User's Guide

Keysight RF PA/FEM Characterization & Test, Reference Solution

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KEYSIGHT TECHNOLOGIES

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A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

WARNING

A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

The following safety precautions should be observed before using this product and any associated instrumentation.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all

installation, operation, and maintenance information carefully before using the product.

WARNING

If this product is not used as specified, the protection provided by the equipment could be impaired. This product must be used in a normal condition (in which all means for protection are intact) only.

The types of product users are:

- Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring operators are adequately trained.
- Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.
- Maintenance personnel perform routine procedures on the product to keep it operating properly (for example, setting the line voltage or replacing consumable materials). Maintenance procedures are described in the user documentation. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.
- Service personnel are trained to work on live circuits, perform safe installations, and repair products. Only properly trained service personnel may perform installation and service procedures.

WARNING

Operator is responsible to maintain safe operating conditions. To ensure safe operating conditions, modules should not be operated beyond the full temperature range specified in the Environmental and physical specification. Exceeding safe operating conditions can result in shorter lifespans, improper module performance and user safety issues. When the modules are in use and operation within the specified full temperature range is not maintained, module surface temperatures may exceed safe handling conditions which can cause discomfort or burns if touched. In the event of a module exceeding the full temperature range, always allow the module to cool before touching or removing modules from chassis.

Keysight products are designed for use with electrical signals that are rated Measurement Category I and Measurement Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Measurement Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Measurement Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the user documentation.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000V, no conductive part of the circuit may be exposed.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance-limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, ensure that the line cord is connected to a properly-grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions, or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with the same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring

circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits – including the power transformer, test leads, and input jacks – must be purchased from Keysight. Standard fuses with applicable national safety approvals may be used if the rating and type are the same. Other components that are not safety-related may be purchased from other suppliers as long as they are equivalent to the original component (note that selected parts should be purchased only through Keysight to maintain accuracy and functionality of the product). If you are unsure about the applicability of a replacement component, call an Keysight office for information.

WARNING

No operator serviceable parts inside. Refer servicing to qualified personnel. To prevent electrical shock do not remove covers. For continued protection against fire hazard, replace fuse with same type and rating.

PRODUCT MARKINGS:

The CE mark is a registered trademark of the European Community.

Australian Communication and Media Authority mark to indicate regulatory compliance as a registered supplier.

This symbol indicates product compliance with the Canadian Interference-Causing Equipment Standard (ICES-001). It also identifies the product is an Industrial Scientific and Medical Group 1 Class A product (CISPR 11, Clause 4).

South Korean Class A EMC Declaration. This equipment is Class A suitable for professional use and is for use in electromagnetic environments outside of the home. A 급 기기 (업무용 방송통신기자재) 이 기기는 업무용 (A 급) 전자파적합기기로서 판매자 또는 사용자는 이 점을 주의하시기 바라며 , 가정외의 지역에서 사용하는 것을 목적으로 합니다 .

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This symbol indicates the instrument is sensitive to electrostatic discharge (ESD). ESD can damage the highly sensitive components in your instrument. ESD damage is most likely to occur as the module is being installed or when cables are connected or disconnected. Protect the circuits from ESD damage by wearing a grounding strap that provides a high resistance path to ground. Alternatively, ground yourself to discharge any built-up static charge by touching the outer shell of any grounded instrument chassis before touching the port connectors.

This symbol on an instrument means caution, risk of danger. You should refer to the operating instructions located in the user documentation in all cases where the symbol is marked on the instrument.

This symbol indicates the time period during which no hazardous or toxic substance elements are expected to leak or deteriorate during normal use. Forty years is the expected useful life of the product.

CLEANING PRECAUTIONS:

WARNING

To prevent electrical shock, disconnect the Keysight Technologies instrument from mains before cleaning. Use a dry cloth or one slightly dampened with water to clean the external case parts. Do not attempt to clean internally. To clean the connectors, use alcohol in a well-ventilated area. Allow all residual alcohol moisture to evaporate, and the fumes to dissipate prior to energizing the instrument.

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Introduction

The Keysight RF PA/FEM Characterization and Test Demo program ("PA Demo program") uses the Keysight M9381A PXIe VSG, M9391A PXIe VSA or M9393A PXIe Performance VSA and the M90XA X-Series measurement application software to perform power amplifier measurements commonly used in the production test of these devices. The PA Demo program supports multiple measurements for cellular and wireless LAN standards. It can be used to demonstrate the measurement speed, repeatability and ranges of measurements for the Keysight PXI instruments used in the program. The measurements can be performed on a wide range of amplifiers or on a through RF cable by configuring the settings in the user interface.

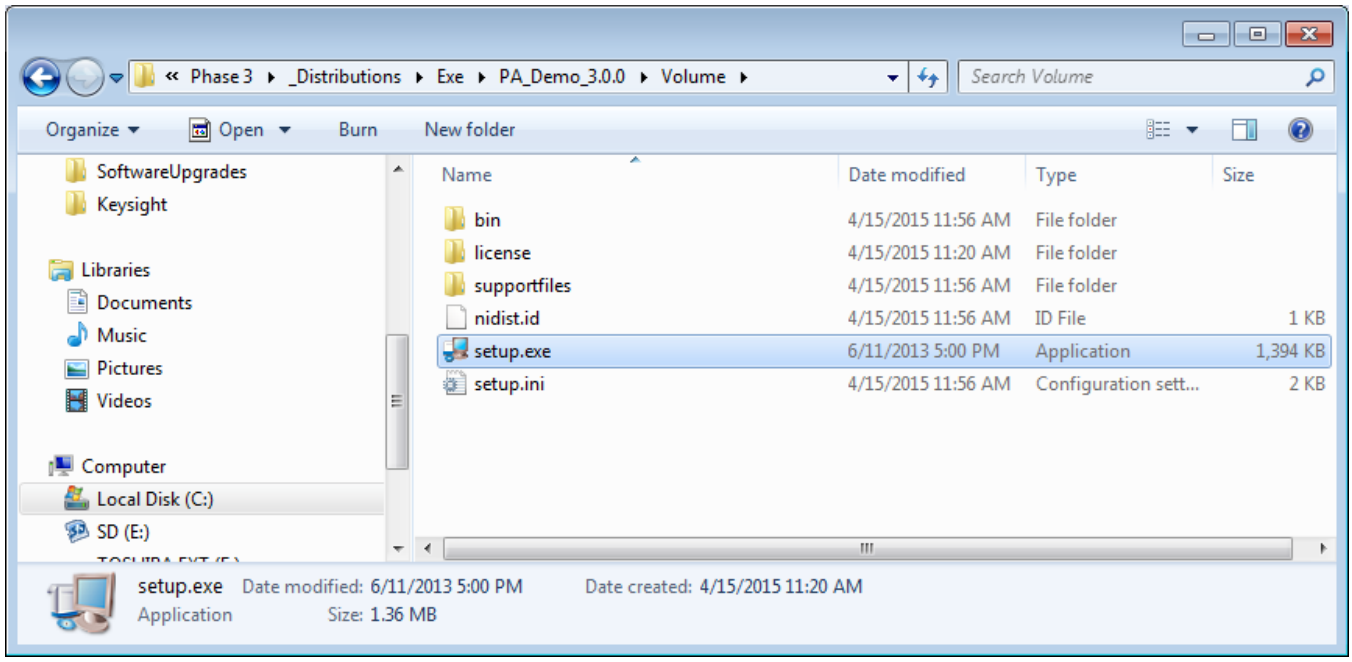
The following optional instruments and measurements are supported in addition to the basic VSG and VSA measurements:

- Keysight Signal Studio for PA Test software programming API (N7614B) to enable Digital Pre-distortion (DPD) and Envelope Tracking tests using the IVI drivers to control PXIe VSA and VSG, as well as a Keysight 33522B or Signadyne SD AOU-H3353 AWG to provide the envelope input signal.
- Keysight M9451A Measurement Acceleration Module to provide improved throughput for DPD model extraction, IQ waveform pre-distortion and envelope waveform generation. The program will use the M9451A when "DPD Acceleration" is enabled and will use the N7614B software when not enabled.
- Keysight M9195A Digital Source Measure module or SignalCraft Scout Model SC4410 to provide an RFFE stimulus to the DUT.
- Keysight N6700B Modular Power System is supported for DC stimulus and current measurements.
- Keysight M937xA PXI Vector Network Analyzer is supported to provide S-Parameter measurements on filters and switches included in PA/FEM modules.
- Keysight USB power sensor is supported to perform a system calibration.

The PA Demo program is C# Windows form application. Source code for the program can be provided. Contact your local Keysight representative to obtain the source code for the program.

Program Installation

The PA Demo program installer is provided in a zip file. Copy the installation zip file to the target machine and unzip the file. Browse the unzipped folder PA_Demo_3.x.x/Volume and run the program setup.exe:



By default, the program is installed at C:\Keysight\PA Demo Program. The installation can be run with all of the default values for each prompt. The Keysight software EULA must be accepted to install the software. The program installs and add shortcuts to the desktop and the Start menu. The Start menu includes shortcuts to run the program, show the User's Guide, and show the list of required drivers.

Licenses are required to run the M90XA X-Series measurement applications (“X-Series apps”), M9451A Accelerated DPD Measurements, N7614B Signal Studio for PA Test software, and to play waveforms generated from any other Keysight Signal Studio applications. The PA Demo systems from Keysight include the required licenses. To obtain a temporary license to run the program on a non-Keysight owned computer, please contact your local Keysight representative or obtain a trial license from Keysight.com.

Driver Installation

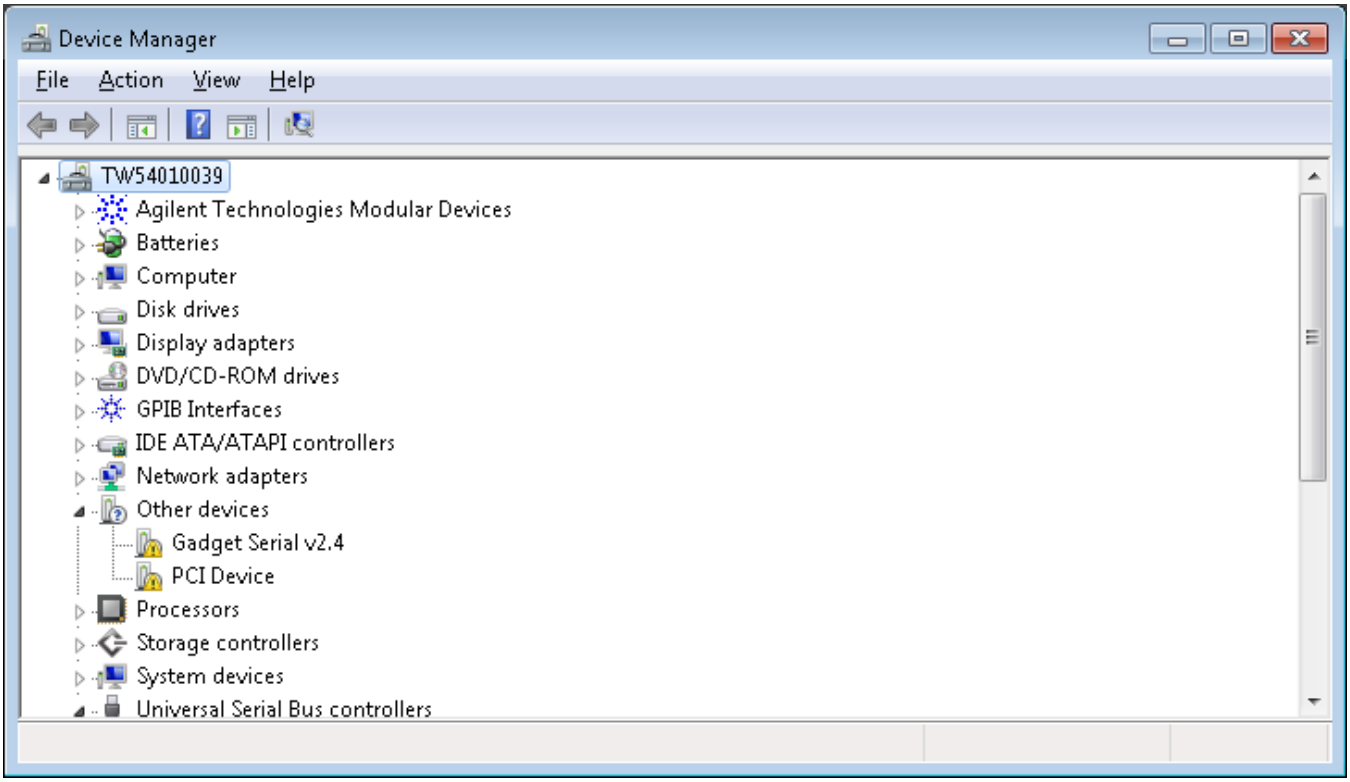
Several instrument drivers and software packages must be installed before the PA Demo program can be run. The following are required:

- Keysight Connection Expert
- M9018A PXI Chassis IVI Driver
- M938x VSG IVI Driver
- M9391A VSA IVI Driver
- M9393A VSA IVI driver
- M90XA Modular X-Applications Software and IVI Driver
- M937xA VNA Software and IVI Driver
- N7614B Signal Studio for PA Test Application
- M9451A Measurement Acceleration Software and Driver
- M9195A Digital Source Measure Software and Driver
- Signadyne Essentials AWG Driver
- SignalCraft Scout INF device driver

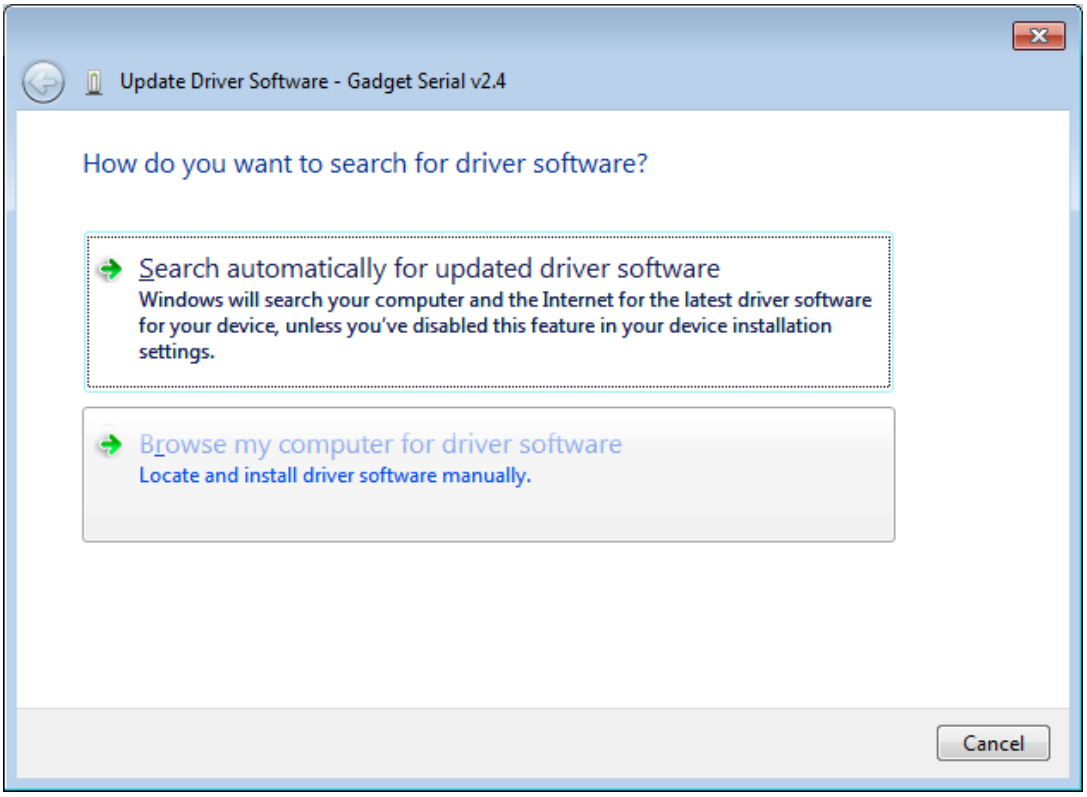
The required versions for each program are described in the Readme file included with the PA Demo program. All of the software packages, except for the Scout INF file are in .exe files that install the software in the required locations. Run each of these programs to install the drivers and software packages.

