MANUAL

RFIC Test Software

This document provides information on getting started with RFIC Test Software using the RFIC Test Automation Wizard, legacy installed examples, and the RFIC Test Soft Front Panel.

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Routing PXI Triggers

For minimum measurement times, RFIC Test Software synchronizes signal generation and analysis by communicating digital trigger signals between the relevant devices. The default PXI trigger lines are listed in the following table. You may need to configure trigger line routing to work with the defaults. Use Measurement & Automation Explorer (MAX) to configure trigger routing for RFIC Test Software.

Note: You must explicitly configure routing if the source and destination devices are in different bus segments.

Source Device	Destination Device	Trigger Line	Trigger Line Can Be Changed	Configuration
PXIe-5646 Vector Signal Transceiver (VST) or PXIe-5840 VST	PXIe-5646 or PXIe-5840	PXI_Trig2	√	Route the PXI trigger away from the bus segment containing the source device.
	PXIe-4139 Source Measure Unit (SMU) or PXIe-414x SMU	PXI_Trig2	√	Route the PXI trigger away from the bus segment containing the source device. **Note:** This trigger line is only required if you enable Vcc sourcing and System PAE measurements.
PXIe-5646	PXIe-5451 Waveform Generator	PXI_Trig7	no	Reserve the PXI trigger and route it away from the bus segment containing the source device. **Note:** This trigger line is only required if the RF generator is a PXIe-5646.
PXIe-5451 or PXIe-5820 Waveform Generator	PXIe-5646	PXI_Trig6	no	Route the PXI trigger away from the bus segment containing the source device. **Note:** This trigger line is only required if the RF generator is a PXIe-5646.
	Digitizer/Scope	PXI_Trig3	√	Route the PXI trigger away from the bus segment containing the source device.

RFIC Test Automation Wizard

The RFIC Test Automation Wizard simplifies designing customized measurement automation environments that target production verification or characterization for RF front-end modules (FEMs) and power amplifiers (PAs).

Based on the selected examples, the Wizard creates a source code distribution that consists of code module libraries built on standard NI drivers and APIs such as NI-RFSG, NI-RFSA, and NI-RFmx. The distribution demonstrates how to use these code modules by providing source code examples and TestStand sequences. Use the basic examples as an entry point to integrate the code modules into the automation environment. Use the examples that configure both NI-RFSG and NI-RFSA to get started in a loopback environment.

The supported development environments are LabVIEW and .NET. You can use the RF measurement standard and optional TestStand version to specify a custom use case. The following standards are supported:

- SpecAn
- 5G NR
- LTE
- WLAN

The Wizard distributes the source code and related examples into a custom project folder with the following structure:

- **Automation**—(Optional) Folder containing the TestStand automation sequences based on the selected examples
- **Examples**—(Optional) Folder containing the development environment specific source code examples based on the selected examples
- **Source**—Source code modules built on top of standard NI drivers and APIs

Related examples integrate standard-specific measurements in combination with digital predistortion (DPD), envelope tracking (ET), and AMPM measurements.

Supported Hardware: PXIe-5820, PXIe-5830/5831/5840/5841 VST, PXIe-4139/4145 Source Measure Unit

Creating LabVIEW Source Code Distributions with RFIC Test Automation Wizard

To create a custom measurement automation environment for LabVIEW development, complete the following steps:

1. Open the RFIC Test Automation Wizard by selecting **Start»All Programs»National Instruments»RFIC Test Automation Wizard**.
2. Select the **LabVIEW** development environment.
3. Select the **LabVIEW Version**.
4. Enter the **LabVIEW Project Name**.
5. Enter the **Project Target Folder**.
   Note: The target folder path includes the project name.
6. Select the desired **Supported Standards** checkboxes.
7. (Optional) Select a version from the **TestStand Support** drop-down.
8. Select the desired examples from the list. If you select TestStand examples, click the **Update Search Directories** button to accept the highlighted changes.
9. Click **Start LabVIEW Project Creation**. Your selected examples and source code are distributed into a custom project folder.

The distribution is ready to be executed in an NI-RFSG to NI-RFSA loopback environment.

When using TestStand examples, ensure the TestStand Adapter is set to **LabVIEW Development System**. Refer to the [TestStand Help](#) for more information on configuring adapters.

Creating .NET Source Code Distributions with RFIC Test Automation Wizard

To create a custom measurement automation environment for .NET development, complete the following steps:

1. Open the RFIC Test Automation Wizard by selecting **Start»All Programs»National Instruments»RFIC Test Automation Wizard**.
2. Select the **.NET** development environment.
3. Enter the **Project Target Folder**.
4. Select the desired **Supported Standards** checkboxes.
5. (Optional) Select a version from the **TestStand Support** drop-down.
6. Select the desired examples from the list.
7. Click **Start .NET C# Project Creation**. Your selected examples and source code are distributed into a custom project folder.

The distribution is ready to be executed in an NI-RFSG to NI-RFSA loopback environment.

Considerations for the Legacy Examples

The legacy examples provide backwards compatibility for hardware such as the PXIe-5646 and the PXIe-5451, including ETSync and other related techniques. These examples also cover features for FPGA power servoing and digital predistortion (DPD) with NanoSemi or MATLAB algorithms.

Before using the legacy examples, you must route the trigger lines for the hardware.

Custom FPGA Bitfile

The custom bitfile installed with RFIC Test Software, `NI-RFIC.lvbitx`, adds application firmware that coexists with the niRFSA and niRFSG driver firmware on the device. This solution uses the FPGA Extensions feature of the PXIe-5646 and PXIe-5840 to implement hardware-accelerated power servoing (PXIe-5646 and PXIe-5840) and to use ETSync for RF synchronization and envelope waveform generation (PXIe-5646 only; PXIe-5840 uses T-Clk for this purpose). Refer to the examples for more information on using the extended functionality through the ETSync and Power Servoing APIs.

Note: When using the custom bitfile for ETSync with the PXIe-5646, PXI_Trig6 and PXI_Trig7 are dedicated to sending the start trigger and synchronization pulse between the RF signal generator (PXIe-5646) and the arbitrary waveform generator (PXIe-5451) whether you are performing a synchronized or unsynchronized measurement.

Bandwidth Limitation of the Power Servo Example

To use the power servo module, ensure that the signal bandwidth you use to calculate the output power level is within the instantaneous bandwidth of the RFSA device. If the shipped power servo example executes with the PXIe-5646, which has an instantaneous bandwidth of 200 MHz, the overall bandwidth of the ACP measurement configuration must stay within the instantaneous bandwidth of the PXIe-5646.

Note: Find the overall bandwidth of your configuration by taking the sum of all integration bandwidths, including all carrier and offset channels. For example, assuming an ACP measurement with one carrier channel and two offset channels with an equal integration bandwidth for all channels, the limit of the signal bandwidth is around 60 MHz.

Shared Local Oscillator

When executing measurements on a single VST (PXIe-5840), the WLAN examples configure the local oscillator (LO) as shared between the RF generator and analyzer by default. Connect the generator LO OUT to the analyzer LO IN on the VST front panel to avoid measurement time-out errors.

Using Generic PAEN Signal Generation LabVIEW Examples

Note: To take Dynamic Error Vector Magnitude (DEVM) measurements, use the digital power amplifier enable pin (PAEN) of the power amplifier (PA) to ensure that the PA output is only enabled during active RF signal bursts.

Limitations and Considerations

- Use a PXIe-5840 as the vector signal generator (VSG), or a PXIe-5646 with a PXIe-5451 arbitrary waveform generator (ARB), for PAEN generation.
- The supported PA enable voltage is 3.3 V.
- Ensure waveform files contain one or more signal burst.
- Export a pulse trigger at the beginning of the first RF signal burst to synchronize other instruments with waveform generation. The default pulse trigger (PXI_Trig0) is used in the examples.
- Use a single PAEN burst to cover RF signal bursts that are too close together to distinguish as separate bursts.
- You must use a minimum value of 100 ns for **t1** and **t2** (defined below).

