Startup
Guide

Keysight
Multi-Channel
Antenna Calibration
Reference Solution

KEYSIGHT
TECHNOLOGIES

Notices

Copyright Notice

Manual Part Number

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Regulatory Compliance

This product has been designed and tested in accordance with accepted industry standards, and has been supplied in a safe condition. To review the Declaration of Conformity, go to http://www.keysight.com/go/conformity.

Warranty

Technology Licenses

U.S. Government Rights

Safety Notices

CAUTION

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.

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.

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.
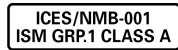
PRODUCT MARKINGS:

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.

**ICES/NMB-001
ISM GRP.1 CLASS A**

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).

KCC-REM-ATi-BLM0DSF01

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 (업 무용 방송통 신기자재) 이 기기는 업무용 (A 급) 전 자 파적합기기로서 판 매 자 또 는 사용자는 이 점을 주 의하시기 바라 며 , 가정외의 지역에서 사용하는 것을 목적으로 합니 다 .

This product complies with the WEEE Directive marketing requirement. The affixed product label (above) indicates that you must not discard this electrical/electronic product in domestic household waste. **Product Category**: With reference to the equipment types in the WEEE directive Annex 1, this product is classified as "Monitoring and Control instrumentation" product. Do not dispose in domestic household waste. To return unwanted products, contact your local Keysight office, or for more information see http://about.keysight.com/en/companyinfo/environment/takeback.shtml.

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.

Contents

Multi-Channel Antenna Calibration (MAC) Introduction

Smart antenna architectures incorporating multiple antenna elements in an array are used in many applications. Wireless communications standards like 802.11ac, radio astronomy and array RADARs are all examples of applications where multiple antennas are employed for various requirements derived from spatial signal processing. Though the types of processing used and beamforming techniques differ by application, there is a common test challenge. It is difficult to align the antennas in an array in phase and amplitude so they can be used together effectively. As the number of antennas increase in an array, the test time to do the alignment increases drastically.

This reference solution is built from modular components and is easily scalable to the number of antennas in the array being tested.Further, it provides parallelism to the test process to increase test throughput. The reference system described, offers flexibility to provide good sensitivity in both the wideband and narrowband measurement scenarios using the same hardware.

Typical System Performance

Feature	Value
Number of Digitizer Channels	8 to 104 depending on configuration
Measurement Throughput	1M narrowband measurements per second (40 channels)
Phase Coherence	‹1 degree across all channels
Non-decimated Bandwidth	600 MHz
Decimated Frequency Span (DDC)	300 MHz and 160/2n MHz (n=0,1,2, ... 18)
Measurement Frequency Range	DC – 40 GHz depending on down converters used (extended to 50GHz with additional calibration considerations)
Spurious Free Dynamic Range	– 60 dBc (typical) (non-decimated) – 80 dBc (typical) (30MHz decimated)
Effective Number of Bits	8.8 (typical)
Acquisition Memory	Up to 1 GSa/ch
Throughput	Use the N5193A when you require fast switchinf and phase coherency. 100 µs switching speed standard; optional 1 µs and 250 ns

The MAC Reference Solution

The following shows a typical MAC Reference Solution block diagram. .
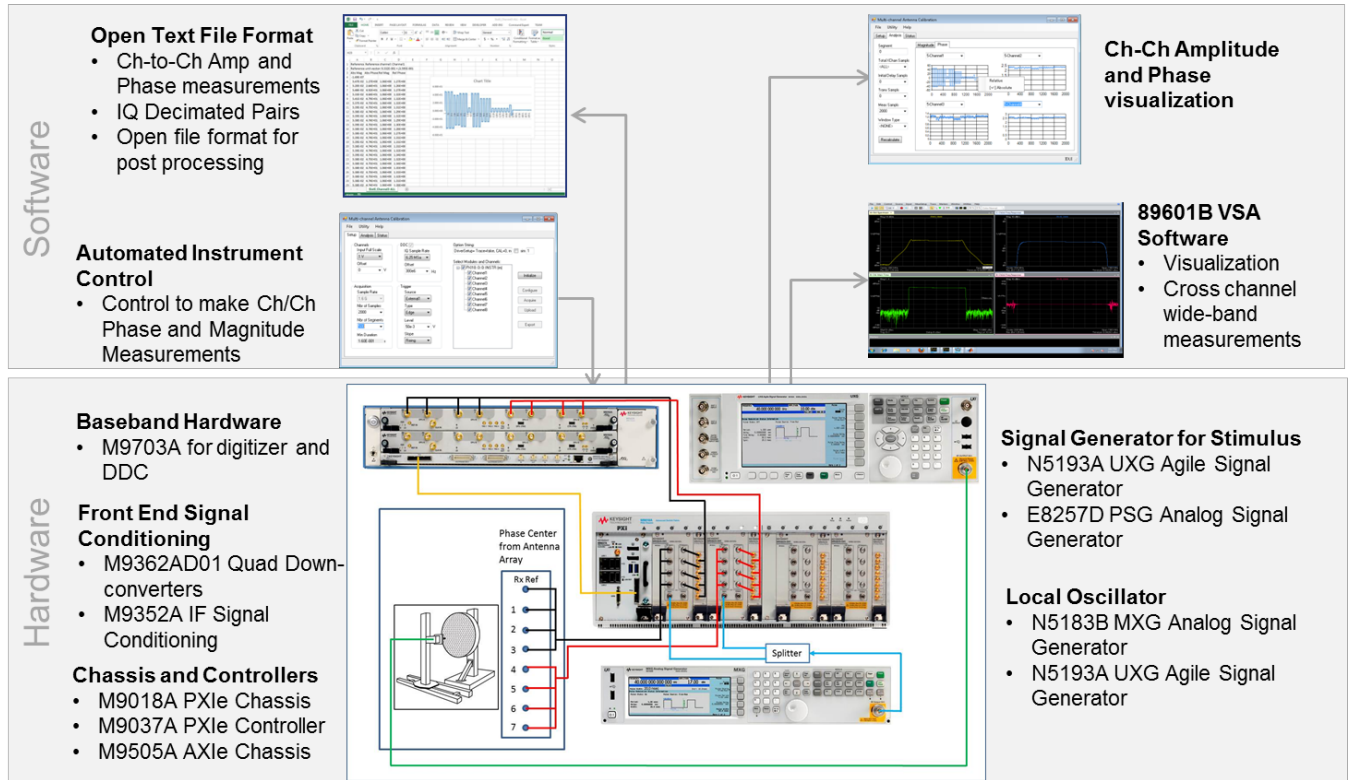
System Software

The MAC Demo Software has been been designed to assist in the development of the overall test system software.