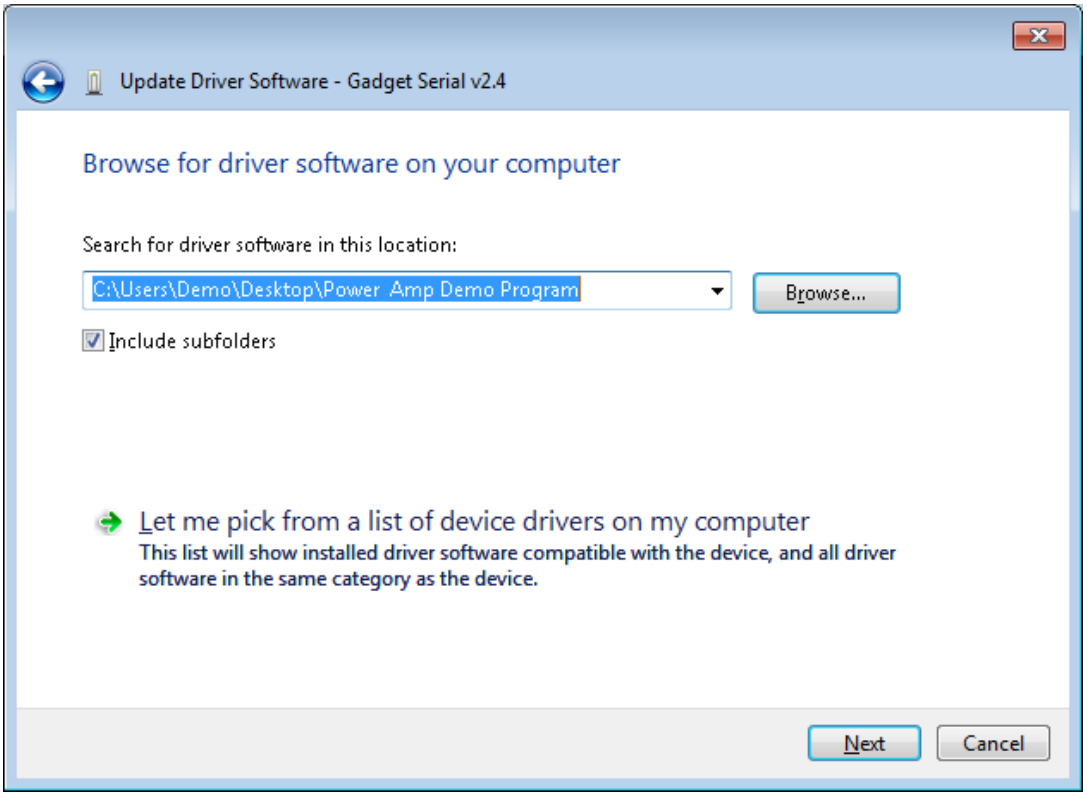
The Scout INF file is included in the folder of the PA Demo program. The INF file is installed using the Device Manager.

To install the INF file, plug in the Scout USB module and start Device Manager. You will see an entry for a *Gadget Serial* device.

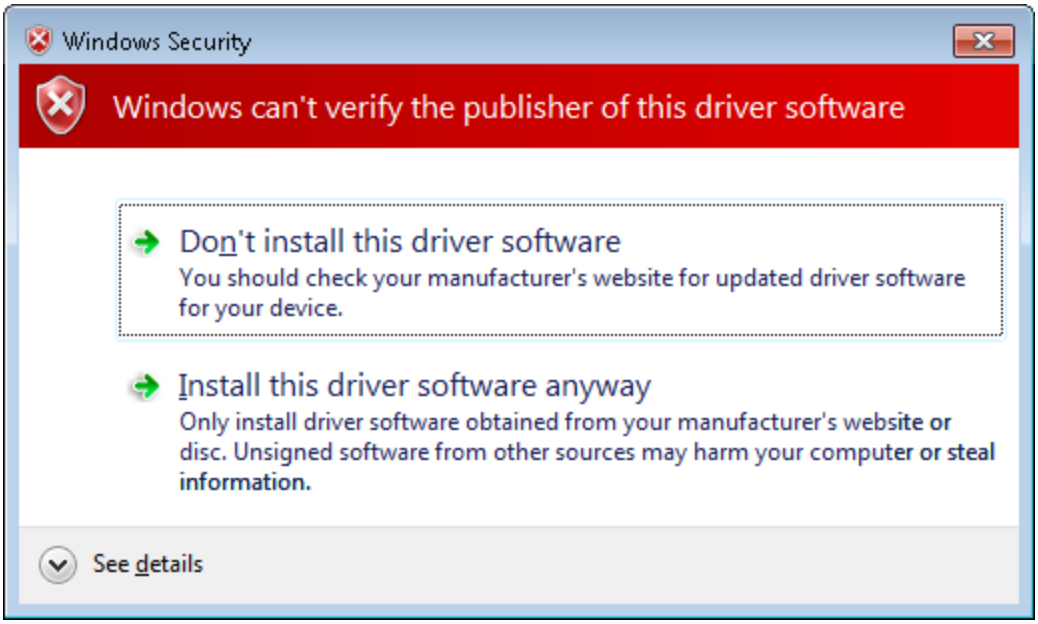


Right-click the mouse on this device and select **Update Driver Software**. Click **Browse my computer for driver software** and then select the path to the PA Demo program. Click **Next**.

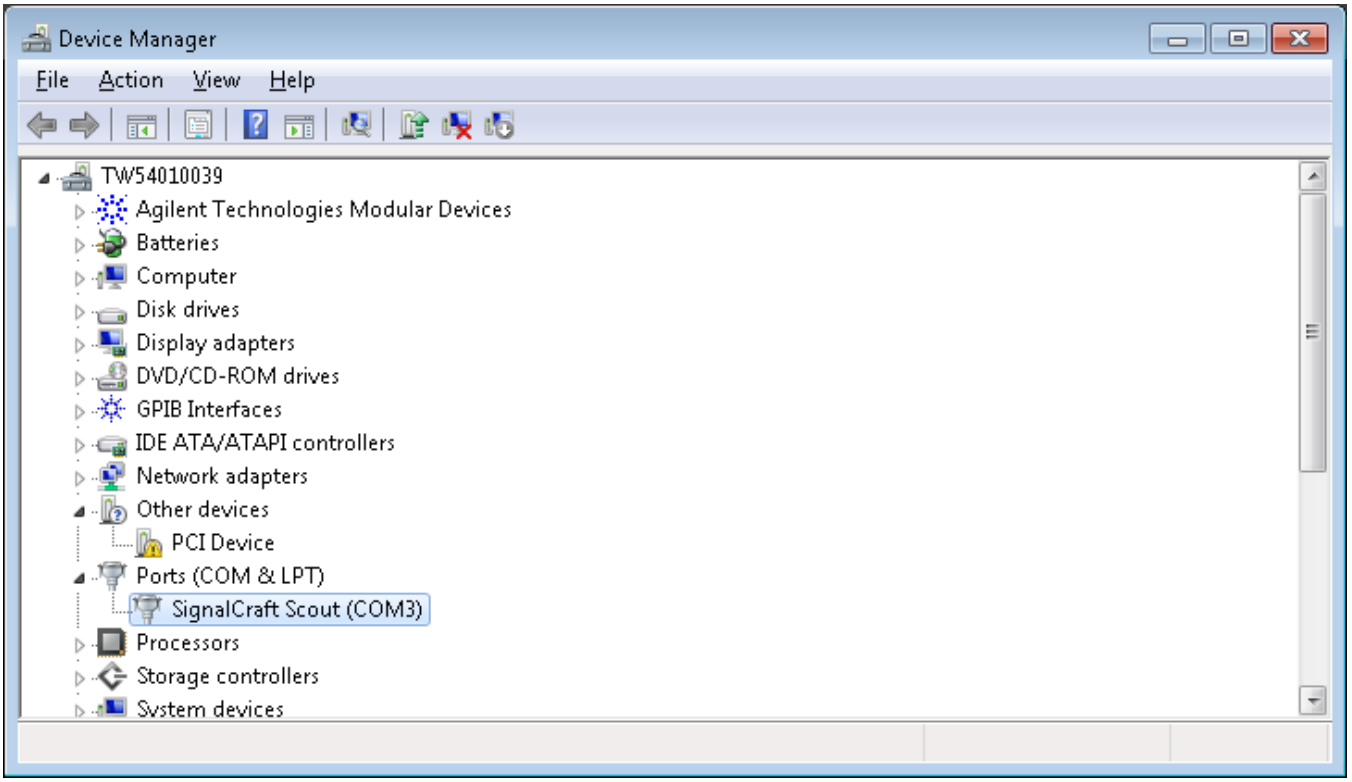




If the following Windows Security Warning is displayed, select **Install this driver software anyway.**



After the driver is installed, the Device Manager shows the Scout module in the COM and LPT port section:



Running the RF PA/FEM Characterization and Test Demo Program

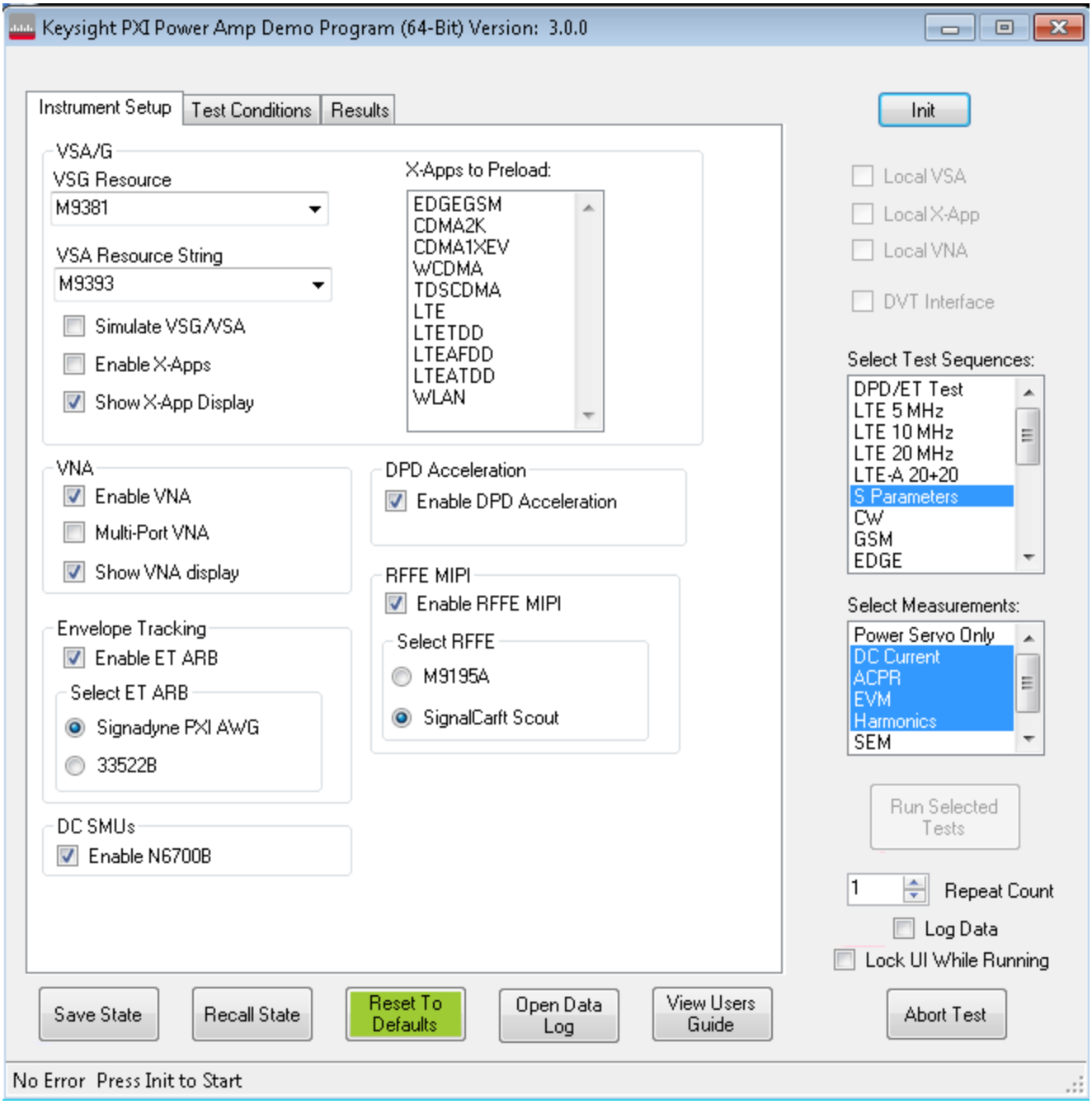
The PA Demo Program provides a user interface to run the tests and display the results. The following is a screen capture of the GUI after the program is launched. Tool tip help is available for each control in the demo program by hovering the mouse over that control.

The View User's Guide button shows this document. The program saves test result and time data to a .CSV file. The most recent data file can be opened by pressing the Open Data Log button.

The Save State, Recall State and Reset to Default buttons enable the user to save the current configuration of the user interface controls to a file, reload previous setting from a file, or reset all of the values to a default condition. When the program is started, the GUI is restored to the last state used. If there is an error, click the Reset to Defaults button to reset the UI.

The program installation includes three saved state files for typical demonstrations:

- *Basic Demo*: Use this state file to demonstrate the basic power amplifier production test capability using the PXIe VSG, VSA and X-Series Applications. This setup is appropriate for testing a cable between the PXIe VSG and VSA or an amplifier that is not controlled by the demo program.
- *DPD-ET Demo Board*: This setup loads all the required configuration files to test the DPD-ET Demo board that is available with some of the Keysight PA Demo systems. Use this state file to demonstrate how the PXIe VSG, VSA, AWG and M9451A or N7614B software can be used for automated design validation testing. Follow the instructions below to select the AWG, DC Power Supply, Measurement Acceleration Module and RFFE module. All these instruments are required to control the DPD-ET Demo Board. Using the DPD-ET software and DVT interface are described later in this document.
- *S-Parameter*: This setup loads the configuration file required for 2 port S-Parameter measurements. Follow the instructions below to enter the resource strings for one or more PXI VNA cards. If multiple cards are used in a multi-port VNA configuration, switch the S-Parameter setup file to one matching the available number of ports. Configuring 2 port and multi-port S-Parameter measurements are described later in this document.