Setting Up Your Hardware

1. Connect the VSG and vector signal analyzer (VSA) to the device under test (DUT) as you normally would.
2. Connect PFI0 to the Enable pin. You may need to use a wiring harness.

   Tip: The center conductor is positive. The shield is ground.

Configuring Signal Generation

The following examples show how to generate the PAEN signal for use with error vector magnitude (EVM) measurements to characterize DEVM.

Programmable Function Input/Output (PFI) Example

1. Select your PXIe-5840 in the **RFSG Resource Name** box. You can view and modify the aliases of your instruments using MAX.
2. Click the folder icon next to the **Reference Waveform File Path** field to select a test waveform file.
3. Select the **Marker Event Output Terminal** that will trigger the measurement in the VSA.
4. Configure the following settings in the **PAEN Pulse Timing** section:
   - **t1 (s)**—The amount of time, in seconds, that the PFI line is driven high prior to the start of each RF signal burst.
   - **t2 (s)**—The amount of time, in seconds, that the PFI line remains high after the end of the RF signal burst.
   - **PAEN Pulse Enabled**—Enables/Disables the PAEN Burst Signal. If the PAEN Pulse is disabled, the PAEN signal will be continuously set on high.

Note: The high state defines an active signal at the PFI pin. A low state defines an inactive signal.

ARB Example

1. Select your PXIe-5646 in the **RFSG Resource Name** box. You can view and modify the aliases of your instruments using MAX.
2. Click the folder icon next to the **Reference Waveform File Path** field to select a test waveform file.
3. Select the **Marker Event Output Terminal** that will trigger the measurement in the VSA.
4. Select your PXIe-5451 in the **FGEN Resource Name** dropdown and enter the **FGEN Channel** connected to the PAEN.
5. Select the **Trigger Line for PA Enable** that will indicate the start of the signal generation by the VSG to the ARB. This trigger is only asserted once, at the beginning of the signal generation.
6. Set the **RF Delay** between trigger assertion by the VSG and processing by the ARB. You can use a scope to determine the appropriate delay for your setup.
7. Configure the PAEN Pulse Timing:
   - **t1 (s)**—The amount of time, in seconds, that the PFI line is driven high prior to the start of each RF signal burst.
   - **t2 (s)**—The amount of time, in seconds, that the PFI line remains high after the end of the RF signal burst.
   - **PAEN Pulse Enabled**—Enables/Disables the PAEN Burst Signal. If the PAEN Pulse is disabled, the PAEN signal will be continuously set on high.
   Note: The high state defines an active signal at the PFI pin. A low state defines an inactive signal.

LTE TDD UL 20 MHz ULDL-1 DEVM Measurement Example

Use the LTE TDD UL 20 MHz waveform example that installs with RFIC Test Software to make DEVM measurements. By default, the panel is configured to play the waveform repeatedly. Refer to the RFmxLTE UL ModAcc measurement in the following figure for an example of EVM measurement.
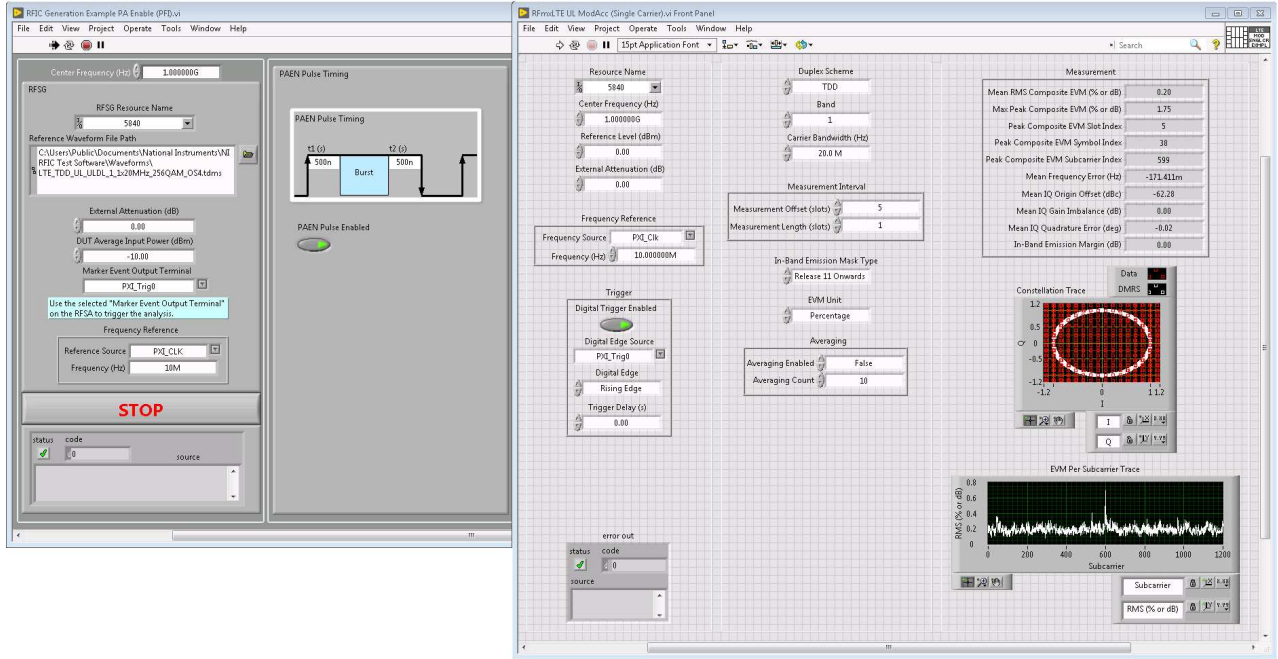
Figure 1: Example EVM Measurement

Note: The scope trace in the following figure shows VSG output in yellow and PFI0 in blue.
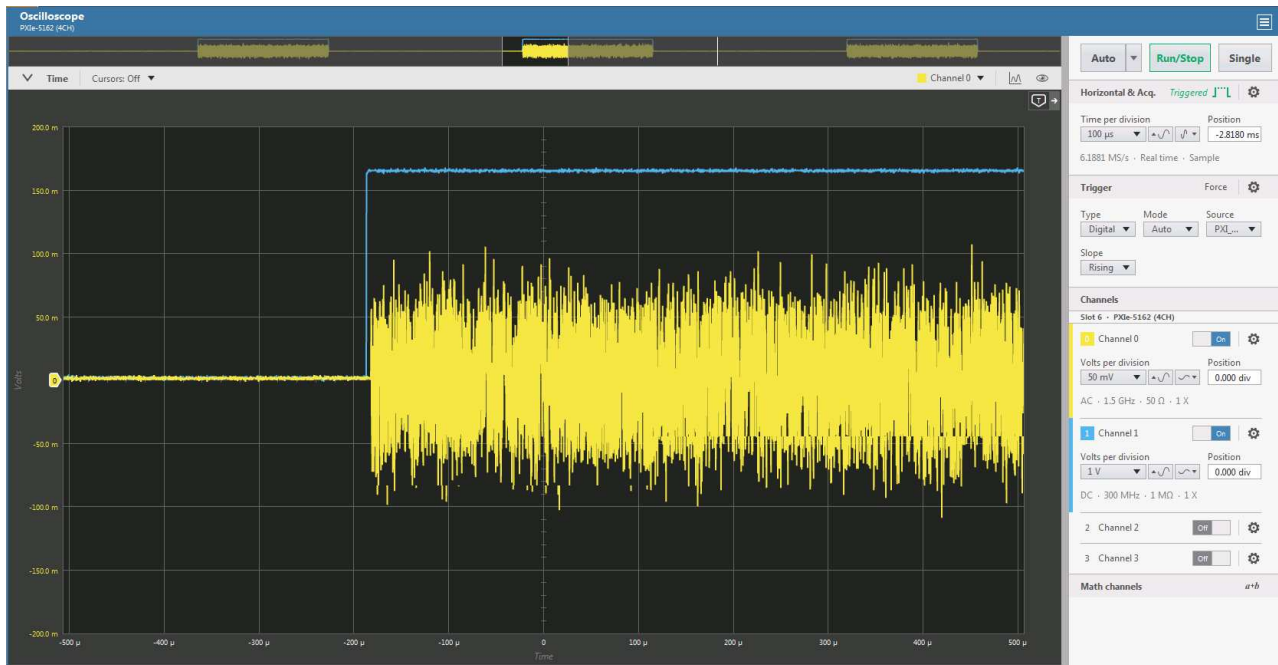

Figure 2: Scope Trace for Example EVM Measurement

RFIC Test Soft Front Panel Help

You can access the RFIC Test Soft Front Panel (SFP) at **Start»All Programs»National Instruments»RFIC Test Soft Front Panel**.