System Hardware

The hardware components used to enhance the reference solution are selected to meet the needs of the test system being developed. Below are some of the modular hardware pieces commonly used to enhance a MAC Reference Solution.

The following documents will assist you in designing and configuring your MAC Reference Solution system:

- Solutions brochure
    - http://literature.cdn.keysight.com/litweb/pdf/5991-4537EN.pdf
- Configuration guide.
    - http://literature.cdn.keysight.com/litweb/pdf/5991-4583EN.pdf

M9703A AXIe High-Speed Digitizerr

M9536A AXIe Embedded Controller
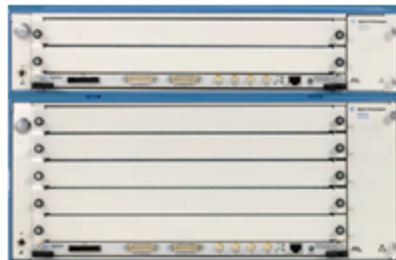
M9502A and M9505A AXIe Chassis

M9018A PXIe Chassis

N5183B MXG Analog Signal Generator

E8257D PSG Analog Signal Generator

M9037A PXIe Embedded Controller

M9352A PXI Amplifier/Attenuator

M9362A-D01 PXIe Microwave
Quad Downconverter

N5193A UXG Agile Signal Generator

Product specifications & characteristics

M9703A AXIe 12-bit digitizer/wide-band receiver

- 8 channels @ 1.6 GSa/s
- 2 GHz analog bandwidth
- Real-time digital downconversion (DDC)

The M9703A AXIe 12-Bit High-Speed Digitizer/Wideband Digital Receiver, based on the AXIe standard, is a revolutionary 8-channel, 12-bit digitizer, able to capture signals from DC up to 2 GHz at 1.6 GS/s. The interleaving capability of this high-speed digitizer allows waveform acquisition at up to 3.2 GS/s with exceptional measurement accuracy. It also provides very long acquisition capability by implementing up to 4 GBytes internal memory and real-time data processing with four Virtex 6 FPGAs.

The M9703A FPGAs feature an optional real-time digital downconverter (DDC), allowing tuning and zooming on the analyzed signal. The DDC improves the dynamic range, reduces the noise floor, and extends the capture time for an accelerated measurement speed. Combine this feature with the Keysight 89600 VSA software for advanced measurement analysis.

When scaling up, a system of 40 synchronous channels acquiring at 1.6 GS/s in only 4U of rack-mount space can be easily built by combining the M9703A with the M9505A 5-slot AXIe Chassis and U1092A AcqirisMAQS software.

- www.keysight.com/find/m9703a
- http://literature.cdn.keysight.com/litweb/pdf/M9703-90001.pdf

M9362A-D01 PXIe microwave quad downconverter

- 4 coherent channels
- 26.5 or 40 GHz frequency range
- 1.5 GHz analog bandwidth

The Keysight M9362AD01-F26 PXIe µW Quad-Downconverter, 10 MHz to 26.5 GHz is well suited for wideband signal capture where multiple channels are required for applications such as multi-channel coherent signal analysis, radar, SIGNIT, ELINT, MASINT, EW signal capture and analysis, and RF and microwave recording and analysis.

- http://literature.cdn.keysight.com/litweb/pdf/M9499-90001.pdf

M9352A PXI hybrid amplifier/attenuator

- 4 channels
- 1 GHz analog bandwidth
- http://literature.cdn.keysight.com/litweb/pdf/5990-9964EN.pdf

The Keysight M9352A PXI-H IF Amplifier/Attenuator, 10 MHz to 1 GHz is a one-slot, 4-channel, PXI Hybrid IF Amplifier/Attenuator with 1 GHz analog bandwidth providing IF signal conditioning for use in multi-channel modular solutions.

Combine with the M9362AD01-F26 PXIe µW Quad-Downconverter, up to four M9202A PXIe Wideband IF Digitizers, and a local oscillator for wideband signal capture where multiple channels are required for applications such as multi-channel coherent signal analysis.

The M9352A modules are custom built and tested to nominal* performance characteristics. Full regulatory and safety testing has been performed. This product has the same warranty and support services as other Keysight instruments. Because it is custom built, keysight recommends checking availability and delivery information before ordering the product.

*Nominal describes representative performance that is useful in the application of the product when operated over a 20 to 30 degree C temperature range. Nominal performance is not warranted.

- www.keysight.com/find/m9362a-d01
- www.keysight.com/find/m9352a

N5183B MXG microwave analog signal generator

- 13, 20, 31.8 or 40 GHz
- +20 dBm output power at 20 GHz
- Frequency switching time 600 µs, typical
- www.keysight.com/find/n5183b

N5193A UXG microwave agile signal generator

- 10 MHz, to 20 or 40 GHz
- +10 dBm output power with optional attenuator
- 100 µs switching speed standard; optional 1 µs and 250 nsl
- www.keysight.com/find/n5193a

E8257D PSG analog signal generator

- 20, 31.8, 40, 50 or 67 GHz
- +26 dBm output power at 20 GHz
- -143 dBc/Hz phase noise, typical (1 GHz signal)

The Keysight E8257D is a fully synthesized signal generator with high output power, low phase noise, and optional ramp sweep capability.

Specifications apply over a 0 to 55 °C range, unless otherwise stated, and apply after a 45 minute warm-up time. Supplemental characteristics, denoted as typical, nominal, or measured, provide additional (non-warranted) information at 25 °C, which may be useful in the application of the product.

Unless otherwise noted, this data sheet applies to units with serial numbers ending with 50420000 or greater.

- www.keysight.com/find/e8257d

M9703A 12-Bit High-Speed Digitizer

- http://literature.cdn.keysight.com/litweb/pdf/M9703-90001.pdf

Unpack and Inspect

CAUTION   The modules are shipped in materials which prevent damage from static. Modules should only be removed from the packaging in an anti-static area ensuring that correct anti-static precautions are taken. Store all modules in anti-static envelopes when not in use.

