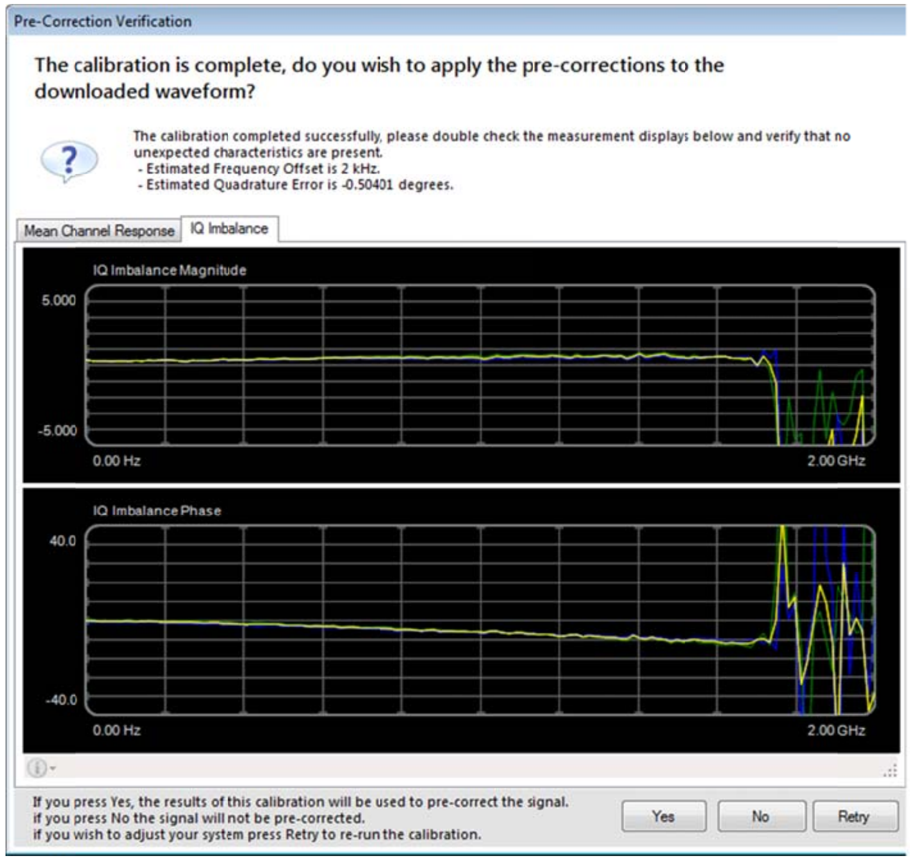

Figure 54. Typical IQ Imbalance for an Analog IF Connection with Tailored 4 GHz Sample Rate.

The revised calibration results exhibit the goodness criteria discussed earlier so we click the Yes button. The software will calculate an appropriate pre-correction filter based on the measured responses, then apply the filter to the final waveform and download it to the M8190A.

The signal present at the oscilloscope inputs should now be a corrected first IF signal.

12.7 Pre-Correcting an RF (N5152A) Connection

The N5152A up-converter can be driven by an IF signal generated digitally, as described in section 12.5, or in analog as described in section 12.6.

Figure 55 illustrates the essential hardware configuration for a digitally generated IF, while Figure 56 illustrates the configuration for an analog generated IF.

We assume here that you have already established correct operation with un-corrected signals. See sections 4 and 5 if you need assistance with basic connectivity.

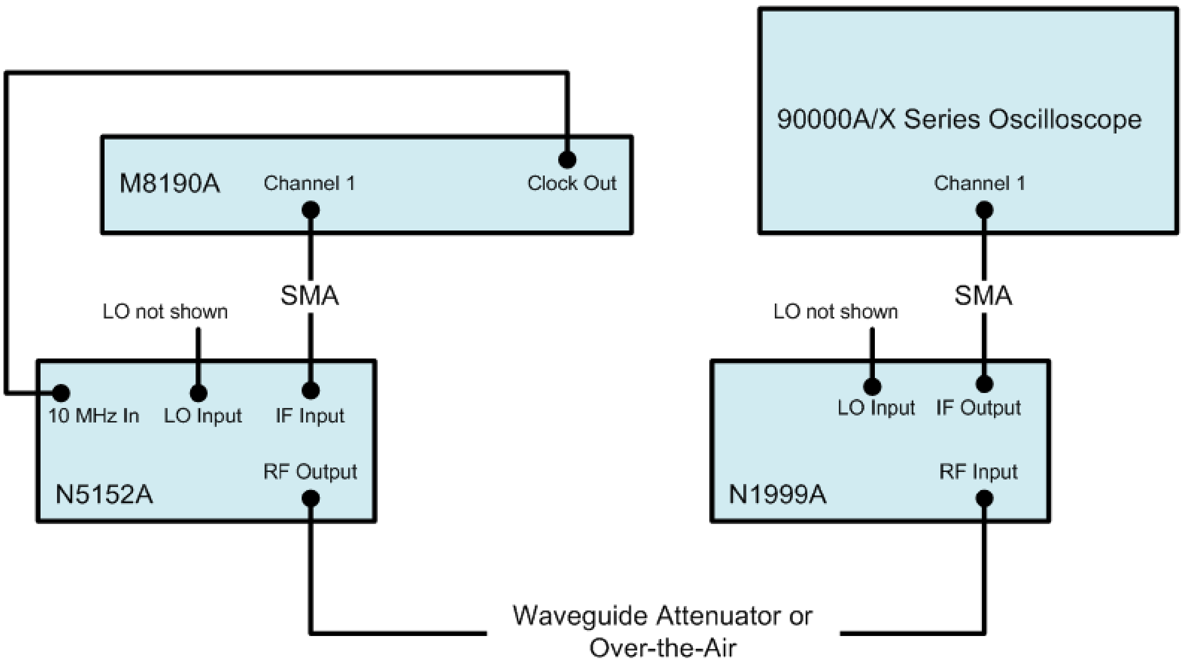

Figure 55. Essentials of Pre-Correcting a 60 GHz RF Link (Digital IF)

For this configuration, pre-corrections calibration proceeds as described in section 12.5.

Since the pre-corrections algorithm is based on an “end-to-end” measurement, the measurement plane is still at the input to the oscilloscope. The N1999A down-converter is considered to be part of the channel and will also be compensated by the pre-correction filter, so that the signal present at the oscilloscope inputs is the corrected signal.

Of course, we would like the RF signal at the output of the N5152A to be the ideal signal. To achieve this, the calibration receiver must be re-defined as the combination of the N1999A and the oscilloscope, and to do that, the ensemble must be separately calibrated to compensate for down-converter performance, thus moving the measurement plane to the 60 GHz interface.

The technique and equipment required to calibrate the N1999A/oscilloscope ensemble to achieve this is documented separately.

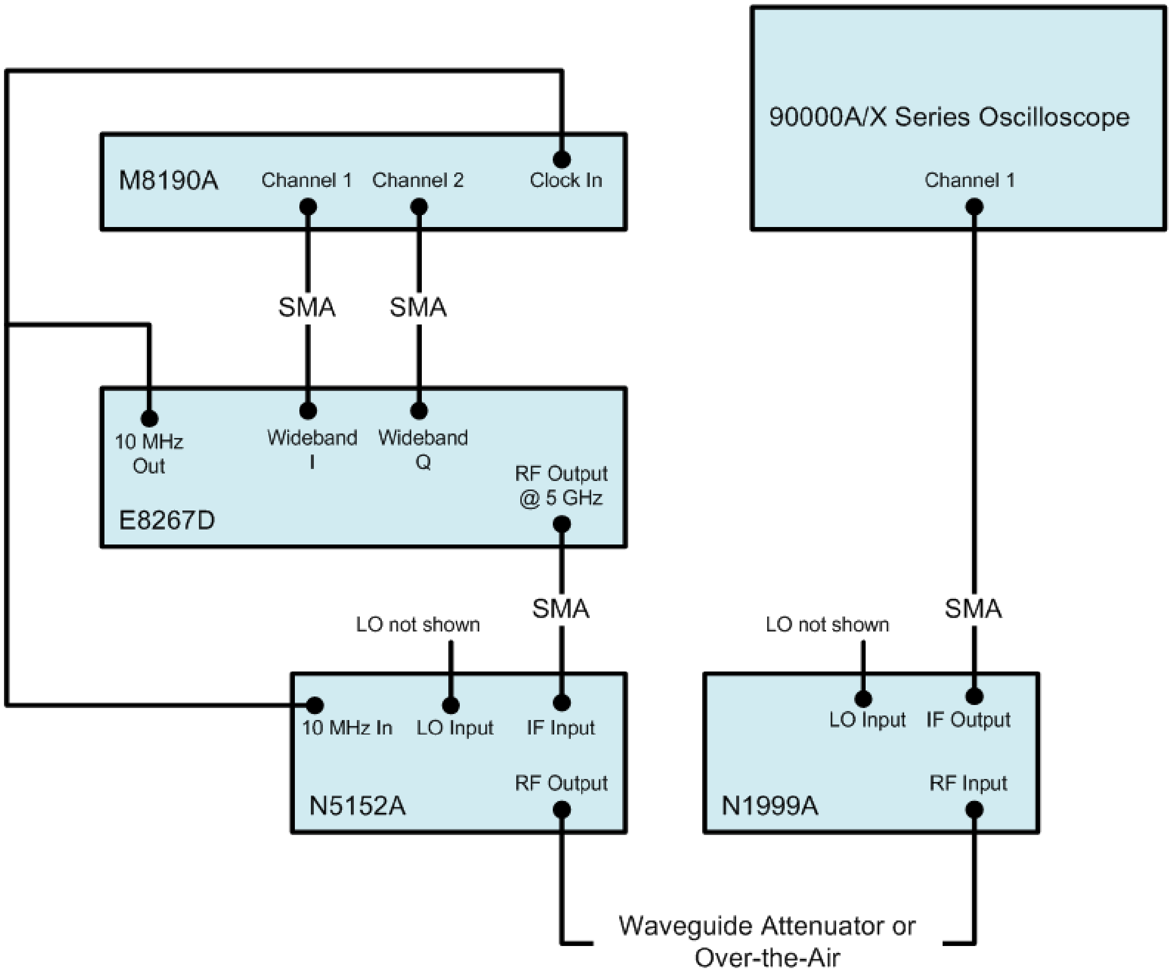

Figure 56. Essentials of Pre-Correcting a 60 GHz RF Link (Analog IF)

For this configuration, pre-corrections calibration proceeds as described in section12.6.

As with the digitally generated IF, the signal present at the oscilloscope inputs is, by default, the corrected signal. To move the measurement plane to the 60 GHz interface we must first calibrate the N1999A/oscilloscope ensemble as documented separately.

12.8 User Defined Pre-Corrections

User-defined pre-corrections can be useful if the user wishes to pre-compute corrections for a variety of signal path configurations, or where the cumulative signal path bandwidth is significantly restricted relative to the bandwidth implied by the source sample rate (but we need a high source sample rate for other reasons); or any other hardware configuration that cannot be satisfactorily pre-corrected by the typical means.

To compute a pre-correction filter, first configure your hardware to implement the signal path you wish to calibrate and ensure that the VSA / oscilloscope are correctly configured to receive the calibration test signal.

Select Generate > Generate User Defined Pre-Corrections. This will bring up the Pre-Correction Generation dialog box.

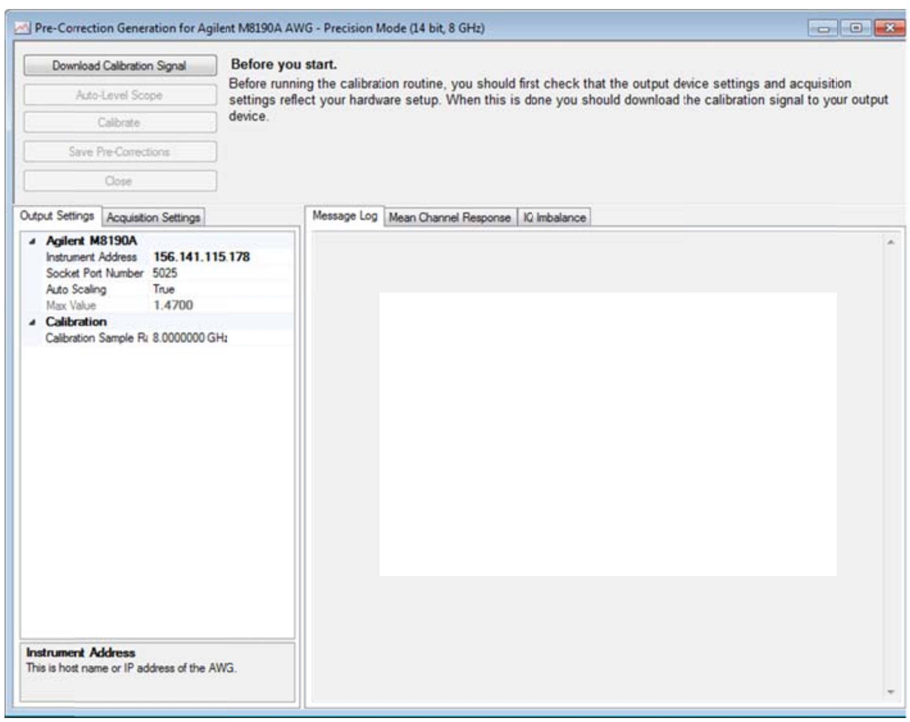

Figure 57. Pre-Corrections Generation Dialog

You should follow the on-screen guidance, but the flow is,

1. Click Download Calibration Signal – wait until the message log says "done".
2. Click Auto-Level Calibration Receiver – wait until the message log says "done". This step is optional if you are confident that the calibration receiver has the correct gain setting.
3. Click Calibrate – wait until the message log says "done"

At this point you should look at the computed pre-corrections to confirm that a good result has been obtained. Review the guidance in sections 12.4 thru 12.6 to help make this judgment.

Figure 58 and Figure 59 show examples of the Mean Channel Response and IQ Imbalance for a baseband connection. Relatively little adjustment is required in this baseband case, but IF and RF connections will typically require significantly more correction.

Figure 58 Mean Channel Response

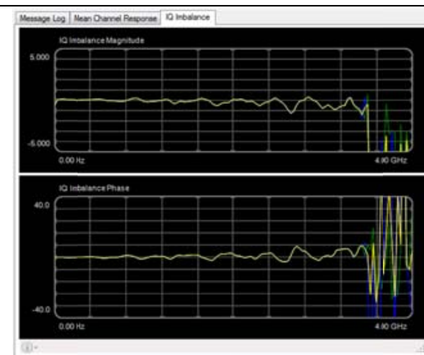

Figure 59 IQ Imbalance

4. Click Save Pre-Corrections and save the file. For simplicity we accept the default name precorr.csv.
5. Click Close.

To apply the computed pre-corrections, in the Final Waveform Settings window configure the following settings

- Calibration Mode : User Defined Cal
- Apply : All Pre-Corrections
- Pre-Corrections Coefficients File : <path/filename>

The pre-corrections filename is entered by selecting the setting then clicking on the small button that appears at the right side of the text box, to bring up a file picker dialog. Select a previously saved pre-corrections filter.

Then click the Generate and Output button. The selected pre-correction filter is applied and the signal is downloaded.

By separating the generation and application of pre-corrections the user has the opportunity to alter the calibration algorithm settings and to create a library of pre-correction filters if required.

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13 Supported Formats (Generate)

13.1 Introduction

This chapter describes the modulation and coding options supported by the waveform generation part of the 81199A software.

Each supported waveform type is represented by one or more entries in the Segment Library. If the 81199A software finds a valid license for a licensed waveform plugin, or any license-free waveform plugins, then the corresponding tabs will appear in the Segment Library.

In addition to the licensed waveform types, there are two standard entries in the Segment Library; Multi-tone and Utility.

If you create your own waveform plugins by following the process described in the Agilent Wideband Waveform Center 81199A – Development Option Guide (P/N 81199-91030), and correctly installed the DLL in the plug-ins directory prior to starting the application, then there will also be Segment Library window tab(s) named according to your class definition(s).

The 81199A software currently supports the following licensed plugins,

- Option IAD – IEEE 802.11ad
- Option WHD – WirelessHD 1.0b

13.2 Multi-Tone

Multi-tone is a standard, license-free, plug-in that enables you to create single tone, two tone and multi-tone signals. The single and two tone waveforms can also be vector modulated to create GMSK, PSK and QAM signals.

13.2.1 Segment Settings

Each of the eight segments in the Multi-tone library has its own settings. The settings for the segment currently selected in the Waveform Layout window are presented in the <current> Segment Settings window.

Tone Type

Set the type of tone-based signal to be generated. the possibilities are,

- Single Tone : This creates a single tone at the specified frequency.
- Two Tone : This creates two tones, at plus and minus the specified frequency.
- Multi Tone : This creates a multi-tone signal centered at 0 Hz.

Number of Tones

Set the number of tones appearing on each side of the center tone (F_C) at 0 Hz.

There is always a tone at F_C (which may be suppressed). So, setting this setting to, for example, 90 will cause a 90 + 1 (at F_C) + 90 = 181 tone comb to be generated.

Occupied Bandwidth

Set the frequency delta from the most negative multi-tone frequency to the most positive. The default values of 90 for the Number of Tones and 1.8 GHz for the Occupied Bandwidth give a come of tones at 10 MHz spacing (with the tone at FC suppressed).

Suppressed Tones	Set the number of center tones to be suppressed. It is common in OFDM modulation for the tone at F_C, or the three tones at F_C and $F_C \pm 1$ to be unused and suppressed because of the negative impact on these tones from any DC components in the modulation. This setting allows you to create multi-tone signals with similarly suppressed center tone(s).
Single Sided	Setting this true will suppress all the negative frequency tones. The tone frequencies are still determined by the number of tones and occupied bandwidth values as if they were present. A single-sided multi-tone signal is a very useful diagnostic signal for setting up a wideband system as the common impairments of LO leakage, quadrature error / gain imbalance, intermodulation distortion, skew and phase noise all have visibly different effects on the spectrum of this signal.
Frequency	Set the tone frequency F_{TONE}. In Single Tone mode, this will generate a zero IF signal with a single sideband modulation at $+F_{TONE}$. Mathematically speaking, there is no signal energy at $-F_{TONE}$, however when the single tone waveform is played on practical hardware there may be a vestigial signal at $-F_{TONE}$ due to imperfect cancellation of the negative frequency component. In Two Tone mode, this will generate a zero IF signal with a double sideband modulation at $\pm F_{TONE}$.
Modulation Symbol Rate	Set the symbol rate of the vector modulation that can optionally be applied to the tone(s).

Modulation Type — Set the type of vector modulation that is applied to the tone(s). The choices are,

- No Modulation
- GMSK
- π/2-BPSK
- QPSK
- PSK
- 16 QAM
- 64 QAM

For all the modulated signals, the modulation data is a 2^{23}-1 PRBS and the mapping to phase/amplitude states is fixed.

Filter Type — Sets the filtering that is applied to the tone modulation. The choices are,

- Gaussian
- Root Raised Cosine
- Raised Cosine

Filter BT / Shape — Sets the shape of the filter applied to the tone modulation. If the Gaussian Filter Type is selected then this number determines the Bandwidth-Time (BT) product. If either of the Cosine Filter Types is selected then this number determines the shape factor (excess bandwidth) of the filter.

Minimum Length — Sets the minimum length of the tone segment in samples.

Simple tone modulations can often be completely represented by just a few samples which can result in very short waveform segments. But in some situations (such as generating pseudo "recordings" for the 81199A / 89601B VSA software) it is useful to have a longer time record to work with (even if the extra data is mathematically redundant). This setting instructs to software to generate at least a certain amount of sample data. The actual segment length will be determined by the periodicity of the signal as well as other factors such as the sample chunk size of the output device.

13.3 IEEE 802.11ad

Published by the Institute of Electrical and Electronic Engineers (IEEE) in December 2012; the IEEE 802.11ad specification defines a 60 GHz MAC/PHY extension to the Wireless LAN standard IEEE 802.11-2012.

The 11ad specification was based on a contribution of earlier work by the Wireless Gigabit Alliance (WGA), under the brand name "WiGig", to develop a 60 GHz MAC/PHY specification.

The draft WiGig and 11ad specifications were subsequently independently taken to completion (mainly for legal reasons) but WGA and IEEE members worked closely to ensure that, as the two specifications were finalized, they remained in exact technical alignment.

In this User's Guide we will refer only to IEEE 802.11ad, but the signal generation and analysis capability is equally applicable to WiGig 1.2 deployments.

13.3.1 Segment Settings

Each segment in the library has its own settings. The settings shown in the Segment Settings window are those of the currently selected segment.

A segment is selected by clicking on either the original in the Segment Library window or one of the copies in the Waveform Layout window.

Modulation and Coding Scheme (MCS)	Sets the modulation and coding scheme for all the packets in the selected segment. The MCS value is also encoded into the packet header(s).

Length

The definition of this field changes depending on the selected MCS.

If MCS0 (CPHY) is selected, this sets the CPHY PSDU length in octets.

If any MCS other than MCS0 (CPHY) is selected, this sets the non-CPHY PSDU in octets.

In both cases, this is the number of data octets in the payload; it does not include any "stuffing" zero octets that may be added by the encoding process to fill out a whole number of modulation symbols.

Although only one value is displayed (depending on the MCS), the CPHY and non-CPHY length values are remembered separately.

Scrambler Initialization

The definition of this field changes depending on the selected MCS.

If MCS0 (CPHY) is selected, this sets the scrambler initialization pattern for the CPHY packet(s) in this segment. In CPHY packets only 4 bits are used as a seed, so the range is 0 to 0x07.

If any MCS other than MCS0 (CPHY) is selected, this sets the scrambler initialization pattern for the non-CPHY packet(s) in this segment. In non-CPHY packets 7 bits are used as a seed, so the range is 0 to 0x7f.

Although only one value is displayed (depending on the MCS), the CPHY and non-CPHY seed values are remembered separately.

Additional PPDU

Sets the Additional PPDU bit in the header of the packet in this segment.

To generate an Additional PPDU packet, set this bit in the first packet segment, and then add a second segment which has Preamble On set to False and Interpacket Gap set to 0.

The two segments taken together constitute an Additional PPDU packet.

Packet Type

Sets the training packet type in the header of all packets in the segment. The choices are TRN-R and TRN-T.

Training Length

Sets the number of pattern repetitions and therefore the length of the training field. If the value is zero, no Beamforming Training Field is appended to the packet.

Aggregation

Sets the state of the Aggregation bit in the header of all packets in the segment.

Beam Tracking

Sets the state of the Beam Tracking Request bit in the header of all packets in the segment.

Tone Pairing Type

Sets the Tone Pairing Type in the header of all packets in the segment. The choices are STP and DTP.

For signal generation, if the DTP bit is set, then the tone pairing defined in the DTP Group Pair Index tab is used to generate the signal. However, this is strictly intended for static verification of DTP decoding in the DUT. It is only "dynamic" in the sense that it is non-standard and user defined. It cannot be changed except by re-defining the segment (or by switching to a differently configured segment). The user defined assignment must be separately communicated to the receiving DUT for correct decoding.

If you attempt to analyze an OFDM signal that is using DTP, measurements based on demodulation such as correlation, channel estimation and IQ Data constellation will be correct, but results that depend on decoding the signal (e.g. the MCS number and the EVM calculations) will be invalid.

This is because the demodulator cannot follow a dynamic mapping in real time and the (assumed) static tone mapping will result in incorrect header and payload decoding. If an OFDM signal has an apparently clean constellation yet has an unstable MCS number and / or reports a very large EVM value, check the Tone Pairing Type of the signal under test.

DTP Indicator	Sets the state of the DTP indicator bit in the header of all packets in the segment.
Last RSSI	Sets the state of the Received Signal Strength Indicator (RSSI) bit in the header of all packets in the segment.
Turnaround	Sets the state of the Turnaround bit in the header of all packets in the segment.
SC Shaping Filter	Select the spectrum shaping filter applied to all Single Carrier (SC) and Low Power Single Carrier (LPSC) modulated packets. Specifically, MCS 0 to 12 and MCS 25 to 31 inclusive. The 802.11ad specification calls for spectral shaping of the single carrier modulations, but, to afford the transmitter designer some flexibility, does not specify the shaping filter. The 81199A software therefore provides a choice. The filter shaping choices are, • None, • Gaussian, • Raised-Cosine, • Root-Raised-Cosine These filter shapes are further parameterized by the BT/Shape factor (excess bandwidth). If another filter shape is required then you can select none and apply a custom filter using the post processing plug-in capability described in Agilent Wideband Waveform Center 81199A – Development Option Guide (81199-91030).

Shaping Filter BT / Shape	Set the Bandwidth / Time (BT) product for Gaussian filtering or the shape factor (excess bandwidth) for RC/RRC filtering.
Symbol Clock Offset	Set the symbol clock offset from its nominal value expressed in parts per million (ppm).
Payload Content	Set the payload content for all packets in this segment. The choices available are, • PN23 : The payload data comprises octets drawn, LSB first, from a 223-1 length PRBS sequence generator as defined in ITU REC O.150 section 5.6. The PN generator is seeded, at the beginning of the first packet in the segment, with a 1 in the first stage and a 0 in all other stages. • All 1's : The payload data comprises octets, each with value 0xff. • All 0's : The payload data comprises octets, each with value 0x00. • 8-bit Count : The payload data comprises octets with an incrementing or "counting" value, reset to 0 at the beginning of every packet in the segment. The count is modulo 256. • 32-bit Count : The payload data comprises little-endian 4-octet chunks with an incrementing or "counting" value, reset to 0 at the beginning of every packet in the segment. The count is modulo 32768. • From File : The payload data is drawn from the file specified by the Payload Content File setting.