Note: You can learn more about using the RFIC Test SFP by launching the SFP and pressing <Ctrl-H>. With the context help window open, move the cursor over an item to display additional help.

Environment

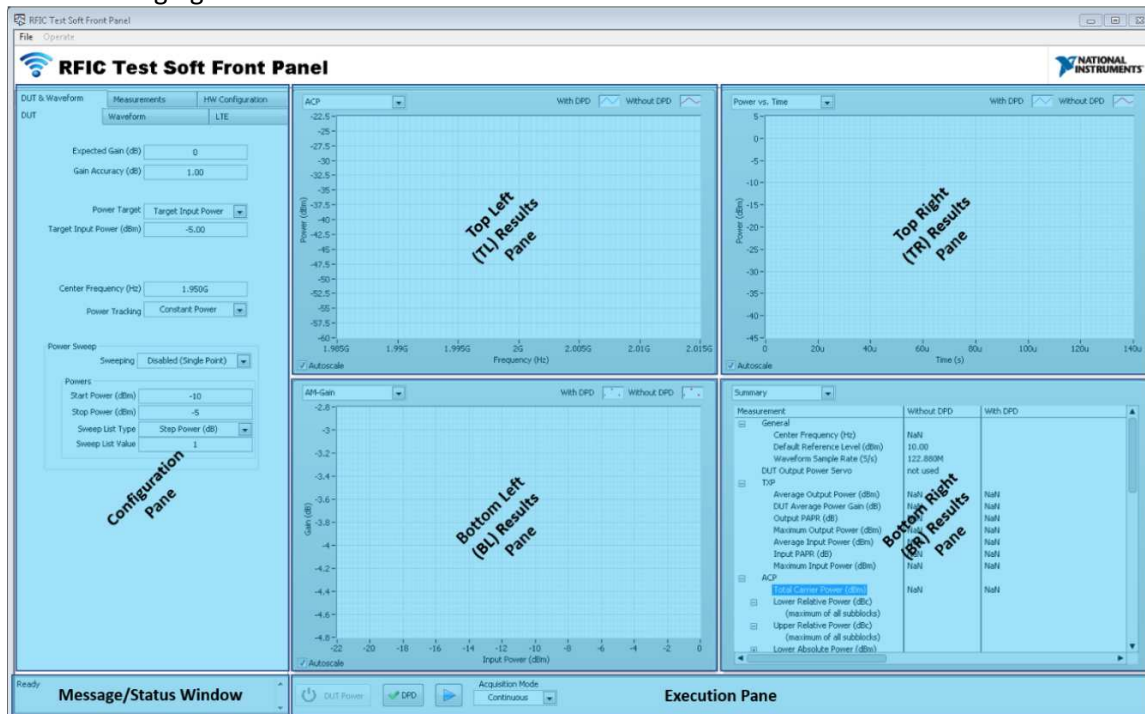The following figure illustrates the elements of the RFIC Test SFP environment.

Figure 3: RFIC Test Soft Front Panel Layout

- **Configuration Pane**—Composed of the following tabs:
  - **DUT & Waveform** tab—Configure parameters for the DUT.
  - **Measurements** tab—Configure the measurements to perform.
  - **HW Configuration**—Configure hardware-specific settings for your instruments.
- **Results Panes**—Show visual information about enabled measurements during runtime in four separate panes.
- **Execution Pane**—Provides controls for interfacing with the RFIC Test SFP
- **Message/Status Window**—Provides context on the status of your measurement, as well as any error information during runtime.

Verifying the System Requirements

To use the RFIC Test SFP, your system must meet certain requirements. Refer to the product readme, which is available online at ni.com/manuals, for more information about minimum system requirements, recommended system, and supported application development environments (ADEs).

Performing Measurements in the RFIC Test SFP

You can use the RFIC Test Soft Front Panel (SFP) to perform the following common measurements:

- Adjacent channel power (ACP)
- EVM

The SFP supports the following wireless standards:

- Long-Term Evolution (LTE)
- 5G New Radio (NR)
- Wireless local area network (WLAN)

Performing Measurements

Upon launch, the RFIC Test SFP initializes and attempts to connect to a RF signal generator or RF signal analyzer if present in the system. If RFSA and RFSG are detected in the system, the SFP initializes all relevant parameters to their default states and displays a **Ready** status.

For each measurement type, complete the following steps to perform the measurement in the RFIC Test SFP:

1. Open the RFIC Test SFP by selecting **Start»All Programs»National Instruments»RFIC Test Soft Front Panel**.
2. Select a waveform file from the **DUT & Waveform»Waveform** tab. Ensure the waveform type matches the measurement you want to perform.
3. Select the corresponding **RF Standard**. The **LTE** tab changes to your selected measurement type.
4. In the tab for the RF standard you selected, adjust the following settings for your measurement:

Measurement Type	Settings
LTE	**Link Direction** **Duplex Scheme** **Bandwidth (Hz)** **Test Model** (for downlink (DL) waveforms only) **UL/DL Configuration** (refer to the <u>Working with TDD Waveforms</u> section)
NR	**Link Direction** **DL Ch Configuration Mode** (for DL waveforms only) **Auto RB Detection Enabled** **Note:** If **Auto RB Detection Enabled** is **False**, click the **Open** button under **Subblock** to configure **RB Allocation**. In general, match your subblock configuration to the provided example waveforms for UL and DL.
WLAN	**WLAN Standard** **Channel Bandwidth**

Note: The RFIC Test SFP is configured for an ACP & EVM measurement of an LTE 20 MHz waveform by default.

5. Click the **Play** button to start execution. By default, the **Acquisition Mode** is set to **Continuous**, so the SFP continues performing all enabled measurements and updates the display each time.