ESD

Electrostatic discharge (ESD) can damage or destroy electronic components. Use a static-safe work station to perform all work on electronic assemblies. The figure (below) shows a static-safe work station using two types of ESD protection: conductive table-mat and wrist-strap combination, and conductive floor-mat and heel-strap combination. Both types, when used together, provide a significant level of ESD protection. Of the two, only the table-mat and wrist-strap combination provides adequate ESD protection when used alone. To ensure user safety, the static-safe accessories must provide at least 1 MΩ of isolation from ground.

WARNING   DO NOT use these techniques for a static-safe work station when working on circuitry with a voltage potential greater than 500 volts.
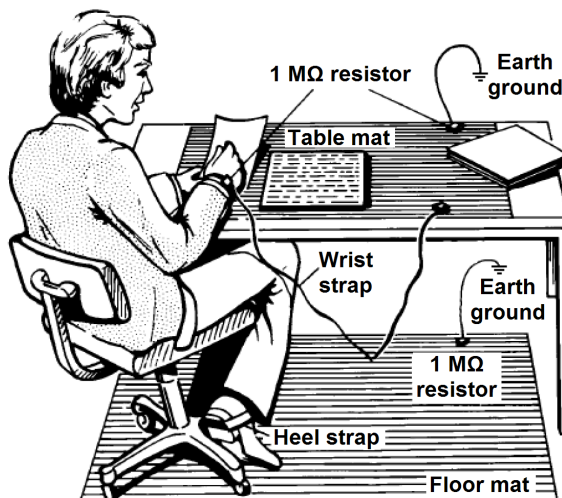
Inspect for Damage

After unpacking an instrument, inspect it for any shipping damage. Report any damage to the shipping agent immediately, as such damage is not covered by the warranty (see warranty information at beginning of this document).

CAUTION To avoid damage when handling a module, do not touch exposed connector pins.

NOTE See www.keysight.com/find/tips for information on preventing damage to your keysight equipment.

Return an Instrument for Service

Should it become necessary to return an instrument for repair or service, follow the steps below:

NOTE It is recommended that you return all modules and cables of the M9381A or M9391A instrument for repair and calibration. If your Keysight M9300A PXIe Frequency Reference is operating properly, you need not send it in with the other modules because your instrument may be repaired and calibrated without your M9300A. Doing so, however, will effect your calibration schedule, since repairs are followed by calibration. The Calibration Due Date for your M9300A will not match the date of your other modules.

1. Review the warranty information shipped with your product.
2. Contact Keysight to obtain a Return Material Authorization (RMA) and return address. For assistance finding Keysight contact information, go to www.key-sight.com/find/assist.
3. Write the following information on a tag and attach it to the malfunctioning equipment:
   - Name and address of owner. A P.O. box is not acceptable as a return address.
   - Module serial number(s). The serial number label is located on the side panel of the module. The serial number can also be read from the Soft Front Panel interface - <u>after</u> the hardware is installed.
   - Description of failure or service required.
4. Pack the instrument in its original packaging. Include all cables. If the original packaging material is not available, use anti-static bubble wrap or packing pea-

nuts and place the instrument in a sealed container and mark the container –FRAGILE–.

5. On the shipping label, write ATTENTION REPAIR DEPARTMENT and the RMA number.

> **NOTE** In your correspondence, refer to the modules by serial number and the instrument by model number.

PXIe Chassis and Modules

PXIe Chassis

The following two documents provide information on setting up the
- M9018A Startup Guide
    - http://literature.cdn.keysight.com/litweb/pdf/M9018-90001.pdf
- M9018A User's Guide
    - http://literature.cdn.keysight.com/litweb/pdf/M9018-90005.pdf

The M9018A Startup Guide is divided into the following sections:
- STEP 1: Verify the Shipment Contents—This section describes how a chassis system is shipped and what is included with the chassis itself.
- STEP 2: Prepare the Hardware and Install the Software—This section describes the computer hardware and software requirements, installation of an embedded controller, connection of a remote controller, and software installation on the controller.
- STEP 3: Turn On and Verify Operation of the Chassis System—This section describes how to use Connection Expert and the chassis soft front panel (SFP) to verify operation of the chassis.
- STEP 4: Overview of Installing and Verifying Keysight Modules—This section provides an overview of installing and verifying Keysight modules in the chassis, and is intended to supplement your module documentation.
- Appendix A: Chassis and Accessory Model Numbers—This appendix lists the model numbers of the chassis and its accessories.
- Appendix B: Chassis Specifications—This appendix provides several of the chassis technical specifications

The M9018A User's Guide provides more information than the Startup Guide, including the following:

- How to configure the M9018A chassis to meet your needs. Parameters such as the following can be configured:
- The PCIe link configuration: 1x8, 2x8, or 4x4
- Voltage limits around the power supply rails at which an alarm will be generated if a rail falls outside of its limit
- The temperature at which an alarm will be generated if the chassis exceeds this temperature
- The fan speed at which an alarm will be generated if a fan speed falls below this limit
- How to ensure that your modules don't exceed the chassis power supply capacity.
- Rack mounting of the chassis
- How to diagnose and troubleshoot issues with the chassis
- How to replace the power supply or the fan assembly

PXIe Modules

Each PXIe module ordered with the MAC Reference Solution will be accompanied with its own startup guide. The startup guide will detail the following:

- How to configure the controller module.
- How to load controller software
- How to install the module into the M9018A chassis.
- How to test the module.

AXIe Chassis and Modules

Introduction

The Keysight M9502A (2-slot) and M9505A (5-slot) AXIe chassis are modular instrument chassis fully compatible with the AXIe 1.0 specification. They allow multiple application-specific instrument modules to share a common chassis frame, power supply, cooling system, PCI Express (PCIe) Gen 2 data bus, Gigabit LAN hub, local bus for module-to-module signaling, and host PC connections. Multiple chassis may be interconnected for scalability, a feature Keysight calls MultiFrame. The full rack chassis provides two or five general purpose peripheral slots that accept 1U AXIe instrument modules. Each module slot has a Gen 2 x4 link (maximum of 2 GB/s data rate per module) to the chassis primary data 'fabric' hub—a x8 PCIe switch and data bus.