Configuring the Instruments

Starting with version 3.0.0, the instrument configuration process has been simplified. The PXIe VSG resource string is selected from a list of saved configurations created with the M9381A PXIe VSG Soft Front Panel. If there are no saved configurations defined, an error message is displayed directing you to use the SFP to create a saved configuration.

The PXIe VSA resource string is selected from a list of saved configurations created with the M9391A PXIe VSA and M9393A PXIe Performance VSA Soft Front Panels. If there are no saved configurations defined, an error message is displayed directing you to use the SFP to create a saved configuration.

The X-Series Applications software is loaded if the **Enable X-Apps** check box is selected. In this case, the M9000 Resource Manager is used to allow the PXI VSA to be accessed both by the VSA IVI driver and by the X-Series Applications software. If the X-Series Applications software is not selected, the PXIe VSA is only controlled by the IVI driver. If the X-Series Applications software is loaded, one or more X-Series Apps can be selected from the list of applications to preload. The X-Series Apps in this list will be loaded as part of the initialization process. Other X-Series Apps can be used later in the program, but there is a delay while these Apps load. For best results, select the X-Series Apps to be preloaded.

The resource strings for all the other instruments are automatically detected by the PA Demo Program. For the VNA, ET AWG, DC SMU, DPD accelerator and RFFE instrument, the **Enable Instrument** check box for each instrument that is to be used needs to be selected.

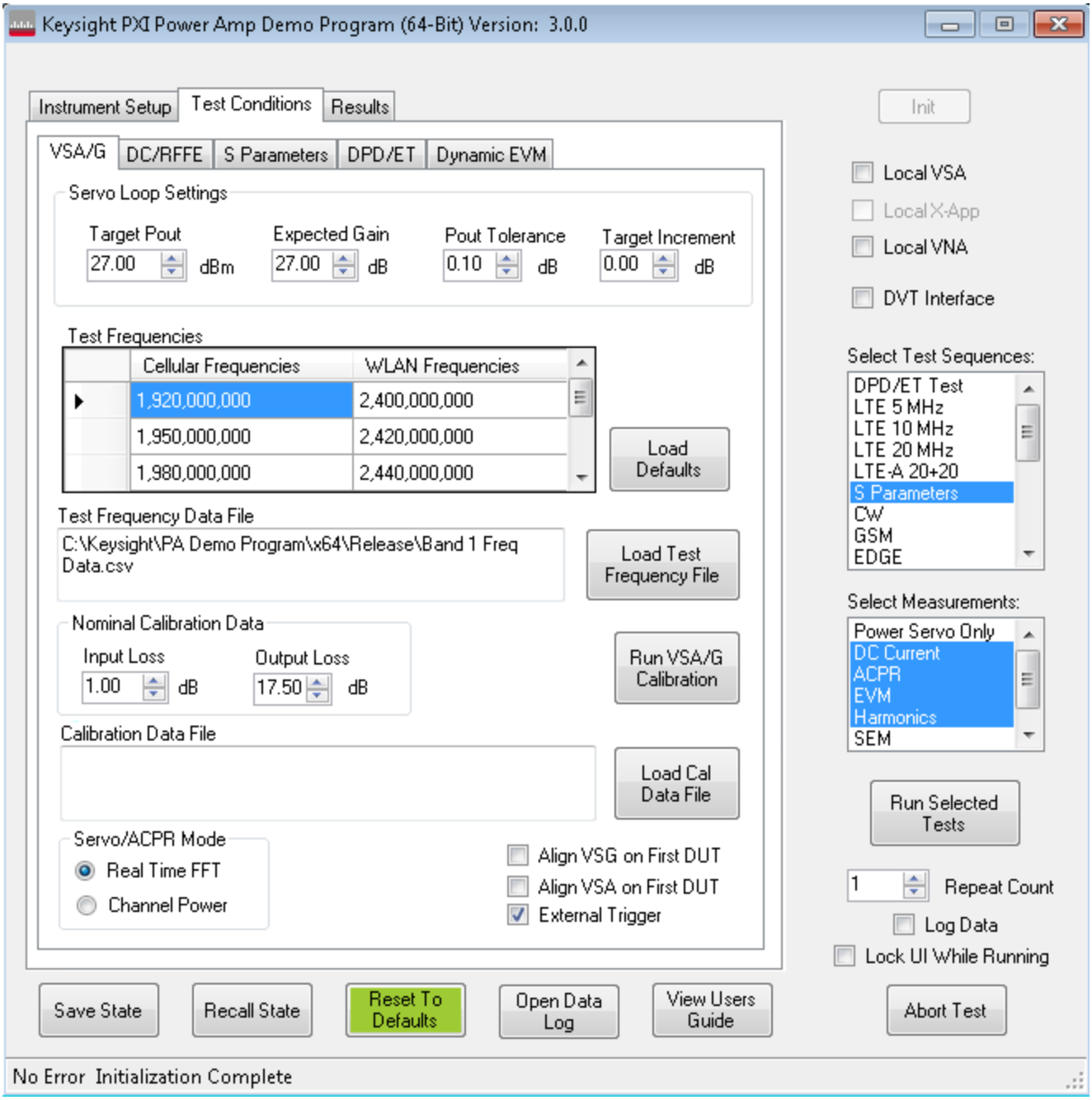
The program supports controlling multiple PXIe VNA cards. When multiple VNA cards are used, they can be configured either as one multi-port VNA or multiple 2-Port VNAs. The configuration is determined by the state of the **Multi-Port VNA** check box.

After the controls in the instrument setup have been set to the desired values, click **Init** to open the sessions to the instrument drivers and start the X-Series Applications software.

After using the demo program, you can close the instruments is closed by clicking the red X in the upper right corner of the user interface.

Configuring the DUT Parameters

After the instruments are initialized, the program switches to the **Test Conditions** tab as shown in the following screen shot:



The controls in the **Servo Loop Settings** section are used to configure the power level setup for the tests. At the beginning of each test, the program performs a servo loop to set the DUT output power level to the value in the Target Pout field. The Expected Gain field is used to set the RF Output Power from the VSG. The RF power level is set to the value that is 3 dB above the required output power of the VSG to achieve the Target Pout of the DUT. The VSG baseband power offset is set to –3 dB. The baseband power offset value is varied in during the servo loop to achieve the correct power level at the DUT output. Using the baseband power offset function during the servo loop provides the fastest execution time. The Pout Tolerance field is used to determine how close the DUT output needs to be to the target output power for the

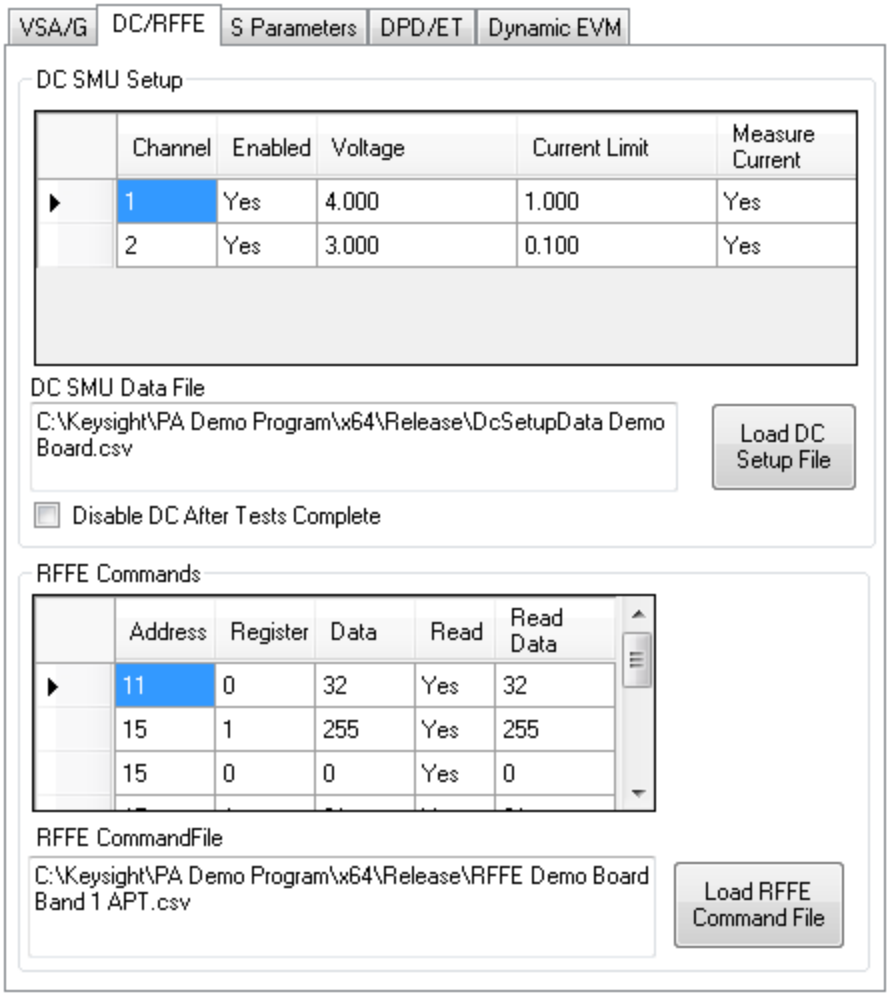
servo loop to complete. The program records the number of steps required to achieve the correct DUT output power. If the servo loop is not able to set the DUT to the correct value, the baseband power offset is set to 0 dB and the step count is set to -1.

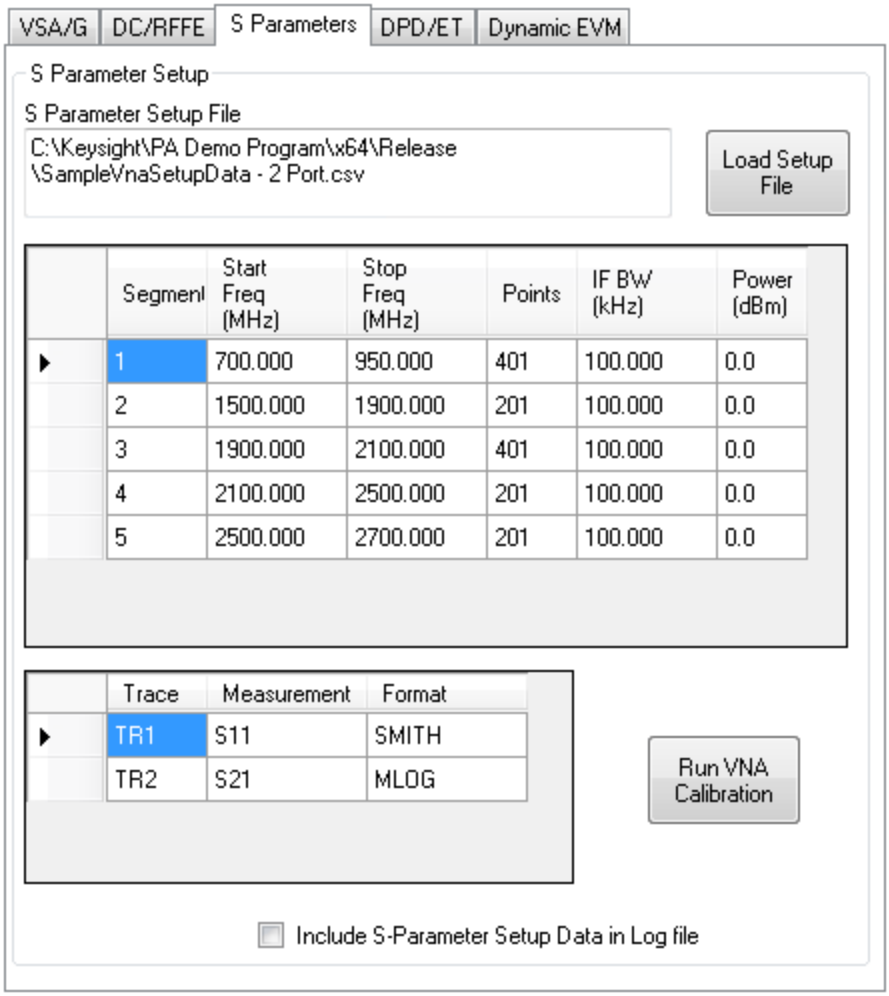
The Target Increment field normally is set to 0 dB. However, this field does allow the program to perform power level sweeps on the DUT when used in conjunction with the Repeat Count field. For example, with the above settings, if the Target increment field is changed to 1 dB and the Repeat count field is set to 10, the DUT tests would run ten times, each time at a target Pout level 1 dB above the previous run, providing data for DUT output power levels from -5 to + 4 dBm.

The program has two sets of default test frequencies. The values in the Cellular Frequencies column are used for all of the cellular standards, such as WCDMA and LTE. The WLAN frequencies are used for all of the 802.11x measurements. The frequencies can also be loaded from a CSV data file. The user can add any number of frequencies to a file. A sample frequency file is included in the program directory.

Input and output loss data can be specified in two manners. The Nominal Calibration Data values are used at all frequencies. To change these values, change the input and/or output loss. Calibration data can also be read from a CSV file, allowing different calibration values by frequency. When a calibration data file is used, the values are interpolated so it is not necessary to supply calibration data for each test frequency. A sample calibration data file is also included in demo program directory. The Calibration data can also be calculated with an automated calibration routine that uses a Keysight USB power sensor. Click Run Calibration to begin the calibration procedure. There will be several prompts during the calibration procedure to connect the power sensor and the input and output cables. When the calibration procedure is complete a CSV data file described above is generated and loaded, allowing the calibration to be used again at a later time.