6. (Optional) Click **DPD** to turn on digital predistortion (DPD). The SFP calculates a predistortion model and a predistorted reference waveform using acquired in-phase/quadrature (I/Q). Refer to the Leveraging RFIC with Custom DPD Models section for more information on using DPD.
   Note: If DPD is enabled while in Continuous Acquisition Mode, the red trace remains constant as a snapshot of the pre-DPD performance. The blue trace shows post-DPD results.
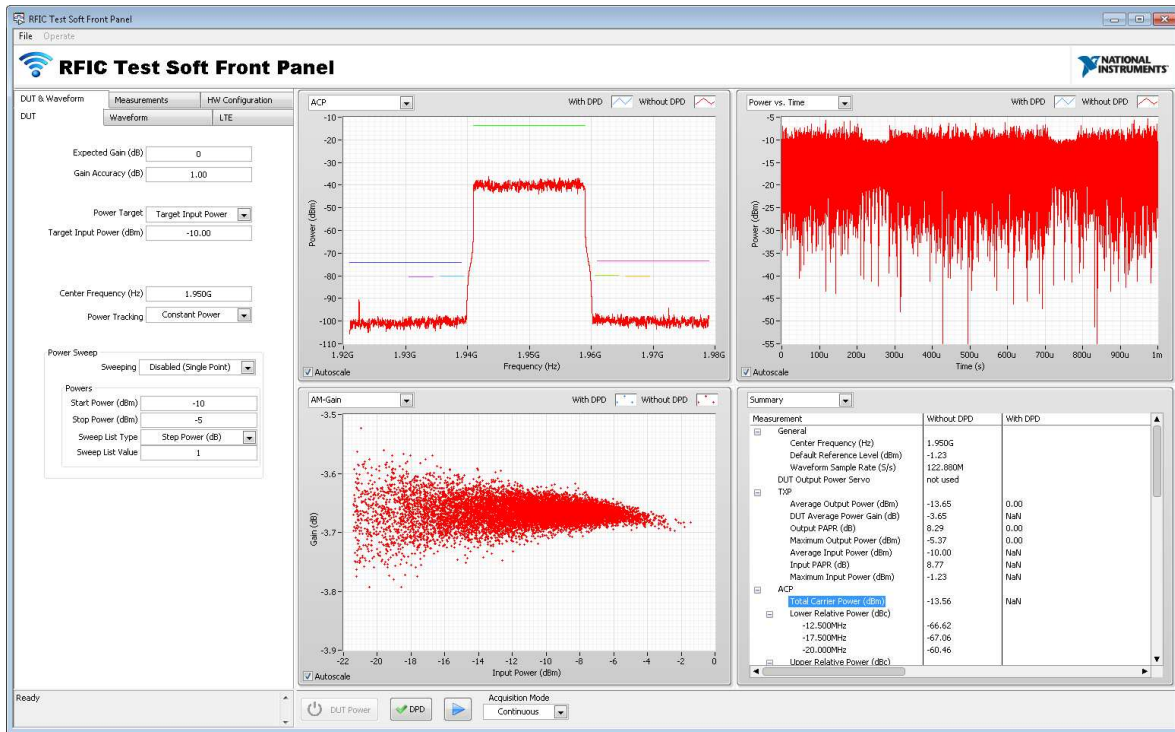

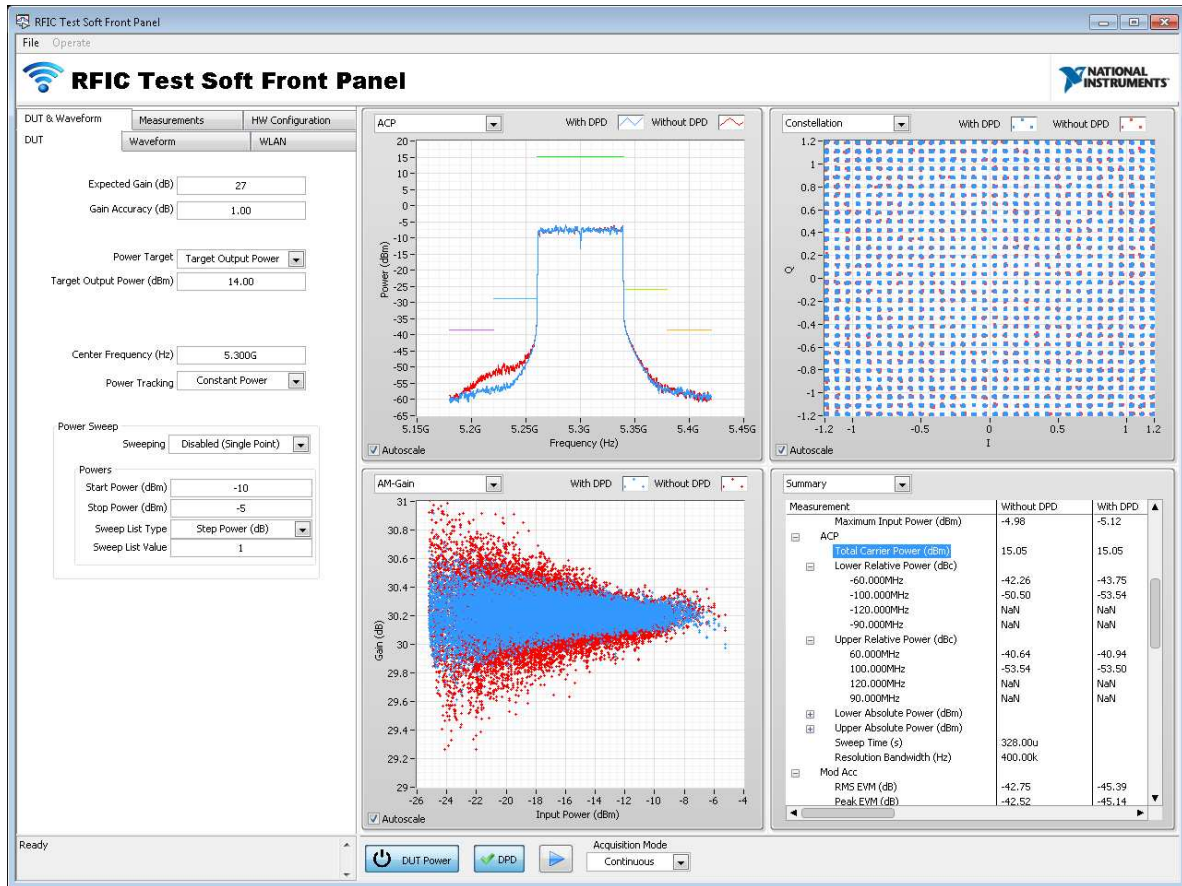*Figure 4: Continuous Operation with Default Settings*

Figure 5: Continuous DPD with Default Settings

Working with LTE TDD Waveforms

1. Load your LTE TDD waveform. In the **Waveform** tab, set **Idle Duration Present** to **True**.
2. Set the **UL/DL Configuration** on the **LTE** tab.
3. If you are using an uplink (UL) waveform, set the **Trigger Delay (s)** in the **HW Configuration**»**VSA** tab to 2 ms for accurate spectral measurements. This is not required for DL waveforms.

LTE Carrier Aggregation

Note: The RFIC Test Soft Front Panel does not ship with any carrier aggregated waveforms.

When using carrier aggregated LTE signals, you must set information about all subblocks and component carriers under the LTE tab. Adjust which carrier constellation is displayed in the results pane under **Visualization: Trace Reference Carrier** in the **Measurements**»**ModAcc (LTE)** tab.

Tip: Right-click within the **Subblock** or **Component Carrier** settings under the LTE tab to delete array elements.
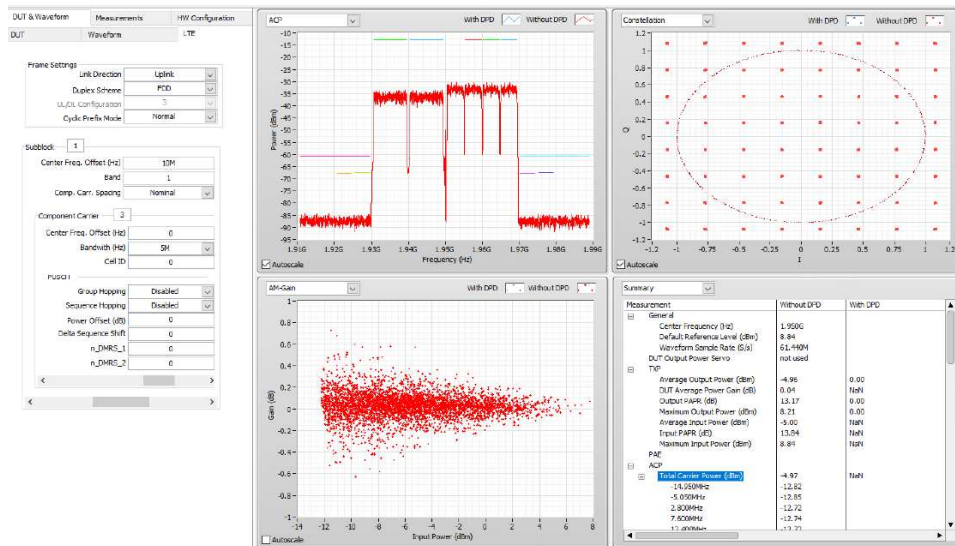
Figure 6: RFIC Test SFP Measuring a Carrier Aggregated Signal

Configuring NR Carrier-Specific Settings

Define carrier-specific settings in the subblock sections of the configuration. You can add and remove carriers from each subblock for single and multi-carrier testing.