M9502A 2-Slot AXIe Chassis at a Glance

Designed for portable or small system testing, the M9502A is shipped with bumpers and a carry handle installed for benchtop use (these remove for rack mounting), Slot 1 open and a filler panel module installed in Slot 2. The front panel is shown below:
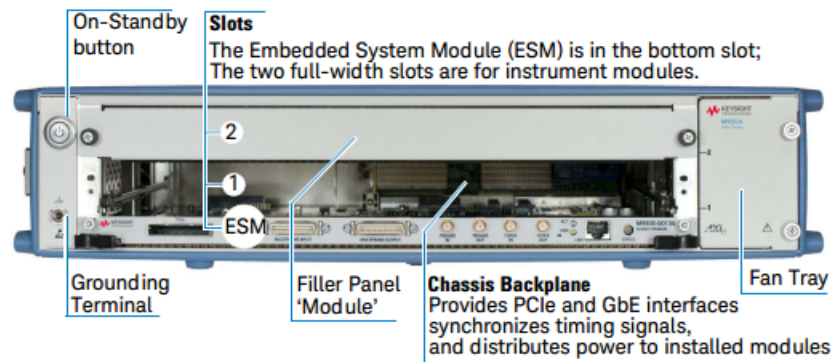
M9505A 5-Slot AXIe Chassis at a Glance

The M9505A is shipped with bumpers and two carry handles installed for benchtop use (these remove for rack mounting), Slot 1 open and filler panel modules installed in Slots 2 through 5. The front panel is shown below:
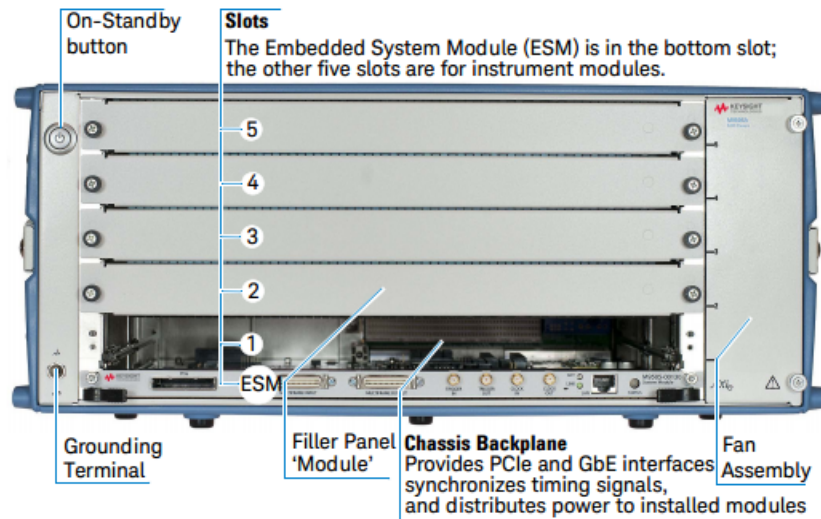
Chassis and Module Details

Detailed instructions for installation, configuration, operation, troubleshooting and service can be found in the M9502A/M9505A AXIe Chassis User Guide, provided in PDF format.

- http://literature.cdn.keysight.com/litweb/pdf/M9502-90001.pdf

Topics included in this manual are:

- – Introduction

  - M9502A 2-Slot AXIe Chassis at a Glance
  - M9505A 5-Slot AXIe Chassis at a Glance
  - AXIe Embedded System Module (ESM)
  - AXIe Embedded System Module (ESM) Option U20 with USB
  - AXIe Instrument Modules
  - AXIe System Block Diagram
  - Performing the Startup Steps

- Step 1: Unpack and Inspect the Chassis
  - Inspect for damage
  - If You Should Need to Return the Chassis for Service

- Step 2: Verify Shipment Contents
- Step 3: Power-Up and Power-Down

  - Circuit Breaker
  - ON/STANDBY Switch
  - Power Modes To Power Up the Chassis
  - To Power Down the Chassis

- Step 4: Set Up the Host PC

  - Hardware Connections to the Host PC

- Step 5: Install IO Libraries and Connect to the Web

  - Installing the Keysight IO Libraries Suite
  - Turning on the Chassis
  - Install Intel Network Driver on Windows XP
  - Using Keysight Connection Expert

- Step 6: Install the Chassis Software
- Step 7: Next steps

  - Host PC/Chassis Interface Topics
  - Safety-Related Specifications

MAC Demo Software

The MAC Demo Software has been designed to assist in the development of the overall test system software.

The MAC Demo Software is installed on the CD that accompanies the system (Y1299-10003). A program such as WinZip will need to be installed on you PC to unzip the MAC Demo Software.

To load and setup the MAC Demo Software from the CD, use the following procedure:

1. Insert and launch the Y1299-10003 CD on your PC
2. Once launched, select the Extract MAC Demo Software button on the Y1299-10003 CD browser
3. Unzip the self extracting zip file to a folder on your PC
4. Once extracted, navigate to the MultiAntennaArrayCalibration.exe file to run the demonstration software

In Win 8 the user should run the self-extracting zip file as administrator by manually opening CD. The user can then change the path of the directory for the self-extracting zip file.

In order to run the MultiAntennaArrayCalibration.exe correctly, the following software needs to be installed on your PC:

- NET framework4.5 (Visual Studio 2012) in Windows 7 or 8 (64 bit). You will be prompted to load this when selecting the MultiAntennaArrayCalibration.exe file
- The latest AgMD1 IVI driver software, which can be obtained from here:

  http://www.keysight.com/main/software.jspx?ckey=2000051&lc=eng&cc=US&nid=-11143.0.00&id=2000051

  Install the version 1.13.7 (this is the package version, whereas the DLL version inside is 1.6.4).

  If you want to try out the code in simulate mode, you also need to copy the included MACsim.dat file into your C:\tmp directory (create C:\tmp if you don't already have this folder).