Payload Content File — Set the name of the file from which the payload data is drawn if the Payload Content setting is From File.

The file should be a text file containing 1's and 0's. Any other characters such as spaces or carriage returns will be ignored. The data is read out of the file character by character and if the end of file is reached, reading will start at the beginning again (that is, when the payload length is longer than the amount of data in the file). The payload length is determined by the setting of the Length (octets) setting.

For example, if the file looks like this;

10111111
10100001

and the payload is set to 5 octets long, the payload will be

1011111110100001101111111010000110111111

and the data in the above example is used in left to right order. (left most bit written out first)

If the payload file contains more data than needed the remainder is ignored.

If the segment has more than one packet, the data runs over from packet to packet (similar to the PN23 data).

Each of the eight segments in the library can have a different payload file.

If the file does not exist or cannot be read, the payload will be all zeros.

Interpacket Gap — Set the Interpacket Gap.

This value determines the duration of the zero signal energy period preceding each packet. The value is limited to 0 to 200 μs. The default value is 2 μs.

Longer silences (up to 3 ms) can be created using a Utility segment.

Packets in Waveform Set how many packets are generated in the segment.

If the segment is specified to contain more than one packet and the payload is specified as PN data, then the PN sequence runs on through each packet in the segment.

The advantage of specifying more than one packet in the segment (assuming a pseudo-random payload) is that the RF spectrum will be more random. The disadvantage is that the resulting output file will take longer to generate and will be larger.

Preamble On Set this to False, to suppress the preamble.

This is used in conjunction with the Additional PPDU bit in the header of the packet to create Additional PPDU packets.

To generate an Additional PPDU packet, set the Additional PPDU bit in the first packet segment, and then add a second segment which has Preamble On set to False and Interpacket Gap set to 0.

The two segments taken together constitute an Additional PPDU packet.

13.3.2 DTP Group Pair Index

The DTP Group Pair Index tab is used to define the tone pairing to be used when generating a signal with dynamic tone pairing.

The tab contains a list of 42 numbers. By default these are the numbers 0 to 41 in ascending order. They are also implicitly indexed in the order 0 to 41. So the default mapping is N to N.

If the DTP bit is set in the header, then the defined tone pairing is used to generate the signal. However, this is strictly intended for static verification of DTP decoding in the DUT. It is only "dynamic" in the sense that it is non-standard and user defined. It cannot be changed except by re-defining the segment (or by switching to a differently configured segment). The user defined assignment must be separately communicated to the receiving DUT for correct decoding.

The Tool Bar at the top of the DTP Group Pair Index tab provides icon buttons to cut and paste different mappings, to reset to the default mapping, and to create a random mapping.

The randomize button is intended to make it easy to create a random yet valid mapping (one in which each number from 0 to 41 appears exactly once). When pasting a mapping, it is the user's responsibility to make sure that it is a valid mapping.

If you attempt to analyze an OFDM signal that is using DTP, measurements based on demodulation such as correlation, channel estimation and IQ Data constellation will be correct, but results that depend on decoding the signal (e.g. the MCS number and the EVM calculations) will be invalid.

This is because the demodulator cannot follow a dynamic mapping in real time and the (assumed) static tone mapping will result in incorrect header and payload decoding. If an OFDM signal has an apparently clean constellation yet has an unstable MCS number and / or reports a very large EVM value, check the Tone Pairing Type of the signal under test.

13.4 Wireless HD (WiHD)

The WirelessHD specification (often abbreviated to WiHD) defines an architecture and technology for short-range (10m) wireless interchange of high-definition multimedia data between audio-visual devices over an ad-hoc network in the 60GHz unlicensed band.

Version 1.0 of the WirelessHD specification was published in January 2008, followed by version 1.1 in April 2010.

The multimedia optimized protocol is underpinned by a physical layer capable of high speed data transmission; originally (v1.0) at rates up to 3.81Gbps, latterly (v1.1) at rates up to 7.138 Gbps, and, in principle, up to 4 x 7.138 = 28.552 Gbps if using 4 x 4 spatial multiplexing (MIMO) .

The ad-hoc network is established and managed through bi-directional protocol exchanges over the Low Rate PHY (LRP) while bulk data transfer takes place over the unidirectional Medium Rate PHY (MRP) or High Rate PHY (HRP). All three PHYs employ beam-steering techniques for Non Line Of Sight (NLOS) operation.

LRP, MRP and HRP transmissions share a common frequency channel using Time Division Multiple Access (TDMA) techniques managed by the protocol layer. LRP, MRP and HRP are all RF burst transmissions starting with a synchronization preamble followed by packet-structured OFDM modulated data.

The 81199A option WHD currently only supports WirelessHD v1.0b features. In particular, it does not include support for the Medium Rate PHY (MRP).

13.4.1 Segment Settings (HRP)

Whenever a WirelessHD High Rate PHY (HRP) segment is dropped into the Waveform Layout window, a settings table for that segment type is displayed in the Segment Settings window. The following sub-sections briefly describe the purpose of each entry in the HRP settings table.

UEP Mapping Bit

This provides control over the UEP mapping bit in the HRP Header. It also controls the constellation amplitude skew of the payload modulation.

When UEP Mapping Bit is set to True, the UEP Mapping Bit is set to 1 in the HRP Header and UEP Mapping is enabled. This means that the axis carrying the MSB data in the QPSK/QAM constellation of the OFDM data carrier modulation is power boosted by a factor of 1.25.

Power boosting is only applied to the data payload symbols, not the HRP header symbols. Furthermore UEP Mapping is only applied to the EEP Coded transmit modes, 0, 1 and 2.

This is the definition of UEP operation that is consistent with the text of WirelessHD v1.0b. However, since UEP mapping was not implemented in any v1.0 compliant devices, the definition was revised in WirelessHD v1.1.

Beam Tracking Bit

This only controls the beam tracking bit in the HRP Header. When true, the beam tracking bit is set, but no other changes are made. This revision of option WHD software does not append a beam tracking postamble to the HRPDU.

Payload Scrambler Seed

This specifies the payload scrambler seed.

The transmitted data is scrambled. The header fields are always scrambled with a default initialization of 0 because the header contains the initialization value for the data payload scrambling. This field allows the user to set the scrambler initialization for the data payload part of the packet.

Content Protection Bit

When this is true, the Content Protection bit is set in the MAC Header.

The octet value in the Content Protection Header field determines the value of the CP Header Field in the MAC Header.

CP Sub-packet Header Fields are added to each sub-packet, with the Field value determined by the sub-packet CP values.

Destination Station ID	Sets the Destination Station ID in the HRP MAC header. Valid values are 0x00 to 0x3F.
Source Station ID	Sets the Source Station ID in the HRP MAC header. Valid values are 0x00 to 0x3F.
WVAN ID	Sets the Wireless Video Area Network ID in the HRP MAC header. Valid values are 0x00 to 0xFF.
Content Protection Header	Sets the Content Protection field the HRP MAC header. This setting is only used when Content Protection Bit field is true.
Time Preamble Power Boost	This determines the power of the time-domain preamble relative to the frequency-domain preamble. The value is expressed in decibels and is range limited to ±6 dB. A positive value corresponds to the time-domain preamble power being larger than the frequency-domain preamble power. The default value is 3.01 dB in accordance with the WirelessHD Specification Version 1.0b.
Packets in Waveform	This controls how many packets are generated in the segment. If the segment is specified to contain more than one packet and the payload is specified as PN data, then the PN sequence runs on through each packet in the segment. The advantage of specifying more than one packet in the segment (assuming a pseudo-random payload) is that the RF spectrum will be more random. The disadvantage is that the resulting output file will take longer to generate and will be larger.

Interpacket Gap

The Interpacket gap value determines the duration of the zero signal energy period preceding each packet. The value is limited to 0 to 200 μs. The default value is 2 μs.

Longer silences (up to 3 ms) can be created using a Utility segment.

13.4.2 Payload Settings (HRP)

The HRP payload is structured as a sequence of up to 7 sub-packets each of which can be configured to use a different transmit mode, with a different payload length and (optionally) content protection value.

To facilitate the description of the required payload, a tabular setting entry is provided. This is accessed by clicking "Configure the Payload" at the top of the Segment Settings window.

The columns of the table are described in the following sub-sections.

Subpacket Enable

If the Enable checkbox is ticked then the sub-packet described by the Payload Data and Payload (Octets) fields will be generated and appended to the output waveform. The sub-packets are generated in the order they are listed, skipping any for which the Enable checkbox is not ticked.

The software only writes information to the HRP header for the enabled sub-packets. This has the effect of packing the header information so if, for example, only SP4 and SP7 were enabled in the GUI, the information for SP4 would be encoded in the sub-packet 1 field of the header, and the information for SP7 would be encoded in the sub-packet 2 field of the header.

This has two benefits. Most importantly it ensures that the header properly describes the transmitted signal but, secondly, it also allows the user to switch payloads quickly, by using the sub-packets as a list of alternatives and simply enabling / disabling them as required.

Subpacket Transmit Mode	Set the transmit mode for each subpacket. The choices available are, • Tx Mode 0 (QPSK, 1/3, EEP) • Tx Mode 1 (QPSK, 2/3, EEP) • Tx Mode 2 (16-QAM, 2/3, EEP) • Tx Mode 3 (QPSK, 4/7, 4/5, UEP) • Tx Mode 4 (16-QAM, 4/7, 4/5, UEP) • Tx Mode 5 (QPSK, 1/3, MSB-only) • Tx Mode 6 (QPSK, 2/3, MSB-only)
Subpacket Content	Set the payload content for each subpacket. The choices available are, • PN23 : The payload data comprises octets drawn, LSB first, from a 223-1 length PRBS sequence generator as defined in ITU REC O.150 section 5.6. The PN generator is seeded, at the beginning of the first packet in the segment, with a 1 in the first stage and a 0 in all other stages. • All 1's : The payload data comprises octets, each with value 0xff. • All 0's : The payload data comprises octets, each with value 0x00. • Count : The payload data comprises octets with an incrementing or "counting" value, reset to 0 at the beginning of every packet in the segment. The count is modulo 256.
Subpacket Payload Length	The Payload (Octets) field allows you to set the number of data octets in the sub-packet. A Payload Check Sequence is automatically calculated and added to the data octets so the length of the sub-packet as reported in the HRP header will always be greater (by 8; the length of the PCS in octets) than the number entered in this field, which means that the maximum permissible value in this field is 8 less than 2^{20}-1, or 1048567.

Subpacket Content Protection Field	The 16-bit hex value in the Content Protection (CP) field is active and can be edited when the sub-packet is enabled AND the Content Protection Bit is set in the MAC Header. When CP is enabled, two additional octets are added to the sub-packet (before the data payload) and their value is set in little-endian order by the value in this field. These two octets, plus the 8 octets required for the PCS means that the total length of the sub-packet (in octets) will be 10 more than the value in the Payload (octets) box. When CP is not enabled, this field is ignored, no CP octets are added to the sub-packet, so the total length of the sub-packet (in octets) will be 8 more than the value in the Payload (octets) box due to the PCS.

13.4.3 Segment Settings (LRP Omni)

Whenever a WirelessHD Low Rate Omni-Directional PHY (LRP Omni) segment is dropped into the Waveform Layout window, a settings table for that segment type is displayed in the Segment Settings window. The following sub-sections briefly describe the purpose of each entry in the LRP Omni settings table.

Destination Station ID	Sets the Destination Station ID in the LRP Omni MAC header. Valid values are 0x00 to 0x3F.
Source Station ID	Sets the Source Station ID in the LRP Omni MAC header. Valid values are 0x00 to 0x3F.
WVAN ID	Sets the Wireless Video Area Network ID in the LRP Omni MAC header. Valid values are 0x00 to 0xFF.

Payload Scrambler

Sets the payload scrambler seed.

The transmitted data is scrambled. The header fields are always scrambled with a default initialization of 0 because the header contains the initialization value for the data payload scrambling. This field allows the user to set the scrambler initialization for the data payload part of the packet.

Transmit Mode

Sets the transmit mode for the MAC Header, HCS and Payload fields of the Omni-directional LRPDU.

The choices available are,

- Tx Mode 0 (BPSK, 1/3, 8x Repeat)
- Tx Mode 1 (BPSK, 1/2, 8x Repeat)
- Tx Mode 2 (BPSK, 2/3, 8x Repeat)
- Tx Mode 3 (BPSK, 2/3. 4x Repeat)

Payload Content

Sets the payload content.

The choices available are,

- PN23 : The payload data comprises octets drawn, LSB first, from a 223-1 length PRBS sequence generator as defined in ITU REC O.150 section 5.6. The PN generator is seeded, at the beginning of the payload, with a 1 in the first stage and a 0 in all other stages.
- All 1's : The payload data comprises octets, each with value 0xff.
- All 0's : The payload data comprises octets, each with value 0x00.

Payload Length

Sets the number of data octets in the packet.

The contents of the length field in the LRP Header is determined by the length of the LRP MAC Header (fixed, in this tool, at 8 octets), plus the length of the HCS (4 octets), plus the user selected Payload length from this field, plus the length of the PCS (4 octets) that is automatically calculated and added to the data octets.

This means that the value in the LRP Header length field reported by decoding the header will always be 8 + 4 + 4 = 16 octets more than the value entered in the Payload (octets) field by the user, which means that the maximum permissible value in this field is 16 less than 2^{20}-1, or 1048559."

Preamble Type

Sets the Omni LRP Preamble which may be Long or Short.

The Long preamble is 56.00μs long, comprising 38.25μs of QPSK or Offset QPSK modulated training sequences, followed by 17.75μs of OFDM training sequences.

The Short preamble is 42.41μs long, comprising 24.66μs of QPSK or Offset QPSK modulated training sequences, followed by the same 17.75μs of OFDM training sequences.

The choice of preamble length has no effect on the structure of the remainder of the packet which remains the same for both options (LRP Header, MAC Header, HCS and Packet Body).

QPSK/OFDM Relative Power

Sets the QPSK/OFDM Relative Power value, which determines the power of the QPSK modulated part of the preamble relative to the OFDM modulated part of the preamble.

The value is expressed in decibels and is range limited to ±3 dB. A positive value corresponds to the QPSK modulation power being larger than the OFDM power.

Use Offset QPSK — The preamble on LRP Omni packets may be QPSK mapped or (optionally) Offset QPSK mapped. This setting defaults to Offset QPSK because this was the design choice favored by the first implementations of WirelessHD.

In the LRP preamble, the same data is applied to both axes (I and Q) of the QPSK / OQPSK modulator. This has the effect that the QPSK option effectively produces a $\pi/4$-rotated BPSK mapped modulation. The specification text in v1.0b was updated from "QPSK" to "$\pi/4$-rotated BPSK" to reflect this.

Preamble Filter Shape Factor — The time-domain part of the preamble is QPSK (or Offset QPSK) modulated.

The specification requires that this modulation is "filtered to comply with the LRP TX mask" but gives no other guidance on the filter type or roll-off.

For low EVM demodulation of the preamble is it useful to know the applied filter shaping.

This software applies Raised Cosine filtering with the user selected shape factor (excess bandwidth).

The range is 0.05 to 0.99.The default shape factor (excess bandwidth) is 0.99.",

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Packets in Waveform — Sets the number of packets in the segment.

If the segment is specified to contain more than one packet and the payload is specified as PN data, then the PN sequence runs on through each packet in the segment.

The advantage of specifying more than one packet in the segment (assuming a pseudo-random payload) is that the RF spectrum will be more random. The disadvantage is that the resulting output file will take longer to generate and will be larger.

Interpacket Gap — The Interpacket gap value determines the duration of the zero signal energy period preceding each packet. The value is limited to 0 to 200 µs. The default value is 2 µs.

Longer silences (up to 3 ms) can be created using a Utility segment.

13.4.4 Antenna Switching (LRP Omni)

In LRP Omni packets the data patterns that constitute the preamble and header fields are repeated 8 times. The payload data patterns may be repeated 8 or 4 times depending on transmit mode.

In a live system each repeat is typically transmitted using a different antenna configuration to achieve quasi-omni-directional operation. When receiving these packets with a single antenna the power level will step up and down depending on the signal strength of each path between transmitter and receiver.

These settings allow you to emulate this effect by creating an LRP Omni signal that steps in amplitude and phase in a manner similar to what you will see from a single antenna receiving a quasi-omni transmitter that is switching its beam direction.

Antenna 0..7 Magnitude and Phase — Set up to eight magnitude / phase value pairs, expressed in dB relative to the normal signal magnitude, and degrees relative to the normal signal phase.

The waveform generator will sequence through the eight value pairs when generating 8 repetition sections of the LRP Omni packet, and will sequence through the first 4 value pairs when generating 4 repetition sections of the LRP Omni packet.

A real system may have fewer than 8 distinct antenna configurations. To emulate a 4, 2 or 1 antenna system, simply duplicate the magnitude / phase settings to create a shorter sequence.

13.4.5 Segment Settings (LRP Directional)

Whenever a WirelessHD Low Rate Directional PHY (LRP Directional) segment is dropped into the Waveform Layout window, a settings table for that segment type is displayed in the Segment Settings window. The following sub-sections briefly describe the purpose of each entry in the LRP Directional settings table.

Header Type

Sets the type of the LRP Directional packet header. If set to Ack then the first bit of the header is set to 0 and the packet is structured as an LRP Directional Ack packet. If it is set to Data then the first bit of the header is set to 1 and the packet is structured as an LRP Directional packet with a payload.

ADT

This setting controls the Antenna Direction Tracking (ADT) header bit in the Data header type and is only applicable to Data packets.

BS Request

This setting controls the BS Request bit in the Ack header type and is only applicable to Ack packets.

ACK 0...4

These five settings control the five ACK bits in the Ack header type and are only applicable to Ack packets.

Destination Station ID

Sets the Destination Station ID in the LRP Directional MAC header. Valid values are 0x00 to 0x3F.

Source Station ID

Sets the Source Station ID in the LRP Directional MAC header. Valid values are 0x00 to 0x3F.

WVAN ID

Sets the Wireless Video Area Network ID in the LRP Directional MAC header. Valid values are 0x00 to 0xFF.

Transmit Mode

If Header Type is set to Data then this determines the transmit mode for the MAC Header, HCS and Payload fields of the Directional LRPDU. The choices available are,

- 5 Mbps (BPSK, 2/3 8x Repeat)
- 10 Mbps (BPSK, 2/3, 4x Repeat)

When Header Type is Ack there is no data payload, so this setting does not apply.

Payload Content

Set the payload content.

The choices available are,

- PN23 : The payload data comprises octets drawn, LSB first, from a 223-1 length PRBS sequence generator as defined in ITU REC O.150 section 5.6. The PN generator is seeded, at the beginning of the payload, with a 1 in the first stage and a 0 in all other stages.
- All 1's : The payload data comprises octets, each with value 0xff.
- All 0's : The payload data comprises octets, each with value 0x00.

When Header Type is Ack there is no data payload, so this setting does not apply.

Payload Length

The Directional LRPDU payload is of very limited size as the length field in the header has only 4 bits. In order to allow 16 data octets, the value recorded in the header is actually length – 1 and does not include any stuffing octets that may be required to create a whole number of modulation symbols.

There is no Payload Check Sequence (PCS) appended to Directional LRP Payload data.

When Header Type is Ack there is no data payload, so this setting does not apply.

Packets in Waveform Sets the number of packets in the segment.

If the segment is specified to contain more than one packet and the payload is specified as PN data, then the PN sequence runs on through each packet in the segment.

Interpacket Gap

The Interpacket gap value determines the duration of the zero signal energy period preceding each packet. The value is limited to 0 to 200 μs. The default value is 2 μs.

Longer silences (up to 3 ms) can be created using a Utility segment.

13.4.6 Segment Settings (LRP Beam Formed)

Whenever a WirelessHD Low Rate Beam Formed PHY (LRP Beam Formed) segment is dropped into the Waveform Layout window, a settings table for that segment type is displayed in the Segment Settings window. The following sub-sections briefly describe the purpose of each entry in the LRP Beam Formed settings table.

Payload Scrambler

Sets the payload scrambler seed.

The transmitted data is scrambled. The header fields are always scrambled with a default initialization of 0 because the header contains the initialization value for the data payload scrambling. This field allows the user to set the scrambler initialization for the data payload part of the packet.

Destination Station ID

Sets the Destination Station ID in the LRP Beam Formed MAC header. Valid values are 0x00 to 0x3F.

Source Station ID	Sets the Source Station ID in the LRP Beam Formed MAC header. Valid values are 0x00 to 0x3F
WVAN ID	Sets the Wireless Video Area Network ID in the LRP Beam Formed MAC header. Valid values are 0x00 to 0xFF.
Transmit Mode	Sets the transmit mode for the MAC Header, HCS and Payload fields of the Beam Formed LRPDU. The choices available are, • Tx Mode 0 (BPSK, 1/3, No Repeat) • Tx Mode 1 (BPSK, 1/2, No Repeat) • Tx Mode 2 (BPSK, 2/3, No Repeat)
Payload Content	Sets the payload content. The choices available are, • PN23 : The payload data comprises octets drawn, LSB first, from a 223-1 length PRBS sequence generator as defined in ITU REC O.150 section 5.6. The PN generator is seeded, at the beginning of the payload, with a 1 in the first stage and a 0 in all other stages. • All 1's : The payload data comprises octets, each with value 0xff. • All 0's : The payload data comprises octets, each with value 0x00.

Payload Length

Sets the number of data octets in the packet.

The contents of the length field in the LRP Header is determined by the length of the LRP MAC Header (fixed, in this tool, at 8 octets), plus the length of the HCS (4 octets), plus the user selected Payload length from this field, plus the length of the PCS (4 octets) that is automatically calculated and added to the data octets.

This means that the value in the LRP Header length field reported by decoding the header will always be 8 + 4 + 4 = 16 octets more than the value entered in the Payload (octets) field by the user, which means that the maximum permissible value in this field is 16 less than 2^{20}-1, or 1048559."

QPSK/OFDM Relative Power

Sets the QPSK/OFDM Relative Power value, which determines the power of the QPSK modulated part of the preamble relative to the OFDM modulated part of the preamble.

The value is expressed in decibels and is range limited to ±3 dB. A positive value corresponds to the QPSK modulation power being larger than the OFDM power.

Use Offset QPSK

The preamble on LRP Beam Formed packets may be QPSK mapped or (optionally) Offset QPSK mapped. This setting defaults to Offset QPSK because this was the design choice favored by the first implementations of WirelessHD.

In the LRP preamble, the same data is applied to both axes (I and Q) of the QPSK / OQPSK modulator. This has the effect that the QPSK option effectively produces a π/4-rotated BPSK mapped modulation. The specification text in v1.0b was updated from "QPSK" to "π/4-rotated BPSK" to reflect this.

Preamble Filter Shape Factor	The time-domain part of the preamble is QPSK (or Offset QPSK) modulated. The specification requires that this modulation is "filtered to comply with the LRP TX mask" but gives no other guidance on the filter type or roll-off. For low EVM demodulation of the preamble is it useful to know the applied filter shaping. This software applies Raised Cosine filtering with the user selected shape factor (excess bandwidth).
Packets in Waveform	Sets the number of packets in the segment. If the segment is specified to contain more than one packet and the payload is specified as PN data, then the PN sequence runs on through each packet in the segment.
Interpacket Gap	The Interpacket gap value determines the duration of the zero signal energy period preceding each packet. The value is limited to 0 to 200 μs. The default value is 2 μs. Longer silences (up to 3 ms) can be created using a Utility segment.

13.5 Utility

The utility segment library contains a miscellany of potentially useful segment types.

Waveform Type

Set the type of waveform generated by this segment. The choices are,

- From CSV file : Import waveform data from a CSV file.
- From HDF file : Import waveform data from an HDF5 file (e.g. a MATLAB 7.3 file)
- Square Wave : Generate a configurable square wave.
- Silence : Generate a zero valued segment of a defined duration. This can be useful as time padding in advanced waveform layouts.

13.5.1 Segment Settings (From CSV or HDF)

Waveform Filename

Set the filename of the CSV or HDF file.

To select the file, select the setting input field then click on the button marked ... that appears in the right of the field to activate the Open File dialog.

Frequency Multiplier

Set a multiplier that will be used to scale the frequency specified in the file.

Amplitude Multiplier

Set a multiplier that will be used to scale the amplitude of the data in the file.

13.5.2 Creating Waveforms for Utility Segments

The process of creating waveform files for use in a Utility Segment is illustrated by the following very simple examples.

MATLAB HDF5 File

You are assumed to have MATLAB (7.3 or above) installed and running.

Write a script to generate the desired complex waveform and save it to a file.

The following script generates a file containing 100,000 random complex numbers.

```
Y = rand(1,100000) + 1i*rand(1,100000);
XDelta = 1/3.52e9;
save('ydata.mat', 'Y', 'XDelta', '-v7.3');
```

The variable Y contains the complex waveform data and the variable XDelta contains the sample period. The variables must be given these names and they are case sensitive.

Run the script and note where the file is saved.

In the 81199A software, drag a Utility segment to the Waveform Layout Window. A small blank segment will appear. (The default Utility Segment is "Silence")

Change the segment's Waveform Type setting to "From HDF File".

Set the segment's Waveform File Name setting to specify your saved waveform file.

The waveform file will be loaded and the waveform displayed in the segment preview (and hence in the Final Waveform window).

The maximum waveform length that can be loaded using this method is dependent on the free memory available.

If you select a file that isn't an HDF5 file, or you select an HDF file that does not have an XDelta value, or you selects an HDF file that does not have waveform data saved a Y, the 81199A software will report an error.

CSV File

To make raw CSV waveform data understandable to 81199A you must preface it with a declaration of the XDelta value, then the letter Y, indicating that the waveform data follows on subsequent lines.