1. Ensure an NR waveform is loaded.
2. Adjust the following settings under the **NR** tab to conform with your waveform.
   - Link Direction (**Downlink**, **Uplink**)
   - DL Ch Configuration Mode (available if **Link Direction** is **Downlink**)
   - RB Detection

   Note: If decoding a specific waveform fails, you may need to set **Auto RB Detection Enable** to **False** and manually configure the Resource Block Allocation settings and the Modulation type.

3. Configure the following settings under the subblock for the carrier.
   - General parameters (for example, **Bandwidth**, **Subcarrier Spacing**)
   - DMRS configuration (especially **Configuration Type, Mapping Type, Type A Position**)
   - Downlink Specific (if **DL Ch Configuration Mode** is set to **User Defined**)
     - PDSCH configuration ()
     - SSB configuration
   - Uplink Specific
     - PUSCH configuration

   Note: The RFIC Test SFP only supports single subblock configurations.

4. Adjust the following measurement-specific settings under **Measurements»ModAcc (NR)**.
   - **Measurement Interval**
   - **Averaging**
   - **Visualization: Trace Reference Carrier**

Dynamic EVM

DEVM is a PA measurement similar to a standard EVM measurement. For dynamic EVM, the PA output is only enabled during active RF signal bursts. The RFIC Test SFP provides a simple digital HI/LO line aligned with the WLAN RF burst when in DEVM mode.

Limitations and Considerations

- You can only use DEVM for WLAN standards.
- You must use a PXIe-5840 as the VSG for DEVM.
- The supported PA enable voltage is 3.3 V.
- Ensure waveform files contain only a single WLAN burst.
- Export a pulse trigger at the beginning of the first RF signal burst to synchronize other instruments with waveform generation. The default pulse trigger is PXI_Trig2 .
- Leave at least 1 µs of idle time between bursts to improve analysis. Bursts that are too close together may cause an error in the SFP.
- You must use a minimum value of **100 ns** for **t1** and **t2** (defined below).

Setting Up Your Hardware for DEVM

To take DEVM measurements, use the digital PAEN to ensure that the output is only enabled during active RF signal bursts.

1. Connect the VSG and VSA to the DUT as you normally would.
2. Connect PFI0 to the PAEN pin. You may need to use a wiring harness.

   Tip: The center conductor is positive. The shield is ground.

Enabling PAEN Pulse Timing for DEVM

Use the controls under **Dynamic EVM Settings** and **PAEN Pulse Timing** in the **DUT & Waveform»WLAN** tab to set how the RF signal burst and PFI line behave. The following figure calls out the settings to enable PAEN pulse timing. Refer to the context help for more information on each setting.
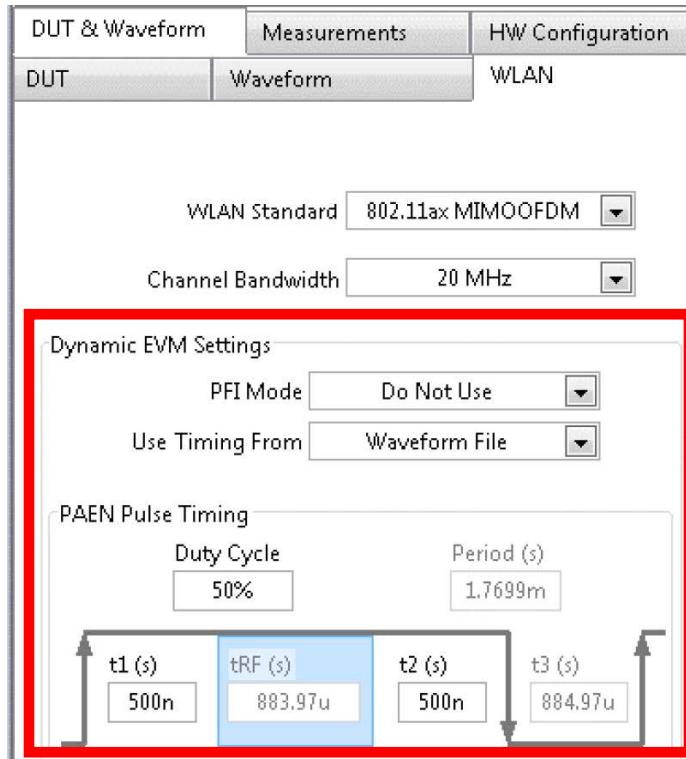
Figure 7: Enable Pulse Settings

80 MHz 802.11ax DEVM Measurement Example

Use the 802.11ax 80 MHz waveform that installs with RFIC Test Software to make interactive DEVM measurements in the RFIC Test SFP. By default, the SFP plays the waveform repeatedly without additional idle time. The scope trace in the following figure shows VSG (PXIe-5840) output in blue and PFI0 in yellow.

1. Select **Do Not Use** as the **PFI Mode**. Notice that PFI0 remains low.

Figure 8: Scope Trace of RF and Enable Pulse without PFI

2. Change the **PFI Mode** to **Static**. Notice that PFI0 is always high.
   Note: The default value for **Duty Cycle** is **50%**. Values for **t1**, **tRF**, and **t2** are extracted from the waveform file.

Figure 9: Scope Trace of RF and Enable Pulse in Static/Waveform File Mode

3. Select **PAEN Pulse Timing** from the **Use Timing From** list. Notice that **t1** and **t2** become editable, and entering different values adjusts playback.
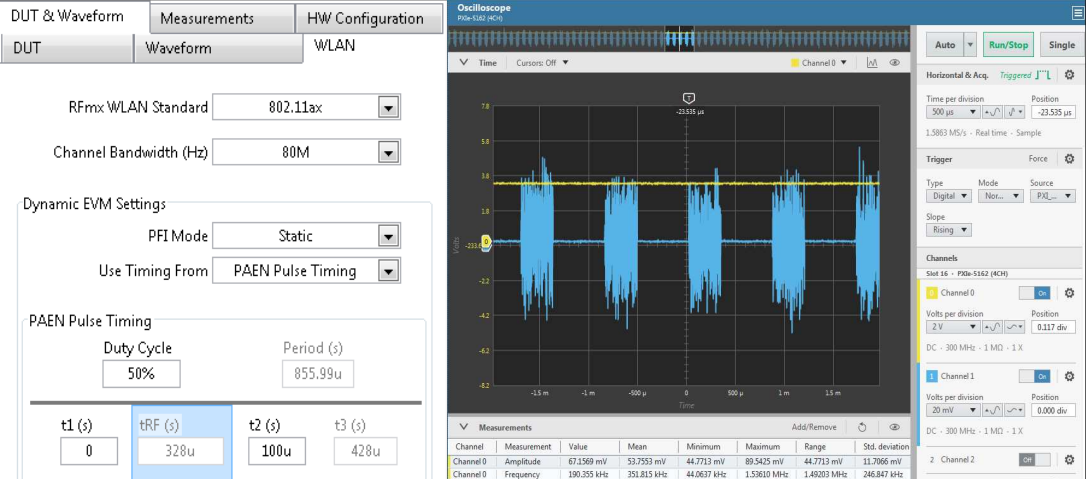

Figure 10: Scope Trace of RF and Enable Pulse in Static/PAEN Pulse Timing Mode

4. Change the **PFI Mode** to **Dynamic** to perform DEVM measurements. Notice that the transitions of PFI0 follow the PAEN Pulse Timing box.