Setup tab
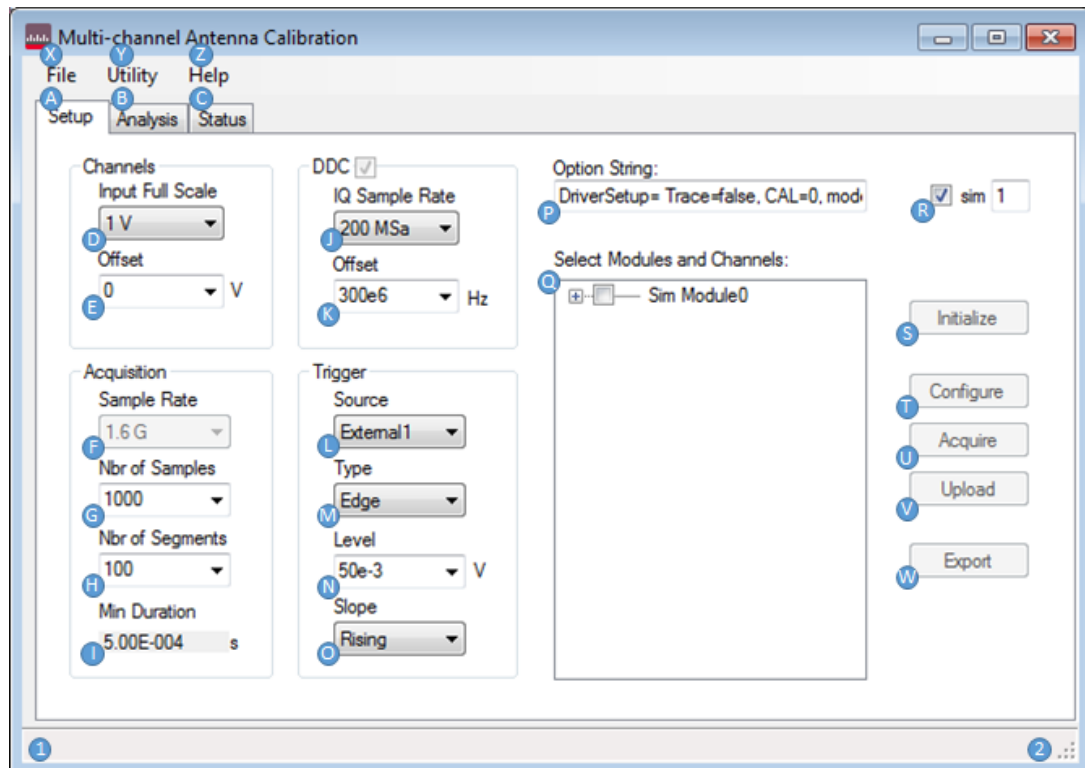
A – Setup tab is used to configure and control the data acquisition of one or more M9703A IF digitizers.

B – The Analysis tab is used to view and parameterize the measurement interval windows that are used (based on the number of samples) for cross channel ratios.

C – Status tab displays information about active M9703A digitizer sessions, and tracks state execution details with time tags during the data acquisition process.

D – Input Full Scale range selection allows the user to choose a full scale range in Volts for the M9703A(s). This is the range of voltages (centered at Offset) over which the 12-bit ADC quantization steps occur. For M9703A this is either 1V or 2V.

E – Offset voltage is the center of the range covered by the ADC quantization steps. Default is 0V (0V DC offset).

F – Sample Rate is the rate at which the raw ADC samples are made. This is always 1.6 Gsa/s for the M9703A with –SR2 sampling rate option (only supported sample rate for MAC currently).

G – Nbr of Samples is the number of samples per segment that the digitizer will

$$\frac{1}{IQ\ Sample\ Rate} * Nbr\ of\ Samples\ * Nbr\ of\ Segments = Min\ Duration$$

acquire.

H – Nbr of Segments is the number of segments in segmented memory mode that will be acquired (one segment per occurrence of trigger event).

I – Min Duration is the minimum duration of acquisition assuming back to back triggers

$$\frac{1}{IQ\ Sample\ Rate} * Nbr\ of\ Samples\ * Nbr\ of\ Segments = Min\ Duration$$

with no gaps.

This field will update if you click on it. It is not auto-updated due to dependencies on other GUI controls, each of whih would try to update the text in this label.

J – IQ Sample Rate is the effective sample rate at which I&Q pairs get stored into the M9703A digitizer's RAM. This is a configuration parameter for the –DDC option which is a required option for MAC. This property can also be set as an IF bandwidth rather than sample rate by changing properites in Utiltiy...Properties menu (see separate documentation on Properties dialog)

K – Offset is the DDC center frequency. It determines where in the M9703As passband that the IF signal is centered.

L – Source (trigger) is the input that drives the trigger for the acquisition(s) by the M9703A digitizer. Options include External1 and M-Channel1...Channel8 (where M stands for master module in a multi-module set).

M – Type (trigger) is used to specify what criteria the trigger will fire on. The options include Edge and Magnitude. The magnitude trigger is NOT compatible with segmented memory as it is part of the DDC and that logic exists downstream of the trigger subsystem in the M9703A architecture. It should also be noted that the MAC software has intelligence built into auto trigger if a timeout occurs with the specified trigger (timeout is set in the Utility...Preferences dialog) and Nbr of Segments = 1. Note: you cannot software trigger the M9703A with more than one segment configured.

N – Level (trigger) is used to specify the voltage level for an edge trigger type.

O – Slope (trigger) is used to distinguish between rising and falling edges when trigger type is set to edge.

P – Option string is the option string literal that is passed to the M9703A IVI-COM driver on initialization. Do NOT change this unless you have consulted the MD1 IVI-COM driver help and clearly understand the syntax because changes can cause seemingly unusual or unpredictable behavior. The default is: DriverSetup= Trace=false, CAL=0, model=M9703A

Q – Select Modules and Channels is a custom control used to pick the M9703A digitizers (from an auto-populated list of already found M9703As) and the associated acquisition channels on each M9703A module. When using this control it is required that you right click one module and signify it as the master module (M) of the acquisition set (even if you are only using one module). You also must right click one channel from the combined set and designate it as the reference channel (R), which will be the channel relative to which all cross-channel magnitude and phase measurement are made to.

R – sim is a radio control that allows the user to use simulated M9703A modules. By entering a number of simulated modules in the box to the right of sim and then checking the box at the left, the modules and channels control is cleared and repopulated with virtual (simulated) instances of M9703A modules. Simulation mode DOES require the MD1 IVI-COM driver to be already installed as the IVI-COM driver functionality is used to initialize simulated driver sessions to confirm the IVI-COM driver is installed properly. This simulation mode also relies on the user copying the macsim.dat file (found in the main installation folder for MAC into the C:\tmp directory) as simulated waveform I&Q samples to be used in analysis. In simulation mode, the same basic operational flow is in place, but the expected result will always be flat 1 cross-channel magnitude and a fixed phase offset from each subsequent channel in the channel list (above or below the reference channel) of +/- and additive 0.5 degrees. This phase offset is actually modulated into the record for purposes of simulation testing of the algorithms in MAC and can be changed to something other than 0.5 degrees quite easily in the source code.