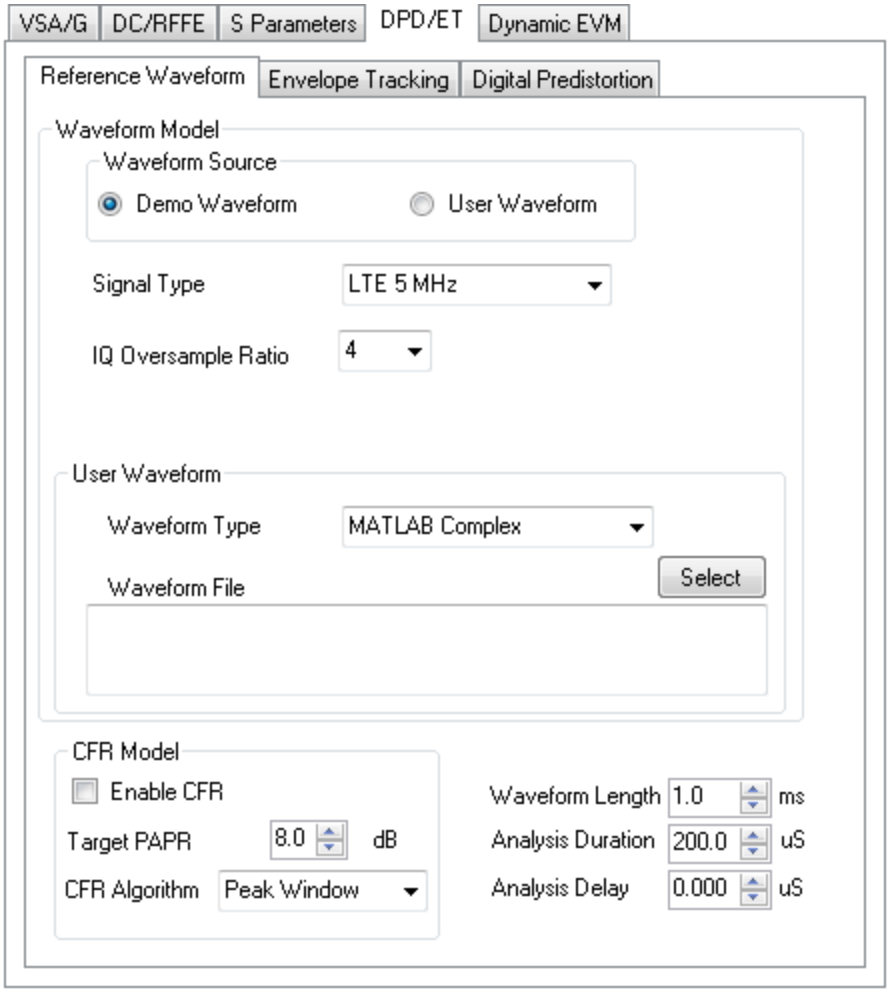
The state setup for the VNA and DC SMUs are read from .CSV configuration files. Samples of these files are provided in the program folder. The commands to be sent to the DUT using the RFFE interface are also configured using a .CSV file. The RFFE commands are sent to the DUT once after the Run Selected Tests button is pressed. If the commands were enabled to read back the set value from the DUT, this result is displayed in the table with the command data.


VSA/G
DC/RFFE
S Parameters
DPD/ET
Dynamic EVM
DC SMU Setup
Channel
Enabled
Voltage
Current Limit
Measure Current
1
Yes
4.000
1.000
Yes
2
Yes
3.000
0.100
Yes
DC SMU Data File
C:\Keysight\PA Demo Program\x64\Release\DcSetupData Demo Board.csv
Load DC Setup File
Disable DC After Tests Complete
RFFE Commands
Address
Register
Data
Read
Read Data
11
0
32
Yes
32
15
1
255
Yes
255
15
0
0
Yes
0
RFFE CommandFile
C:\Keysight\PA Demo Program\x64\Release\RFFE Demo Board Band 1 APT.csv
Load RFFE Command File



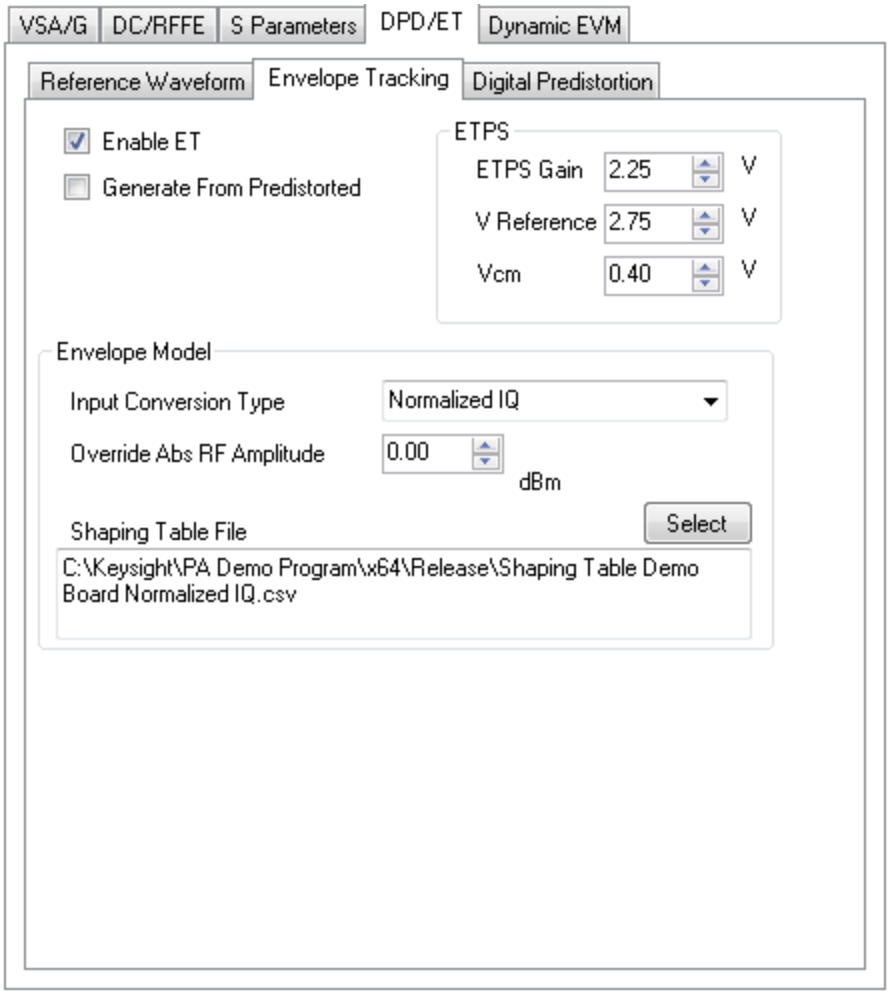
DPD/ET and Dynamic EVM have additional settings to enable and configure. DPD and ET are now supported for LTE, WCDMA and WLAN. In addition to the demo waveforms, you can now provide your own waveform to use for DPD and ET. The user waveform can be one of the following formats: signal studio, MATLAB, binary or text. Dynamic EVM measurements in are only used in WLAN.

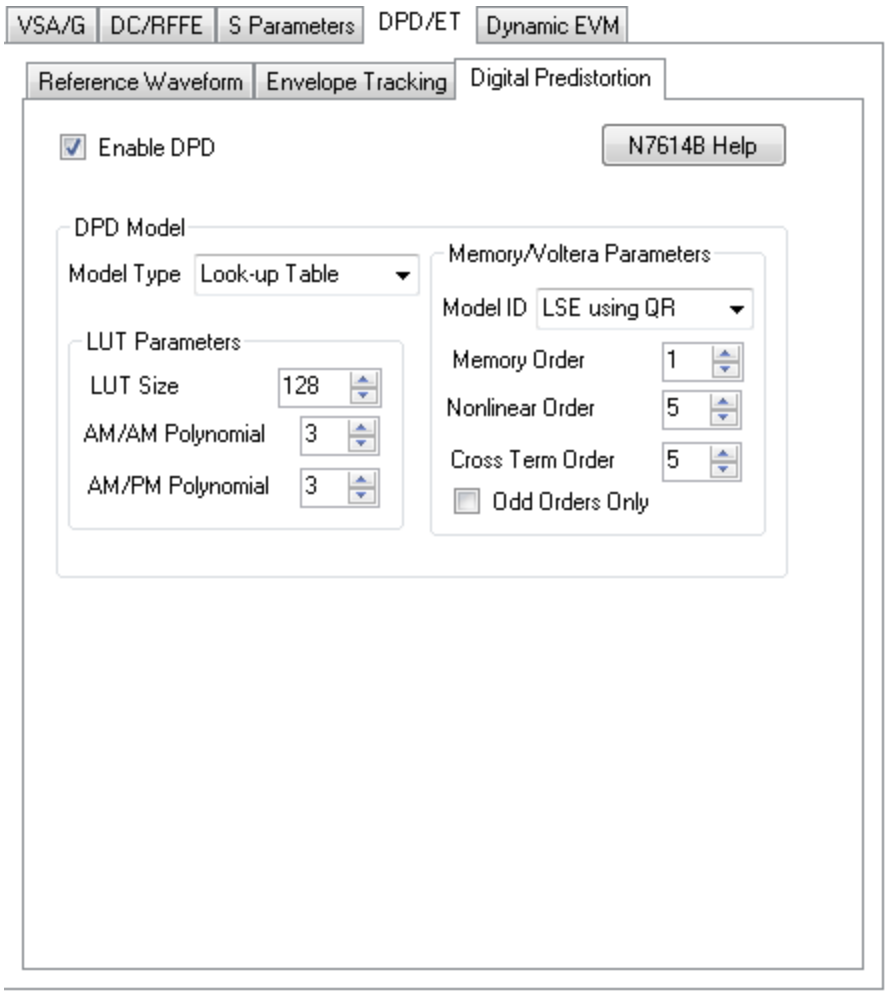
For DPD and ET, the Keysight N7614B Signal Studio for PA Test software application is used via the programming API to generate the up-sampled reference waveform in the demo program to allow maximum flexibility. In production or DVT testing, the reference waveforms can be developed ahead of time, avoiding the time to generate these waveforms each time a test is run.



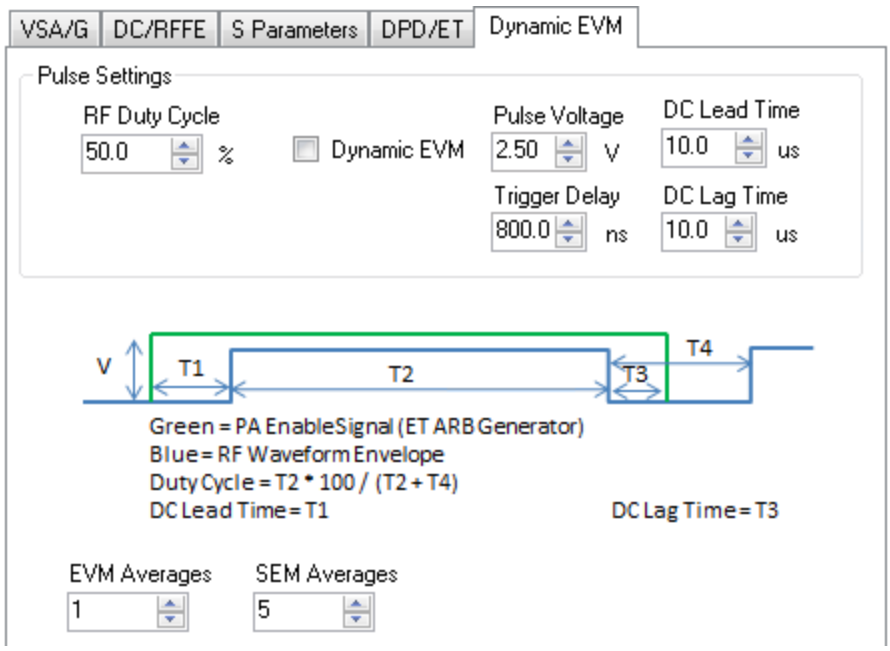
The length of the waveforms loaded into the PXIe VSG and AWG can be set from the GUI, as can the length of time and the time offset for the DPD Model Extraction. A link to the N7614B online documentation is provided for a complete reference on the use of the N7614B software.

DPD model extraction and pre-distorted and envelope waveform generation will be performed using the M9451A Measurement Acceleration Module, when enabled, or by the N7614B software. The GUI for N7614B is not shown. The most commonly used parameters in N7614B are included in the PA Demo Program GUI, as shown below. The GUI is the same for the N7614B and M9451A.


VSA/G
DC/RFFE
S Parameters
DPD/ET
Dynamic EVM
Reference Waveform
Envelope Tracking
Digital Predistortion
Enable ET
Generate From Predistorted
ETPS
ETPS Gain
2.25
V
V Reference
2.75
V
Vcm
0.40
V
Envelope Model
Input Conversion Type
Normalized IQ
Override Abs RF Amplitude
0.00
dBm
Shaping Table File
Select
C:\Keysight\PA Demo Program\x64\Release\Shaping Table Demo Board Normalized IQ.csv

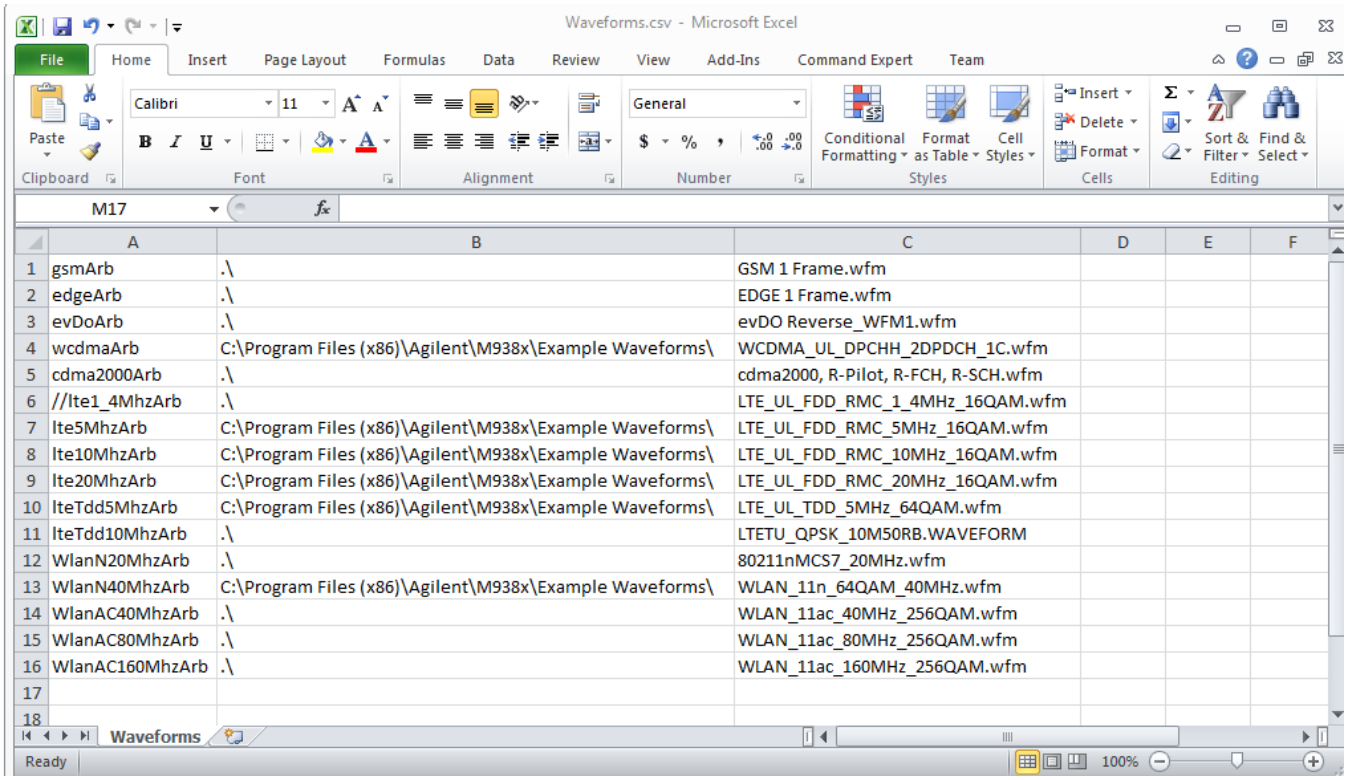


For WLAN Dynamic EVM, the settings shown in the following screen capture are available to adjust the test conditions:



The Trigger Delay is set to a nominal value allowing for the internal delays of the VSG and AWG. This value should not need to be changed, but could require slight changes under unusual cable setups. The WLAN tests use waveforms with 100% duty cycle with off time added in a sequence to create the requested duty cycle.