Figure 11: Scope Trace of RF and Enable Pulse in Dynamic/PAEN Pulse Timing Mode

5. Use **t1** and **t2** to finely adjust timing on either side of the RF burst.
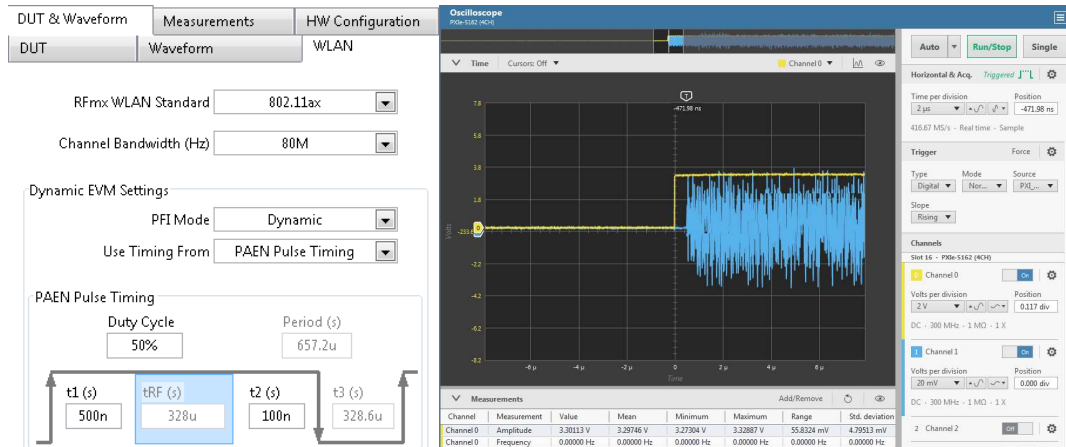

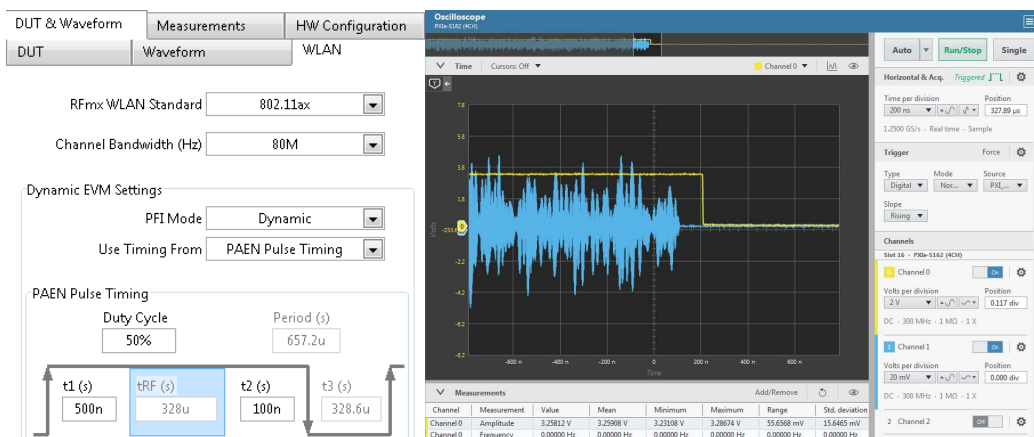*Figure 12: Scope Trace of RF and Enable Pulse t1 Timing*

Figure 13: Scope Trace of RF and Enable Pulse t2 Timing

Noise Compensation

The RFIC Test SFP supports noise compensation for VST instruments.

1. In the RFmx Soft Front Panel, select **WLAN Personality»WLAN Settings»OFDM ModAcc»Single-Point Calibrate** or **Multi-Point Calibrate**.
2. After running a calibration, enable **Noise Compensation** in the drop down on the **Measurements»ModAcc (WLAN)** tab in the RFIC Test SFP.

Refer to the RFmxWLAN OFDMModAcc EVM Noise Compensation example for more information on customized noise compensation.

Running the RFIC Test SFP with a DUT

You must use an RF power amplifier.

1. Ensure the RFIC Test SFP is not running.
2. Connect and power up the DUT manually.
   Note: To power the DUT using the RFIC Test SFP's DC Power, refer to the DC Power section.
3. Update the following settings to reflect the DUT:
   - Under **HW Configuration»VSA**, enter the **External Attenuation (dB)**. Use the total path loss between the DUT output and the VSA input connectors.
   - Under **HW Configuration»VSG**, enter the **External Attenuation (dB)**. Use the total path loss between the VSG output and the DUT input connectors.
   - Under **DUT & Waveform»DUT**, enter the **Expected Gain (dB)**. An approximate value, such as the typical gain from the DUT datasheet, is adequate.
   - Under **DUT & Waveform»DUT**, set the **Power Target** as **Target Input Power** and enter the **Target Input Power (dBm)** for the test. To use **Target Output Power**, refer to the Output Power Servoing section.
4. Leave the other settings in the default configuration.
5. Ensure the DUT is powered on and click the **Play** button.
6. (Optional) Click the **DPD** button to apply DPD.

Saving Results

To save results for offline processing, select **File»Save Results**. The default directory for saved results is
`<Public Documents>\National Instruments\NI RFIC Test Software\Results`.

The saved results file is a binary TDMS file that contains scalar results and traces of all enabled measurements, with and without DPD. You can load and parse this file in any programming language with the NI TDMS API, or load the file in Microsoft Excel with the TDMS Importer Utility that installs with NI Drivers.

Saving a Configuration

The RFIC Test SFP allows you to save all the current settings and later recall them to restore the SFP to a predefined state.

To save your current settings, complete the following steps:

1. Select **File»Save Configuration**.

2. Specify a path and file name in the dialog box.
3. Click **OK**.

To apply a configuration that was previously saved, complete the following steps:

1. Select **File»Load Configuration**.
2. In the file dialog box, navigate to the configuration that you want to recall.
3. Click **OK**.

Note: The default directory for saved configurations is `<Public Documents>\National Instruments\NI RFIC Test Software\Configurations`.

Advanced Topics

Crest Factor Reduction

You can use crest factor reduction (CFR) directly on the reference waveform and post-DPD. CFR reduces the peak to average power ratio (PAPR) of a generated signal. Visit www.ni.com/r/bysve3 to learn more about CFR.

Reference Waveform CFR

To configure CFR for your reference waveform, complete the following steps:
1. In the **DUT & Waveform»Waveform** tab, enter the output PAPR that you want post-CFR in **Target PAPR (dB)**.
2. (Optional) If you select **Clipping** as the **CFR Method**, you can use the frequency domain for the post-clipping filter to help with spectral regrowth.

 Tip: For carrier aggregated signals, select a single carrier with bandwidth equal to the aggregated bandwidth you want to filter. Specify multiple carriers only when they use separate frequencies, such as LTE non-contiguous carrier aggregated signals.

Post-DPD CFR

The predistortion process expands a waveform's PAPR to compensate for compressed samples. The RFIC Test SFP maintains the RMS DUT input power after DPD, so a high post-DPD PAPR may damage the DUT.

 Notice: Configure a maximum safety PAPR to avoid damaging the DUT.

1. Under **Measurements»DPD**, set the **Target PAPR Type** to **Custom**.
2. Enter a **Target PAPR (dB)** to set a maximum PAPR.

Output Power Servoing

Use output power servoing to test a DUT at a specified output power instead of combination of input power and gain to reach your desired output power. The RFIC Test SFP supports both software-based and hardware-accelerated output power servoing.