S – Initialize is the first button pressed after all setup parameters in the Setup tab have been configured. The initialize button will remain disabled until at least one channel is selected from the modules and channels list. Initialize will initialize as many M9703A IVI-COM driver sessions as modules chosen in the Select Modules and Channels control. It will also run a self test for each session if that options is specified in the Utility...Preferences dialog. Status including time tags is available in the Status tab, and brief state messages will also show in the state display (2) of the GUI.

T – Configure is the second button pressed in the GUI (after Initialize), when using actual M9703A hardware. In simulate mode, the configure step is skipped (the IVI-COM driver in simulated mode currently does not support DDC). Either a fast or full calibration is also run after configuration of each module (fast/full as specified in the Utility...Preferences dialog). Configuration can fail in a couple of different ways. First, if the IVI-COM driver is pre-1.7.1 RC version, there is a known issue where the multi-module sync handle passing of slave modules to the master can fail, but that is fixed for the next release, and incorporated in RC 1.7.1 or later. A failure also can occur if the Ext clock mode is configured and no sample clock is being provided to the M9703A's front panel clock input, (you will see an unusual divide by zero error if performing fast calibration).

U – Acquire is the third button pressed in the GUI when using actual M9703A hardware. In simulate mode, there is no real hardware to send an initiate command to, so the acquire step is skipped in simulate mode. Acquire will initiate an acquisition across the entire configured M9703A module set and cause the M9703A modules to fill their acquisition RAM. Again status and states are tracked and displayed while this step runs.

V – Upload is the fourth (or second in the case of simulate mode) button pressed in the process of stepping through a data acquisition cycle. Upload pulls all the I&Q samples out of the M9703A(s) on a per channel basis and populates an equivalent number of waveform data structures. Because the app is compiled using a 64-bit DLL, the upload operation is capable of using large amounts of RAM (up to, or even exceeding the total RAM in system controllers with 16GB+ RAM). Status and states are tracked with time tags.

W – Export (optional) will write out magnitude and phase measurements to a CSV file for additional analysis on a per channel basis. One or more segments of the individual channel can be processed and exported (see separate documentation on export dialog).

X – File menu contains the options to import calibration table data, export CSV measurement records (once the data is in controller memory) and exit the program.

Y – Utility menu contains the options to open the Preferences dialog (see separate help documentation) or to reset the software to default state (reset closes any open M9703A digitizer sessions and resets GUI parameters back to the last values used for a complete acquisition).

Z – Help menu provides access to an about dialog, but no online help menu has yet been developed.

1 – This status bar location is reserved to display text of errors and form validation information to the user.

2 – This status bar location is reserved to display text of state information to the user.

Preferences pane
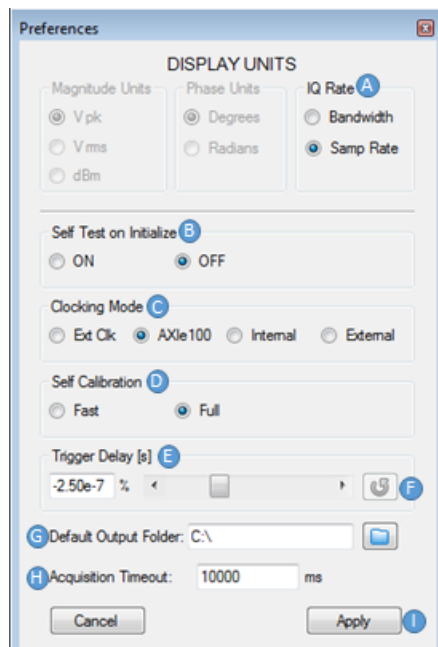
A – IQ Rate is a selection of how to display the IQ rate selection in the main form setup tab (either Bandwidth or Sample Rate)

B – Self Test on Initialize specifies whether or not a self test is run via the IVI-COM driver upon initialization (Initialize button on main form setup tab)

C – Clocking Mode specifies which clock mode is used:

Ext Clk [=] 3.2GHz sample clock is provided to each M9703A via front-panel SMA clock input (this is currently the only supported option for multi-module sync to achieve best variance)

AXIe100 [=] AXIe 100MHz backplane reference clock multiplied up using M9703A internal PLL.

Internal [=] Exclusively onboard clocking circuits in the M9703A (single M9703A only)

External [=] External reference clock applied to front panel of M9703A (single M9703A only)

D – Self Calibration specifies whether a fast calibration or full calibration is conducted per M9703A during configuration (Configure button on main form setup tab). For more details on the differences or consequences of one calibration type vs the other, please see MD1 IVI-COM driver documentation. Currently not doing a calibration is not supported because of these types of measurements we strongly advise against it (especially when using multi-module sets because time alignment will not work correctly).

E – Trigger Delay allows the user to adjust the position of the trigger inside the acquisition period (per segment). The range of the trigger delay is programmatically set to a symmetric range around t=0 based on the limits imposed by the IVI-COM driver. This limit is dependent on the number of samples and raw ADC sample period (1/1.6GSa/s = 625ps).

F – Re-acquire button. This button is supplied for the purpose of bringing up the preferences dialog while viewing the analysis tab and being able to re-run the acquisition. It is also possible to tweak the trigger delay between re-running attempts to try to fine tune the measurement interval timing (by changing the start of the measurement time relative to the trigger event). The analysis tab settings are preserved when using this button whereas using the acquire+upload from the setup tab will reset the measurement interval parameters in the analysis tab to default values.

G – Default Output Folder is the default location where exported data sets will be stored. The export dialog will point to this directory upon pressing Export from the main form setup tab (also pressing CTRL-E from the analysis tab or File…Export from the top toolbar drop down menu).

H – Acquisition Timeout is the amount of time allowed after the acquire button is pressed from the main form setup tab for a valid trigger to be found. If the timeout time is exceeded, an error will be reported and the application will reset.