Here are the first few lines of an example file.

```
XDelta,2.840909091E-10
Y,
0.424309916,0.160213492
0.074028167,-0.032745291
-0.276156476,-0.572602034
0.146932835,-0.047312666
0.3981...
```

You must have a comma between XDelta and its value, and between the real and imaginary parts of the waveform samples. The comma following the Y is optional (but if you generate your CSV file using Microsoft Excel you will get a comma here).

13.5.3 Segment Settings (Square Wave)

Amplitude

Set the peak-to-peak amplitude of the square wave.

This value does not translate directly to the magnitude of the output signal because, as for all waveforms generated by 81199A, that depends on the cumulative effect of several factors.

The amplitude is a relative quantity, where 1 is equivalent to the nominal RMS magnitude of the vector modulations produced by other libraries.

Frequency	Set the frequency of the square wave.
I/Q Phase Difference	Set the phase offset between the I and Q components of the segment.
Number of Cycles	Set the number of cycles of square wave in the segment.

13.5.4 Segment Settings (Silence)

Length	Set the time duration of a silence. During a silence, the segment samples will be zero valued unless an impairment has been added, for example, noise.

13.6 Custom

You can create your own waveform creation plug-ins by following the process described in the Agilent Wideband Waveform Center 81199A – Development Option Guide (P/N 81199-91030).

14 Measure

14.1 Introduction

This chapter describes the modulation analysis part of the 81199A software.

The 81199A modulation analysis capability is built upon the signal acquisition capability of the 89601B VSA.

For modulation analysis of formats supported directly by the 81199A software, an instance of the 89601B VSA software is spawned to acquire calibrated time records which are then post-processed by the overlay 81199A software to perform the standards compliant analysis and results presentation.

For analysis of general purpose signals such as those generated by the Multi-tone segment library, the 89601B VSA software should be invoked directly.

An additional advantage of delegating signal acquisition to the VSA is that the 81199A can immediately take advantage of the wide range of hardware platforms supported by the 89601B VSA.

Basic and Advanced Menus

To ensure that the 81199A software maintains a consistent understanding of the 89601B VSA state, all of the 89601B acquisition settings can be configured from the 81199A Acquisitions Settings window.

However, the 89601B VSA software is a very configurable general purpose tool, with a correspondingly large list of settings, most of which you are unlikely to need to alter from their default values when working with 802.11ad or WirelessHD signals.

So at the top of the Acquisition Settings window there are two buttons, Basic and Advanced, to select between a simplified and full settings list.

The basic acquisition settings list presents only the most commonly needed settings, while the advanced menu simply lists all of the 89601B VSA acquisition settings.

14.2 Acquisition Settings (Basic)

Click the Basic button to get the short list of settings most relevant to 802.11ad or WirelessHD acquisition.

14.2.1 Basic Settings

89600 Connection String

This read-only field reports the VISA connection string for the acquisition hardware that the 89601B VSA is currently connected to.

Center

Set the measurement center frequency.

For baseband IQ inputs, this will normally be 0 Hz. For IF analysis this will be the IF frequency of your DUT; specifically, 5 GHz if you are taking the IF from an N1999A 60 GHz / 5 GHz Down-Converter.

Span

Set the measurement frequency span.

A setting of 2.25 GHz or more is suggested. Wider spans will affect the amount of integrated noise in the measurement. Excess noise can affect synchronization and equalization

---

Points

Set the number of un-aliased frequency points to display.

The suggested starting value is 102,401.

Setting large numbers of points or long Main Length values can cause the demodulator to report an Out of Memory exception.

Mirror Frequency

Set whether the measurement data is mirrored around the center frequency.

Set this to True if your RF chain includes a spectrum inversion, perhaps due to swapped I and Q components, an inverted Q component or a high-side mix.

The Agilent N5152A 5 GHz / 60 GHz Up-Converter includes a spectrum inversion due to a high-side mix.

Range

This setting controls the oscilloscope input range setting. If you are using the "I and Q Baseband Inputs" channel configuration, the range of Inputs 1 and 2 are locked together, so you only ever need to change Input 1.

The optimum range for the signal being received can be automatically found by clicking the Auto-Range button on the Tool Bar.

Channel Config

This setting offers all the possible channel configurations available from the underlying 89601B VSA software. However, you will generally use one of two possibilities.

If you are connecting to the DUT at I and Q baseband (typically with I connected to oscilloscope channel 1 and Q connected to oscilloscope channel 3) then you should choose "I and Q Baseband Inputs".

If you are connecting to the DUT at an IF (typically with the IF signal connected to 'scope channel 1) then you should choose "Input Channel 1",

You should always set this setting first as it will change other acquisition settings to maintain compatibility with the chosen channel configuration.

Continuous Measurement

This setting performs the same function as the **Measure** > **Continuous Measurement** and **Measure** > **Single Measurement** menu entries.

Main Length

Set the length of the un-aliased time record to display (and process in the demodulator).

Setting large numbers of points or long Main Length values can cause the demodulator to report an Out of Memory exception.

14.3 Acquisition Settings (Advanced)

The advanced settings list provides control of all of the underlying 89601B VSA's acquisition settings.

The most likely reasons you will want to access advanced settings are to make the 89601B GUI visible, to configure triggering, or to switch the data source between hardware and recordings.

Some guidance on these commonly used advanced capabilities is provided below, but for a full description of all the settings please consult the 89601B VSA documentation.

14.3.1 Accessing the 89601B GUI

89600 State

This sets whether the graphical user interface (GUI) of the underlying 89601B VSA instance is visible or hidden.

Normally the 89601B GUI is hidden because it is under the control of the 81199A software. Changes to the 89601B configuration should be made through the 81199A GUI to ensure state consistency.

However, there are occasions when you will want to access the additional analysis capabilities of 89601B VSA. This is best done by stopping 81199A measurements temporarily and making the 89601B VSA visible.

14.3.2 Triggering

The 81199A software can operate satisfactorily in free running mode as long as the Main Length (the duration of the Main Time record) is set long enough that there is high probability of capturing at least the preamble of one or more packets.

If packets are too infrequent or too long to capture consistently then you may need to configure triggering.

Triggering on noise-like modulation is never particularly easy to configure but here is an example use case that should help.

Triggering Example

In this example, the signal being received is an 802.11ad MCS1.

When you start the measurement you should see the segment being randomly captured by the oscilloscope.

1. Set the number of frequency points (or Main Length) to capture to a little more than one packet.
2. Set the input level of the scope to maximize the sensitivity.
3. Configure a Measurement display to display Main Time, Real data and Auto Scale the Y Axis (right mouse button).

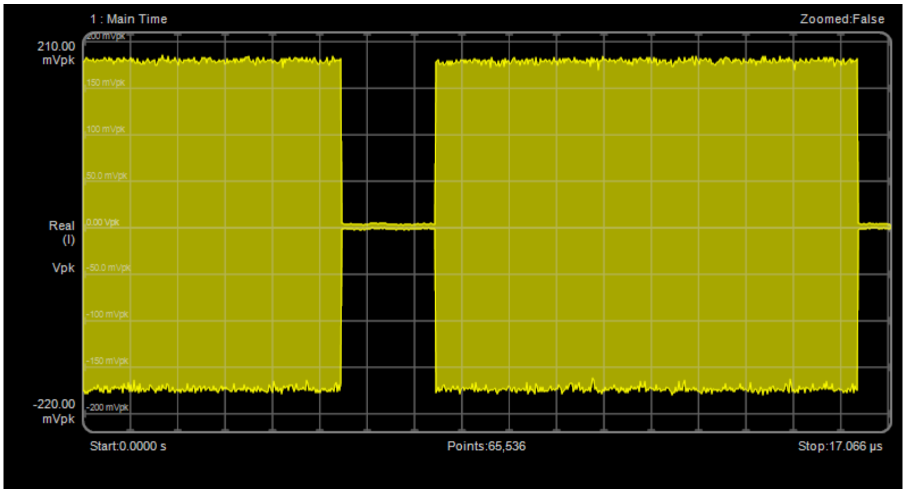

Figure 60. Free Running MCS1

4. Change the Hardware Trigger type to Channel
5. Set the Level to about half of the waveform height (e.g. 100mV)
6. Set the Holdoff Style to Below.

When applying these settings the measurement may pause because the (partial) trigger conditions are not being met - when this happens, a "Data Acquisition, waiting for trigger..." message can be seen in the Errors, Warning and Information display.

7. Set Hold Off to 1us
8. Set Delay to -1us.

In this example, the acquisition will trigger and looks like this.

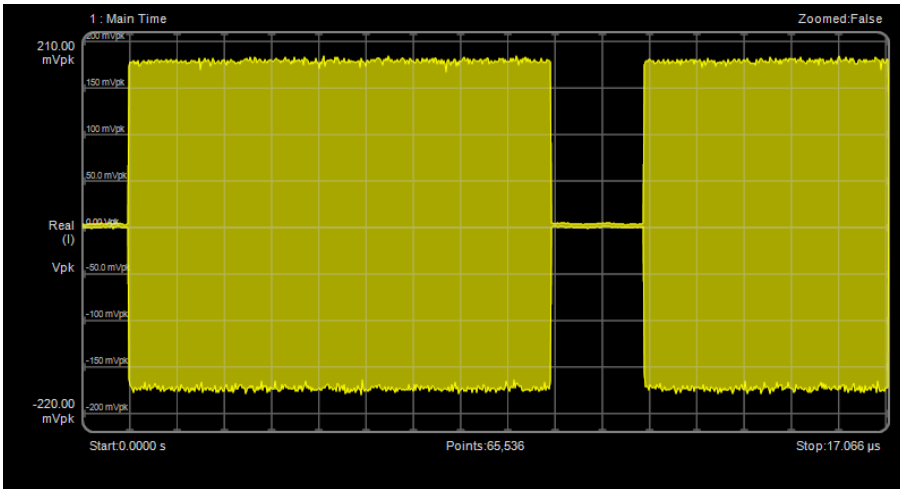

Figure 61. Triggered MCS1

When using Channel triggering and Below holdoff with different signals and settings, the key settings behave as follows.

Delay

This is the simplest setting. It simply shifts the triggering "left and right". A negative delay value is usually appropriate as it lets you acquire a small amount of the signal that precedes the burst, which can help the demodulator. If the oscilloscope is not triggering, changing this usually does not help.

Holdoff

This time relates to length of the gap between bursts, and it should be set to less than the interpacket gap (about 50% of the typical interpacket gap size is often a good choice). Basically, in Below holdoff mode, we are asking to trigger on the silence between bursts, that is, if the signal is below the Level setting, for the Holdoff time it will trigger.

Level

This is the hardest setting to get right. It needs to be greater than the noise level between bursts, but less than the height of the packet. Starting at zero and increasing slowly is a good approach.

Input Range

Though not a Trigger setting, Input Range, plays a very important part. If the signal is not ranged correctly to start with, the oscilloscope may never trigger.

14.3.3 Data Source

Data From	By default, when the 81199A software starts it will set its data source for modulation analysis as hardware (specifically, whatever hardware is currently configured as the default hardware source in the underlying 89601B VSA). If you subsequently load a recording into the 81199A software (in practice this means loading a recording into the 89601B software) then the data source will be automatically changed from Hardware to Recording and the recording filename will be remembered. This will also happen if you have paused the 81199A software and used the 89601B software to make a recording of a live signal for later analysis. To return to live signal acquisition, change this setting back to Hardware.
Recording File Name	This setting holds the path to the most recently loaded recording file.
Reload Recording File if Changed	When this setting is set to True, the recording will be re-loaded if the recording file on disk is updated.

14.3.4 Logging to HDF5 File

Results Logging	This turns IEEE 802.11ad results logging on and off. This feature is currently not supported by the WirelessHD demodulator. The setting defaults to off because results log files save all measurement data and so can become large quite quickly. This capability should therefore be used prudently. A new log file is created each time the measurement restarts and is closed off when the measurement stops. So, for example, if you are in continuous mode and you press Start, let the demodulator perform 10 demodulation cycles then press Stop, you will get one file with 10 measurements in it. When you press Start again, a new file will be opened.

Logging Directory

This specifies the directory on the host PC where log files will be saved.

The automatically generated file names will look similar to,

WWC_log_20120608_160537.hd5

where the embedded numbers are date and time stamps.

HDF File Format

The files are written in the Hierarchical Data Format (HDF) proposed by the HDF Group (www.hdfgroup.org).

HDF files can be read and edited with HDFView, which is an open source utility available from the HDF group.

http://www.hdfgroup.org/hdf-java-html/hdfview/

Log File Structure

The HDF files created by 81199A contain two top level HDF groups.

The first is called "All Results" and it contains a group for every measurement taken.

Each "measurement" group contains a sub-set of 11ad demodulation results and time and spectrum data.

Even if no packets are found, or if packets are incomplete or the 11ad demodulator is turned off, a measurement group is still created for each measurement.

The second group is called "Protocol" and it contains groups for every complete 11ad packet found (complete means that the number decoded octets equals or exceeds the number specified in the header).

Each packet group contains decoded data and the packet start time. It also contains a link to the measurement group for more information. Note that there's nothing in the Protocol group that isn't in the Measurement group, the Protocol group's purpose is to make it easy to see if any complete packets were found.

15 Supported Formats (Measure)

15.1 Introduction

This chapter describes the functionality of the measuring demodulators currently supported by 89601B VSA time-capture post-processing in the 81199A software. These new demodulators address specific emerging technologies in the 60 GHz unlicensed band. For other, more established formats, and for general purpose demodulation, the underlying 89601B VSA demodulation capability should be used directly.

15.2 Using the VSA directly

If you are working with signals that comply with the specifications supported by the 81199A software, specifically 802.11ad or WirelessHD signals, then you should have option(s) IAD and / or WHD installed and use the modulation analysis capabilities described in sections 15.3 and 15.4.

If you are working with multi-tone signals, or custom signals (whether by means of Utility segments or custom plug-ins) then you will need to use the underlying 89601B VSA software directly.

To access the 89601B VSA software.

Stop 81199A measurements (if they are running) by clicking the Stop button in the Tool Bar or selecting **Measure** > **Stop Measurement** from the menu, then in the Acquisition Settings menu select Advanced and set 89600 State to Visible.

Refer to the 89601B VSA on-line help (**Help** > **User's Guide...**) for full information on using the VSA analysis capabilities.

15.3 IEEE 802.11ad

This section introduces the 802.11ad demodulator.

To keep the explanations short, we have not detailed all the display configuration options available in each measurement result. Please refer to Chapter 10 for guidance.

15.3.1 Demodulator Settings

The 802.11ad demodulator is designed to be as automated as possible, so there are relatively few settings, and those are largely optional.

Simply setting Demod On to True should be sufficient to get started.

Demod On

If set to True then the acquired time data records will be sent to the 802.11ad demodulator for analysis. If false no data will be sent.

If more than one demodulator is enabled (for example 802.11ad and WirelessHD) then the time data will be sent to all of them in parallel and the measurement results will be gathered and displayed. This can prove useful when analyzing an unknown or mixed signal.

De-Rotate

802.11ad specifies that $\pi/2$ rotation is applied to all its single carrier modulations (BPSK, QPSK and 16QAM). The constellation displays for these modulations are, by default, shown as they are received, without de-rotation.

This setting allows you to display the constellations after de-rotation. The most obvious effect of this is to return the BPSK modulation to a two state constellation. ($\pi/2$-BPSK normally looks like QPSK because of the rotation).

The reason for defaulting to the de-rotated constellation is that any I/Q distortions remain separated onto the I and Q axes, which is helpful for problem identification, whereas in the de-rotated constellation, any I/Q distortions are smeared equally onto all constellation points.

Packet Search Mode	Set the packet search mode. This determines how the demodulator will select which packet to demodulate if multiple packets are present in the time record. "Largest Packet" means that the packet with the largest preamble correlation will be selected. "First Packet" means that the first packet in the time record that exceeds the correlation threshold specified in the Search Threshold setting will be selected.
Search Threshold	Set the correlation search threshold to be used by "First Packet" search mode.
Symbol Clock Compensation Mode	The 802.11ad demodulator always estimates the symbol clock error as part of the measurement set reported in the Error Summary. This setting controls whether the demodulator will offset its symbol clock from the nominal value using the estimated symbol clock error (auto) or the fixed value supplied by the user in the the Symbol Clock Offset setting (manual). Auto mode is slower than manual mode because it requires some additional pre-processing of the signal data to estimate the symbol clock error before full demodulation. It can also have difficulties if the DUT symbol clock is unstable during the preamble. In general, the additional flexibility offered by manual mode is advantageous for DUT debug.
Symbol Clock Offset	If the transmitter clock's understanding of frequency is slightly different from that of the test equipment (based on the 90000A/X oscilloscope's reference clock), then the demodulator's understanding of symbol clock frequency will be similarly in error relative to the transmitter and this will degrade the accuracy of the demodulation. This setting permits the demodulator's symbol clock to be adjusted to match the transmitter symbol clock. Symbol clock errors of a few parts per million can make a large difference to the received constellation. The appropriate value for this setting can be determined from the Symbol Clock Error value reported in the Error Summary measurement results.

Control PHY Carrier Tracking

The 802.11ad Control PHY (MCS0) uses DBPSK and therefore does not need to maintain an absolute phase reference to demodulate the signal. In other words, it does not require carrier tracking to be implemented. However, MCS1 and above use BPSK, QPSK etc. and therefore do require carrier tracking.

Because there is this freedom to dispense with carrier tracking in MCS0, this setting is provided (for MCS0 only) so the user can see what the constellation looks like with and without tracking for system evaluation purposes.

If the DUT implements carrier tracking in all modes, then set this to True, if it does not use carrier tracking in MCS0, then set it to False. That way, the 802.11ad demodulator "sees" the MCS0 signal the same way the DUT receiver will "see" it.

With Control PHY Carrier Tracking set to False, EVM is usually degraded due to phase wander over the duration of the burst.

The definition of EVM in 802.11ad specifies that the receiver should perform "carrier lock" when measuring EVM on both CPHY and SCPHY signals, so Control PHY Carrier Tracking should be set to True to make an EVM measurement for comparison with the specified values.

SC PHY Amplitude Tracking

This setting is provided as an aid to DUT debugging.

Normally the 11ad demodulator will track the signal amplitude of all Single Carrier modulations (MCS1 to MCS12, MCS25 to MCS31), however it can be instructive to disable this correction in order to explore the raw DUT performance.

SC PHY Phase Tracking

This setting is provided as an aid to DUT debugging. (See the description of SC PHY Amplitude Tracking for more information on the purpose of these settings).

OFDM PHY Amplitude Tracking	This setting is provided as an aid to DUT debugging. Normally the 11ad demodulator will track the signal amplitude of all OFDM modulations (MCS13 to MCS24), however it can be instructive to disable this correction in order to explore the raw DUT performance.
OFDM PHY Phase Tracking	This setting is provided as an aid to DUT debugging. (See the description of OFDM PHY Amplitude Tracking for more information on the purpose of these settings).
OFDM PHY Timing Tracking	This setting is provided as an aid to DUT debugging. (See the description of OFDM PHY Amplitude Tracking for more information on the purpose of these settings).

IQ Generation

This setting informs the 802.11ad demodulator whether the transmitter under test implements its vector modulation on-axis, or offset by 45° to enable correct attribution of gain and quadrature errors.

Specifications typically illustrate constellations either on-axis (a diamond) or offset by 45° (a box), but in practice, as long as the specified relative phasing of the constellations of different parts of the signal is maintained, the absolute phase is unimportant. Indeed there is no absolute phase reference at the receiver, because the signal phase is entirely dependent on the transmission delay.

Radio designers are essentially free to choose an on-axis or 45-degree offset implementation depending on which is a better fit for their design constraints, and for normal operation this is of little consequence. However to correctly attribute the impairments of gain error and quadrature error in a measuring demodulator it is important to know which transmitter design choice was made.

Quadrature error in an on-axis transmitter is indistinguishable from gain error in a 45° offset transmitter, both give a rectangular constellation. The reverse is also true; gain error in an on-axis transmitter is indistinguishable from quadrature error in a 45° offset transmitter, both give a rhomboid constellation.

To separate these errors, the 802.11ad demodulator assumes by default that the transmitter has implemented the constellations as they are illustrated in the specification, but this switch is provided for users who know that their DUT has chosen the other possibility, so that the gain and quadrature errors can be correctly attributed.

15.3.2 Measurements

In addition to the two primary measurement displays taken directly from the underlying 89601B VSA software (Main Time and Spectrum), the 802.11ad demodulator adds a further 14 measurement displays, several of which contain multiple measurement results.

In this section we consider each measurement display in detail.

Main Time

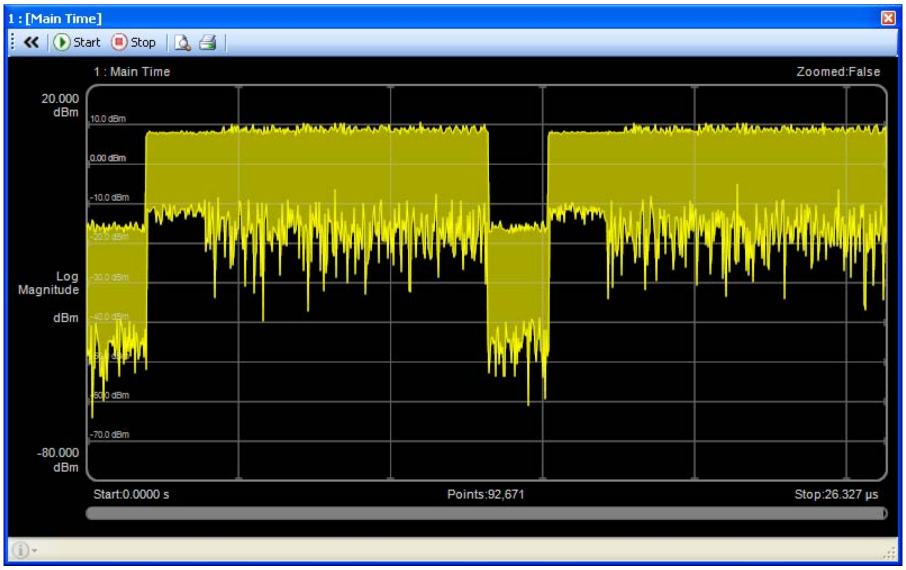

Figure 62. Main Time Display of an 802.11ad Signal

The main time measurement result is independent of the 802.11ad demodulator and is discussed generally in section 4.6.

When working with 802.11ad signals the time display is useful for some simple checks before attempting to demodulate the signal.

- What is the approximate signal to noise ratio? Because 802.11ad is a burst mode signal you can estimate the received SNR by looking at the ratio of the power in the burst and in the gap. Because of the close relationship between SNR and EVM this will give you guide to the best EVM you can hope to achieve with a given signal.
- Does the signal look clipped or compressed? Especially in a QAM or OFDM signal we expect the header and payload fields to have significantly higher peaks than the constant amplitude preamble.
- Are there any transient effects? Amplifier issues such as slow power ramping or ringing may be visible.

When the 802.11ad demodulator is enabled, the detected packet is highlighted as shown in Figure 63. This is the packet in the time record that was selected by the demodulator for demodulation to give the results in the Error Summary and other measurement displays. The demodulator's packet search criteria are programmable.

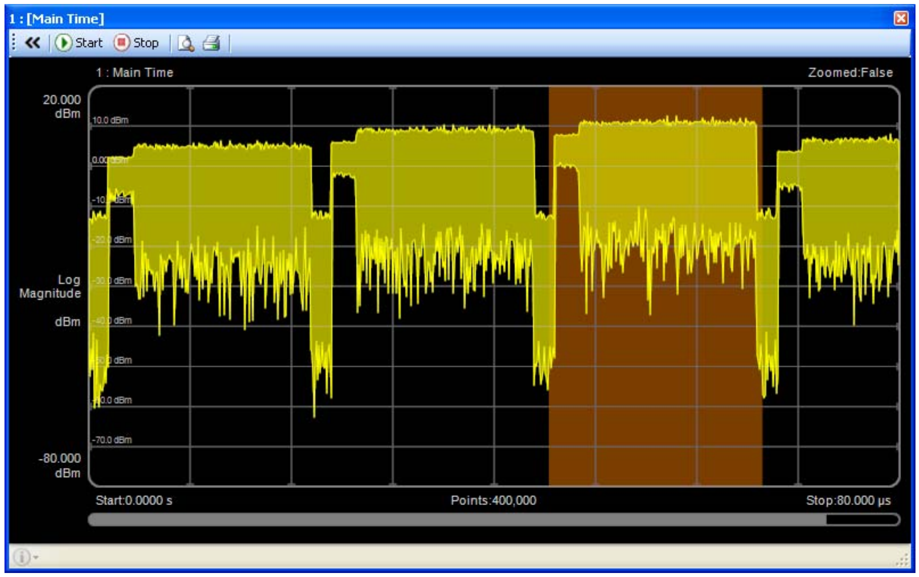

Figure 63. Main Time Display of an 802.11ad Signal with Selected Packet Highlighting.