Notice: Changing to output power servoing while the SFP is running may damage the DUT.

Notice: Running the SFP with incorrect relations may damage the DUT.

Complete the following steps to use output power servoing:

1. Ensure the RFIC Test SFP is not running.
2. Verify that the expected gain and attenuation settings are correct.
3. In the **DUT** and **Waveform** tabs, select **Target Output Power** in the **Power Target** box.
4. Enter the **Target Output Power (dBm)** that you want to test, where *Target Output Power = Previous Input Power + DUT Gain*.
5. Under **Measurements»Power Servo**, enter your **Desired Accuracy (dB)** and select the **Power Servo Method** from the list.

Software-Based Power Servo

The software-based power servo uses a LabVIEW RFmx algorithm to adjust the output power of the DUT, as measured by TX Power, to your desired accuracy. Visit www.ni.com/r/0q4kly for more information about NI-RFmx.

Hardware-Accelerated Power Servo

Refer to the installed Power Servoing documentation for more information on hardware-accelerated power servoing.

Envelope Tracking

You can use the RFIC Test SFP to test an envelope tracking PA, which includes both a tracker and a power amplifier.

1. Under **DUT & Waveform»DUT**, select **Envelope Tracking** from the **Power Tracking** list.
2. Under **HW Configuration»ARB**, configure the envelope generator parameters.
   a. Select your envelope generator. You can select either **FGEN (PXIe-5451)** or **RFSG (PXIe-5820)**.
   b. Select the name of your device in the **RF Env Device** list.
   c. (Optional) Under **Export Marker**, select a **Destination** if the envelope should trigger an external instrument.

   Note: The RFIC Test SFP calculates the optimal RF-to-Envelope delay with the current **Envelope Delay (s)** and **Delay Sweep Parameters**.

3. In the **Tracker** tab, configure the following parameters based on the power modulator.
   - **Shaping Method**—Specifies whether the envelope waveform is determined from a look up table (.CSV file on disk) or through a generic detroughing method directly on the RF waveform.
   - **Shaping Table**—If the **Shaping Method** is set to **Look Up Table**, select a CSV table that maps RF powers to envelope voltages.
   - **Detrough Parameters**—If the **Shaping Method** is set to **Detrough**, select the type of mapping function and enter the V_{min} and $V_{max.}$ If you set the **Type** to **Power**, you must also enter an **Exponent** value.
   - **Tracker Transfer Function**—Enter your **Gain (V/V)** and **Offset (V)** values to understand what will happen to the envelope past the tracker.
   - **Tracker Input**—Configure the **Impedance (Ohm)**, **Terminal Configuration**, and **Common Mode Offset (V)** according to your power modulator.
4. Click **Play**.

5. Click the **Sweep Delay** button to optimize the RF-to-Envelope delay and align the DUT. Ensure the start, stop, and step delays are configured correctly under **HW Configuration»AWG**.
Tip: When the sweep is complete, you can visualize the AMPM memory vs. set delay to find the local minimum that corresponds to the optimal RF-to-Envelope delay, as shown in the following figure.
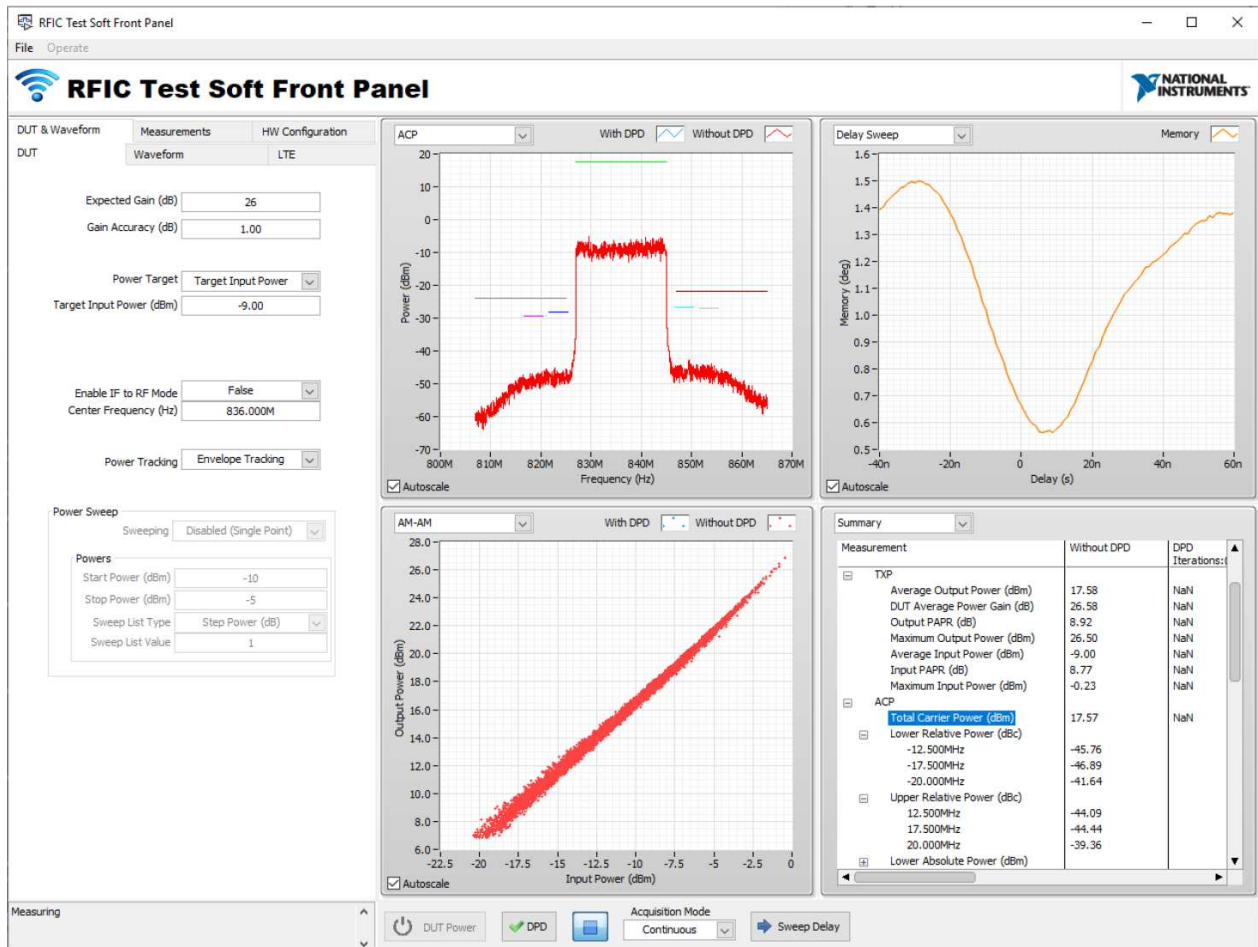

Figure 14: Delay Sweep Visualization

You can save the calculated envelope waveform output and the predicted tracker waveform output, which you can use to scope the actual tracker output as opposed to the calculated tracker output.

Power Sweeping

You can perform a one-dimensional sweep to see the behavior of a DUT over input or output power. Notice that only the target input or output power changes during the sweep. All other settings stay the same, including external attenuation values.

1. In the **DUT & Waveform»DUT** tab, under **Power Sweep**, change **Sweeping** to **Enabled**.
2. Configure the **Start Power (dBm)**, **Stop Power (dBm)**, and **Sweep List Type** to set up the one-dimensional array of powers to sweep over. Notice that these values will be either input or output powers based on your selected **Power Target**.

3. Press **Play**. The one-dimensional sweep automates the power transitions and performs all enabled measurements at each point. You can visualize the ACP, EVM, and Gain vs. Power curves in the top right graphs.
4. (Optional) After the sweep, save the sweep results. Saved sweep results include the most relevant measurement results at each power step for offline processing.