I – Apply button is required to commit the settings and serialize them to the application settings in the app.config file so that when re-opening this dialog the values will be restored.

Choosing the Default Export Folder
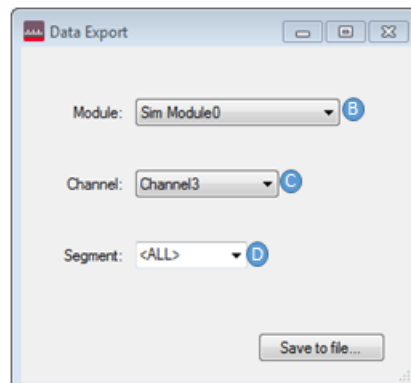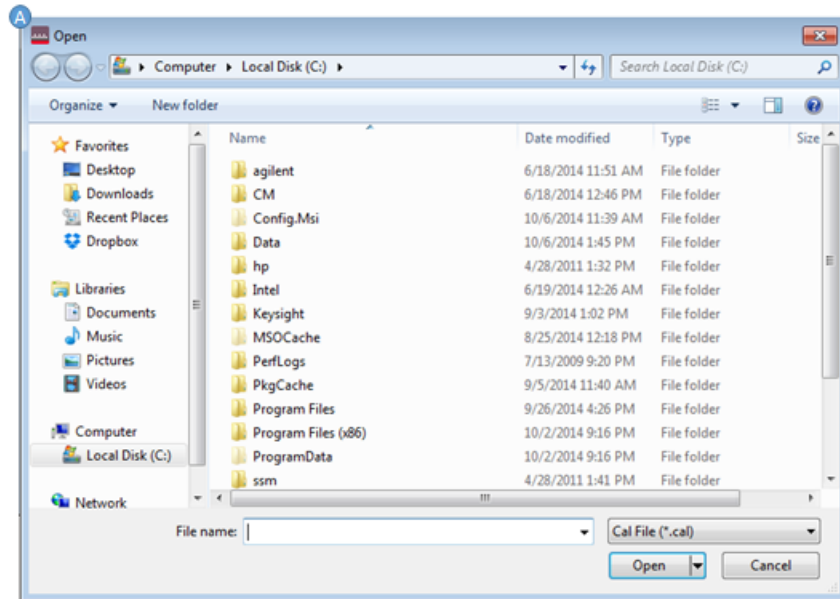
A – The open file dialog allows the user to pick a calibration input table following the format as shown in the example below. The file starts with a specifier for phase angle units ("Degrees" or "Radians") and then follows with tables of magnitude and phase correction values per M9703A digitizer module. The first line of each M9703A table is the VISA PXI address of the specific M9703A that the cal constants are provided for. If there is more than one M9703A, then the next PXI address is given on the very next line followed again by the list of channels with associated magnitude, phase correction.

- Degrees
 - PXI17::0::0::INSTR
  - Channel2,1,1.74

- Channel3,1,1.99
- Channel4,1,2.28
- Channel5,1,3.30
- Channel6,1,4.48
- Channel7,1,3.36
- Channel8,1,2.24

B – Module is the specific module that contains the acquisition channel from which we wish to extract magnitude and phase measurements from. It will be identified by the PXI address or a simulated name as shown in the example above.

C – Channel is the channel from which the magnitude and phase values will be made.

D – Segment is the specific segment (in range of 0...n-1 where n is the number of segments specified in the setup tab main form GUI). You can also select <ALL> from the drop down box to signify that all segments should be exported (one after the other sequentially) in the exported data.

Analysis tab
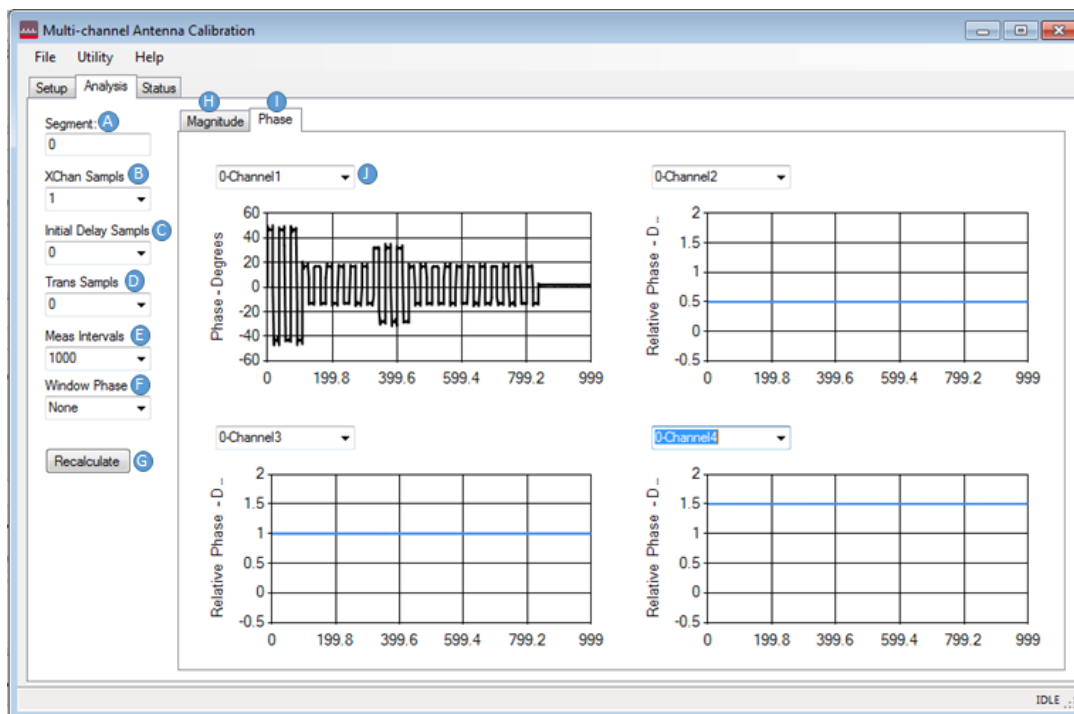
A – Segment is the selected segment for analysis in this tab. All analysis in the plots will concentrate on the segment chosen (in range of 0...n-1 where n = Nbr of Segments from setup tab in main form of GUI). A different value than 0 can be entered here and then subsequently the Recalculate button (G) needs to be pressed to update all plots.

