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3 June 2019

From: Scott P. Chapman
Radiant Technologies, Inc.

To: Magneto-Electric Response Bundle User

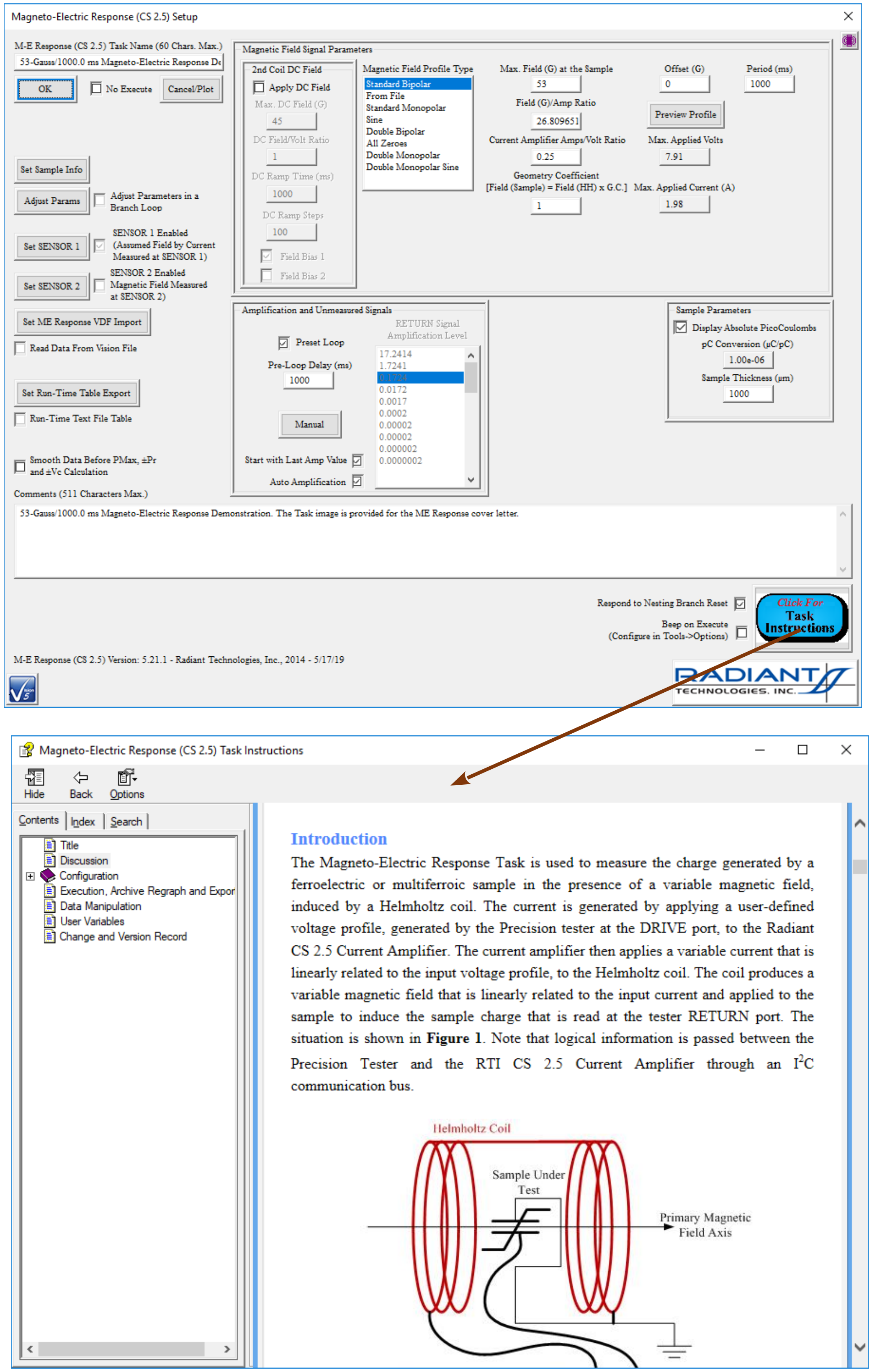
Subj: Discussion of Magneto-Electric Installation

Dear Sir or Madam:

The Magneto-Electric bundle that you purchased includes a number of accessories and Vision Tasks that must be understood to configure and operate the test bundle. Unfortunately, the bundle's documentation is spread over a number of documents that are both individually incomplete and together include a fair amount of redundancy. Radiant Technologies, Inc. is working to correct this. In the meantime, this document presents concentrated detail regarding the connections between the various and regarding the Vision Magneto-Electric Response Task configuration and execution.

Please note that the CS 2.5 Current Source and the thin-film and/or bulk METTFIX sample holder and shield box both come to the customer fully calibrated so that an experiment is ready to configure and execute with no calibration on the part of the user.