DC Power, Vcc IV, and Power Added Efficiency Measurements

At all times, you can connect a source measure unit (SMU) driven by NI-DCPower to connect, power up, and measure the Vcc input of a DUT. This connection enables additional measurements in the RFIC Test SFP, including power consumption and power added efficiency.

1. Under **HW Configuration»SMU**, select an SMU Device from the drop-down list to enable DC Power functions and measurements. See the context help for more information on other **Sourcing Settings**.
   Tip: You can add another Source Settings array element with a different **Vcc Channel** to define additional channels.
2. Under **Measurements»System PAE**, configure the **Measurement Settings**. See the context help for more information on each setting.

Controlling DC Power to DUT

To enable SMU output, complete the following steps:

1. Select an SMU in the **HW Configuration** tab. The **DUT Power** button becomes active in the Execution Pane.
2. Press the **DUT Power** button to enable the SMU channels and apply DC voltage to the DUT.

To disable SMU output, press the **DUT Power** button again.

Note: The **DUT Power** button is inactive while the SFP is running.

Leveraging RFIC with Custom DPD Models

You can save the required I/Q data to your disk when you want to perform custom DPD.

Saving Custom DPD Models

1. Select **File»Save Waveforms**.
2. In the **Select Waveforms to Save to Disk** dialog, select the **Aligned DPD IQ (Ref and Acq)** checkbox and click **Save**. This creates a CSV file with the necessary information for a custom DPD algorithm.

```
1   #t0, 0.000020
2   #Fs, 61440000.000000
3   #I_Ref, Q_Ref, I_Acq, Q_Acq
4   -0.094702,0.024336,-1.913524,0.555501
5   -0.064193,0.038359,-1.251062,0.852061
6   -0.036040,0.053952,-0.645316,1.148623
7   -0.013310,0.071152,-0.164680,1.465070
8   0.002105,0.089992,0.141971,1.844918
```

Figure 15: Example Aligned DPD Waveforms File

- **I_Ref and Q_Ref**—Aligned samples at the DUT Input Port

- **I_Acq and Q_Acq**—Aligned samples captured from the DUT Output Port

  Note: You can use the sampling rate **Fs** and starting time **t0** when loading a post-DPD waveform.

3. Use the Reference and Acquired I/Q data to model and pre-distort your desired reference waveform.
4. Save your predistorted waveform as a TDMS or CSV file.

Loading Saved DPD Models

1. Under **Measurements»DPD**, select **DPD Wfm from CSV** in the **DPD Model** list to load the waveform. The **DPD Custom** tab appears.
2. In the **DPD Custom** tab, browse to your saved waveform in the **Custom DPD Waveform** box.
3. Click the **DPD Power** button. The RFIC Test SFP loads your Custom DPD Waveform directly and plays it out of the generator to perform post-DPD measurements as shown by the blue trace in the following figure.
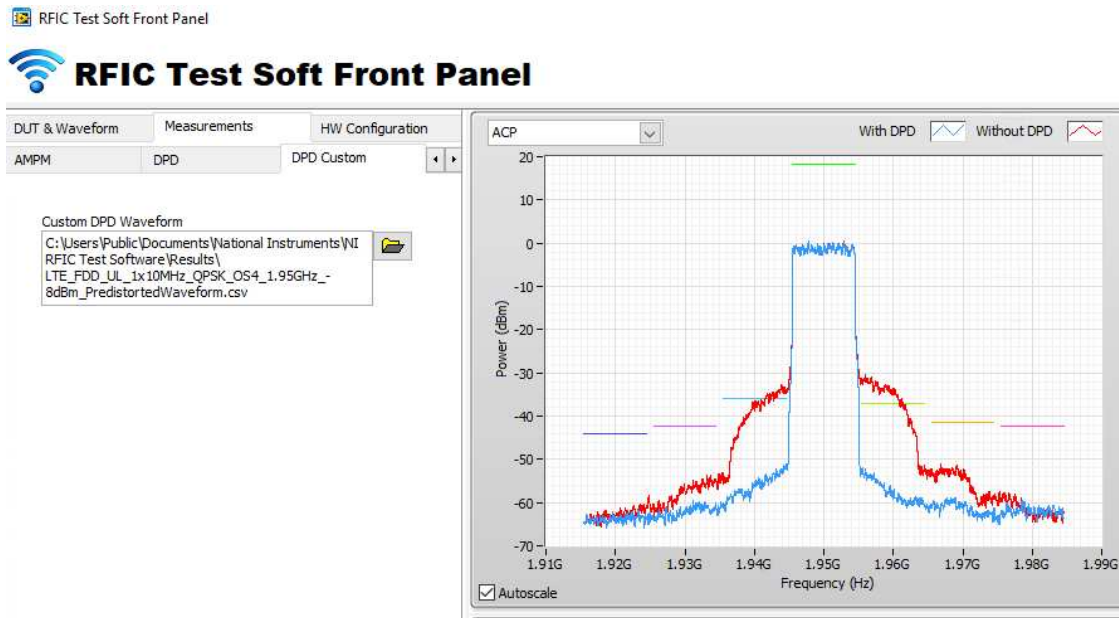
Figure 16: Visualization of Custom DPD Spectrum

Debugging RFIC Applications

RFIC uses NI-RFmx to control analyzers for supported measurements and other instruments, such as SMUs and pattern generators, for DUT control. You can use RFmx tools and SFPs to debug RFIC applications.

Pausing an Application with Breakpoints

To pause your application with a breakpoint:

1. Open the source code of your application in LabVIEW or in C#.
2. Locate `RFmxInstr Initialize NIRFSA.` Place a breakpoint at any location after this function.

3. Configure your application to use the desired hardware.
4. Start your application. The application runs until it reaches the breakpoint.

Use the RFmx SFP to view what is happening at the breakpoint, or use Instrument Studio to control SMUs, digital I/O, or oscilloscope modules used in the application.

Using the RFmx Soft Front Panel to View What is Happening at a Breakpoint

Pause your application at a breakpoint before using the RFmx SFP to view what is happening.

To inspect with the RFmx SFP:

1. Open RFmx Soft Front Panel (SFP) from the Start Menu.
2. In the Select Device dialog box, select the device that you configured in your RFIC application.
3. Click **OK**.
4. Wait for the SFP to load. When loading is complete, the right panel displays `Monitoring`.
5. Click **CONTROL** to take control of the signal analyzer session. The RFmx session represented in the SFP is configured based on the location of the breakpoint.
   Note: You can save the current RFmx configuration as a TDMS file at any time by selecting **File»Save Configuration**. Use the saved TDMS file to compare settings after running the measurement(s).
6. Click **ADD/REMOVE** under **Measurements** and select the desired measurement(s).
7. Configure the measurement(s).
8. Click **RUN** to run the measurement(s).

You can now tune all settings to debug your application.

Tip: You can restore your original settings by clicking **REVERT CONFIGURATION**. NI recommends reverting the configuration at the end of your debugging session to prevent conflicting settings in your application.

Viewing a Saved RFmx Configuration

You can read a configuration file with the TDMS File Viewer.

To use the TDMS File Viewer:

1. Open LabVIEW.
2. Create a new VI.
3. In the Functions Palette, select **Programming**»**File I/O**»**TDM Streaming**»**TDMS File Viewer**.
4. Place the viewer in the new VI and run it.
5. When prompted for the path to your TDMS file, select the correct path and click **OK**. The viewer displays the contents of your TDMS file.

   Close the viewer and start it again to view a different TDMS file.

Controlling SMUs, Digital I/O, or Oscilloscope Modules with Instrument Studio

You can use Instrument Studio to control SMUs, Digital I/O, or Oscilloscope modules used in your RFIC application for debugging.

For example, to debug the SMU or power supply, you can change parameters that might lead to a bad measurement performance (such as voltage level and current limit) while the measurement waits at the breakpoint.