Different waveforms can be substituted by changing the data in the waveforms.csv file located in the demo program folder for the program. The following screen capture shows the default values for the waveforms.



	A	B	C
1	gsmArb	.\	GSM 1 Frame.wfm
2	edgeArb	.\	EDGE 1 Frame.wfm
3	evDoArb	.\	evDO Reverse_WFM1.wfm
4	wcdmaArb	C:\Program Files (x86)\Agilent\M938x\Example Waveforms\	WCDMA_UL_DPCHH_2DPDCH_1C.wfm
5	cdma2000Arb	.\	cdma2000, R-Pilot, R-FCH, R-SCH.wfm
6	//lte1_4MhzArb	.\	LTE_UL_FDD_RMC_1_4MHz_16QAM.wfm
7	lte5MhzArb	C:\Program Files (x86)\Agilent\M938x\Example Waveforms\	LTE_UL_FDD_RMC_5MHz_16QAM.wfm
8	lte10MhzArb	C:\Program Files (x86)\Agilent\M938x\Example Waveforms\	LTE_UL_FDD_RMC_10MHz_16QAM.wfm
9	lte20MhzArb	C:\Program Files (x86)\Agilent\M938x\Example Waveforms\	LTE_UL_FDD_RMC_20MHz_16QAM.wfm
10	lteTdd5MhzArb	C:\Program Files (x86)\Agilent\M938x\Example Waveforms\	LTE_UL_TDD_5MHz_64QAM.wfm
11	lteTdd10MhzArb	.\	LTETU_QPSK_10M50RB.WAVEFORM
12	WlanN20MhzArb	.\	80211nMCS7_20MHz.wfm
13	WlanN40MhzArb	C:\Program Files (x86)\Agilent\M938x\Example Waveforms\	WLAN_11n_64QAM_40MHz.wfm
14	WlanAC40MhzArb	.\	WLAN_11ac_40MHz_256QAM.wfm
15	WlanAC80MhzArb	.\	WLAN_11ac_80MHz_256QAM.wfm
16	WlanAC160MhzArb	.\	WLAN_11ac_160MHz_256QAM.wfm
17			
18			

Column A contains the internal waveform description and should not be changed. Column B is a full or relative path to the waveform file. Column C contains the waveform name. .wfm files are generated by the Keysight Signal Studio programs. .WAVEFORM files are common to user generated files for the Keysight MXG. When using this file type there should also be a .MARKER and .HEADER file with the same base name. The default files are located either in the program folder of the in the example waveform folder for the M9381A VSG. Files can be located anywhere as long as a valid path is specified in column B.

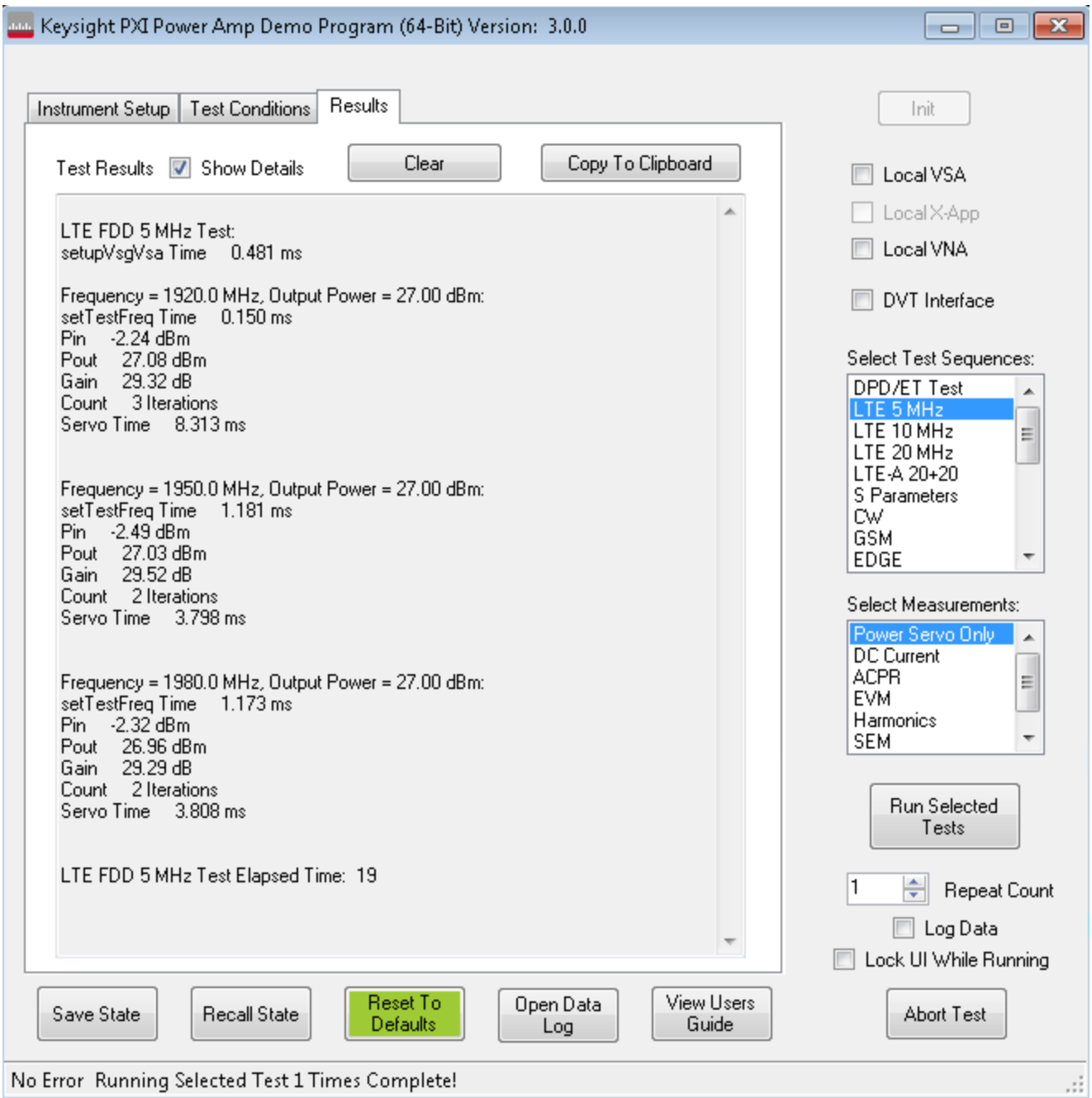
Running Tests

The tests to be run are selected from the **Select Standards** and **Select Measurements** lists. Both the lists allow selection of multiple items. The items do not need to be consecutive in the lists. For example, WCDMA and LTE 5 MHz can be selected from the standards list and ACPR and Harmonics can be selected from the measurement lists.

The program uses both the IVI drivers and the M90XA X-Series Applications software for measurements with the M9391A and M9393A PXIe VSAs. Power Servo, ACPR and Harmonics measurements are performed using the IVI driver. EVM measurements for all standards and SEM measurements for WLAN standards are performed using the X-Series Applications software. For GSM and EDGE, if ACPR and EVM are selected, the X-Series App Combined Measurement will be used for EVM and ORFS.

When using X-Series Applications software, the X-Series App display can optionally be shown. If shown, the display is visible in a separate window. To obtain the best throughput, the display should not be visible. The option to select the visibility can be changed at any time that tests are not running.

After selecting the desired values from these lists, the tests are performed by clicking **Run Selected Tests**. After running the tests, the user interface switches to the test **Results** tab as shown in the following screen shot:



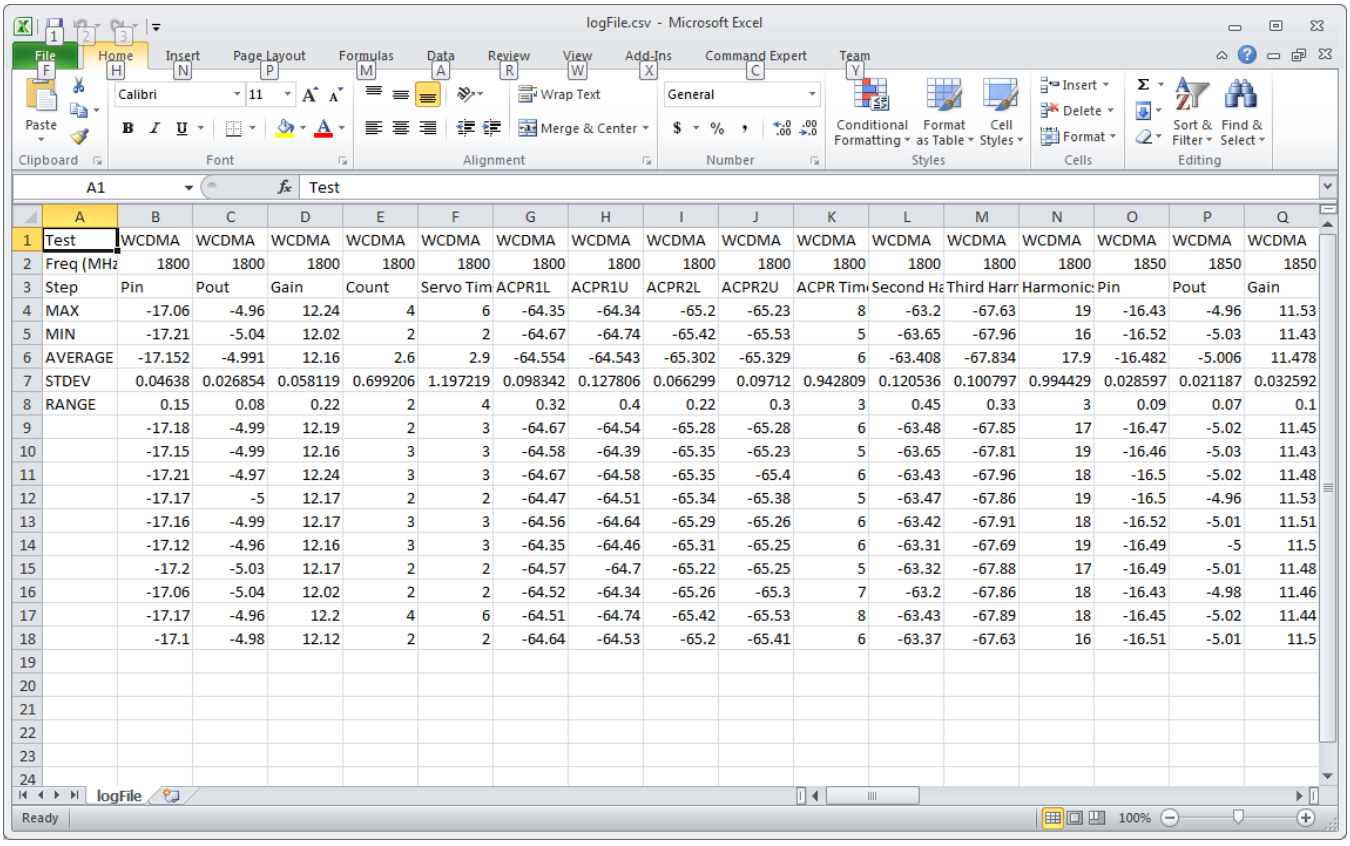
For each test, the test conditions, measured values and test times are shown in the results display. The total test time for each standard is shown at the end of the

results for that standard. Showing the results in the GUI can be omitted by clearing the **Show Details** check box. This improves the test time by omitting the occasional test time increases when the GUI thread is writing the results. To further reduce any GUI event handling, select the **Lock GUI While Running** check box.

Abort Test can be used to terminate the tests. The tests are terminated at the completion of the current repetition, not immediately after Abort Test is clicked. Abort Test does not operate when the Lock UI While Running check box is selected.

The **Repeat Count** field and the **Log Data** check box can be used to record measurement results and statistical variations of measured values.

To collect measurement repeatability data, set the repeat count to the desired value, select the **Log Data** check box and set the Target Increment in the Servo Loop Settings section to 0 dB. The program generate a CSV file that includes headers, all test results and formulas for statistics. The data files will be in C:\Temp. A new file is generated each time **Run Selected Tests** is clicked if the log data box is selected. The file names will be logFile[TimeStamp].csv. The most recent data file can be loaded by clicking Open Data Log. This launches the default program for .CSV files on the PC. The following screen shot shows the file loaded into Microsoft Excel:

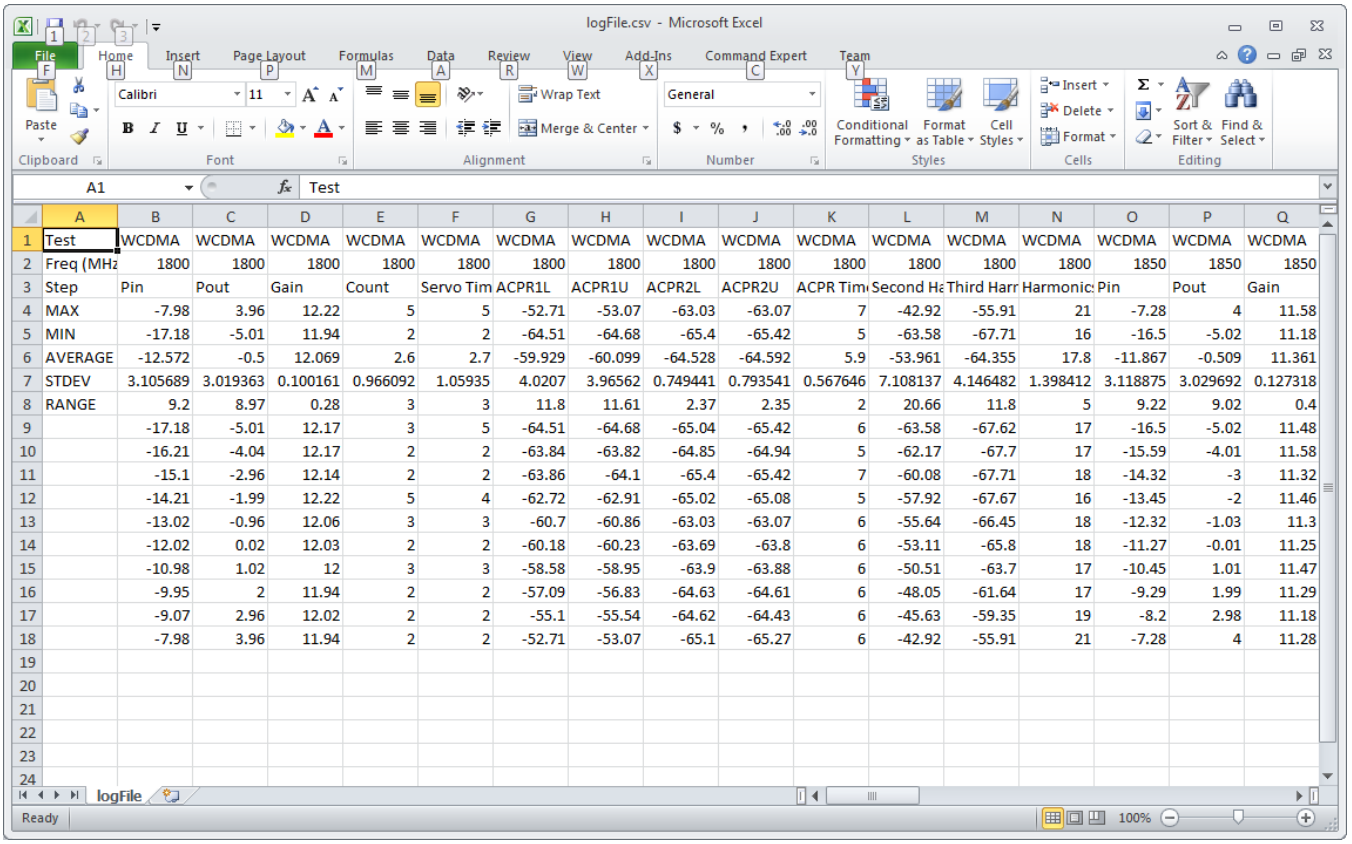


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Test	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA
2	Freq (MHz	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1850	1850	1850
3	Step	Pin	Pout	Gain	Count	Servo Tim	ACPR1L	ACPR1U	ACPR2L	ACPR2U	ACPR Tim	Second Ha	Third Harr	Harmonic	Pin	Pout	Gain
4	MAX	-17.06	-4.96	12.24	4	6	-64.35	-64.34	-65.2	-65.23	8	-63.2	-67.63	19	-16.43	-4.96	11.53
5	MIN	-17.21	-5.04	12.02	2	2	-64.67	-64.74	-65.42	-65.53	5	-63.65	-67.96	16	-16.52	-5.03	11.43
6	AVERAGE	-17.152	-4.991	12.16	2.6	2.9	-64.554	-64.543	-65.302	-65.329	6	-63.408	-67.834	17.9	-16.482	-5.006	11.478
7	STDEV	0.04638	0.026854	0.058119	0.699206	1.197219	0.098342	0.127806	0.066299	0.09712	0.942809	0.120536	0.100797	0.994429	0.028597	0.021187	0.032592
8	RANGE	0.15	0.08	0.22	2	4	0.32	0.4	0.22	0.3	3	0.45	0.33	3	0.09	0.07	0.1
9		-17.18	-4.99	12.19	2	3	-64.67	-64.54	-65.28	-65.28	6	-63.48	-67.85	17	-16.47	-5.02	11.45
10		-17.15	-4.99	12.16	3	3	-64.58	-64.39	-65.35	-65.23	5	-63.65	-67.81	19	-16.46	-5.03	11.43
11		-17.21	-4.97	12.24	3	3	-64.67	-64.58	-65.35	-65.4	6	-63.43	-67.96	18	-16.5	-5.02	11.48
12		-17.17	-5	12.17	2	2	-64.47	-64.51	-65.34	-65.38	5	-63.47	-67.86	19	-16.5	-4.96	11.53
13		-17.16	-4.99	12.17	3	3	-64.56	-64.64	-65.29	-65.26	6	-63.42	-67.91	18	-16.52	-5.01	11.51
14		-17.12	-4.96	12.16	3	3	-64.35	-64.46	-65.31	-65.25	6	-63.31	-67.69	19	-16.49	-5	11.5
15		-17.2	-5.03	12.17	2	2	-64.57	-64.7	-65.22	-65.25	5	-63.32	-67.88	17	-16.49	-5.01	11.48
16		-17.06	-5.04	12.02	2	2	-64.52	-64.34	-65.26	-65.3	7	-63.2	-67.86	18	-16.43	-4.98	11.46
17		-17.17	-4.96	12.2	4	6	-64.51	-64.74	-65.42	-65.53	8	-63.43	-67.89	18	-16.45	-5.02	11.44
18		-17.1	-4.98	12.12	2	2	-64.64	-64.53	-65.2	-65.41	6	-63.37	-67.63	16	-16.51	-5.01	11.5
19																	
20																	
21																	
22																	
23																	
24																	

Each column will include the measured values for one measurement at one test condition. Rows 1-3 include the test name, frequency and parameter name. Rows 4-8 include statistics. Each row below row 8 will include the data for one repetition of the measurements. The S-Parameter setup data information can be included in the

log file by selecting that option in the PXI VSA setup tab. This is useful when comparing measurement and test time results with multiple different setup conditions.

To collect data for different DUT output power levels, set the Target Increment value to the desired value, such as 1 dB. The following screen shot shows the log file from these test conditions:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Test	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA	WCDMA
2	Freq (MHz	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1850	1850	1850
3	Step	Pin	Pout	Gain	Count	Servo Tim	ACPR1L	ACPR1U	ACPR2L	ACPR2U	ACPR Tim	Second Ha	Third Harr	Harmonic	Pin	Pout	Gain
4	MAX	-7.98	3.96	12.22	5	5	-52.71	-53.07	-63.03	-63.07	7	-42.92	-55.91	21	-7.28	4	11.58
5	MIN	-17.18	-5.01	11.94	2	2	-64.51	-64.68	-65.4	-65.42	5	-63.58	-67.71	16	-16.5	-5.02	11.18
6	AVERAGE	-12.572	-0.5	12.069	2.6	2.7	-59.929	-60.099	-64.528	-64.592	5.9	-53.961	-64.355	17.8	-11.867	-0.509	11.361
7	STDEV	3.105689	3.019363	0.100161	0.966092	1.05935	4.0207	3.96562	0.749441	0.793541	0.567646	7.108137	4.146482	1.398412	3.118875	3.029692	0.127318
8	RANGE	9.2	8.97	0.28	3	3	11.8	11.61	2.37	2.35	2	20.66	11.8	5	9.22	9.02	0.4
9		-17.18	-5.01	12.17	3	5	-64.51	-64.68	-65.04	-65.42	6	-63.58	-67.62	17	-16.5	-5.02	11.48
10		-16.21	-4.04	12.17	2	2	-63.84	-63.82	-64.85	-64.94	5	-62.17	-67.7	17	-15.59	-4.01	11.58
11		-15.1	-2.96	12.14	2	2	-63.86	-64.1	-65.4	-65.42	7	-60.08	-67.71	18	-14.32	-3	11.32
12		-14.21	-1.99	12.22	5	4	-62.72	-62.91	-65.02	-65.08	5	-57.92	-67.67	16	-13.45	-2	11.46
13		-13.02	-0.96	12.06	3	3	-60.7	-60.86	-63.03	-63.07	6	-55.64	-66.45	18	-12.32	-1.03	11.3
14		-12.02	0.02	12.03	2	2	-60.18	-60.23	-63.69	-63.8	6	-53.11	-65.8	18	-11.27	-0.01	11.25
15		-10.98	1.02	12	3	3	-58.58	-58.95	-63.9	-63.88	6	-50.51	-63.7	17	-10.45	1.01	11.47
16		-9.95	2	11.94	2	2	-57.09	-56.83	-64.63	-64.61	6	-48.05	-61.64	17	-9.29	1.99	11.29
17		-9.07	2.96	12.02	2	2	-55.1	-55.54	-64.62	-64.43	6	-45.63	-59.35	19	-8.2	2.98	11.18
18		-7.98	3.96	11.94	2	2	-52.71	-53.07	-65.1	-65.27	6	-42.92	-55.91	21	-7.28	4	11.28
19																	
20																	
21																	
22																	
23																	
24																	

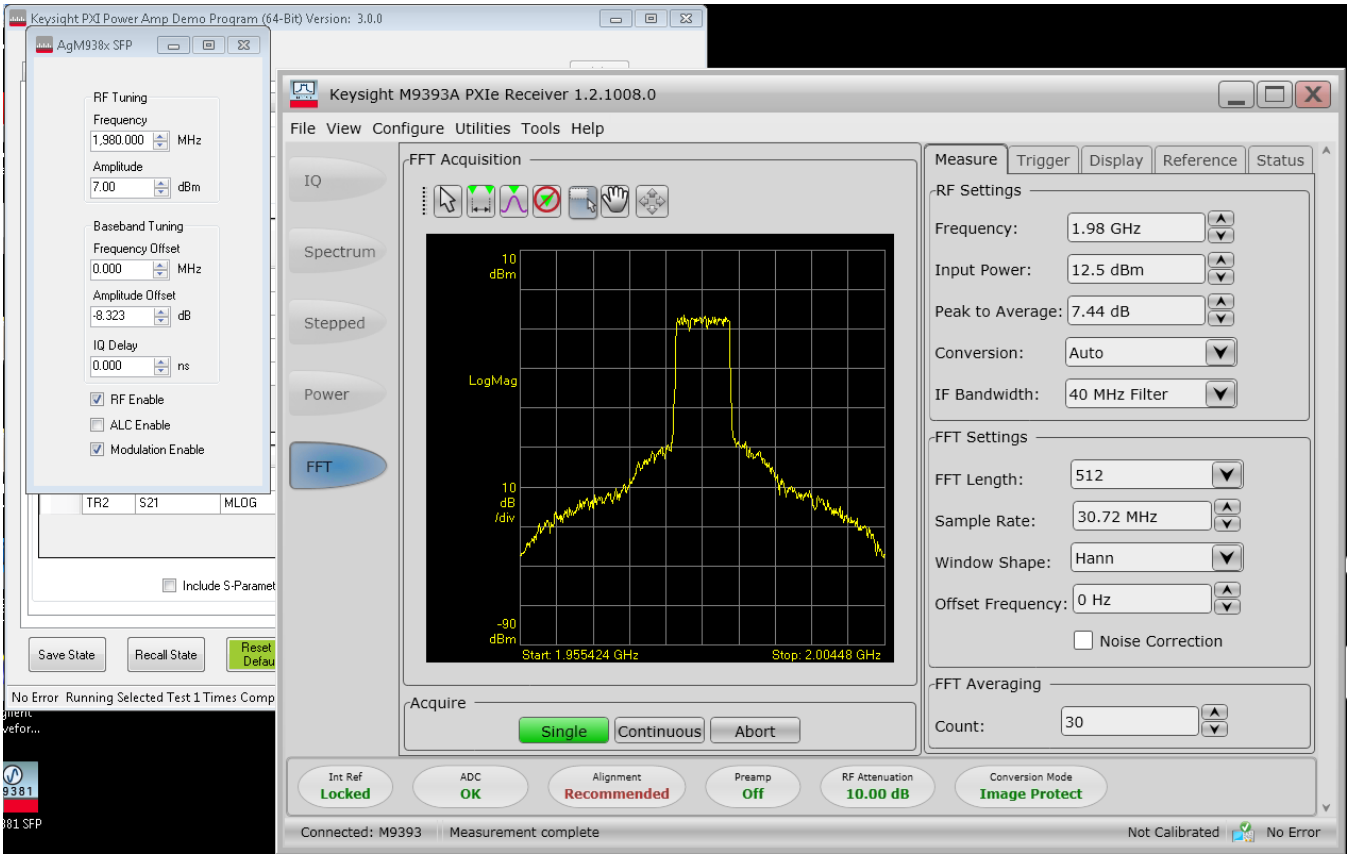
Note that the statistics are still calculated in this test, however the values will not be a true indication of measurement repeatability since the test condition is different for each repetition of the tests.

Local Control of Instruments

The PA Demo program allows interactive use of the PXI VNA, VSG, VSA and X-Series Applications software. After the selected tests are run, the program maintains the conditions of the last measurement. To go into local mode, select the **Local X-App**, **Local VSA** or **Local VNA** check box.

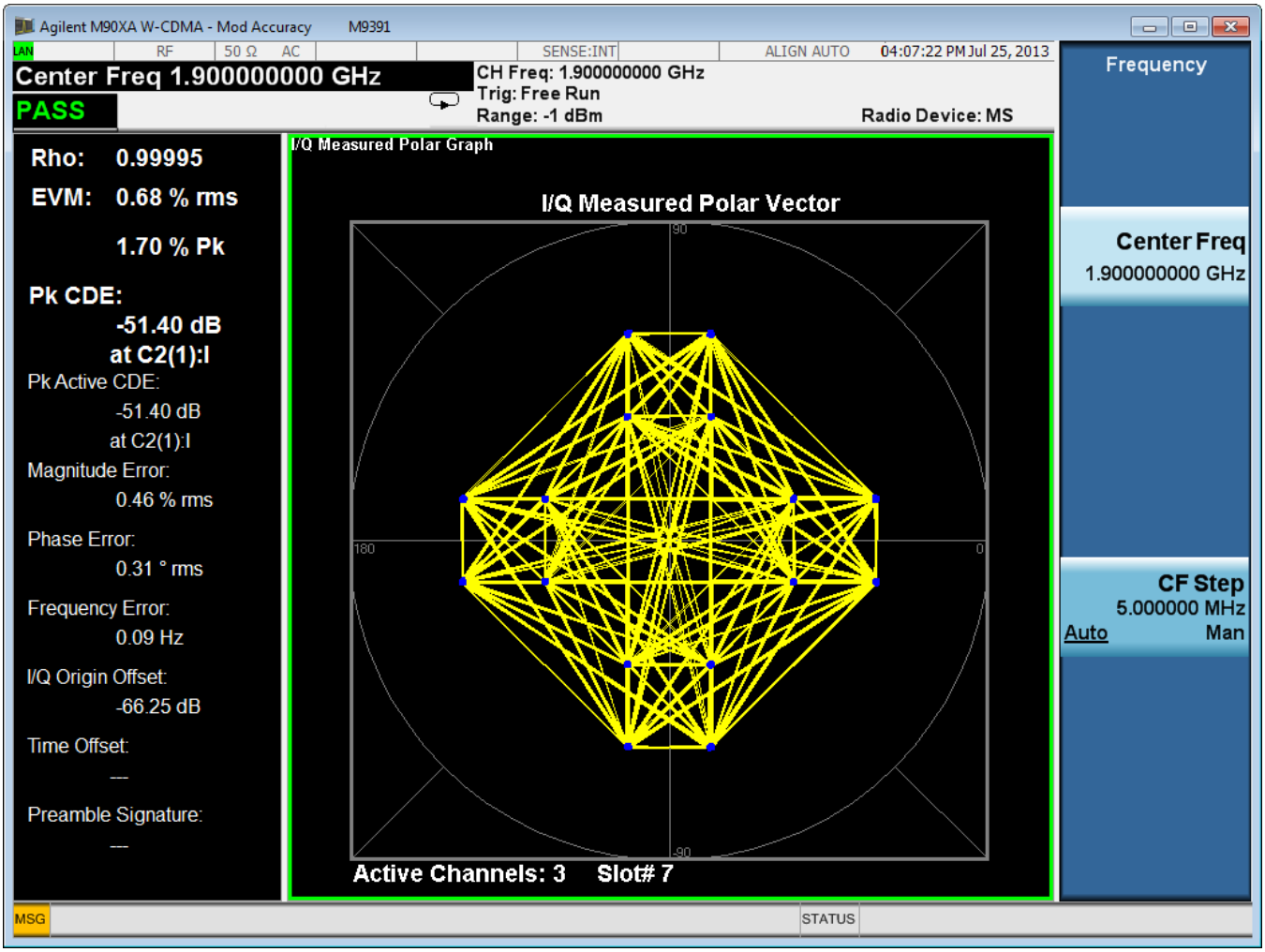
When the Local VSA check box is checked, two windows are shown. The first window shows the state of the M9381A and allow the displayed settings to be modified. For the M9391A, the second window shows the state of the VSA IVI driver, enables settings to be changed, and enables measurements to be performed in the each of the acquisition modes. The tabbed area of the PXI VSA SFP automatically changes to

the selected acquisition mode. For the M9393A, the SPF is launched with the current state of the IVI driver. The M9393A SFP can also be used to adjust settings and make additional measurements. The M9381A window and M9393A SFP are shown below:



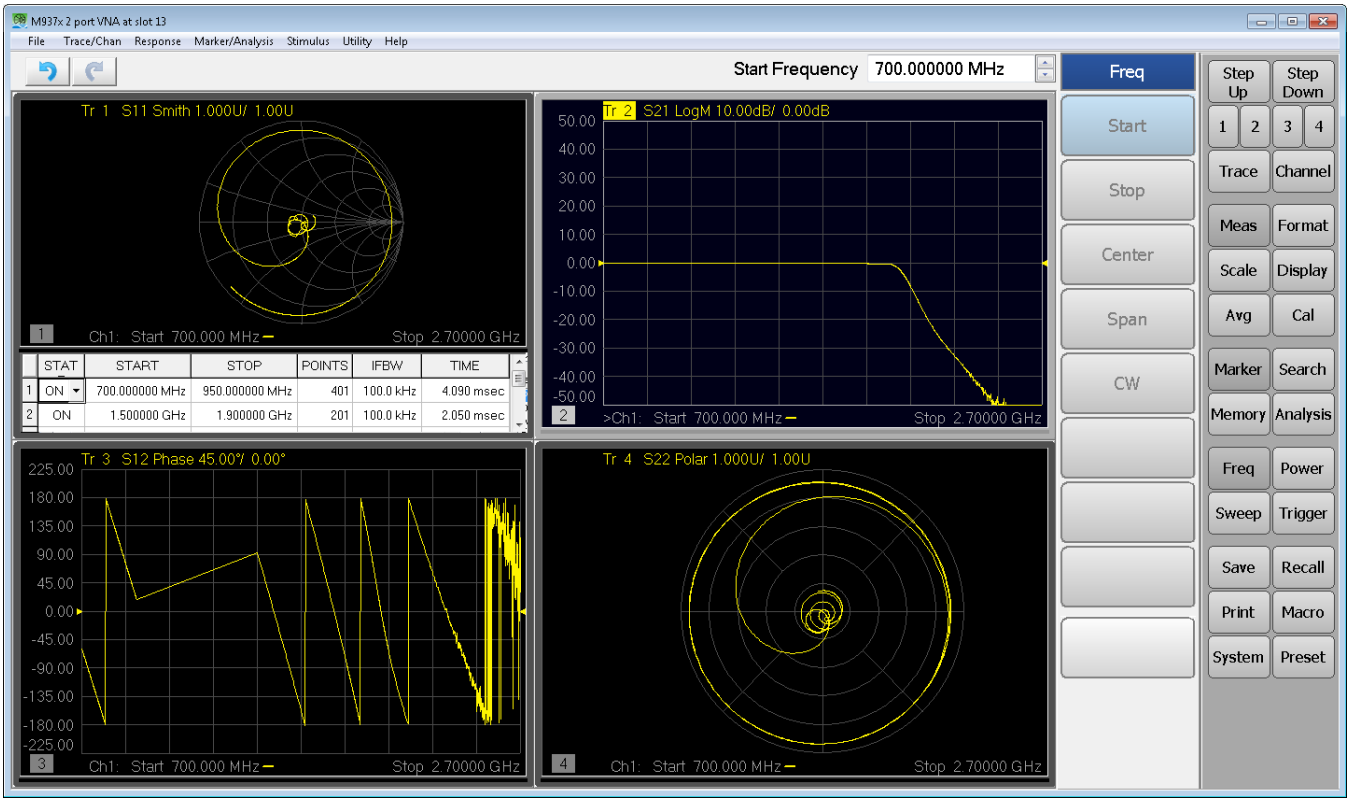
While local mode is enabled, the **Run Selected Tests** button is disabled. To end local control, clear the **Local VSA** check box.

When the Local X-App box is checked, the PXIe VSG display is shown as above and the X-App display is shown and the X-Series App is put in continuous sweep mode, as shown in the following screen shot.



When local mode is enabled, the Run Selected Tests button is disabled. To end local control, clear the Local X-App check box.

When the Local VNA box is selected, the PXI VNA is placed in a continuous sweep mode. Again, while local mode is enabled, the Run Selected Tests button is disabled. To end local control, clear the Local VNA box.



S-Parameter Measurements Using the M937xA PXI VNA

S-Parameter measurements are made by selecting “S-Parameters” from the standards menu. No selection in the measurements menu is required. The parameters measured are configured in the VNA setup file described above. For each S-Parameter measured, the minimum and maximum values are displayed in the results.

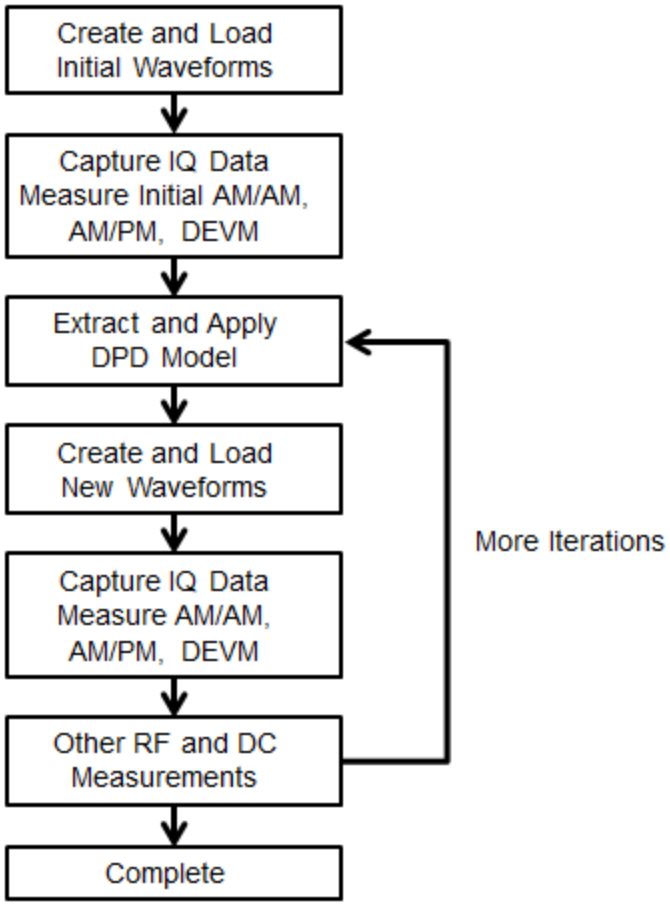
Two use models are supported when multiple PXI VNA cards are installed in the PXI chassis. Multiple cards can be configured for one multi-port VNA or as several 2-port VNAs. Depending on the DUT and test conditions, either configuration may provide the best results. The multi-port VNA allows S-Parameter measurements between any combinations of ports. For example, with 3 cards there will be 6 ports in the multi-port VNA. Ports 1 and 2 will be on the card furthest to the left in the chassis, followed by ports 3 and 4 in the next card and 5 and 6 in the third card. Match and transmission parameters can be measured between any ports - for example S51, S63, and S42. Since parameters such as S51 and S63 could interfere with each other, they will not be measured at the same time. Any collection of measurement can be defined in the trace section of the S-Parameter setup file used with the PA demo program.

The second use model is for multiple, parallel 2-port VNAs. In this use model, measurements can only be made between the two ports on one VNA card. However, measurements on different VNA cards can be made in parallel as they are

independent instruments in this configuration. In the configuration, the PA Demo will make the same measurements on each VNA card. These measurements can also be defined in the S-Parameter setup file for the PA Demo Program. Measurements defined for this mode can only reference ports 1 and 2.

Digital Pre-distortion and Envelope Tracking Using M9451A or N7614B

The Digital Pre-distortion model extraction and Envelope Tracking signal setup are performed by selecting "DPD/ET Test" from the select test sequences menu. The following diagram shows the basic test flow of the DPD/ET procedure:



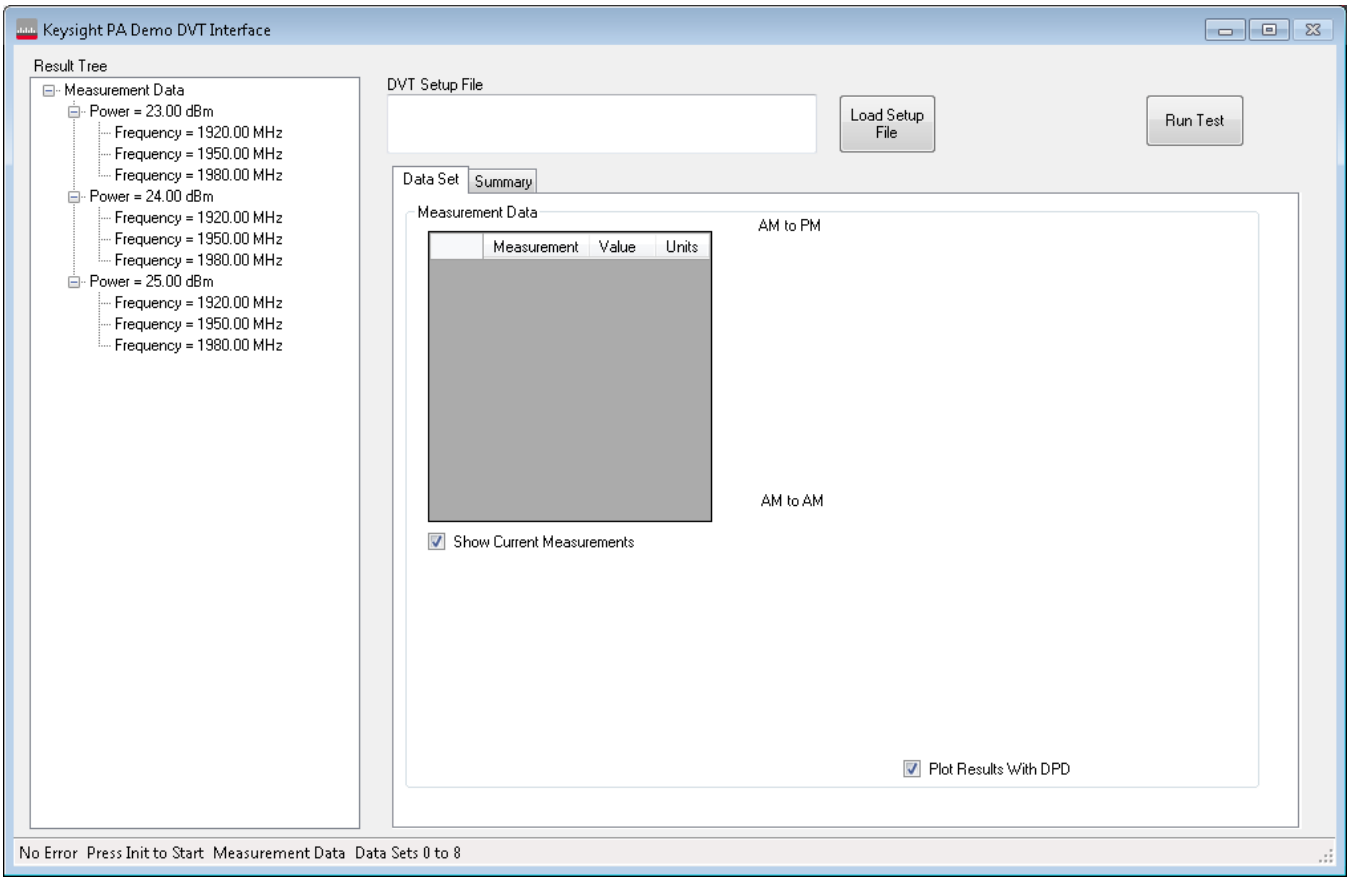
This procedure is only run for the first frequency in the cellular frequency table. ACPR, EVM DC Current and PA tests can also be run as part of the DPD/ET procedure by selecting these measurements from the Select Measurements menu. If ACPR is selected, it is run both before and after the DPD model is applied. The EVM measurement is provided as Delta EVM from the DPD module or software, not X-Application EVM.

With version 3.0, DPD and ET can be used with a wider variety of waveforms, but DPD and ET are only available when running the DPD/ET Test sequence.

Keysight N7614B Signal Studio for PA Test software application is used via the programming API to generate the up-sampled reference waveform in the demo program to allow maximum flexibility, even when the M9451A Measurement Acceleration module is in use. In production or DVT testing, the reference waveforms can be developed ahead of time, avoiding the time to generate these waveforms each time a test is run.

Design Validation Test (DVT) Interface

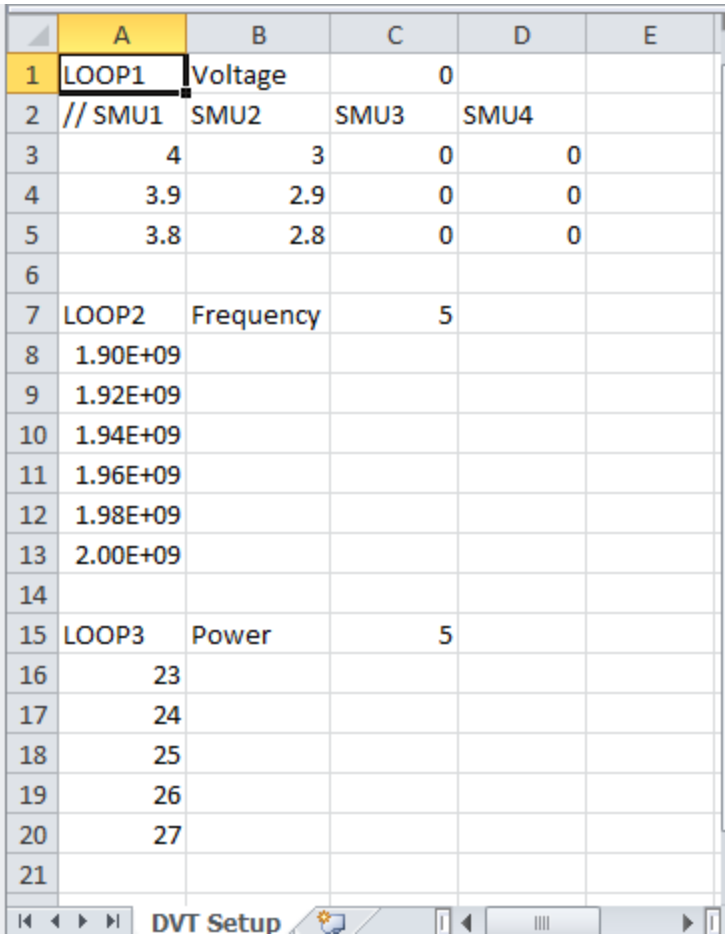
The LTE DPD and ET testing is typically performed as part of design validation testing, not as part of a product test. To better demonstrate this capability, we have added a DVT Interface to the PA Demo Program. The DVT interface allows running one test from the selected standards menu over multiple test conditions, defined in two or three nested loops. The DVT Interface is selected by selecting the DVT Interface check box on the right side of the main GUI. When the DVT Interface is started, the following GUI is shown:



The DVT Interface has two main sections. The left hand side shows all of the test points that are measured in a tree structure. For the default value, the tree contains

two nested loops. The inner loop is each of the frequencies in the main GUI Cellular Frequency list. The outer loop is the DUT output level, with three values. These values are the level in the target output power field and 1 and 2 dB below that level.