Spectrum

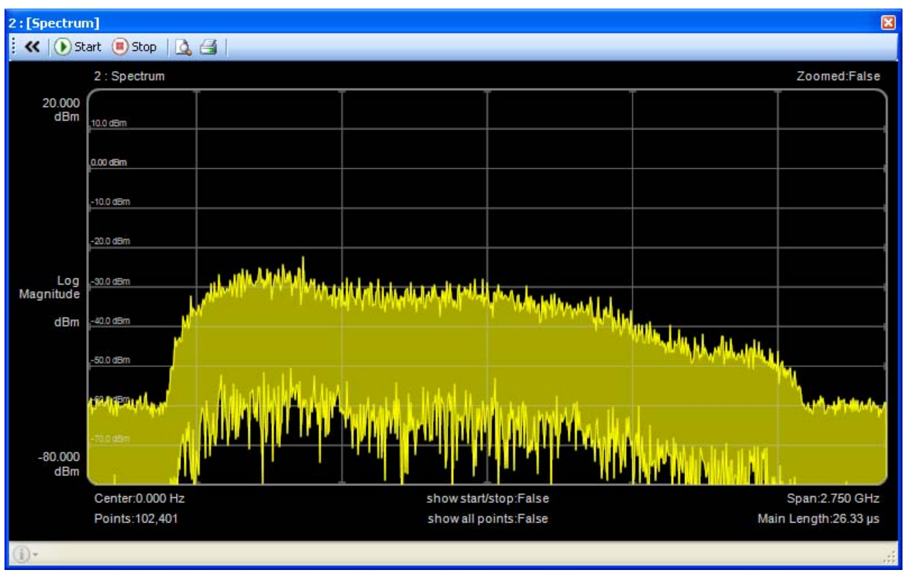

Figure 64. Spectrum Display of an 802.11ad Signal With Significant Non-Flatness Across the Channel.

The spectrum measurement result is independent of the 802.11ad demodulator and is discussed generally in section 4.6.

When working with 802.11ad signals the spectrum display is useful for some simple checks before attempting to demodulate the signal.

- Is the spectrum the right sort of shape? If it's SCPHY, does it have the Gaussian / Cosine / custom shape you expect? If it is OFDMPHY is it the usual "sand castle" shape?
- Are there any big dips or peaks? Some non-flatness is expected and will be equalized out, but extreme changes can defeat an equalizer and hence be problematic.
- Is the bandwidth about right? That is, about 1.8 GHz?
- Are there any spurs or adjacent channel spectral regrowth? In band spurs will degrade EVM. An elevated noise floor on either side of the expected signal may indicate intermodulation products due to non-linearities such as gain compression.

Error Summary

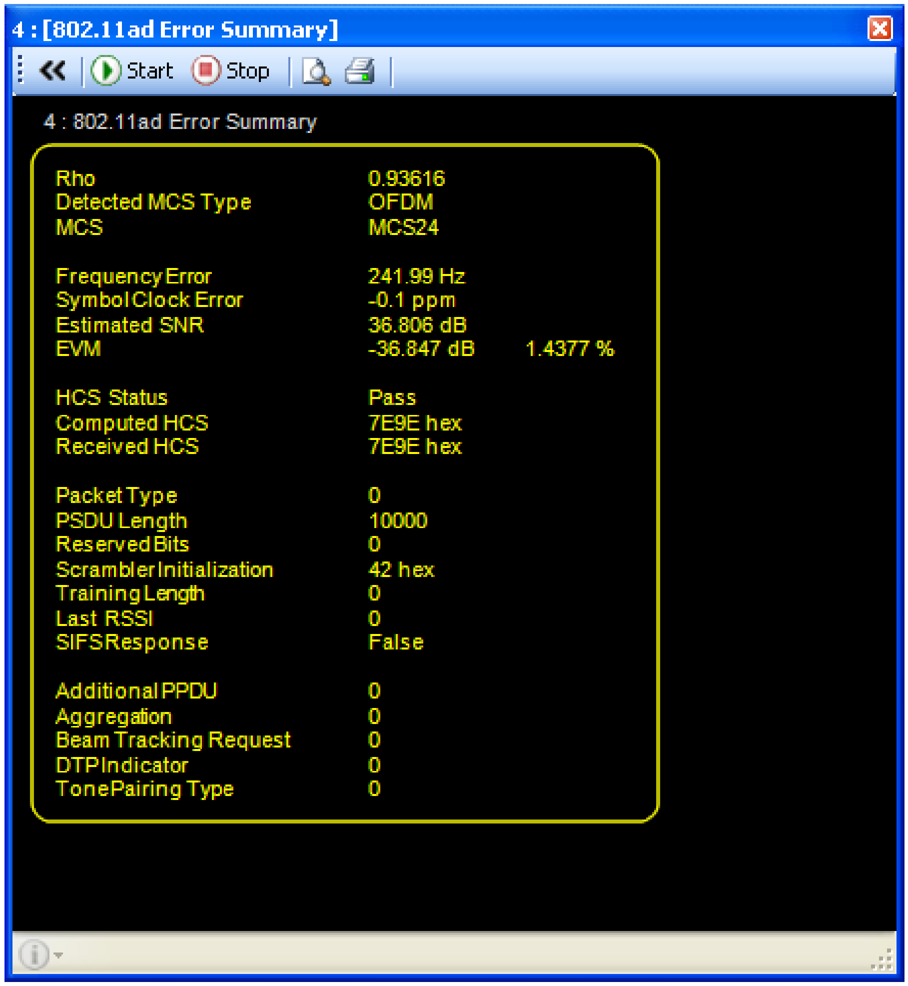

Figure 65. 802.11ad Error Summary for MCS24 (OFDM)

All of the following results are presented on the Error Summary display.

Rho

This is the ratio of the mean of the peak powers at the output of the Ga128 and Gb128 Golay correlators to the mean power in the signal, both computed over the preamble (STF + CEF). It has a range of zero to one, where one indicates a perfect signal with only the expected Golay sequences present.

Rho is only computed over the preamble. It is an Agilent created measurement definition intended to provide a correlation based figure of merit for the preamble.

Rho is a common measure of normalized correlated power in other communication systems (such as CDMA).

As mentioned a Rho of 1.00 indicates a “perfect” preamble, however the preambles on OFDMPHY packets are, by definition, imperfect due to the specified resampling necessary to match the single carrier preamble to the OFDM reference sample rate.

This has the effect that the best achievable Rho for an OFDM signal is around 0.94.

Detected MCS Type

The 802.11ad PHY supports three distinct modulation methods:

1. Spread spectrum modulation; the Control PHY.
2. Single carrier (SC) modulation; the Single Carrier PHY (including the Low Power Single Carrier PHY).
3. Orthogonal Frequency Division Multiplex (OFDM) modulation; the OFDM PHY.

The CPHY is distinguished from the other PHYs by its use of a repeating Gb128 sequence in its preamble short training field. The other PHYs use a repeating Ga128 sequence.

The single carrier (CPHY, SCPHY and LPSCPHY) PHYs are distinguished from the OFDM PHY by the ordering of the Golay sequences in the preamble channel estimation field.

These simple, correlator based checks on the received signal enable the 802.11ad demodulator to determine whether the incoming packet is a Control, Single Carrier or OFDM PHY, and this result reports the demodulator's decision.

Both SCPHY and LPSCPHY are detected as Single Carrier MCS types.

Frequency Error

This is the estimated frequency error in the received carrier frequency (subject to the accuracy of the measuring hardware's own sampling clock.)

This is a signal-based estimate so there is usually a few hundred Hz of “noise” on this measurement, but significant offsets (10’s of kHz) are accurately reported.

Symbol Clock Error

This is the estimated frequency error in the received symbol clock (subject to the accuracy of the measuring hardware's own sampling clock.)

The demodulator can accurately measure symbol clock errors well in excess of the ±20 ppm permitted by the 802.11ad specification. Any symbol clock error present can be compensated for by adjusting the demodulator's Symbol Clock Offset setting.

An unstable Symbol Clock Error result may indicate that the symbol clock itself is unstable.

Estimated SNR

This is the estimated random content (variance) of the received signal (additive noise and phase noise, for example).

Its main value is as a comparison with EVM. If the two numbers are similar magnitude (ignoring the sign difference due to how the measurements are defined) then you can assume that random noise is the dominant component of the EVM result. If there is a significant difference then there are likely other impairments present. At very low SNRs this estimate can become inaccurate.

EVM

This is the estimated Error Vector Magnitude (EVM) of the signal. It is reported in dB and percent.

A complex modulation is constantly varying in amplitude and phase (versus time). Its complex value is sampled periodically (at the symbol rate) and, at those sampling instants, a perfect signal would be found to be exactly at one of a finite number of pre-defined positions in the complex plane, which can then be uniquely mapped back to an equivalent data pattern.

In practice a real signal will rarely be at exactly the ideal value. We hope it will be sufficiently close to the ideal that it can be unambiguously decoded, but its measured position will differ from the ideal by an error vector. If we compute the average magnitude of these error vectors (EVM) we obtain an objective measure of the signal perturbation.

In a real system, this perturbation is an aggregation of many effects; some, such as noise, phase jitter, inter-symbol interference, timing skew, and symbol clock frequency error will smear or diffuse the received sample values relative to the ideal in very distinctive ways, cumulatively creating the familiar “cloud of flies” around each ideal position.

Other impairments such as IQ gain imbalance, quadrature error, IQ DC offset, and gain compression will, in single carrier modulations, distort the geometry of the received signal so that even a best fit to the ideal constellation necessarily leaves some points "off target". In OFDM modulation these impairments will cause structured clusters of points (often looking like miniature constellations) around the ideal positions. In either case degrading the EVM.

Objective summation of the error vectors to give a single EVM result is a useful benchmark, but subjective assessment of an impaired constellation based on an understanding of the error mechanisms can often provide greater insight to fault-finding the root cause of problems.

Error Summary EVM (DC Compensated)

This result is available for SCPHY and LPSCPHY only, and is reported in dB and in percent.

DC offsets on the I and Q signals will often be removed by the DUT receiver, so it is useful to also compute EVM without this contribution, to give a more accurate assessment of the signal quality as it will be seen by the DUT.

The DC compensated EVM may still be slightly higher than the EVM of a signal without DC as DC can also negatively impact the performance of the equalizer.

I & Q DC Offset

The DC content of the signal. In an OFDM signal DC offset only affects the central carrier (if present). The OFDM modulation used in 802.11ad suppresses the central carrier and, indeed the carrier either side of that too.

IQ Amplitude Imbalance	The estimated IQ Amplitude Imbalance indicates the gain matching of the I and Q channels. For single carrier modulations, gain mismatch will result in a distorted constellation which the receiver will not be able to fit exactly to the expected square shape, resulting in degraded EVM. LO Quadrature Error has similar distorting effects to IQ Amplitude Imbalance and it is not always possible to unambiguously attribute the measured distortion without some additional information about the transmitter. See the description of the IQ Generation setting in section 15.3.1. For OFDM modulation, gain mismatch causes inter-carrier interference causes the constellation points to separate into structured clusters of points (often looking like miniature constellations) around the ideal positions.
LO Quadrature Error	The estimated LO Quadrature Error indicates how close to exactly 90° phase difference there is between the I and Q axes. For single carrier modulations, LO Quadrature Error will result in a distorted constellation which the receiver will not be able to fit exactly to the expected square shape, resulting in degraded EVM. IQ Amplitude Imbalance has similar distorting effects to LO Quadrature Error and it is not always possible to unambiguously attribute the measured distortion without some additional information about the transmitter. See the description of the IQ Generation setting in section 15.3.1. For OFDM modulation, quadrature causes inter-carrier interference causes the constellation points to separate into structured clusters of points (often looking like miniature constellations) around the ideal positions.

Header Information The header information results listed below are simply reported by the 802.11ad demodulator as they are decoded from the packet header.

- MCS – The number of the Modulation and Coding Scheme decoded from the header. This value is also used by the demodulator to determine how to decode the payload.
- HCS Status – Flag indicating whether the HCS from the header matches the HCS recomputed by the demodulator from the decoded header bits.
- Computed HCS – The checksum decoded from the header.
- Received HCS – The checksum recomputed by the demodulator from the decoded header bits.
- Packet Type - Decoded from the header.
- PSDU Length - Decoded from the header.
- Scrambler Initialization - Decoded from the header. This value also seeds the descrambler in the demodulator.
- Training Length - Decoded from the header.
- Last RSSI - Decoded from the header. (Not CPHY)
- Turnaround - Decoded from the header.
- Additional PPDU - Decoded from the header. (Not CPHY)
- Aggregation - Decoded from the header. (Not CPHY)
- Beam Tracking Request - Decoded from the header. (Not CPHY)
- DTP Indicator - Decoded from the header. (OFDMPHY only)
- Tone Pairing Type - Decoded from the header. (OFDMPHY only)

EVM Display

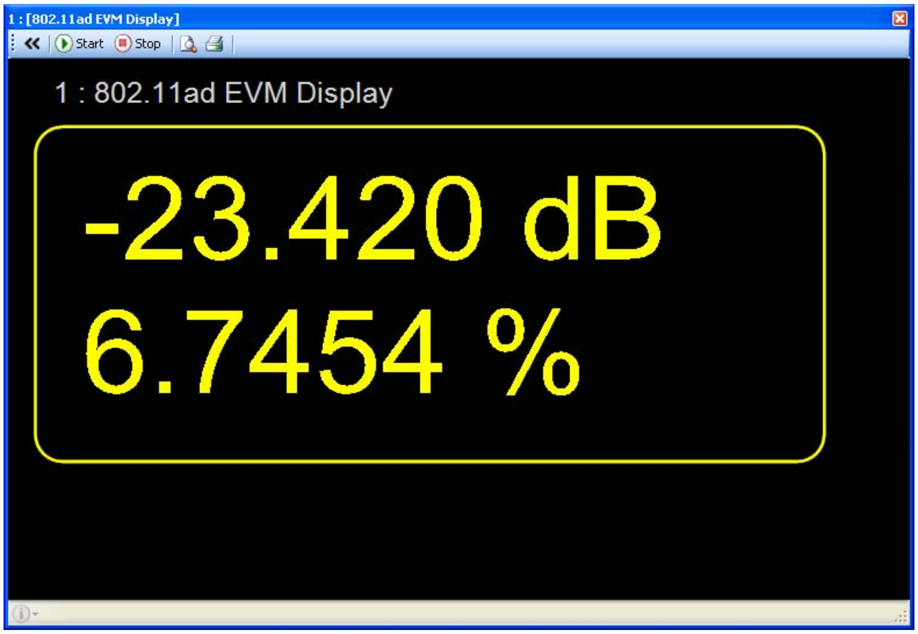

Figure 66. 802.11ad Big EVM Display

This display simply provides an alternative large format display of the EVM value in dB and %. This is the same value as is displayed under EVM in the Error Summary.

It is intended as a convenience feature to facilitate monitoring EVM from a distance, for example, while adjusting DUT settings to optimize EVM.

Decoded Data

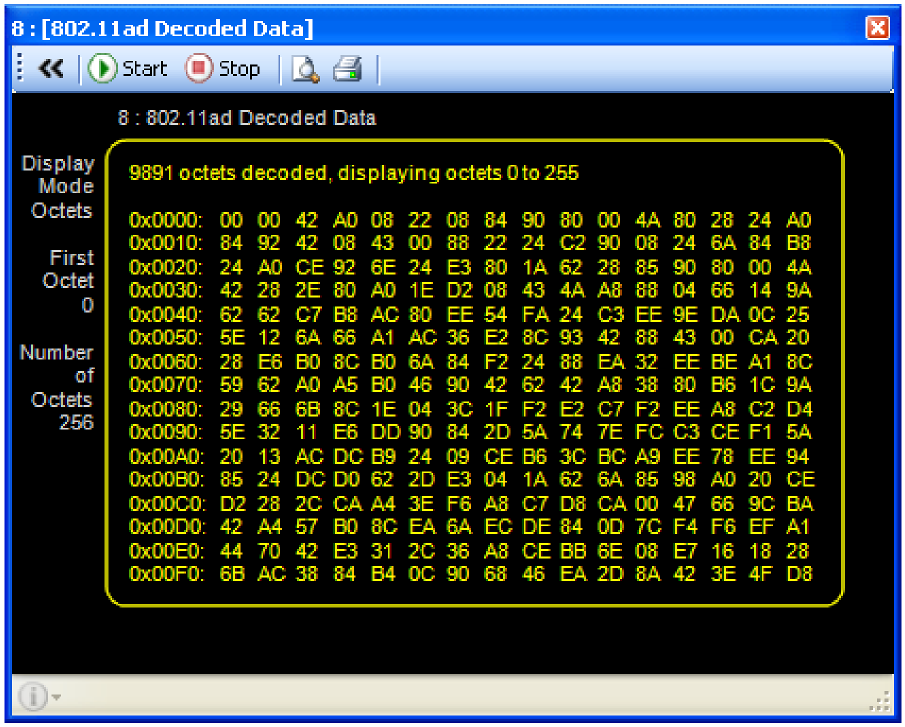

Figure 67. 802.11ad Decoded Data

This display shows the result of fully decoding the received 802.11ad packet to recover the original payload data.

In order to extract the parametric results, the 81199A software has to implement a more or less complete demodulator, including the error correction algorithms to recover, as far as possible, the original transmitted data for reference purposes, so the 802.11ad demodulator also implements the descrambling, de-stuffing etc., to recover the original payload data.

The labels on the left of this display are active and can be changed by clicking on them.

The display mode can be in octets or binary. The distinction between these representations is that the binary display shows the data bits in the little endian order they are transmitted, whereas the octet display shows the same bit pattern interpreted as octets.

The information at the top of the display reports how many octets have been decoded and the sub-set being displayed. The starting position and the number of octets displayed are both configurable.

Codeword Display

Figure 68. 802.11ad Codeword Display

This display shows the result of error correction decoding the 802.11ad packet.

Depending on the MCS, this display will show the result of Low Density Parity Check (LDPC) decoding (MCS0 to MCS24) or Reed-Solomon (RS) decoding (MCS25 to MCS31).

In both cases the information at the top of the display reports how many codewords have been decoded (158 in the case illustrated).

Following that, there is a grid of letters each representing a received codeword. If the letter is a green P then the codeword passed parity checking, if it's a red F then it failed.

For LDPC codewords this means the decoding algorithm failed to converge within the iteration limit. For RS codewords this means the decoding algorithm failed to find unambiguous roots of the error locator and magnitude polynomials.

The labels on the left of this display are active and can be changed by clicking on them.

The code word index controls which codeword data is displayed. The current selection is also highlighted by the inverse video cursor on the Pass / Fail display. If a codeword decoded successfully the display shows the corrected data. If decoding failed the original uncorrected data is displayed.

LDPC codewords contain 672 bits. RS codewords contain 24 or 224 octets depending on whether the codeword belongs to the header or payload respectively.

The display mode can be in octets or binary. The distinction between these representations is that the binary display shows the data bits in the little endian order they are transmitted, whereas the octet display shows the same bit pattern interpreted as octets.

In general, bits is the most suitable mode for LDPC codewords, while octets is better for RS codewords.

Correlator Outputs

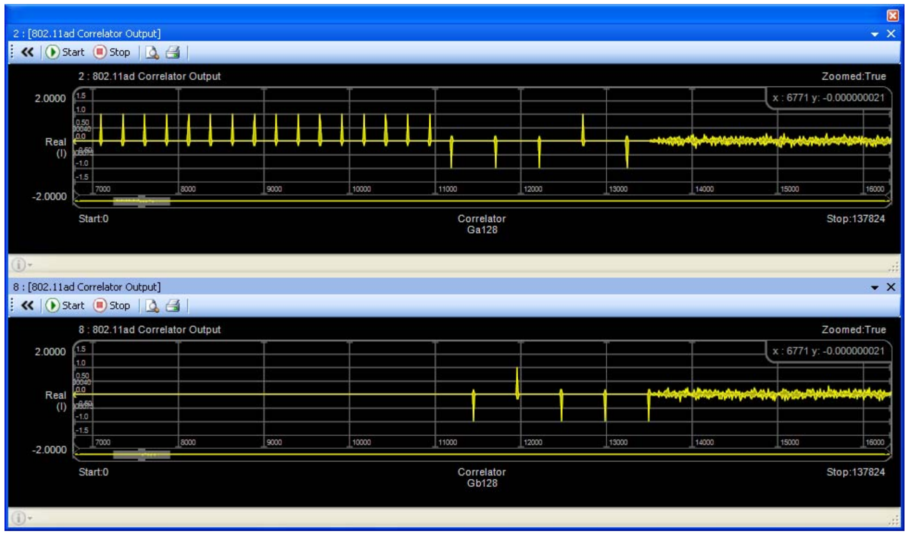

Figure 69. 802.11ad Correlator Outputs for Ga128 and Gb128

Correlator Outputs

This measurement result shows the output from a selected Golay sequence correlator. In Figure 69 we are looking at two instances of this result, showing the Ga128 and Gb128 correlator outputs zoomed in on the preamble of a very clean single carrier signal.

Which correlator output to display is selected by right clicking on the X-axis label and choosing from the drop-down list.

Only the correlators applicable to the detected MCS type (CPHY, SCPHY or OFDMPHY) are provided.

Tiling Example

Figure 69 illustrates how you can use the tiling capability of the docking panels to put two (or more) related displays together into one window.

In this case we have tiled Measurement Display windows 2 and 8 into a single window, set both displays to show the Correlator Outputs result, but then selected the Ga128 correlator in the upper window and the Gb128 correlator in the lower window.

The correlator output is reported as a complex number. Nominally it is real valued, but phase noise and other impairments can cause spreading in the complex plane resulting in an imaginary component as well.

The default Y-axis data is Real, but by right clicking on the Y-axis label other representations can be selected.

The most useful representations, after Real, are I-Q which is particularly helpful in revealing any phase modulation present, and Log Magnitude which can uncover unintended variations in signal level.

The amplitude of the Real part may fluctuate when the transmitter has drifting phase. In this case, use the Linear Magnitude representation.

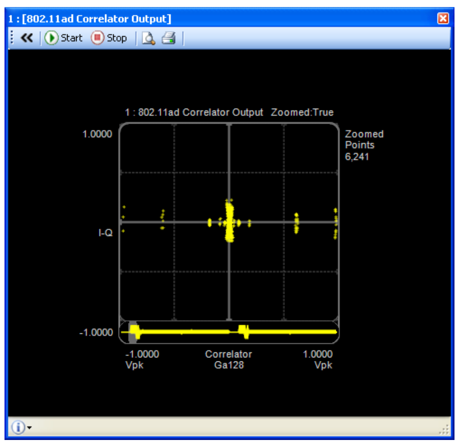

Figure 70. Example of Ga128 Correlator Output, represented in I-Q mode, to Reveal Approximately 20° Phase Modulation

Golay Sequences

Golay complementary sequences are pairs of sequences of bipolar symbols (±1) that have been mathematically constructed to have very specific autocorrelation properties. They are used extensively in 802.11ad for a variety of purposes.

In a receiver, correlators are used to detect which sequence was transmitted.

The nomenclature of Golay sequences is G for "Golay" followed by an 'a' or 'b' to indicate which sequence in the pair, followed by the sequence length.

IEEE 802.11ad uses Ga32, Ga64, Ga128 and Gb128 sequences.

Ga32, Gb32

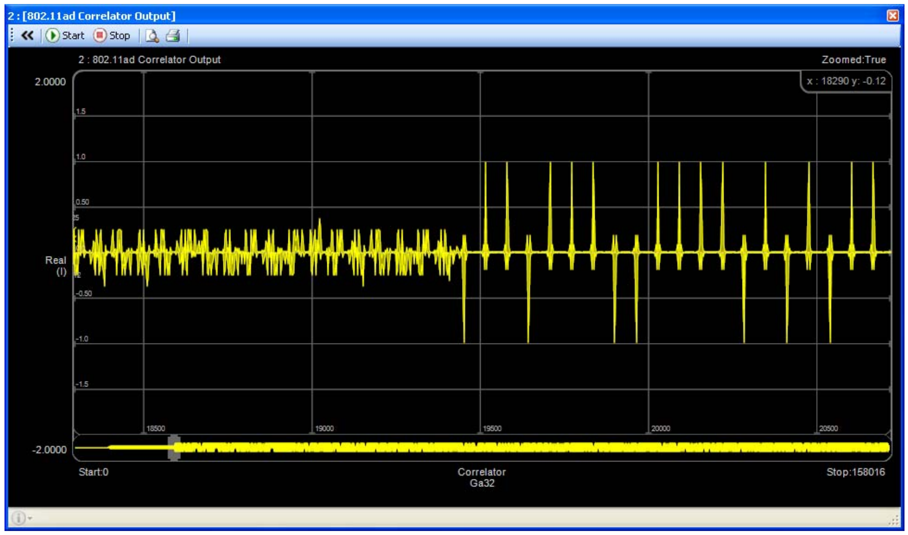

Figure 71 Ga32 Correlator Output (Zoomed)

Ga32, Gb32

The first two choices in the drop-down list are Ga32 and Gb32.

Ga32 is used as the data spreading sequence in MCS0 (CPHY) to provide coding gain.

Selecting Ga32 when in MCS0 should display a densely packed sequence of correlation spikes corresponding to the header and payload parts of the packet. As illustrated in Figure 71.

Each spike on this display corresponds to a spread modulation symbol, with a positive spike representing +1 and a negative spike representing -1. The chip rate is 1.76 GHz and the spreading factor is 32, so the correlation spikes should occur at a 1.76 GHz / 32 = 55 MHz repetition rate.

The Gb32 sequence is not used by 802.11ad, but the 81199A software provides the data in case the wrong sequence has been used in the DUT.

The Ga32 / Gb32 correlator traces are only active when receiving an MCS0 signal.