B – Xchan Sampls are the number of samples that span a single measurement interval. For example, how many samples at the IQ sample rate does it take to cover the duration of dwell time for a single phase/frequency state within the acquisition segment.

C – Initial Delay Sampls is the number of samples to skip at the beginning of a segment after the trigger before iterating over measurement intervals. The stepping across intervals involves first skipping the specified number of Initial Delay Sampls and then in a loop:

1. Loop: Step <Trans Sampls> number of transition samples
2. Integrate <Xchan Sampls> during the dwell time
3. Step <Trans Sampls> number of transition samples
4. ...Next Loop

D – Trans Sampls is the number of samples that occur during a transition between measurement intervals. The code architecture assumes that there is a symmetric transition sample duration at the beginning and end of each measurement interval.

E – Meas Intervals is the total number of measurement intervals in a single acquisition segment.

F – Window Phase allows for enabling a special implementation of a Hanning window on the phase of the current IQ segment. It is not a traditional window in the sense that it extracts, windows, and then re-modulates back in the phase. This process helps minimize the edge effects on phase modulated waveforms like the example given above by reducing the weighting of the phase towards the window edge -> coefficient approaches 0. The example waveform here has ringing on the edges of the phase transitions due to IF filter bandwidth of the DDC in the M9703A, and this windowing technique can improve the precision of the resulting phase measurement assuming some imperfections in centering the rectangular measurement interval using the parameters just discussed.

G – Recalculate button is used to recalculate the plots after changes are made to any of the parameters in the left input column.

H – Magnitude tab is used to display single channel (referred to as absolute in the GUI) and cross-channel (relative) magnitude measurements.

I – Phase tab is used to display single channel (referred to as absolute in the GUI) and cross-channel (relative) phase measurements.

J – Channel selection box. These drop down boxes (one per plot) allow for the selection of the channel to be displayed in a given plot.

After specifying measurement interval parameters and pressing Recalculate...

Right click plot menu (opens when right-clicking on a given plot in the Magnitude/Phase Analysis tabs)

A – Relative is cross-channel measurements (relative to the reference channel which is always plotted in black)

B – Absolute is the single channel point to point calculation option

C – Clear Cursors allows for turning off any enabled cursors in the plot (via left click on the plot)

D – Zoom Out allows resetting the plot back to the original state (including any changes made with zoom boxes or axis scaling)

E – Properties... opens a property grid for the given chart object. This is a very complex, multi-level dialog that effectively exposes any property you can imagine (if you can find it J). But, it can also be dangerous and possibly cause the chart object to crash by making changes that result in unpredictable results at run-time. Care should be taken in its use.

Status tab
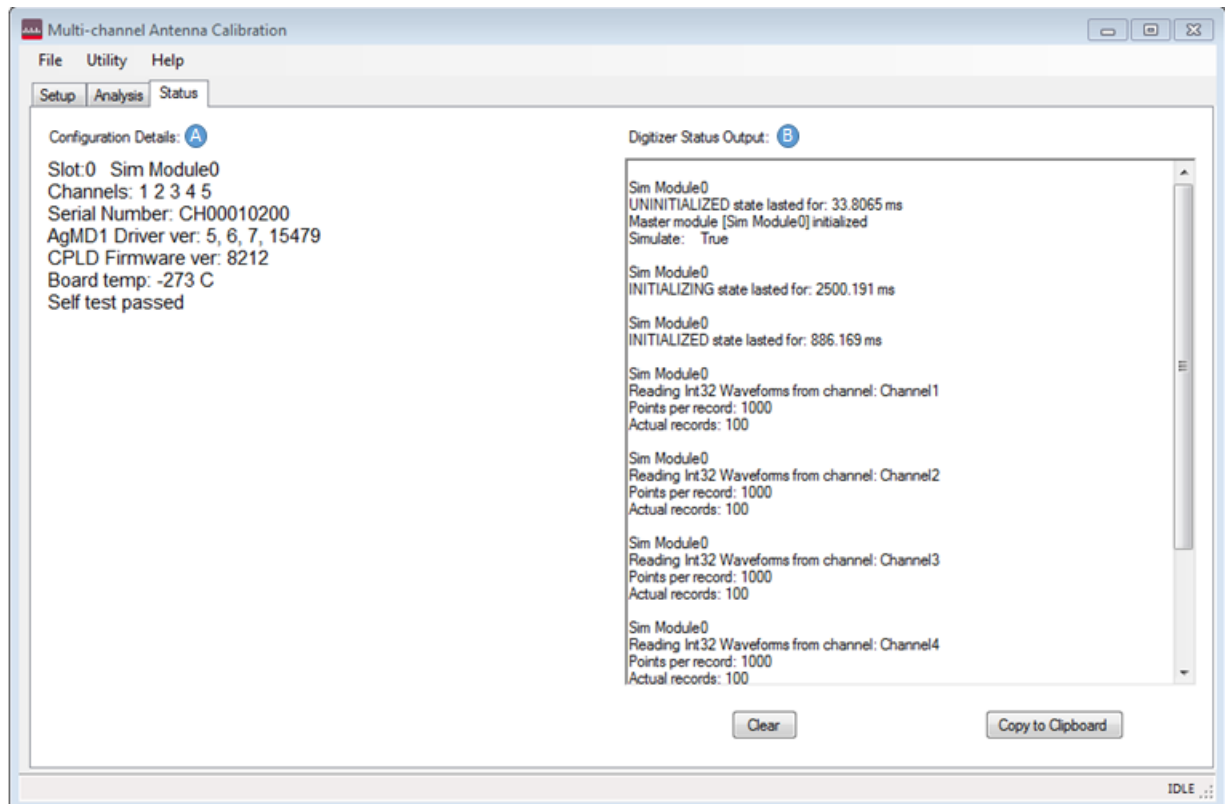
A – Configuration Details provides details about the M9703A modules in active sessions that are being used by the application. This information is useful to verify proper configuration and also for checking the result of any self tests performed during the initialize step.

B – Digitizer Status Output is a history of all operations performed by the application since initialization. Time tags are tracked using a Stopwatch object embedded inside the M9703A object in the application code. The copy to clipboard button is provided to quickly grab the complete history into the PC's clipboard to paste into a test report. Clear button also can clear the history at any time.

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