The test points can be configured in a .CSV file that defines each of the three loops:

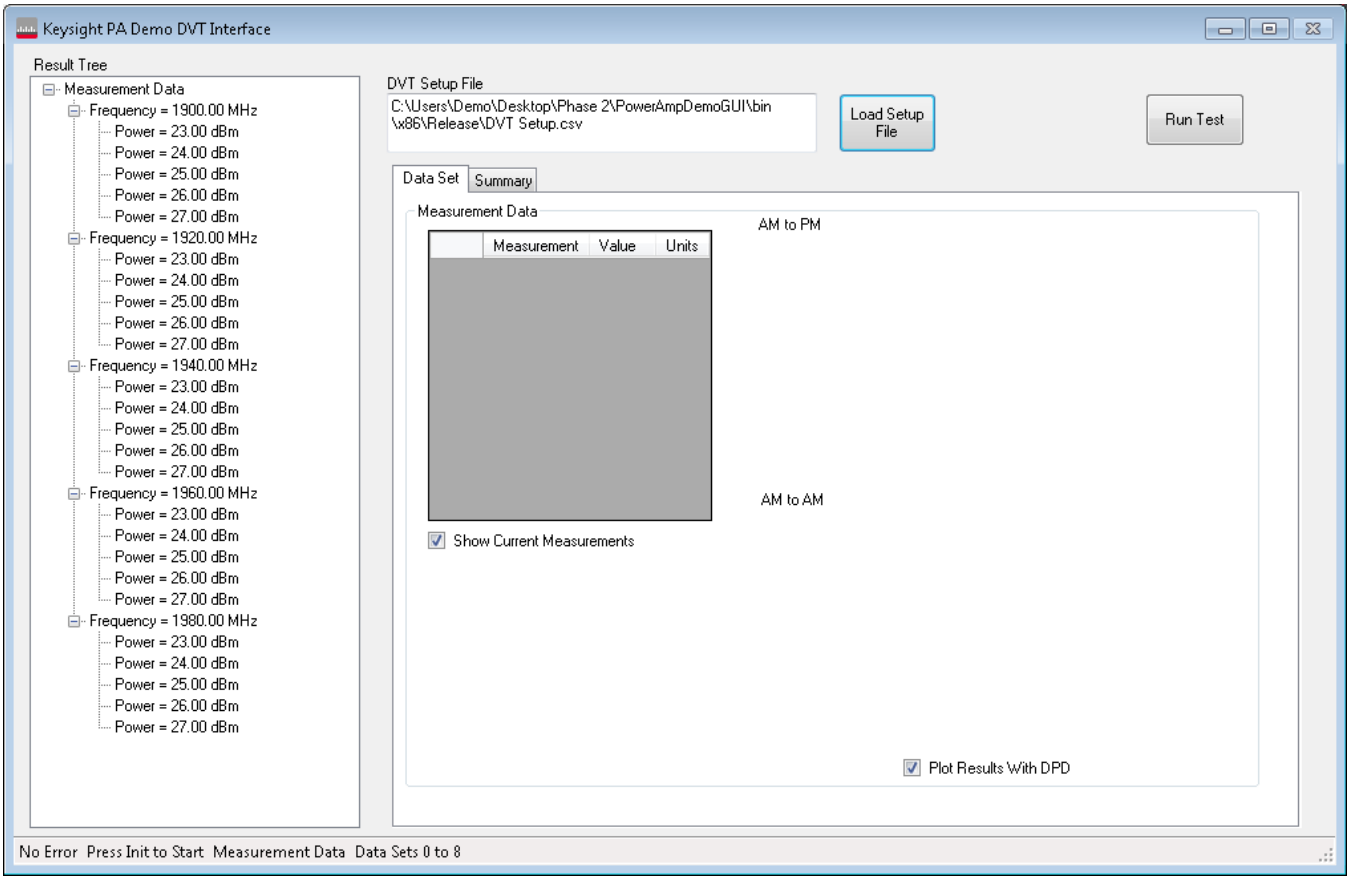


	A	B	C	D	E
1	LOOP1	Voltage	0		
2	// SMU1	SMU2	SMU3	SMU4	
3	4	3	0	0	
4	3.9	2.9	0	0	
5	3.8	2.8	0	0	
6					
7	LOOP2	Frequency	5		
8	1.90E+09				
9	1.92E+09				
10	1.94E+09				
11	1.96E+09				
12	1.98E+09				
13	2.00E+09				
14					
15	LOOP3	Power	5		
16	23				
17	24				
18	25				
19	26				
20	27				
21					

DVT Setup

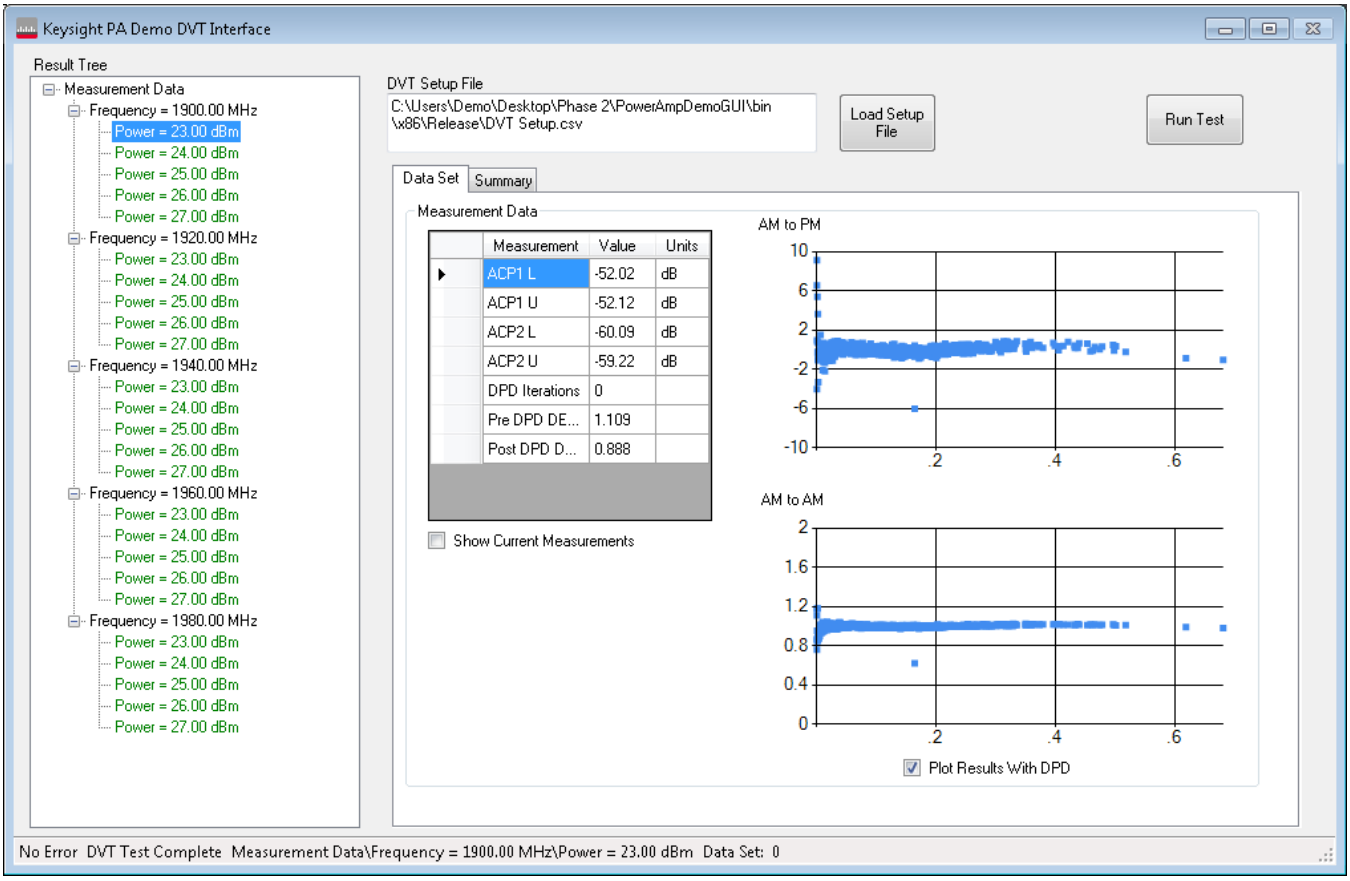
Each loop can be configured for DC voltages, RF Frequencies or DUT output power levels. The value in column C of rows 1, 7 and 15, as shown above, defines the number of steps in that loop. In the above example, there are only 2 nested loops as the count for loop 1 is zero.

To change the DVT setup, click **Load Setup File** and select the desired file name. Below is the GUI with the previous setup file loaded:

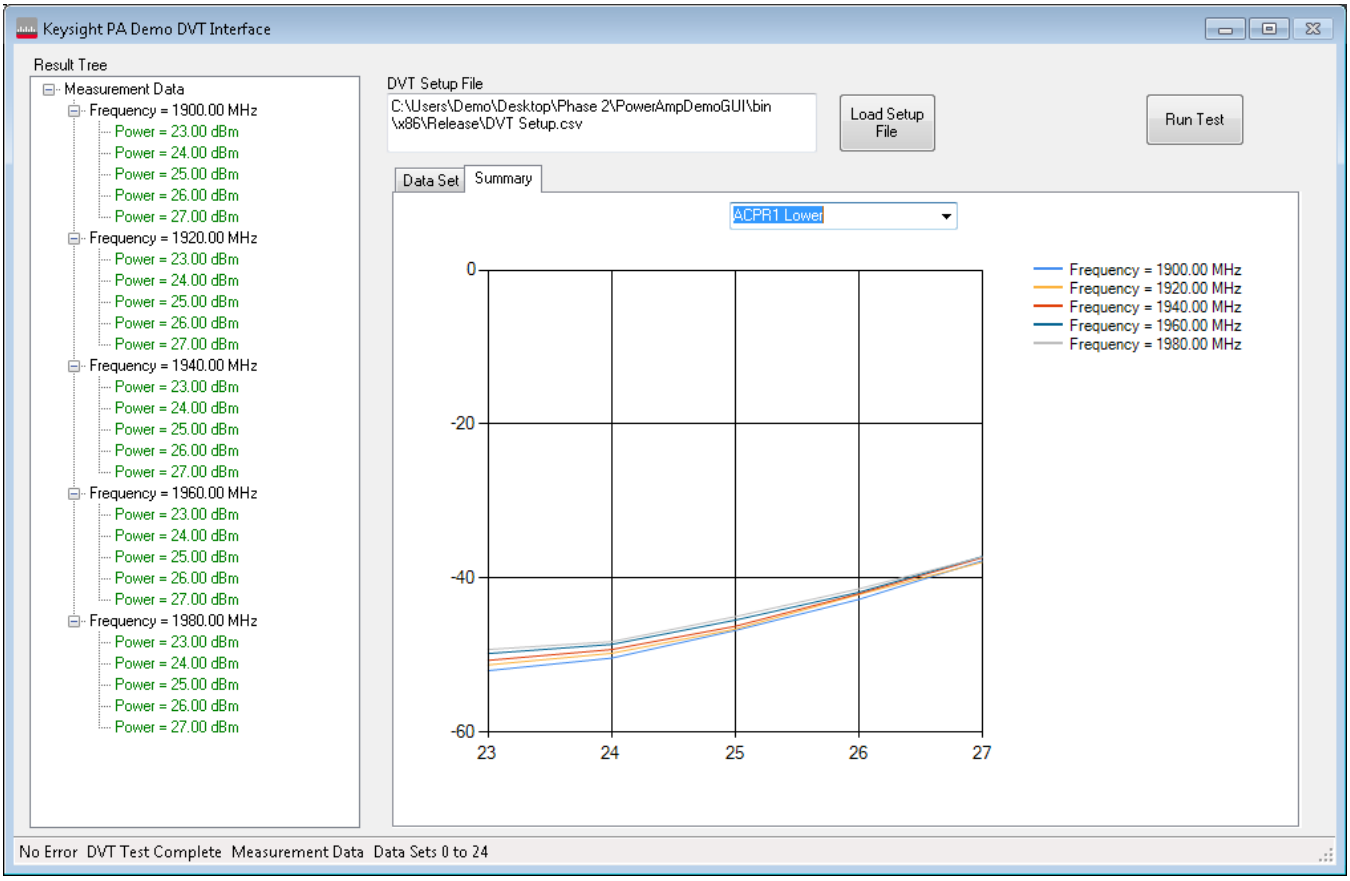


To start the DVT tests, click **Run Test**. This runs the first item highlighted in the Select Standards menu in the main GUI. Any measurements selected in the Select Measurements menu are run. The results are displayed in the Data Set tab as they are measured. In the Result Tree, the current test point changes to red font and then to green when the test point is complete. After the tests are complete, the data for any test point can be viewed by selecting that test in the tree.

For DPD/ET tests the plots of AM/AM conversion and AM/PM conversion are also be shown in the Data Set tab. These values can be viewed for the initial, undistorted waveform and after the DPD model extraction is complete.



Summary data for all of the test points can be viewed by switching from the Data Set tab to the Summary tab. In this view, the amount of data shown is determined by which node in the tree is selected and the plotted parameter is chosen from the drop down menu in the Summary tab:


Keysight PA Demo DVT Interface
Result Tree
Measurement Data
Frequency = 1900.00 MHz
Power = 23.00 dBm
Power = 24.00 dBm
Power = 25.00 dBm
Power = 26.00 dBm
Power = 27.00 dBm
Frequency = 1920.00 MHz
Power = 23.00 dBm
Power = 24.00 dBm
Power = 25.00 dBm
Power = 26.00 dBm
Power = 27.00 dBm
Frequency = 1940.00 MHz
Power = 23.00 dBm
Power = 24.00 dBm
Power = 25.00 dBm
Power = 26.00 dBm
Power = 27.00 dBm
Frequency = 1960.00 MHz
Power = 23.00 dBm
Power = 24.00 dBm
Power = 25.00 dBm
Power = 26.00 dBm
Power = 27.00 dBm
Frequency = 1980.00 MHz
Power = 23.00 dBm
Power = 24.00 dBm
Power = 25.00 dBm
Power = 26.00 dBm
Power = 27.00 dBm
DVT Setup File
C:\Users\Demo\Desktop\Phase 2\PowerAmpDemoGUI\bin\x86\Release\DVT Setup.csv
Load Setup File
Run Test
Data Set
Summary
ACPR1 Lower
0
-20
-40
-60
23
24
25
26
27
Frequency = 1900.00 MHz
Frequency = 1920.00 MHz
Frequency = 1940.00 MHz
Frequency = 1960.00 MHz
Frequency = 1980.00 MHz
No Error DVT Test Complete Measurement Data Data Sets 0 to 24

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