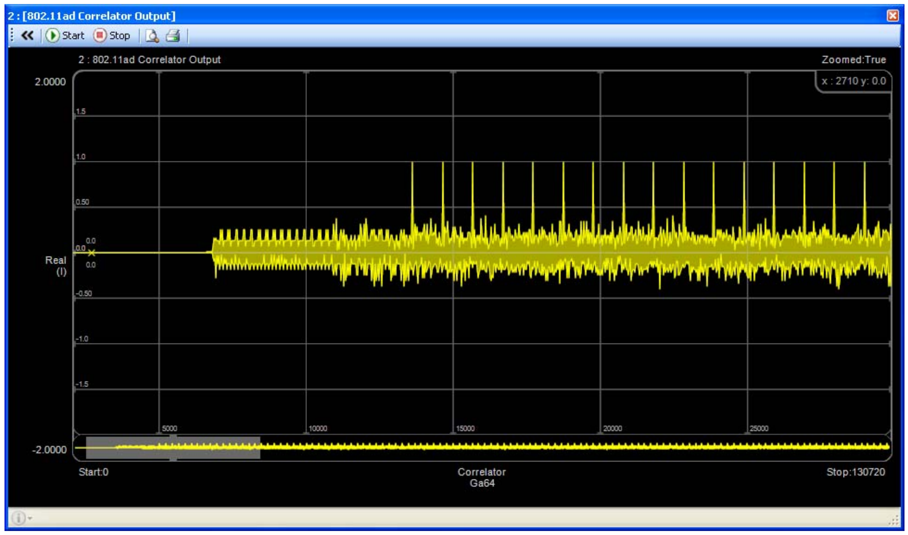

Figure 72 Ga64 Correlator Output (Zoomed)

Ga64, Gb64

The next two choices in the drop-down list are Ga64 and Gb64.

Ga64 is used as a Guard Interval (GI) in all the Single Carrier modulated modes to provide a periodic known symbol sequence for gain and phase tracking.

Ga64 is also used to construct the AGC part of the optional Beam Refinement Field which may be present at the end of the packet.

Selecting Ga64 when in MCS1 to MCS12, or MCS25 to MCS 31, should display a comb of correlation spikes corresponding to the GI in the header and payload parts of the packet. As illustrated in Figure 72.

Each spike on this display corresponds to the occurrence of a 64 symbol guard interval marking the start of a modulation symbol block. The symbol rate is 1.76 GHz and the symbol blocks are 512 long, so the correlation spikes should occur at a 1.76 GHz / 512 = 3.4375 MHz repetition rate.

In any MCS (0 through to 31) There may also be a burst of Ga64 correlation spikes at the end of the packet, if there is a Beam Refinement Field present.

The Gb64 sequence is not used by 802.11ad, but the 81199A software provides the data in case the wrong sequence has been used in the DUT.

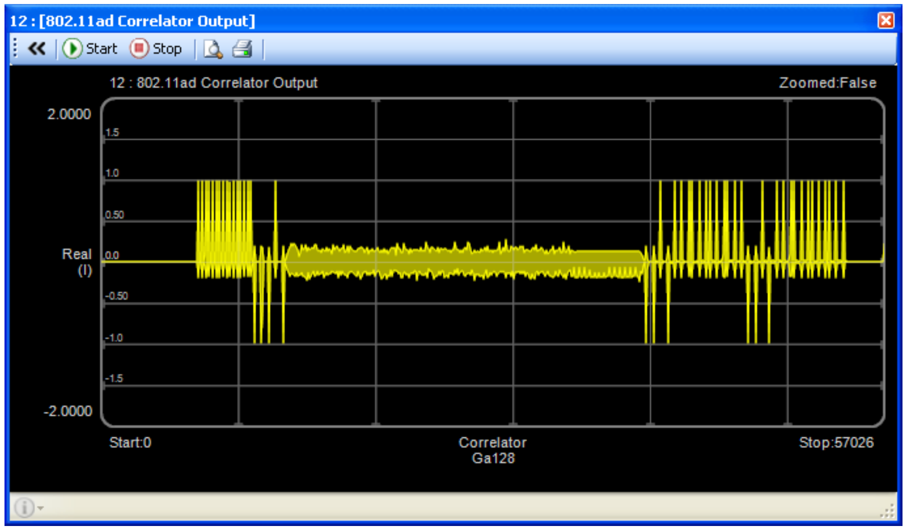

Figure 73. Ga128 Correlator Output Showing the Preamble and Two BRP Training Fields at the End of the Packet.

Ga128, Gb128

The last two choices in the drop-down list are Ga128 (the default setting) and Gb128.

Ga128 is used in the Short Training Field of all MCS preambles except MCS0 for clock synchronization, and AGC adjustments. Gb128 is used for the same purpose in MCS0 packets. The MCS0 (CPHY) is distinguished from the other MCS by means of this coding difference.

Ga128 and Gb128 are used together in the Channel Estimation Field as a stimulus that can be processed to compute an estimate of the channel response. They are also used for a similar purpose in constructing the optional Beam Refinement Field which may be present at the end of the packet.

As illustrated in Figure 69, selecting Ga128 when in any MCS (except MCS0), should display a comb of correlation spikes at the beginning of the packet corresponding to the Short Training Field in the preamble of the packet.

Each spike in this part of the display corresponds to the occurrence of a Ga128 sequence. The preamble symbol rate is 1.76 GHz and the sequences are 128 long, so the correlation spikes should occur at a 1.76 GHz / 128 = 13.75 MHz repetition rate.

Selecting Gb128 in MCS0 should display a similar progression of correlation spikes.

Following the STF, there should be a sequence of correlation spikes on the Ga128 and Gb128 outputs corresponding to the Channel Estimation Field.

In any MCS (0 through to 31) There may also be a burst of Ga128 and Gb128 correlation spikes at the end of the packet, if there is a Beam Refinement Field present.

Channel Estimation

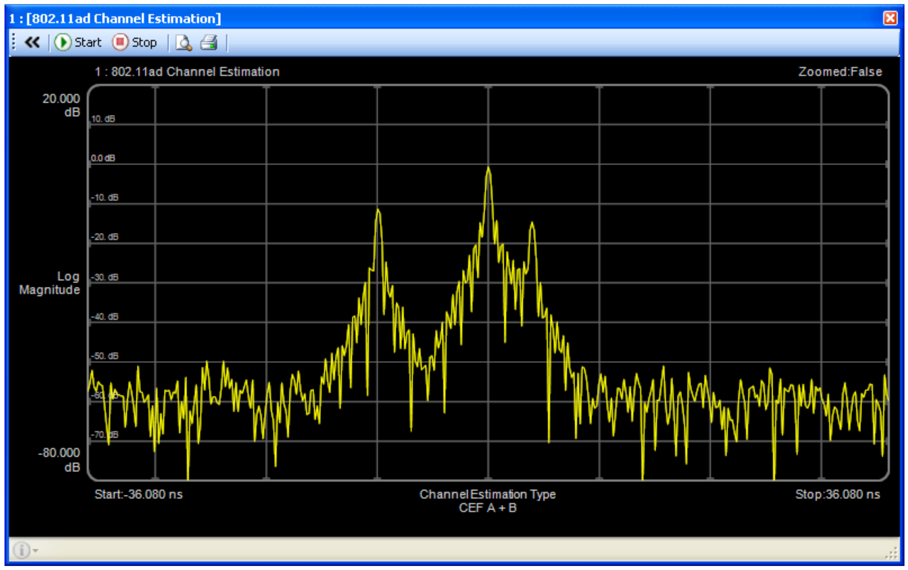

Figure 74. Channel Estimation Showing Some Multipath

This measurement result shows a channel estimation based on the received channel estimation field. In 802.11ad, the channel estimation field provides two independent channel estimation opportunities which are referred to in the 81199A software as CEF A and CEF B.

The software can display CEF A, CEF B or their summation (CEF A + CEF B).

Which to display is selected by right clicking on the X-axis label and choosing from the drop-down list.

The channel estimation output is reported as a complex number. The default Y-axis data is Log Magnitude, but by right clicking on the Y-axis label other representations can be selected.

However, Log Magnitude is usually the most useful representation.

Peaks in the channel estimation display correspond to different paths from transmitter to receiver. The X-ordinate is time so you can determine the spread of path delays.

The exact amplitude and delay values are easily determined by using the cursor annotation in Zoomed mode. See section 10.4.

In Figure 74 we have contrived to have three clearly distinct paths for illustrative purposes (-10 ns at -10 dB, 0 ns at 0 dB, and +4 ns at -15 dB), but it is more common for there to be a smear of delayed responses in the 0 to 20ns range.

Channel Estimation Theory

The Ga128 and Gb128 sequences in the channel estimation field are grouped into blocks of four. Each block provides the stimulus signals required to make a single channel estimation. So each channel estimation field contains two channel estimation opportunities.

Channel estimation is based on sequentially passing the two sequences in a Golay complementary pair through the channel and combining the results.

Within each block the Ga128 and Gb128 sequences have been arranged to form a complementary pair of 256-long sequences.

Channel estimation depends on the key property of complementary Golay sequences, specifically that when you add the autocorrelation functions of the 'a' and 'b' sequences together all the false correlation peaks cancel exactly to give a perfect autocorrelation response.

Key Principle

We have two time sequences, a and b. If we pass sequence a through the channel H, we convolve the sequence and the channel impulse response, h(t).

If we pass the received signal through a Golay correlator for the known input sequence then we get the autocorrelation of sequence a convolved with the channel impulse response.

If sequence b is processed similarly, we get the autocorrelation of sequence b convolved with the same channel impulse response.

If we add the two results together then, because sequences a and b are Golay complementary sequences, the sum of their autocorrelations is an impulse response and we are left with the channel response, h(t).

CEF A — With this option selected, the display shows the channel estimation based on the first four Ga128/Gb128 sequences in the CEF.

CEF B — With this option selected, the display shows the channel estimation based on the second four Ga128/Gb128 sequences in the CEF.

CEF A+B — With this option selected, the display shows the sum of the two channel estimations.

Channel Frequency Response

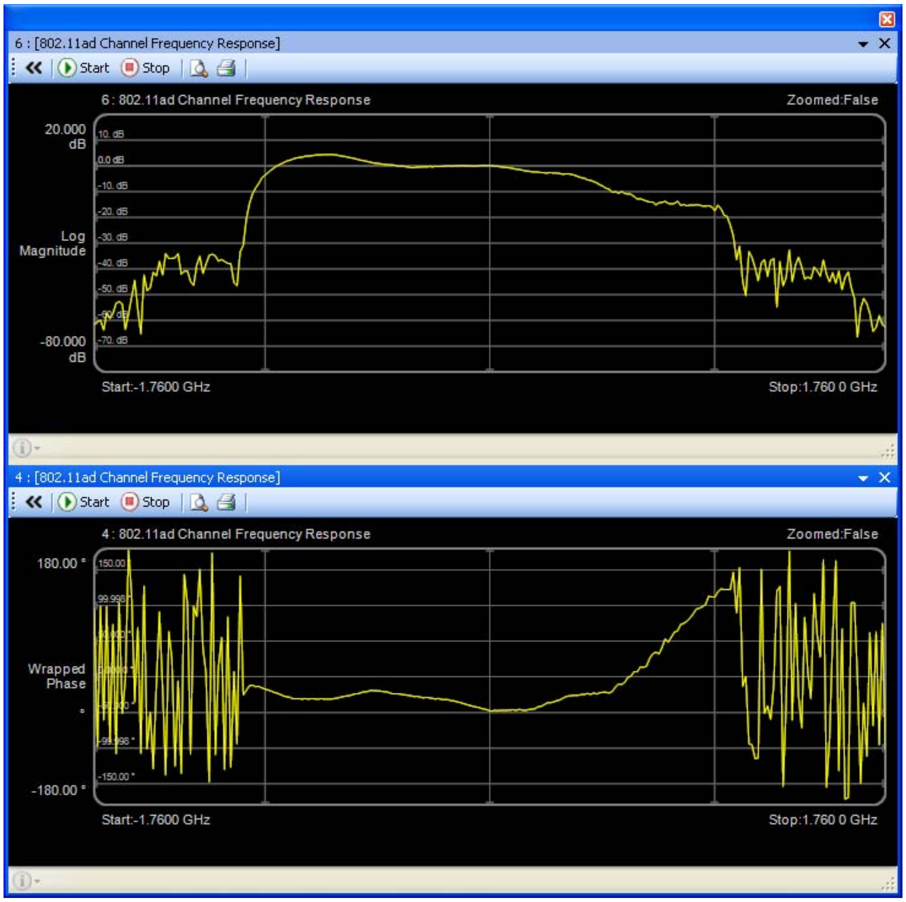

Figure 75. Channel Frequency Response (Magnitude and Phase)

This measurement result shows the estimated channel frequency response based on the estimated channel impulse response. In Figure 75 we are looking at two instances of this result so that we can see both magnitude and phase responses.

Tiling Example

Figure 75 illustrates how you can use the tiling capability of the docking panels to put two (or more) related displays together into one window.

In this case we have tiled Measurement Display windows 6 and 4 into a single window, set both displays to show the Channel Frequency Response result, but then selected the Y axis representation as Log Magnitude in the upper window and Wrapped Phase in the lower window.

The channel impulse and frequency response results include the transmitter shaping filter response because the Golay codes used to create the estimates pass through both the transmit filter and the channel.

IQ Data

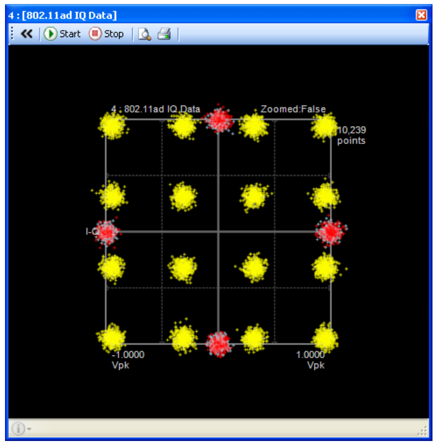

Figure 76. MCS12 16-QAM SC

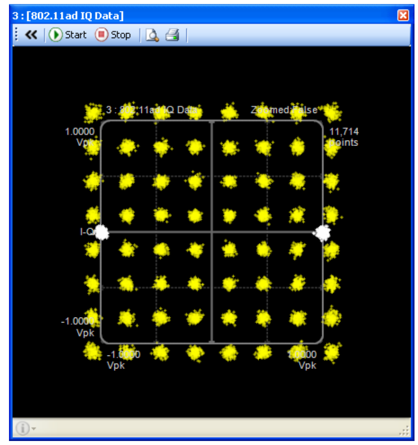

Figure 77. MCS24 64-QAM OFDM

This measurement result is the so called "constellation display". It shows the position of the vector modulation in the complex plane at the symbol decision instants.

The colored dots indicate the measured values. Different colors represent different parts of the waveform.

- Data Symbols : Yellow
- Guard Symbols : Red
- Header Symbols : Cyan
- Pilot Symbols : White

The different symbol types can be turned on and off to enable you to inspect the different parts of the constellation. In the IQ Data measurement result the normal right-mouse-click menu is augmented with four additional choices which toggle the different symbols on and off.

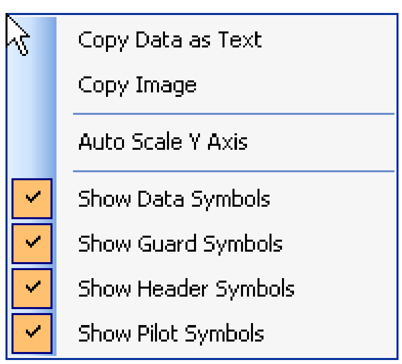

Figure 78. IQ Data Right-Mouse-Click Menu

What to look for

As mentioned in the description of the EVM result, subjective assessment of an impaired constellation based on an understanding of vector modulation error mechanisms can often provide great fault finding insight.

To learn more about vector modulation analysis in general, please refer to the following Agilent documents,

- Vector Signal Analysis Basics (Literature No. 5990-7451EN)
- Vector Modulation Analysis in Digital RF Communications Systems (Literature No. 5091-8687E)

EVM Time

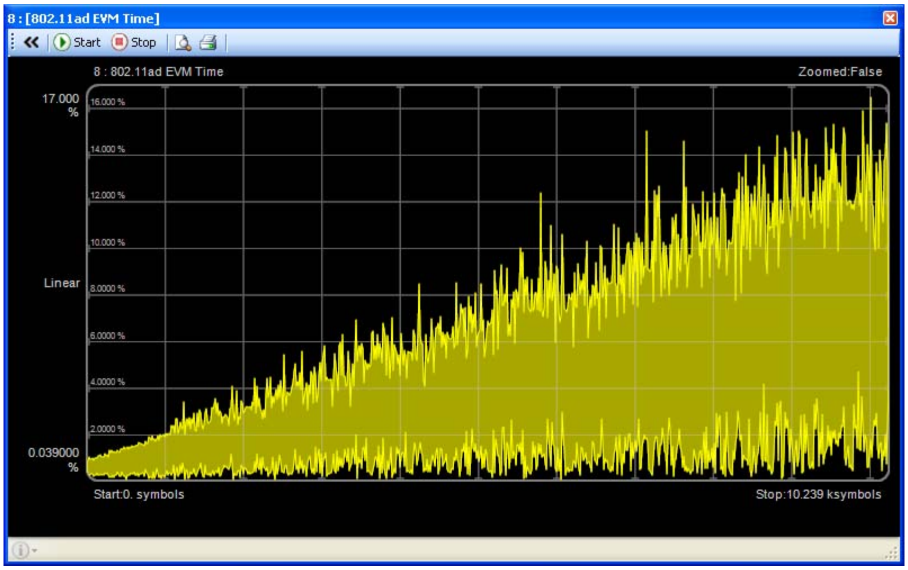

Figure 79 EVM Time Showing a 2 ppm Symbol Clock Error

This measurement result shows the constellation error vector versus time.

Constellation error vectors can be summed to give a single EVM result, but each error vector value can also legitimately be considered as a sample of the continuous error signal that represents the difference between the ideal and actual signals. As such, this time-sequence of error values contains information about the time and frequency domain properties of the error signal.

In showing how the error vector varies over time, this result can often quickly identify drift or instability in a signal. It can also identify amplitude dependent effects such as if the EVM degrades when switching from a QPSK header to a QAM16 payload, suggesting that perhaps there is a gain non-linearity.

The example shown in Figure 79 illustrates the effect on EVM of an uncorrected 2 ppm error between the transmit and receive symbol clock reference frequencies. The error gets progressively worse as the burst progresses as the symbol timing discrepancy grows from the initially low value for phase lock at the start of the burst.

EVM Spectrum

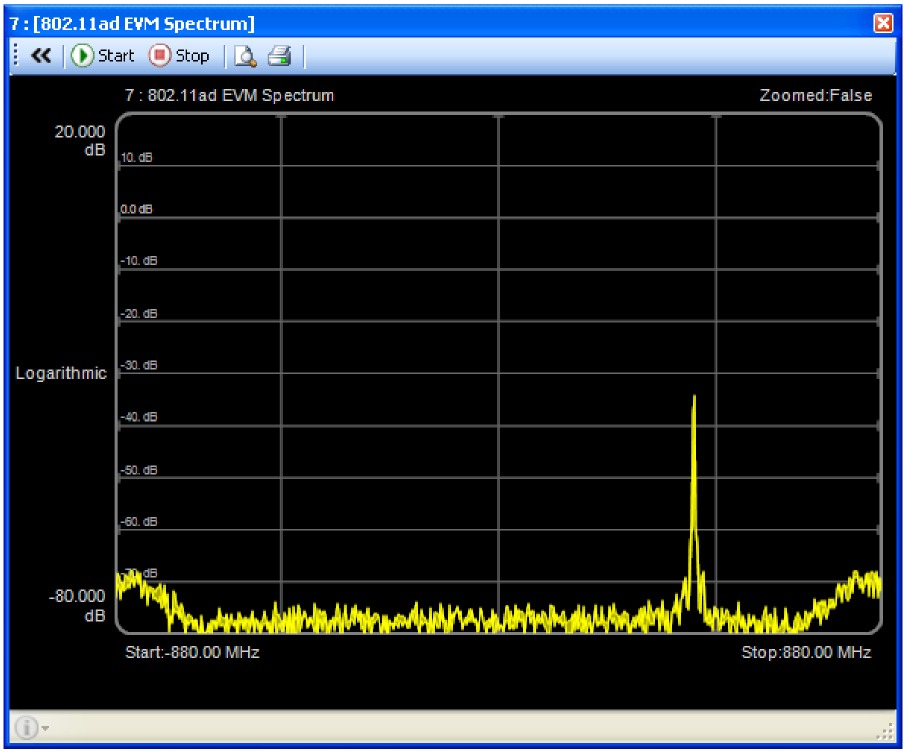

Figure 80. EVM Spectrum Showing an In-Band Interferer at 450 MHz

This measurement result shows the EVM spectrum which is the Fourier Transform of the error vector versus time.

If there are any dominant frequency components in the error signal they will show as increased energy at those frequencies in the spectrum plot.

The example shown in Figure 80 illustrates two distortions.

The first is an in-band interferer at 450 MHz, this is buried (approx. 35 dB down) and would be invisible in the normal Spectrum result, but becomes very obvious in the EVM spectrum.

The second is revealed by the way that the error increases at the band edges indicating that the actual spectrum shaping is different from the 0.25 RRC assumed by the 802.11ad demodulator. In this example the transmit spectrum shaping was actually 0.5 RRC.

OFDM EVM .vs. Symbol

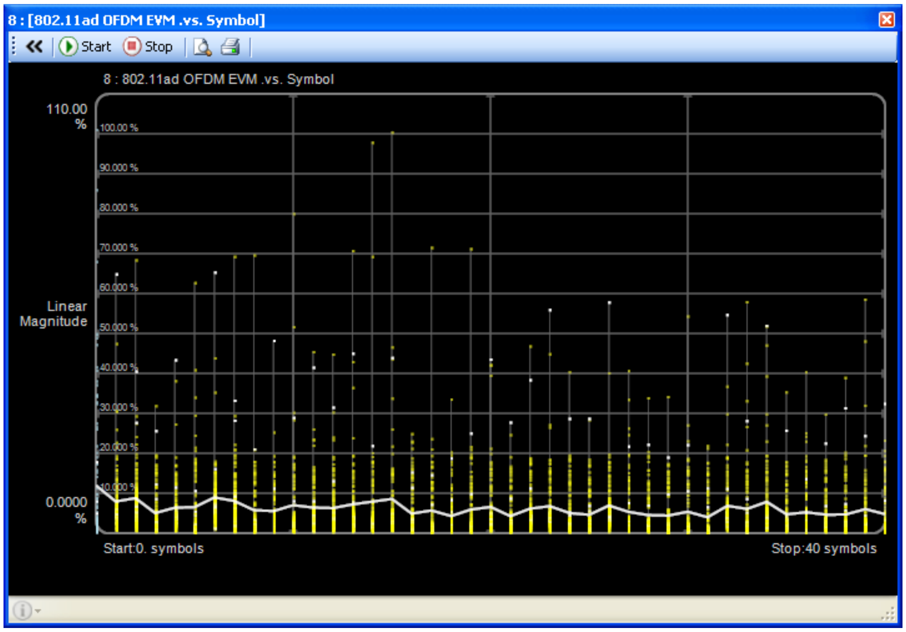

Figure 81. EVM .vs. Symbol

This measurement result displays, for each symbol over time, the spread of error vector values across the modulated carriers in the OFDM symbol.

This is essentially a variation of the EVM time measurement result adapted for OFDM modulation.

Each vertical strip of dots represents the data for one OFDM symbol. The dots are color coded as for the IQ Data display. So cyan dots (in the left-most vertical strip) represent the error vector values for the modulated carriers in the header symbol, while the yellow dots in the remaining strips represent the error vector values for the modulated carriers in the data symbols.

So in a data symbol strip there are 336 yellow dots representing the data bearing carriers in the OFDM symbol and 16 white dots representing the error vector values of the pilot carriers.

It is evident that there are some carriers with relatively high error vector values (and we can look at EVM .vs. Subcarrier to see if there is any trend there), but the average error value, represented by the white trace, is below 10 %. In this example trace there does not appear to be any significant variation in EVM over time.

OFDM EVM .vs. Subcarrier

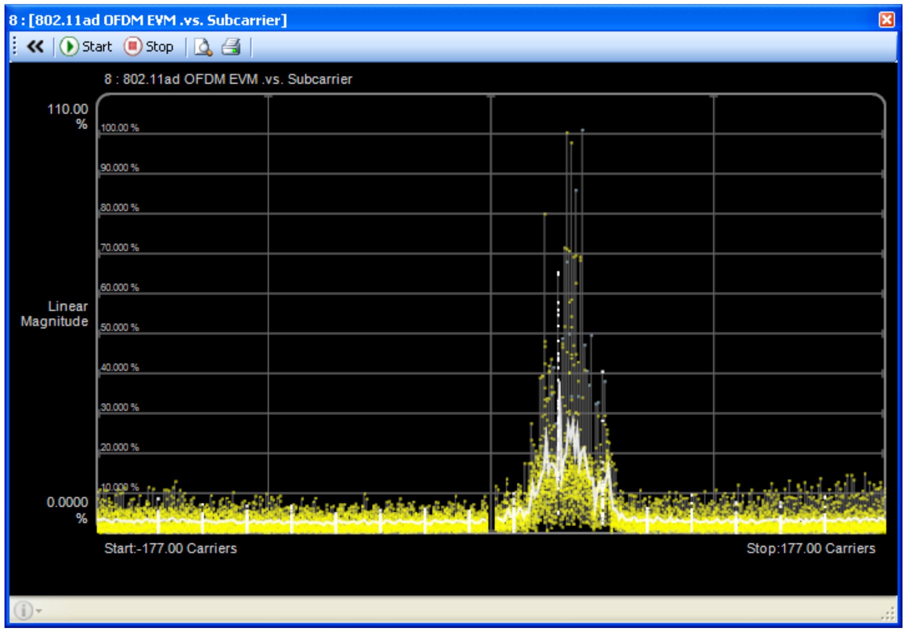

Figure 82. OFDM EVM .vs. Subcarrier

This measurement result displays, for each of the modulated carriers in each OFDM symbol, the spread of error vector values over time.

This is essentially a variation of the EVM spectrum measurement result adapted for OFDM modulation.

Each vertical strip of dots represents the data for the same OFDM carrier in each symbol. The dots are color coded as for the IQ Data display, and you can see the position of the static pilot tones as the periodic white lines in the otherwise predominantly yellow spectrum.

In this example we can see by the elevated error in some of the carriers that there is a modulated in-band interferer present, (it happens to be a WirelessHD LRP burst at F_C + 159.625 MHz at about 25 dB down.), but again the average error value, represented by the white trace, is generally well below 10 %.

Carrier Tracking

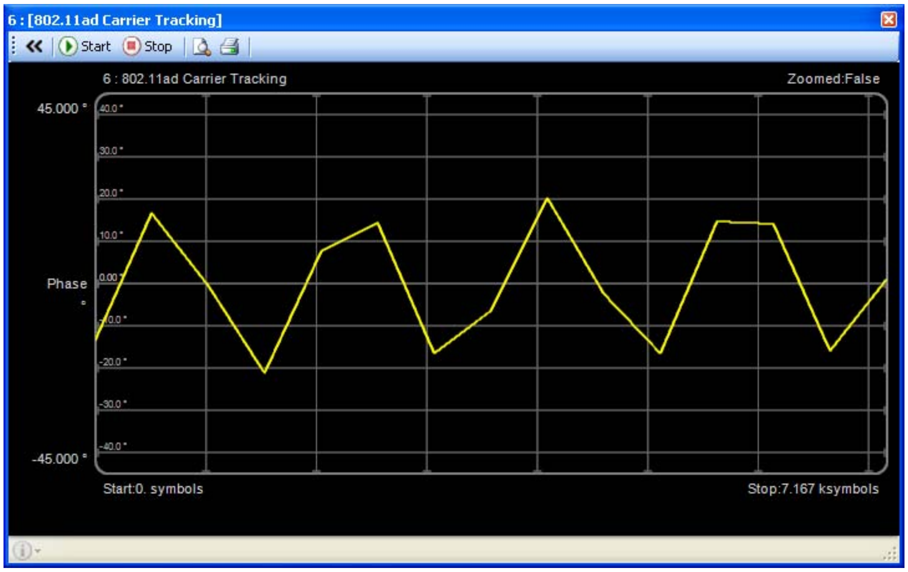

Figure 83. Carrier Tracking a 1 MHz Phase Modulation

This measurement result displays the carrier tracking that is being applied by the 802.11ad demodulator's carrier tracking loop.

Practical receivers will include carrier tracking loops to remove frequency instability from the received signal, however it is still good practice to minimize this impairments in the DUT where possible.

In a measuring demodulator it is useful to display the carrier tracking error versus time to help quantify the nature of the perturbation; in particular whether there is any coherent content in the error signal.

In the example we see a carrier tracking plot revealing that it is subject to phase modulation at 1 MHz with peak amplitude of 20°.

Each data point in this result represents the location of a GI symbol.

Phase Error

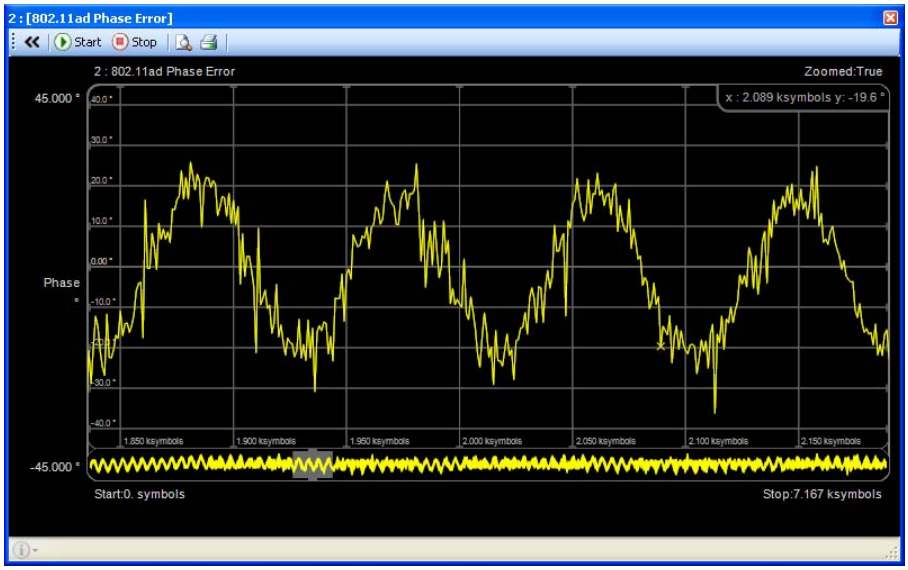

Figure 84. Residual Phase Error (20 MHz Modulation)

This measurement result displays the residual phase error between the measured and reference signals after the measured signal has been fully compensated for amplitude, timing, channel, carrier frequency and phase, etc.

In a measuring demodulator, as for carrier tracking, it is useful to display the phase error versus time to help quantify the nature of the perturbation.

In the example we see a phase error plot revealing that it is subject to phase modulation at 20 MHz with peak amplitude of 20°.

Power .vs. Time

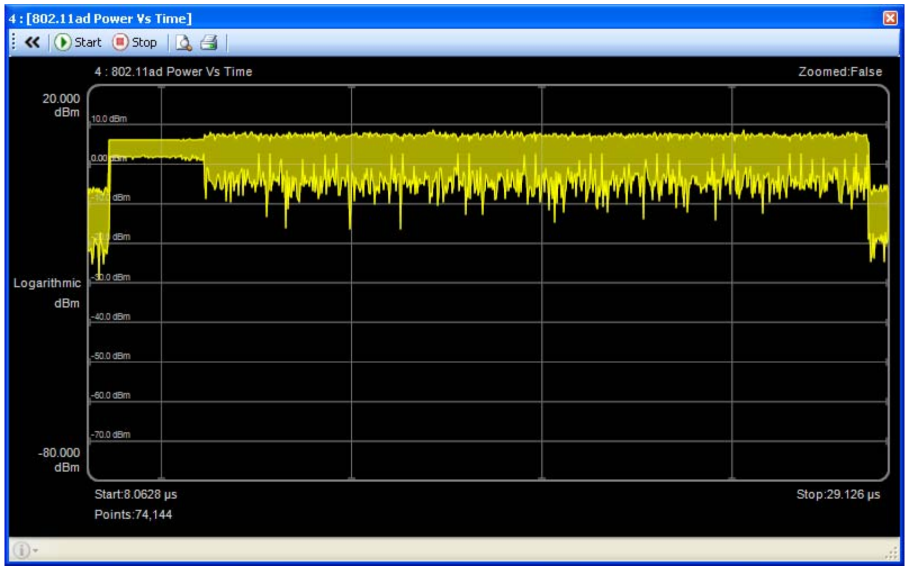

Figure 85. Power .vs. Time

This measurement result displays the power versus time plot of the packet from the current time record that was selected by the demodulator

Unlike the Main Time result, which just shows the acquired time domain signal and may include several packets and partial packets, this result is locked to the packet that was demodulated to give the current set of measurement results. As such, this display will vary in X-axis duration and position depending on the packet received.

15.4 WirelessHD

This section introduces the WirelessHD demodulator.

WirelessHD v1.0 has two quite distinct physical layer (PHY) definitions, the High Rate PHY (HRP) and the Low Rate PHY (LRP). In addition, the LRP may employ any of three sub-configurations; LRP Omni, LRP Directional and LRP Beam Formed, depending (as their naming suggests) on the antenna mode of operation.

WirelessHD v1.1 adds a third physical layer definition, the Medium Rate PHY (MRP), but this version of the 81199A software does not support the MRP; it is compliant with version 1.0b of the specification.

15.4.1 Demodulator Settings

The WirelessHD demodulator does not automatically detect which PHY is being received, that must be configured appropriately using the Analysis Mode and LRP Type settings. However, with those set correctly, the default values for the remaining settings should be sufficient to get started.

Demod On

If true then the acquired time data records will be sent to the WirelessHD demodulator for analysis. If false no data will be sent.

If more than one demodulator is enabled, the time data will be sent to all of them in parallel and the measurement results will be gathered and displayed. This can prove useful when analyzing an unknown signal.

Analysis Mode	This specifies the analysis mode. If it is set to HRP, then the received signal is analyzed as an HRP signal. If it is set to LRP, then the received signal is analyzed as an LRP signal, subject to qualification by the LRP Type setting. If it is set to DUT/RTU Relative Timings then the received signal is analyzed as a mixture of HRP and LRP Directional Ack packets, but only for the purpose of making the specified HRP/LRP Relative Frequency Error and Relative Symbol Clock Error measurements.
Auto Coupling	This is an "ease of use" setting. If set to true then some other settings are automatically set based on the Analysis Mode and cannot be set manually. The following settings are affected, • Equalizer Training • Track Amplitude • Track Phase • Track Timing • Pulse Search
LRP Type	If the Analysis Mode is set to LRP then this sets the LRP Type. The choices are, • Omni-long • Omni-Short • Directional • Beam Formed
IQ Imbalance Compensation	If this is set to True, then any IQ gain imbalance in the constellation is compensated before the EVM is calculated. If it is set to False then any IQ gain imbalance present will degrade the computed EVM.

Equalizer Training	If this is set to True than the equalizer will be updated by information derived from the reference signals (pilots) after the initial estimate based on the preamble. If set to False, then the equalizer setting is based on the preamble only and is not updated.

Symbol Timing Adjust	In principle, when demodulating an OFDM symbol, the guard interval is omitted and a Fourier Transform is performed on the last portion of the symbol time. However, this would result in the transform including the transition region between this symbol and the next, which has been shaped to minimize the symbol-to-symbol phase discontinuity inherent in OFDM modulation. To avoid this small period where the signal is intentionally distorted and so prevent it from inappropriately degrading the measured EVM, the analysis window (the time record that is Fourier transformed) is backed off from the end of the symbol period (and so uses a part of the guard interval). The value must be between zero (meaning no back off) and -x%, where x% is the size of the guard interval as a percentage of the Fourier Transform period. So, for example, if the guard interval replicated 12.5% of the symbol period, the range would be 0% to -12.5%.
	The value is negative because the Fourier Transform start time is moved backwards by this setting.

Mirror Frequency Spectrum	If this is set to True then the frequency spectrum of the input signal is flipped horizontally.

HRP UEP Mapping	If this is set to true then the demodulator expects the constellation in HRP modes 0, 1 and 2 to be rectangular with an aspect ratio of 1.25 : 1. This setting has no effect in modes 3, 4, 5 or 6.
	This interpretation of UEP mapping is based on the text of the WirelessHD v1.0 specification and is not compatible with WirelessHD v1.1.

Decode HRP Payload	If this is set to true then the demodulator will decode the HRP payload back to the original payload octets. If it is set false it will not. This setting defaults to false because the processing time to decode the very large payloads common in live WirelessHD traffic can degrade the measurement cycle time, which is inconvenient if you are not interested in the payload content.
Displayed sub-packet ID	HRP payloads can contain up to 7 sub-packets, this setting determines which sub-packet is displayed in the HRP Decoded Data measurement result.
Displayed Octets Length	This sets the number of payload octets that will be displayed in the HRP Decoded Data measurement result.
Displayed Octets Offset	This sets the offset, from the start of the specified sub-packet, of the payload octets that will be displayed in the HRP Decoded Data measurement result.
LRP Preamble Type	The preamble on LRP Omni and LRP Beam Formed packets may be QPSK mapped or (optionally) OQPSK mapped. This setting defaults to OQPSK because this was the design choice favored by the first implementations of WirelessHD.
	In the LRP preamble, the same data is applied to both axes (I and Q) of the QPSK / OQPSK modulator. This has the effect that the QPSK option effectively produces a $\pi/4$-rotated BPSK mapped modulation. The specification text in v1.0b was updated from "QPSK" to "$\pi/4$-rotated BPSK" to reflect this.
LRP Preamble Filter Alpha	Set this to match the shape factor (excess bandwidth) of the Raised Cosine filter that is used to shape the spectrum of LRP Omni and LRP Beam Formed packets.

Combine Repetitions When set to True, all repetitions in the LRP Omni packet are combined in order to improve the available SNR. If it is set to False then only every eighth (or fourth) repetition of the symbol is used. The preamble repetition that is used, is selected on the basis of payload transmit mode and the received power of each repeat.

In LRP Omni packets the data patterns that constitute the preamble and header fields are repeated 8 times. The payload data patterns may be repeated 8 or 4 times depending on transmit mode.

In a live system each repeat is typically transmitted using a different antenna configuration to achieve quasi-omni-directional operation. When receiving these packets with a single antenna the power level will step up and down depending on the signal strength of each path between transmitter and receiver. Since each is a repetition of the same signal, they can be summed (taking account of phase differences) to improve the received signal to noise ratio.

LRP Mode Index Set the expected mode index of the received LRP packet.

Track Amplitude If set to True, the demodulator will track the pilot signal amplitudes from symbol to symbol in the packet. Amplitude tracking is not always beneficial, but can correct for amplitude droop on longer pulses.

Track Phase If set to True, the demodulator will track the pilot signal phases from symbol to symbol in the packet. Phase tracking is always beneficial, but it can be useful to be able to turn it off temporarily when fault finding.

Track Timing If set to True, the demodulator will track the pilot timing from symbol to symbol in the packet. This can be beneficial in removing a constant symbol clock error. On very clean signals, where it is effectively unnecessary, timing tracking can degrade EVM slightly.

Measurement Interval	This is a legacy setting; it should always be set equal to Result Length – Measurement Offset.
Measurement Offset	This sets the offset in the Result Length to the first symbol that will be measured. The Measurement Interval, starting at the Measurement Offset cannot extend past the Result Length. The Measurement Offset allows you to focus on measuring just specific parts of the WirelessHD signal, such as individual payload sub packets.
Result Length	This sets the maximum number of OFDM symbols that will be processed by the WiHD demodulator. If the packet being demodulated does not contain this many symbols between the Measurement Offset position and the end of the packet then processing will be limited to the number of symbols available, regardless of this setting.
Pulse Search	If this is set to True then the demodulator will use the packet start as the starting point for the correlation search and initial timing acquisition. If it is set False then correlation search will start from the beginning of the time record. If the received signal is continuous then this setting should be set False to avoid looking for a non-existent pulse.
Pulse Threshold Auto Compute	If this is set to True then the pulse search trigger threshold is computed automatically based on the signal.
Pulse Threshold	When Pulse Threshold Auto Compute is disabled, this sets the size of amplitude step considered to mark the start of a pulse.
Time Scale Factor	This setting can be used to adjust the receiver sampling rate.

15.4.2 Measurements

In addition to the two primary measurement displays taken directly from the underlying 89601B VSA software (Main Time and Spectrum), the WirelessHD demodulator adds a further 12 measurement displays, some of which contain multiple measurement results.

In this section we consider each measurement display in detail.

Main Time

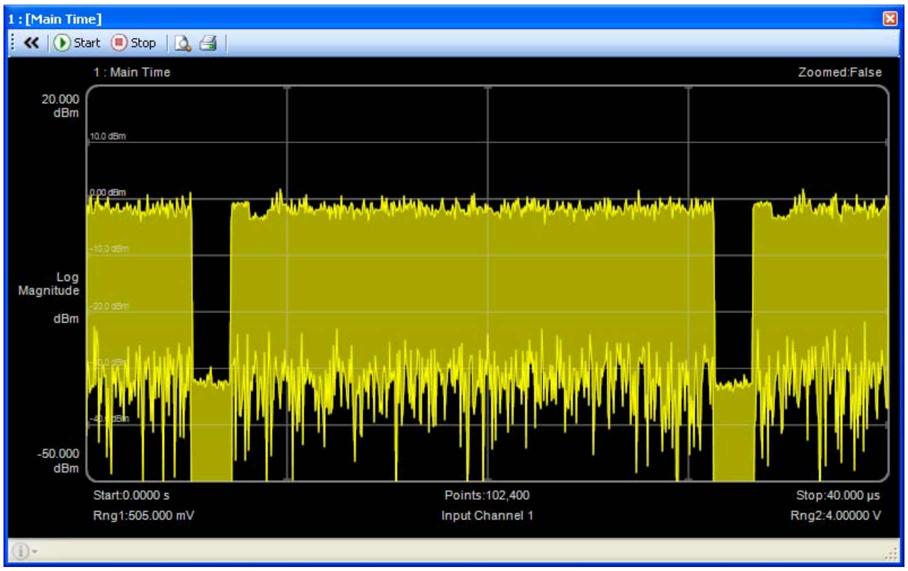

Figure 86. WirelessHD Main Time

The main time measurement result is independent of the WirelessHD demodulator and is discussed generally in section 4.6.

When working with WirelessHD signals the time display is useful for some simple checks before attempting to demodulate the signal.

- What is the approximate signal to noise ratio? Because WirelessHD is a burst mode signal you can estimate the received SNR by looking at the ratio of the power in the burst and in the gap. Because of the close relationship between SNR and EVM this will give you guide to the best EVM you can hope to achieve with a given signal.
- Does the signal look clipped or compressed? In WirelessHD the time domain preamble is transmitted at 3 dB higher power than the rest of the signal, and the payload can be 16-QAM OFDM which has a visibly higher peak-to-average ratio than the QPSK OFDM of the header. If the expected step up/down in packet signal level is not present at the start of the packet, there may be a gain compression problem.
- Are there any transient effects? Amplifier issues such as slow power ramping or ringing may be visible.

Spectrum

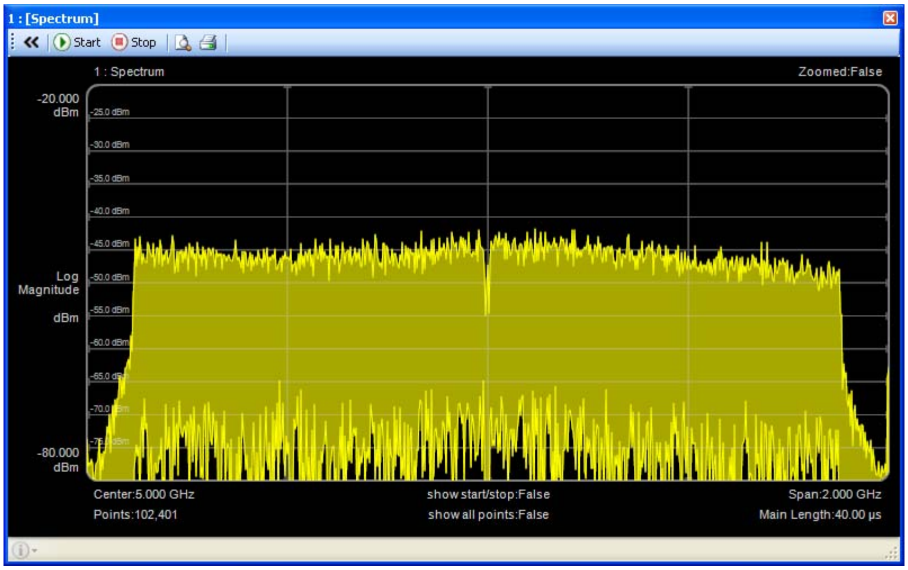

Figure 87. WirelessHD Spectrum

The spectrum measurement result is independent of the WirelessHD demodulator and is discussed generally in section 4.6.

When working with WirelessHD signals the spectrum display is useful for some simple checks before attempting to demodulate the signal.

- Is the spectrum the right sort of shape? Does it have the usual "sand castle" shape of the OFDM modulation used in the frequency domain preamble, header and payload, occasionally flipping to the Raised Cosine shape due to the time domain preamble? Does it have the notch in the center due to the suppressed carriers at FC and FC±1?
- Are there any big dips or peaks? Some non-flatness is expected and will be equalized out, but extreme changes can defeat an equalizer and hence be problematic.
- Is the occupied bandwidth about right? That is, about 1.76 GHz?
- Are there any spurs or adjacent channel spectral regrowth? In band spurs will degrade EVM. An elevated noise floor on either side of the expected signal may indicate intermodulation products due to non-linearities such as gain compression.

IQ Data

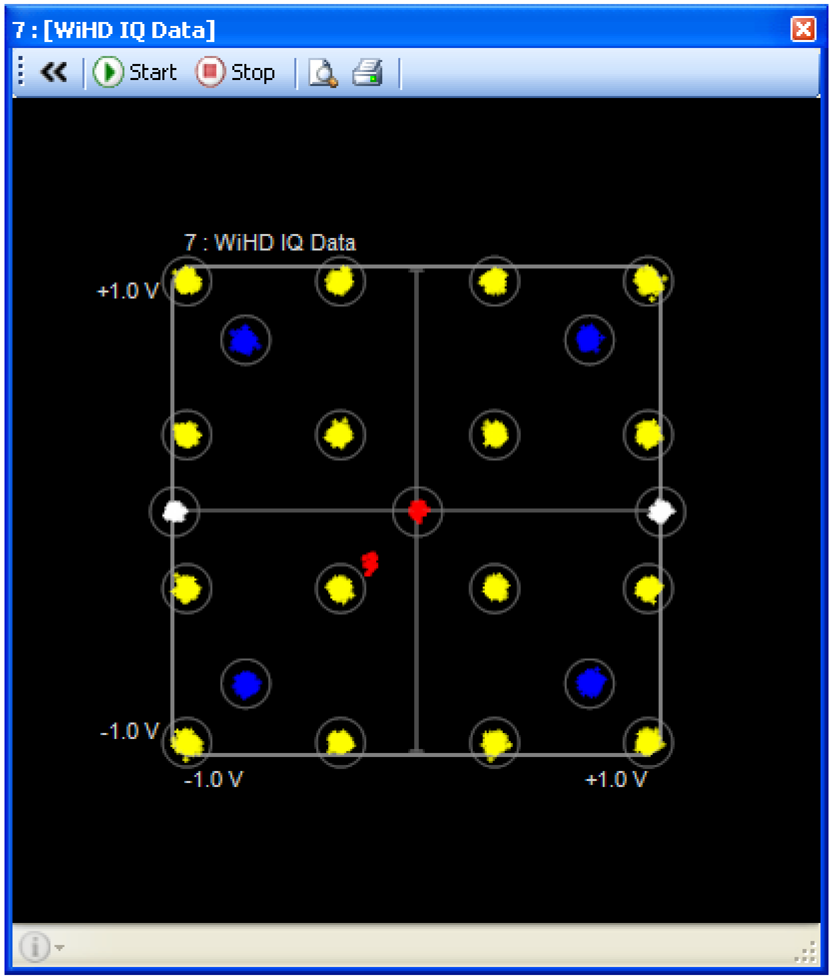

Figure 88. WirelessHD IQ Data

This measurement result is the so called "constellation display". It shows the position of the vector modulation in the complex plane for each carrier in the OFDM symbol at the decision instants.

The colored dots indicate the measured values. Different colors represent different types of carrier in the OFDM signal.

- Payload Symbol Data Carriers : Yellow
- Suppressed Carriers : Red
- Header Symbol Data Carriers : Blue
- Pilot Carriers : White

In Figure 88 you can see the blue QPSK modulated header data, the yellow 16-QAM modulated payload data, the white BPSK modulated pilots and the red un-modulated, suppressed or "DC" carriers. You can also see that the only significant impairment on this signal is noise.

The small cluster of red dots to the left and down from the origin in Figure 88 is due to an un-cancelled DC feedthrough in the signal. This unwanted DC term can be cancelled easily by adjusting DC offsets in the transmitter or receiver until all the red dots are at the origin. In this example, a 9 mV offset on I and a 7 mV offset on Q corrected the error.

What to look for

Constellation displays are usually more distorted than this example and subjective assessment of an impaired constellation based on an understanding of vector modulation error mechanisms can often provide great fault finding insight.

To learn more about vector modulation analysis in general, please refer to the following Agilent documents,

- Vector Signal Analysis Basics (Literature No. 5990-7451EN)
- Vector Modulation Analysis in Digital RF Communications Systems (Literature No. 5091-8687E)

EVM Spectrum

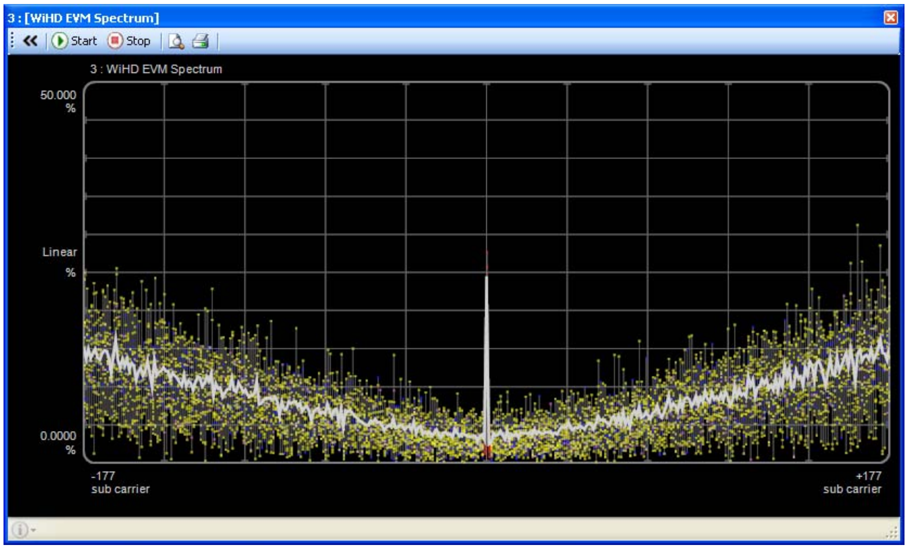

Figure 89. WirelessHD EVM Spectrum

This measurement result shows the EVM spectrum which is the Fourier Transform of the error vector versus time for each symbol in the measurement interval.

If there are any dominant frequency components in the error signal they will show as increased energy at those frequencies in the spectrum plot.

Each vertical strip of dots represents the data for the same OFDM carrier in each symbol. The dots are color coded as for the IQ Data display. The pilot carriers are not easy to identify because their position changes on a symbol-by-symbol basis. The average error value is represented by the white trace.

The example shown in Figure 89 illustrates two distortions.

The first is the spike at the center frequency indicating that there is an uncompensated DC offset present in the received signal. In this example the spike is due to 7mV DC on I and 9mV DC on Q.

The second is revealed by the way that the error ramps up as we move away from the center frequency. This is V-shaped growth in the EVM is typically due to IQ timing skew. In this example there is 50 ps of skew between the I and Q components.

OFDM EVM .vs.Symbol

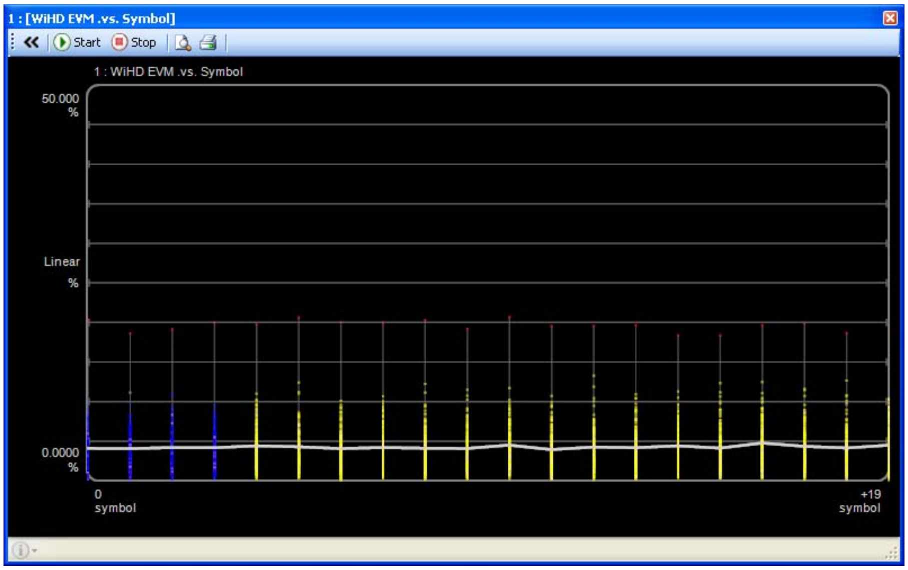

Figure 90. WirelessHD EVM .vs. Symbol

This measurement result displays, for each symbol over time, the spread of error vector values across the modulated carriers in the OFDM symbol.

Each vertical strip of dots represents the data for one OFDM symbol. The dots are color coded as for the IQ Data display. So blue dots (in the four left-most vertical strips) represent the error vector values for the modulated carriers in the header symbols, while the yellow dots in the remaining strips represent the error vector values for the modulated carriers in the data symbols.

So in a data symbol strip there are 336 yellow dots representing the data bearing carriers in the OFDM symbol and 16 white dots representing the error vector values of the pilot carriers.

OFDM EVM .vs. Subcarrier

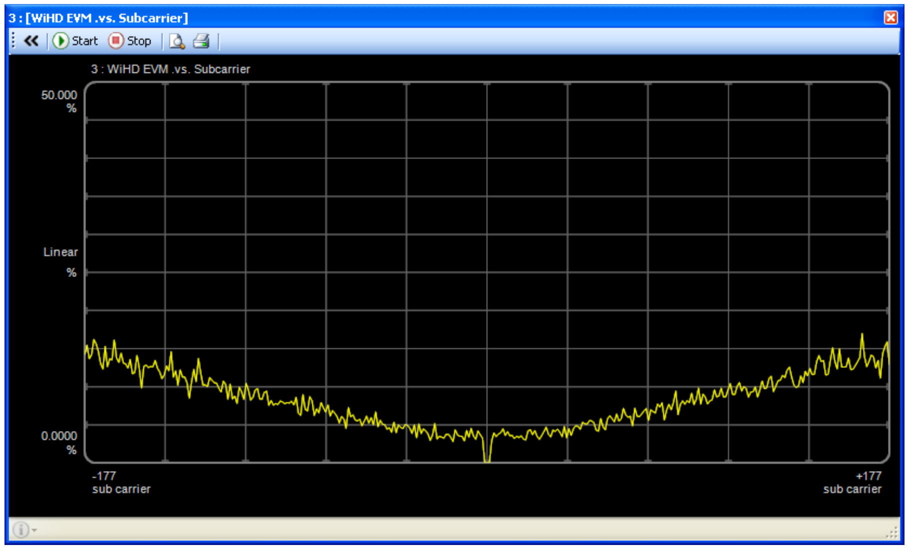

Figure 91. WirelessHD EVM .vs. Subcarrier

This measurement result displays, for each of the modulated carriers the error vector values averaged over the OFDM symbols in the measurement interval.

This is essentially a variation of the EVM spectrum measurement result adapted for OFDM modulation.

This example display shows the same V-shaped growth in the EVM as was shown in the example EVM Spectrum Display (Figure 89). As it was for that display, this is due to 50 ps of skew between the I and Q components.

Unlike the EVM Spectrum Display, this display does not include the spike due to DC leakage because the carriers at F_C and $F_C \pm 1$ are suppressed.

Channel Frequency Response

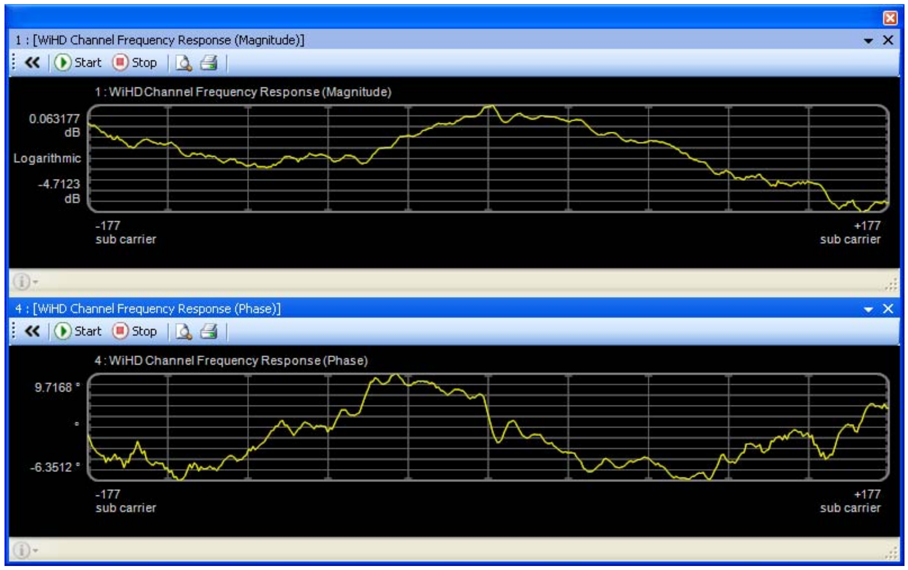

Figure 92. WirelessHD Channel Frequency Response

This measurement result shows the estimated channel frequency response derived from the demodulator equalizer. In Figure 92 we are looking at both the magnitude and phase displays.

Tiling Example

Figure 92 illustrates how you can use the tiling capability of the docking panels to put two (or more) related displays together into one window.

In this case we have tiled Measurement Display windows 1 and 4 into a single window, set window 1 to show the Channel Frequency Response (Magnitude) result, and set window 2 to show the Channel Frequency Response (Phase) result.

Common Tracking Error

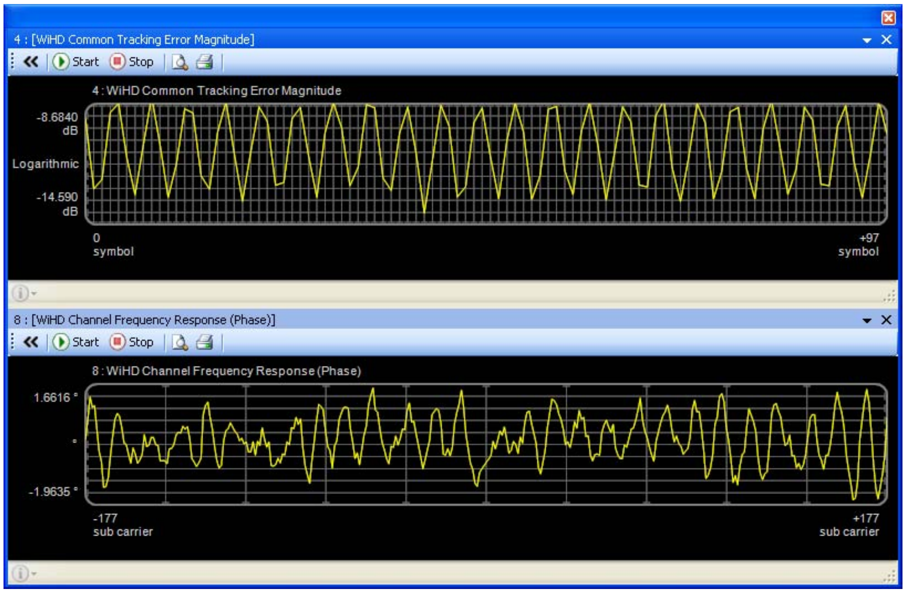

Figure 93. WirelessHD Common Tracking Error

This measurement result shows the Common Tracking Error. In Figure 93 we are looking at both the magnitude and phase displays.

The WiHD demodulator estimates an average magnitude and phase value for the measurement interval from the known pilot carriers in the OFDM symbols, then the Common Tracking Error graphs variations about this average.

This result can be useful in revealing unwanted AM and PM, as well as symbol clock frequency errors (which show as a phase slope).

Figure 93 illustrates the presence of a 1 MHz phase modulation. This low frequency perturbation is compensated by the demodulator and so does not significantly affect the IQ data constellation display.

Cross Correlation Coefficient

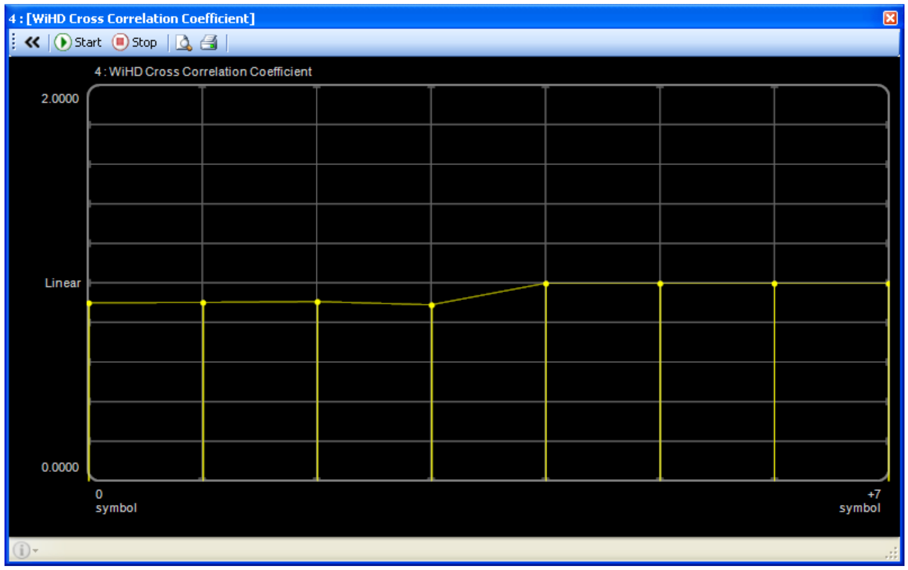

Figure 94. WirelessHD Cross Correlation Coefficient

In HRP Mode

This measurement result is only available in HRP mode. It shows the correlation coefficients for the eight symbol periods that make up the WirelessHD HRP preamble.

The WirelessHD preamble starts with a fixed time-domain (TD) preamble that is 907.8 ns long (the same duration as 4 OFDM symbols). The TD preamble is followed by a fixed frequency domain (FD) preamble that comprises four OFDM symbols. These preambles are intended to be used for timing and channel estimation respectively.

This representation of the correlation for each of the 8 preamble symbol periods is intended to reveal any temporal variation in the preamble correlation, perhaps due to transient problems near the start of the burst.

The example result in Figure 94 was contrived by creating a signal that had a high level noise burst exactly coincident with the TD preamble. We can see that, as a result, the correlation of the first four symbols is significantly degraded. This degradation would also be reflected in the TD Preamble Correlation result on the Error Summary display.

In LRP Mode

This measurement result is not available in LRP mode. Instead, the cross-correlation coefficients of all the fields in the preamble are tabulated in the Error Summary result because the preamble structure is different for each LRP packet type.

Error Summary

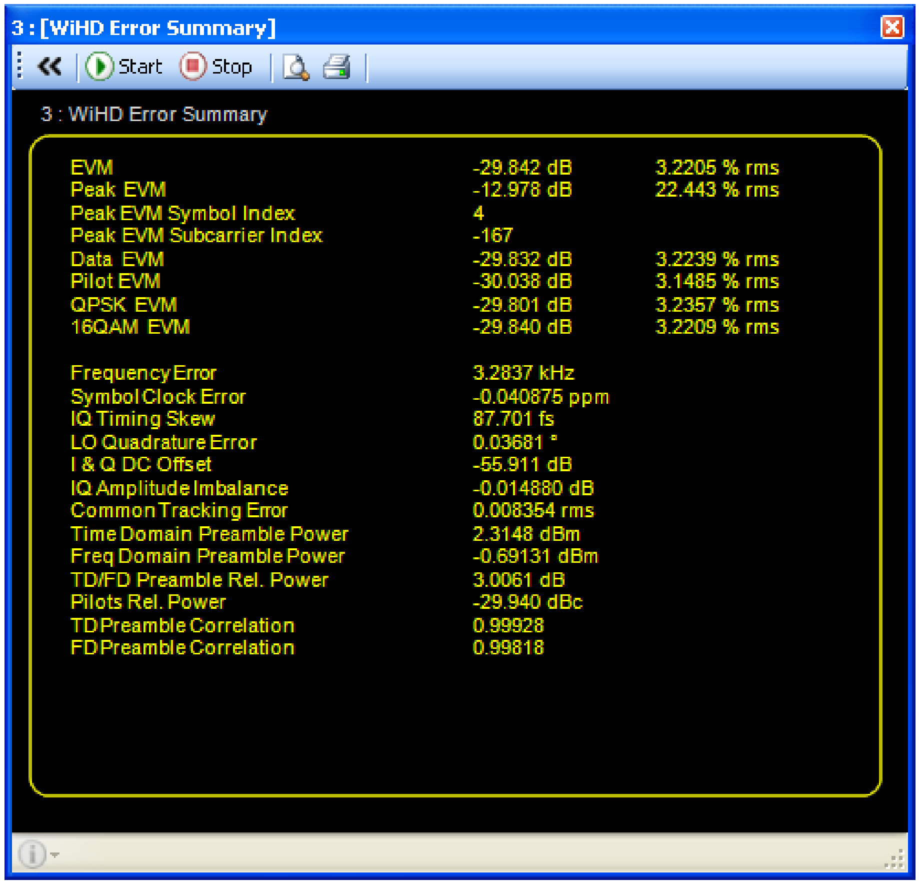

Figure 95. WirelessHD Error Summary for an HRP Packet

All of the following results are presented on the Error Summary display.

EVM

This is the estimated Error Vector Magnitude (EVM) of the signal. It is reported in dB and percent.

A complex modulation is constantly varying in amplitude and phase (versus time). Its complex value is sampled periodically (at the symbol rate) and, at those sampling instants, a perfect signal would be found to be exactly at one of a finite number of pre-defined positions in the complex plane, which can then be uniquely mapped back to an equivalent data pattern.

In practice a real signal will rarely be at exactly the ideal value. We hope it will be sufficiently close to the ideal that it can be unambiguously decoded, but its measured position will differ from the ideal by an error vector. If we compute the average magnitude of these error vectors (EVM) we obtain an objective measure of the signal perturbation.

In a real system, this perturbation is an aggregation of many effects; some, such as noise, phase jitter, inter-symbol interference, timing skew, and symbol clock frequency error will smear or diffuse the received sample values relative to the ideal in very distinctive ways, cumulatively creating the familiar "cloud of flies" around each ideal position.

Other impairments such as IQ gain imbalance, quadrature error, IQ DC offset, and gain compression will distort the geometry of the received signal so that even a best fit to the ideal constellation necessarily leaves some points "off target", again degrading EVM.

Objective summation of the error vectors to give a single EVM result is a useful benchmark, but subjective assessment of an impaired constellation based on an understanding of these error mechanisms can often provide greater insight to fault-finding the root cause of problems.

Peak EVM

EVM is an average (RMS) measurement; however it is sometimes useful to also know the peak EVM. It is reported in dB and percent.

Peak EVM Symbol Index

This reports the symbol within the measurement interval in which the peak EVM occurred.

This can help diagnose the source of EVM problems, for example, if the peak EVM is consistently in an early symbol it might indicate a settling problem whereas if the EVM is consistently in later symbols it might indicate a symbol clock drift problem.

Peak EVM Subcarrier Index

This reports the index of the carrier within the symbol identified by the Peak EVM Symbol Index in which the peak EVM occurred.

This can help diagnose the source of EVM problems, for example, if the peak EVM is consistently on or around a specific carrier it might indicate the presence of an interferer whereas if the EVM is consistently in outer carriers it might indicate a filter match problem.

Data EVM	This is the estimated Error Vector Magnitude (EVM) of the OFDM data carriers only. It is reported in dB and percent.
Pilot EVM	This is the estimated Error Vector Magnitude (EVM) of the OFDM pilot carriers only. It is reported in dB and percent.
QPSK EVM (HRP only)	This is the estimated Error Vector Magnitude (EVM) of the QPSK modulated data carriers only. It is reported in dB and percent. This result is only available for HRP packets.
16QAM EVM (HRP only)	This is the estimated Error Vector Magnitude (EVM) of the 16QAM modulated data carriers only. It is reported in dB and percent. This result is only available for HRP packets.
	If the 16QAM EVM is degraded relative to the QPSK EVM this may indicate gain compression or non-linearity. Look at the IQ Data display for off-grid points, particularly the outer corners of the QAM16 constellation.
Frequency Error	This is the estimated frequency error in the received carrier frequency (subject to the accuracy of the measuring hardware's own sampling clock.)
Symbol Clock Error	This is the estimated frequency error in the received symbol clock (subject to the accuracy of the measuring hardware's own sampling clock.)
IQ Timing Skew	This is the estimated timing skew between the I and Q components of the complex modulation.
LO Quadrature Error	The estimated LO Quadrature Error indicates how close to exactly 90° phase difference there is between the I and Q axes. LO Quadrature Error will result in a distorted constellation which the receiver will not be able to fit exactly to the expected square shape, resulting in degraded EVM. IQ Amplitude Imbalance has similar distorting effects to LO Quadrature Error and it is not always possible to unambiguously attribute the measured distortion without some additional information about the transmitter.
I & Q DC Offset	The DC content of the signal.

IQ Amplitude Imbalance	The estimated IQ Amplitude Imbalance indicates the gain matching of the I and Q channels. Gain mismatch will result in a distorted constellation which the receiver will not be able to fit exactly to the expected square shape, resulting in degraded EVM. LO Quadrature Error has similar distorting effects to IQ Amplitude Imbalance and it is not always possible to unambiguously attribute the measured distortion without some additional information about the transmitter.
Common Tracking Error	The WiHD demodulator estimates an average magnitude and phase value for the measurement interval from the known pilot carriers in the OFDM symbols. This is the average common tracking magnitude error across the measurement interval.
Time Domain Preamble Power	This is the measured power level of the Time Domain (TD) Preamble at the oscilloscope's 50Ω terminated input.
Freq Domain Preamble Power	This is the measured power level of the Frequency Domain (FD) Preamble at the oscilloscope's 50Ω terminated input.
TD/FD Preamble Rel. Power	This is the relative power of the TD to FD preamble. The WirelessHD specification requires this ratio to be 3 dB.
Pilots Rel. Power (HRP only)	This is the power of the OFDM pilots relative to the power of the whole OFDM signal. This result is only available for HRP packets.
TD Preamble Correlation (HRP only)	This is the average correlation of the Time Domain (TD) preamble. A display of preamble correlations versus time is presented in the Cross Correlation Coefficient result. This result is only available for HRP packets.

FD Preamble Correlation (HRP only)

This is the average correlation of the Frequency Domain (FD) preamble.

A display of preamble correlations versus time is presented in the Cross Correlation Coefficient result.

This result is only available for HRP packets.

Preamble Field Cross Correlations (LRP only)

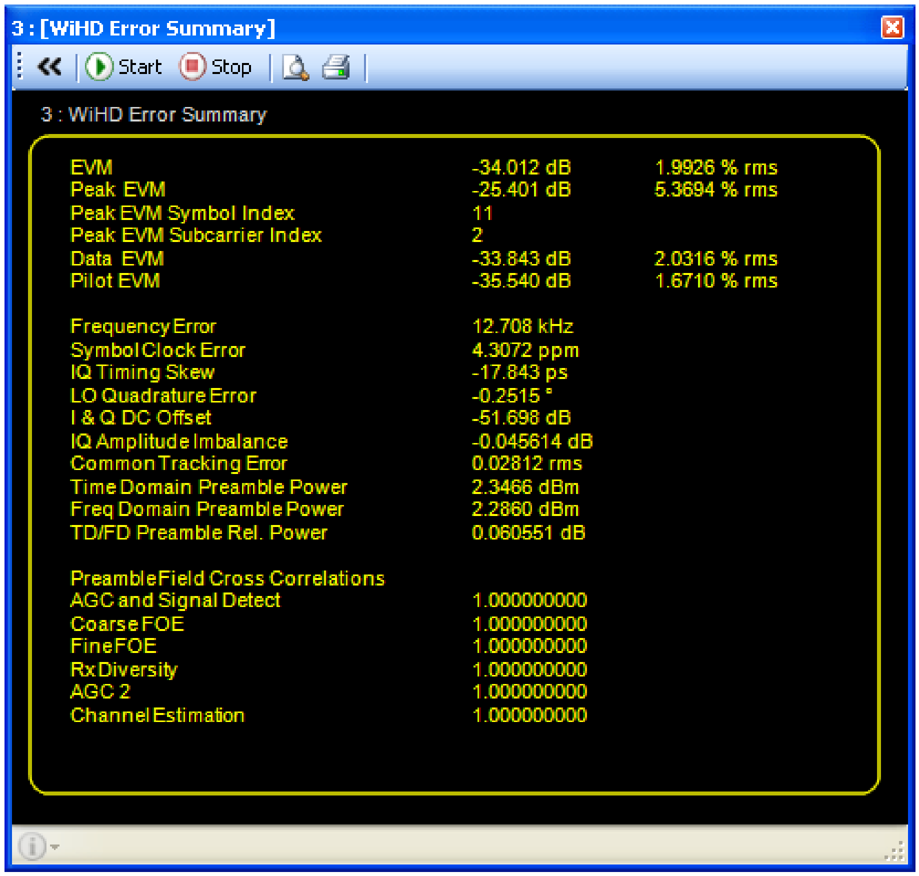

Figure 96. WirelessHD Error Summary For an LRP Omni Long Packet

Figure 96 illustrates how the Error Summary changes for LRP packets. Specifically, the TD and FD correlation results are replaced by a field-by-field listing of the cross correlations in the preamble.

The preamble structure of the LRP packets is quite different from the HRP and also varies according to the LRP packet type. This result reports the relevant cross-correlations for the configured LRP packet type.

Correlation Result	Omni (Long)	Omni (Short)	Beam Formed
AGC and Signal Detect	✓		
AGC1		✓	
AGC2		✓	
Signal Detect		✓	
Coarse FOE	✓		
Fine FOE	✓		
Rx Diversity	✓	✓	
AGC		✓	
AGC 2	✓		
Packet Sync and AGC			✓
Channel Estimation	✓	✓	✓

This result is only available for Omni and Beam Formed LRP packets. Preamble correlation for LRP Directional packets is not reported.

The Error Summary variants for Omni-short and Beam Formed packets are shown in Figure 97 and Figure 98 respectively.

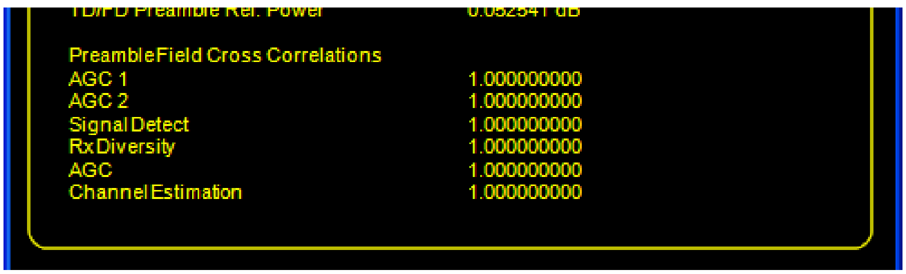

Figure 97. WirelessHD Preamble Field Cross Correlations for an LRP Omni Short Packet.

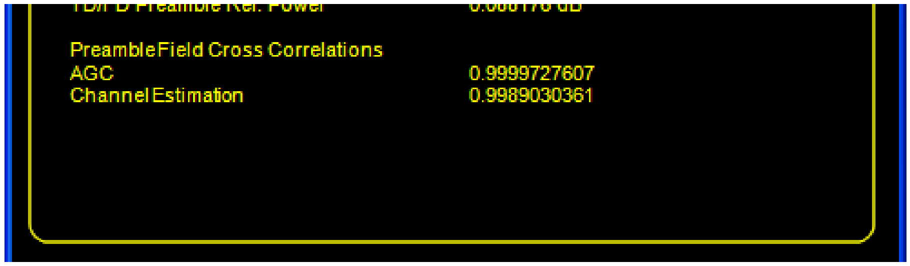

Figure 98. WirelessHD Preamble Field Cross Correlations for an LRP Beam Formed Packet

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HRP Header

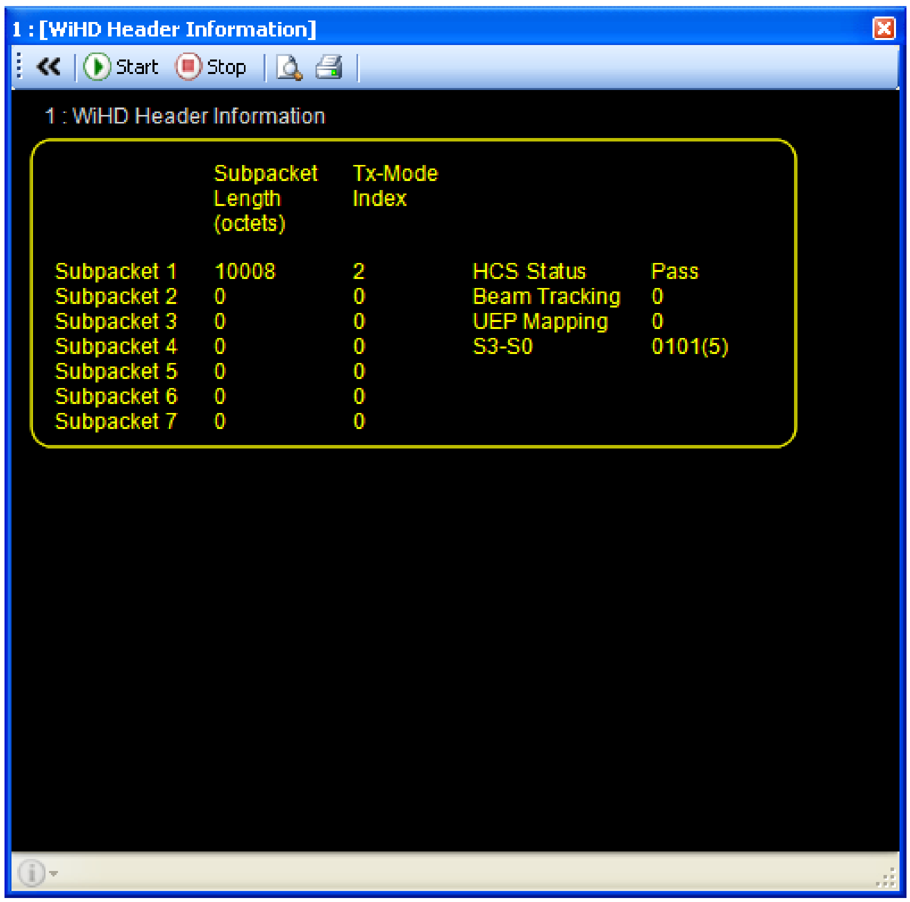

Figure 99. WirelessHD HRP Header Information

The header information results listed below are simply reported by the WiHD demodulator as they are decoded from the HRP packet header.

- Subpacket Lengths and Tx-Mode Indices - This is the reported length and transmit mode for each sub-packet in the payload. The length will always be exactly 8 or 10 more than the expected number of data octets because this count includes the 8 octets required for the Payload Check Sum (PCS). If Content Protection (CP) is enabled, then a further two octets are added to the sub-packet (before the data octets) to contain the CP codeword, giving a total of 10 extra octets.
- HCS Check – This reports the status of the Header Check Sum (HCS). A Pass indicates that the content of the HCS field matches the checksum re-computed by the demodulator from received header data. If HCS reports Fail, then all the other values on this display may be invalid.
- Beam Tracking – This reports the binary state of the Beam Tracking bit.
- UEP Mapping – This reports the binary state of the UEP Mapping bit.
- S3-S0 – The bits S3...S0 comprise the payload scrambler seed value. Their state is reported in binary and the equivalent decimal value.

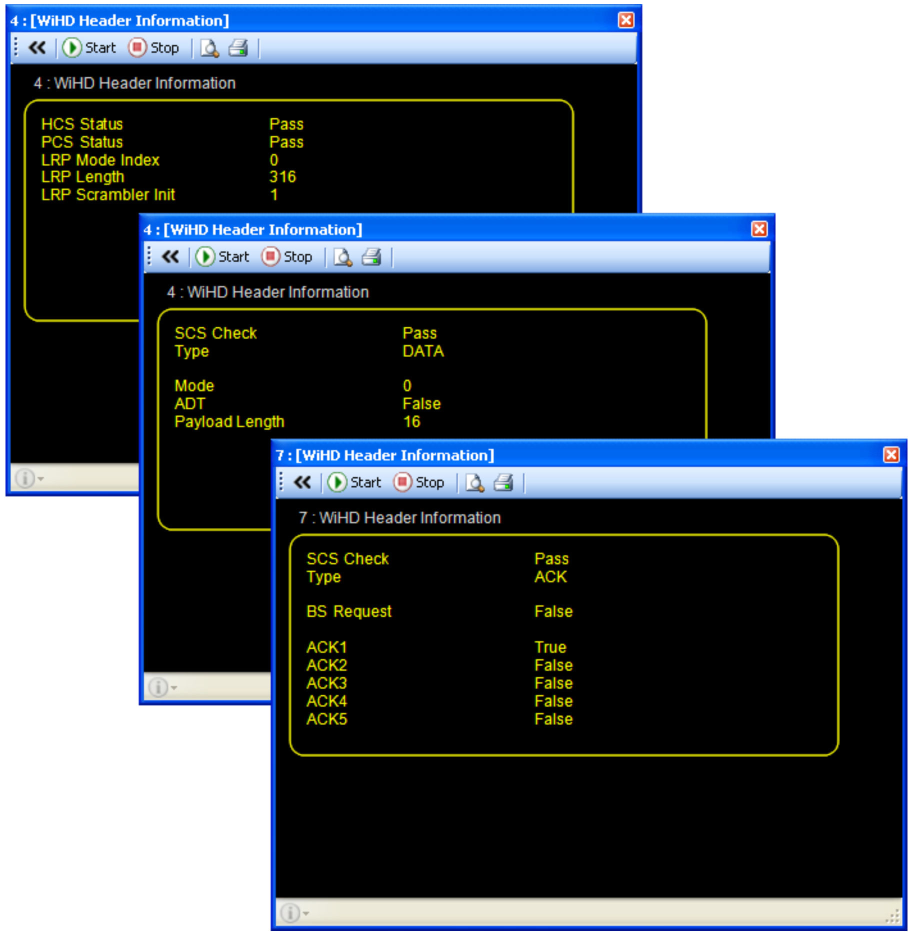

Figure 100. WirelessHD Alternative Presentations of LRP Header Information Depending on LRP Packet type.

LRP Header

The header information results listed below are simply reported by the WiHD demodulator as they are decoded from the LRP packet header.

Omni Headers	• HCS Status – This reports the status of the Header Check Sum (HCS). for LRP Omni packets. A Pass indicates that the content of the HCS field matches the checksum re-computed by the demodulator from received header data. If HCS reports Fail, then all the other values on this display may be invalid. • PCS Status – This reports the status of the Payload Check Sum (PCS). for LRP Omni packets. A Pass indicates that the content of the PCS field matches the checksum re-computed by the demodulator from received payload data. If PCS reports Fail, this may be due to data errors or it may be due to not having demodulated the whole packet. • LRP Mode Index - This reports the status of the Transmit Mode Index. for LRP Omni packets. • LRP Length – This reports the value in the payload length field. for LRP Omni packets. The length will always be exactly 16 more than the expected number of data octets because this count includes the 16 octet LRP Payload Check Sum (PCS). • LRP Scrambler Init – This reports the value in the LRP payload scrambler seed field.
Directional Headers	• SCS Check – This reports the status of the Short Check Sum (SCS). for LRP Directional packets. A Pass indicates that the content of the SCS field matches the checksum re-computed by the demodulator from received header data. If SCS reports Fail, then all the other values on this display may be invalid. • Type – This reports whether the packet is an LRP Directional Ack or LRP Directional Data packet. • Mode – This reports the status of the Transmit Mode bit for LRP Directional Data packets. • ADT - This reports the status of the Antenna Tracking bit for LRP Directional Data packets. • Payload Length - This reports the value in the Payload Length field for LRP Directional Data packets. • BS Request – This reports the status of the BS Request bit in LRP Directional Ack packets. • ACK1...5 - These 5 results report the status of the 5 ACK bits in LRP Directional Ack packets.

Decoded Payload Data

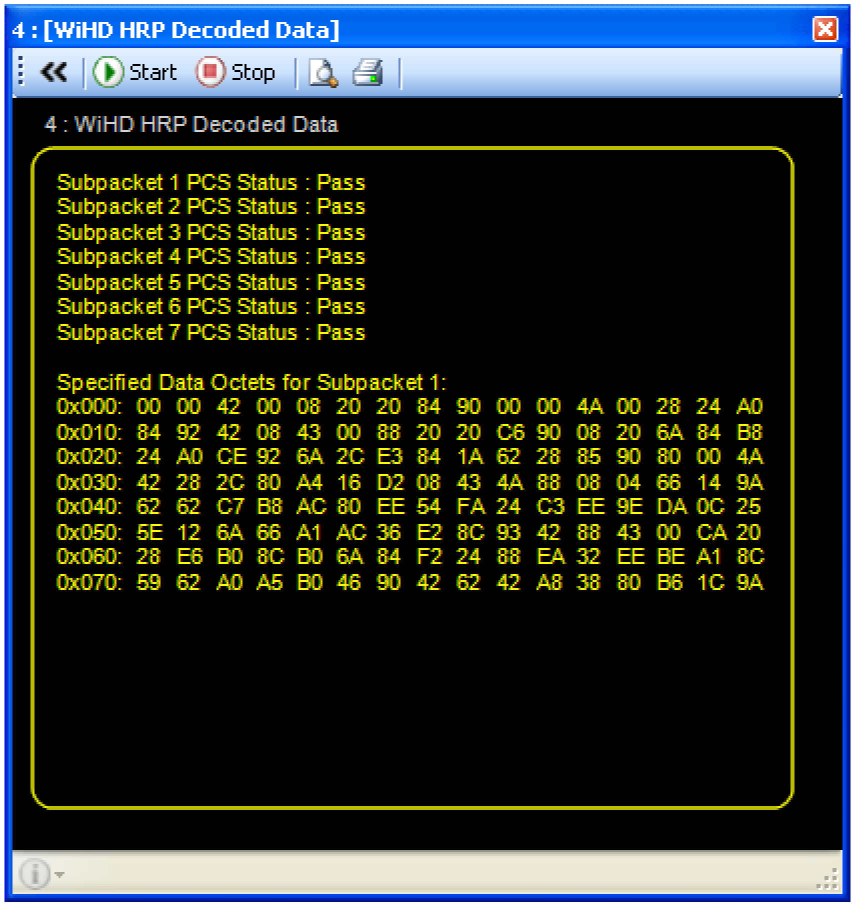

Figure 101. WirelessHD HRP Decoded Data

This display shows the result of fully decoding the received WirelessHD packet to recover the original payload data.

In order to extract the parametric results, the 81199A software has to implement a more or less complete demodulator, so the WirelessHD demodulator also includes the FEC and decoding processes to recover the original payload data.

HRP PCS Checks

The information at the top of the display reports the Payload Check Sum (PCS) status for each sub packet present in the received packet payload.

The specific sub packet and octets to display are selected by the settings Displayed sub-packet ID, Displayed Octets Length and Displayed Octets Offset.

15.4.3 DUT/RTU Relative Timings

The DUT/RTU Relative Timings mode is a special demodulation mode designed specifically to measure the relative frequency and symbol clock errors between the Device Under Test (DUT) and the RF Test Unit (RTU).

The measurement is performed between an LRP Directional Ack packet and an HRP packet captured in the same time record.

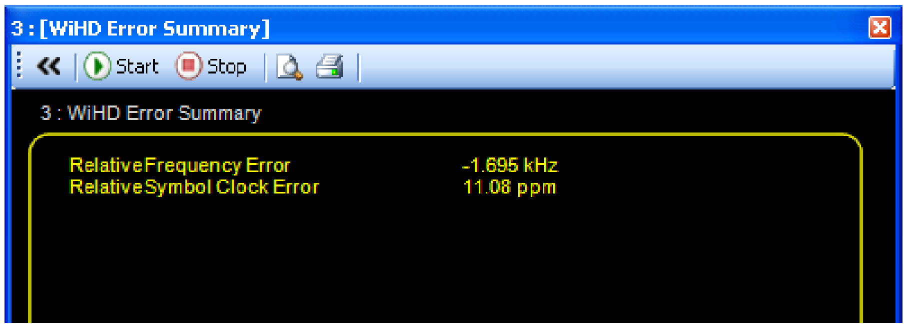

Figure 102. WirelessHD DUT/RTU Relative Timings

Relative Frequency Error	This is the relative error between the DUT and RTU center frequencies.
Relative Symbol Clock Error	This is the relative error between the DUT and RTU symbol clock frequencies.

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16 FAQ

16.1 Introduction

This chapter provides answers to frequently asked questions about the 81199A software.

16.2 FAQ

The Frequently Asked Questions (FAQ) section of this User's Guide is updated more often than the installation package that includes it. If your question is not answered in this revision, check for a more recent version of this User's Guide.

16.2.1 The EVM of a 5 GHz IF from an M8190A in its special N5152A mode seems to have similar performance to an IF from an E8267D PSG, why would I choose one over the other?

The measured EVM of the PSG-based solution is perhaps 0.3 ~ 0.4% better than just using the M8190A directly. However there are other factors to consider.

The M8190A output is not image suppressed. In addition to the wanted signal energy at 5 GHz, there is significant image energy at 1.67 GHz, and 8.33 GHz, and sample clock energy at 6.67 GHz. If you wish to use the 5 GHz IF directly you will want to pass the signal through a band pass filter to remove the unwanted images. The N5152A includes a band pass filter. The E8267D output is image-free.

The M8190A as an IF source is essentially fixed at 5 GHz. If you need an IF signal at a higher frequency, say 10 or 15 GHz, then the E8267D has that flexibility.

The M8190A output power is limited, if you need a higher power IF, then the E8267D has that capability.

If you only need to generate test signals at RF, then the M8190A/N5152A mode provides a lower cost solution because it eliminates the E8267D PSG and requires only a single channel M8190A.

If you need baseband IQ generation, then you will require a two channel M8190A, and if you also require flexible IF signal generation then the E8267D PSG will be necessary.

16.2.2 How can I read the EVM value from the 802.11ad Error Summary?

Use the SCPI command "FETCH:AD:METRICS?". This returns all the results in the Error Summary window as a comma separated list, e.g.

9.9592E-01,1.0157E+03,7.6260E+00,9.91E+37,6.9537E+00,9.91E+37,9.91E+37,
1.9451E+03,-4.5E+00,1.9451E+03,-3.0087E+01,1.7164E-01,3.2507E-03,9.91E+37,
10122,1,10122,0,0,0,0,10,0,100,0,66,0,0,0,0

The EVM value is the third item and is expressed in percent. The SCPI Command Reference lists each response and its units.

16.2.3 How can I synchronize the acquisition and demodulation step in the software, in order to update the Error Summary metrics packet by packet?

You can synchronize measurement result fetches by checking the value of STAT:OPER:COND?

- If a measurement is running bit 4 (value 16) will be set.
- If a waveform is being generated or downloaded bit 8 (value 256) will be set.

The following MATLAB example shows how to do this.

```
function[] = SendTo81180A()

    % open a socket to 81199A
    function[] = Connect()
        t = tcpip('localhost', 5025);
        % t = visa('agilent','TCPIP0::localhost::inst0::INSTR');
        t.Timeout = 240;
        fopen(t);
        idn = query(t,'*IDN?');
        disp(['You are talking to ' strtrim(idn)]);
        ReadSystErrorQ();
    end

    function[] = ReadSystErrorQ()
        instrumentError = strtrim(query(t,':SYST:ERR?'));
        while ~isequal(instrumentError,'0,"No error"')
            disp([' syt:err : ' instrumentError]);
            instrumentError = strtrim(query(t,':SYST:ERR?'));
        end
    end

    % poll STAT:OPER:COND until the measuring bit is zero
    function[] = WaitForMeas()
        measBit = 1;
        while measBit
            pause(0.5);
            statOper = strtrim(query(t,':STAT:OPER:COND?'));
            disp([' stat:oper:cond : ' statOper]);
            measBit = bitget(str2num(statOper),5);
        end
    end

    % poll STAT:OPER:COND until the generation bit is zero
    function[] = WaitForGeneration()
        genBit = 1;
        while genBit
            pause(0.5);
```

```
            statOper = strtrim(query(t,':STAT:OPER:COND?'));
            disp([' stat:oper:cond : ' statOper]);
            genBit = bitget(str2num(statOper),9);
        end
    end

Connect();
ReadSystErrorQ();

% clear track 1, add a single AD segment and configure it and add noise
disp('building a waveform');
fprintf(t,'SOUR:TRACK1:SLIS:CLEAR');
fprintf(t,'SOUR:TRACK1:SLIS:ADD AD,1');
fprintf(t,'SOUR:RAD:AD1:MCS 6');
fprintf(t,'SOUR:RAD:AD1:LEN:NCPH 2000');
fprintf(t,'SOUR:RAD:AD1:CONT PN23');
fprintf(t,'OUTP:NOIS:CNR 20DB');
fprintf(t,'OUTP:NOIS:STAT ON');
% it's a good idea to wait here while the waveform finishes being built
WaitForGeneration();

% check what output devices are available
fprintf('available devices : %s\n', strtrim(query(t,'OUTP:DEV:CAT?')));

% select the 81180A and configure its address
fprintf(t,'OUTP:DEV:SEL AGT81180A');
fprintf(t,'OUTP:A81180A:ADDR "156.141.115.79"');

% ask the 81199A to generate and download the waveform
disp('downloading a waveform');
fprintf(t,'OUTP:DEV:RUN');
% wait for the download to finish, and print the messages it returned
WaitForGeneration();
ReadSystErrorQ();

% configure the measurement acquisition and turn the demod on
fprintf(t,':INPut:DATA:FEED HARDWARE');
fprintf(t,':INPut:CHANnel:CONFigure IQ');
fprintf(t,':SENSE:FREQ:SPAN 3e9');
%fprintf(t,':SENSe:TIME:LENgth 1e-6');
%fprintf(t,':INPut:RANGe:AUTO');
fprintf(t,':SENSe:TIME:LENgth 30e-6');
fprintf(t,'SENSe:DEModulation:AD ON');

% here we put the measurement into continuous mode and just query results
% every few seconds - this is easy but we don't know if we are getting old
% or new data - this is unsynchronized
fprintf(t,'INIT:CONT ON');
for i=1:10
    pause(2);
    metrics = eval( [ '[', query(t,'FETCH:AD?'), ']' ] );
    disp(['rho : ' num2str(metrics(1),6) ', evm = ' num2str(metrics(3),6)]);
    beep;
end
```

```
ReadSystErrorQ();

% here we put the measurement into single step mode and trigger each
% measurement one at a time - this ensures new data each time
fprintf(t,'INIT:CONT OFF');
for i=1:10
    fprintf(t,'INIT:IMM');
    WaitForMeas();
    metrics = eval( [ '[', query(t,'FETCH:AD?'), ']' ] );
    disp(['rho : ' num2str(metrics(1),6) ', evm = ' num2str(metrics(3),6)]);
    beep;
end
ReadSystErrorQ();

fclose(t);
end
```

16.2.4 How can I read the properties of built library segments, such as length?

When composing a multi-track composite waveform programmatically, it is often useful to know the time duration and other properties of the various segments once they have been built (since these depend upon the settings values used to build the segment).

The following SCPI commands

[:SOURce]:RADio:AD{1:8}:DATA:AMAX?
[:SOURce]:RADio:AD{1:8}:DATA:LENGth?
[:SOURce]:RADio:AD{1:8}:DATA:NSAMples?
[:SOURce]:RADio:AD{1:8}:DATA:SRATe?

return the absolute max value, length (in seconds), number of samples and sample rate of the selected 802.11ad segment in the 81199A segment library. There are similar commands for the other segment libraries.

16.2.5 How can I control 81199A via SCPI when the M8190A firmware is hosted on the same computer?

There are three distinct 81199A / M8190A remote control cases:

1. If the remote user is SCPI controlling the M8190A directly, the user expects to find the M8190A on the default SCPI control port 5025.
2. If the remote user of the M8190A is actually the 81199A software (which, in turn, is being manually operated), the 81199A expects to find the M8190A on the default SCPI control port 5025.
3. If the remote user is controlling the 81199A software (which is, in turn, controlling the M8190A), the remote user expects to find the 81199A on the default SCPI control port 5025.

It is the third case that is the root cause of this frequently asked question.

In this case, the programmable entity from the user's point of view is the 81199A (it is, in a sense, of no interest to the user that the 81199A is "wrapped around" the M8190A). For consistency, the control link between the 81199A and the M8190A has to move onto another port, so that port 5025 is available for the SCPI remote control of the 81199A.

This is done by configuring the 81199A / M8190A to use, for example, port 5026, which is achieved by changing a command line switch on M8190A and the Port parameter in the 81199A Output Device menu.

For example add /s 5026 to the M8190A target field as shown in Figure 103.

In the second case (the most common situation) where the 81199A is being operated manually and the 81199A / M8190A link uses port 5025, the 81199A software cannot acquire port 5025 and therefore cannot itself be remotely controlled, but since the user is operating manually, that does not matter. The status indicators in the bottom left of the 81199A screen simply indicate that LAN control is not available.

Incidentally, this is also why the user must start the M8190A firmware before the 81199A software. If the 81199A software is started first it will take ownership of port 5025 in anticipation of being remote controlled, so making it unavailable for the M8190A when it is later started. In this case, when the 81199A later attempts to communicate with the M8190A on port 5025 it ends up talking to itself. This case is evident by the M8190A software reporting that SCPI control is unavailable.

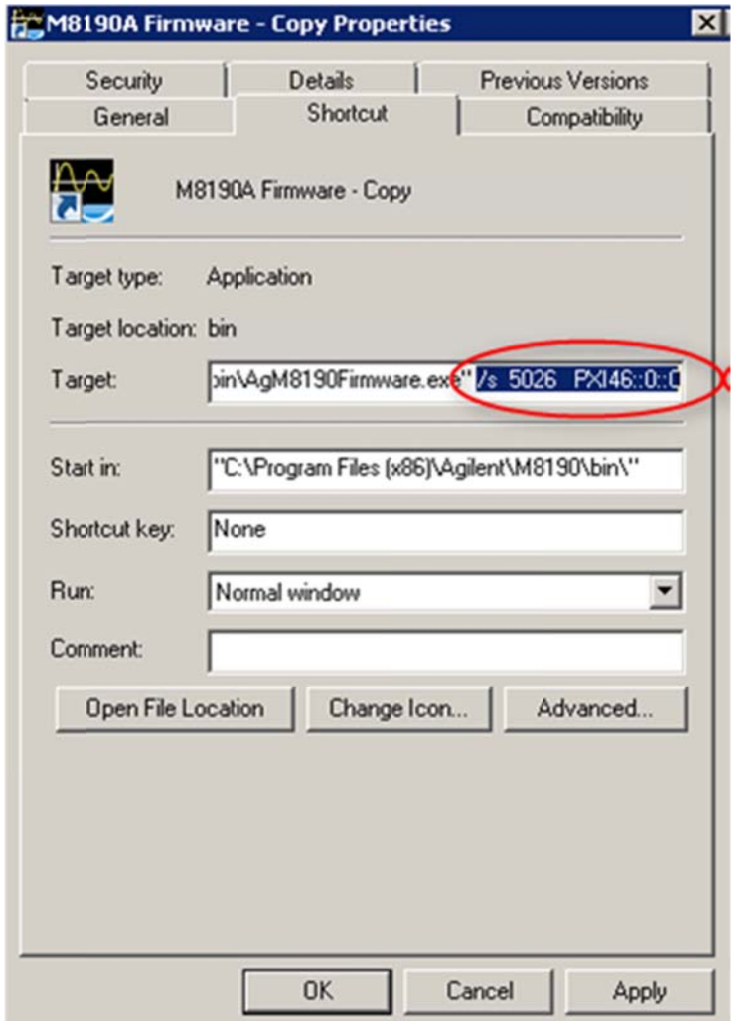

Figure 103. Changing the M8190A default SCPI control port.

16.2.6 Does the 81199A support floating licenses?

Currently, only node locked licenses are available for the 81199A software.

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17 Release Notes

17.1 Introduction

The latest 81199A software release notes are installed along with the software and can be found in the directory,

C:\Program Files\Agilent\81199A Wideband Waveform Center\Documentation.

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18 Contacting Agilent

18.1 Contacting Agilent

This chapter provides contact information for support on the 81199A Wideband Waveform Center and the associated hardware platform.

18.2 Where to Go For Help

For more information about 81199A Wideband Waveform Center and for a current sales office listing, visit our web site:
http://www.agilent.com/find/81199

You can also contact one of the following centers and ask for a test and measurement sales representative.

United States	1 800 829 4444 1 800 829 4433 (FAX)
Canada	1 877 894 4414 1 905 282 6495 (FAX)
Europe	+31 20 547 2111 +31 20 547 2190 (FAX)
Japan	120 421 345 120 421 678 (FAX)

Mexico	(52 55) 5081 9469 (52 55) 5081 9467 (FAX)
Australia	800 629 485 800 142 134 (FAX)
Asia-Pacific	+852 800 930 871 +852 2 506 9233(FAX)
Latin America	+55 11 4197 3600 +55 11 4197 3800 (FAX)

This chapter provides a glossary of the terms and acronyms used in this User Guide.

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