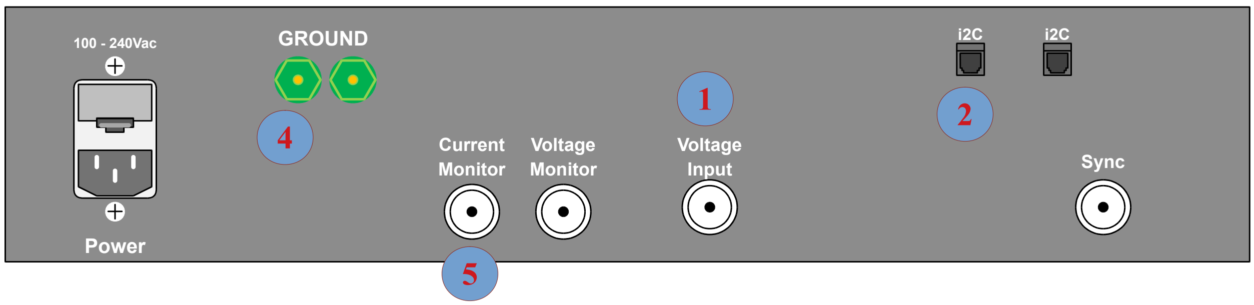
Please note that, aside from this document, the best source for Magneto-Electric Response assembly, configuration and execution are the Magneto-Electric Response Task Instruction. These are found by clicking the *Click For Task Instructions* button on any Magneto-Electric Response Task dialog.



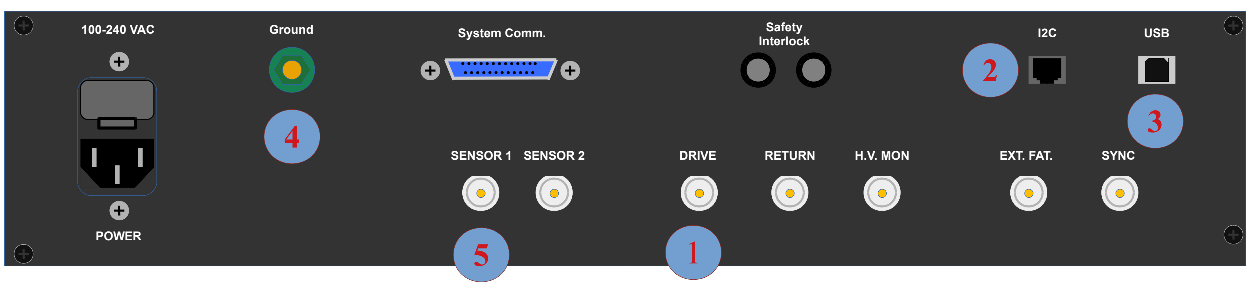
Accessing the Magneto-Electric Response Task Instructions.

Experiment Assembly

Here is a complete list of the connections that need to be made to make a Magneto-Electric measurement.

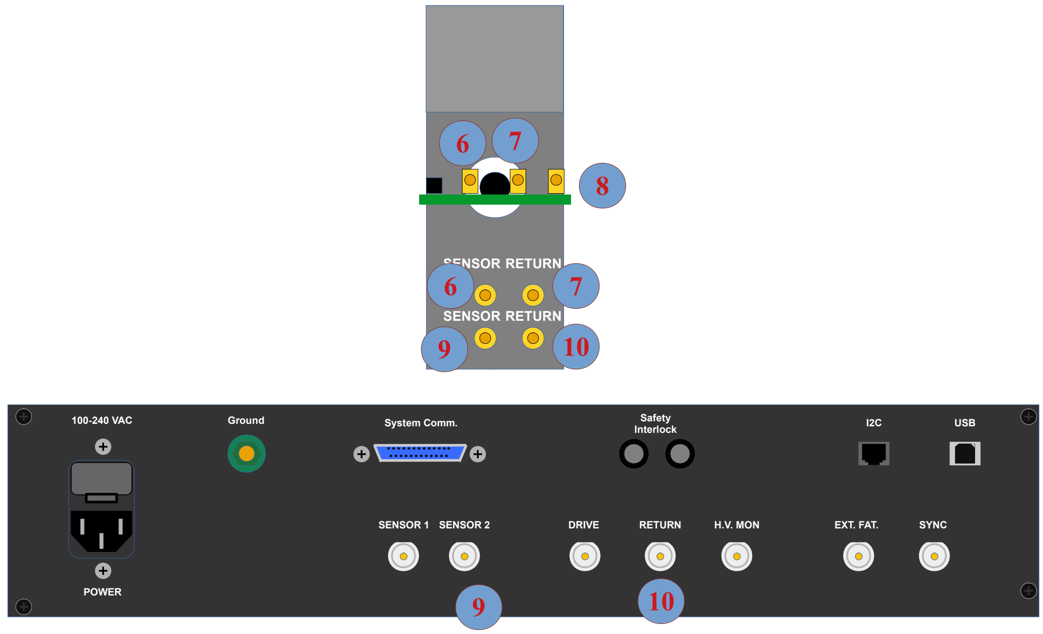


Current Source CS 2.5 Rear Panel



Connection Reference Image 1

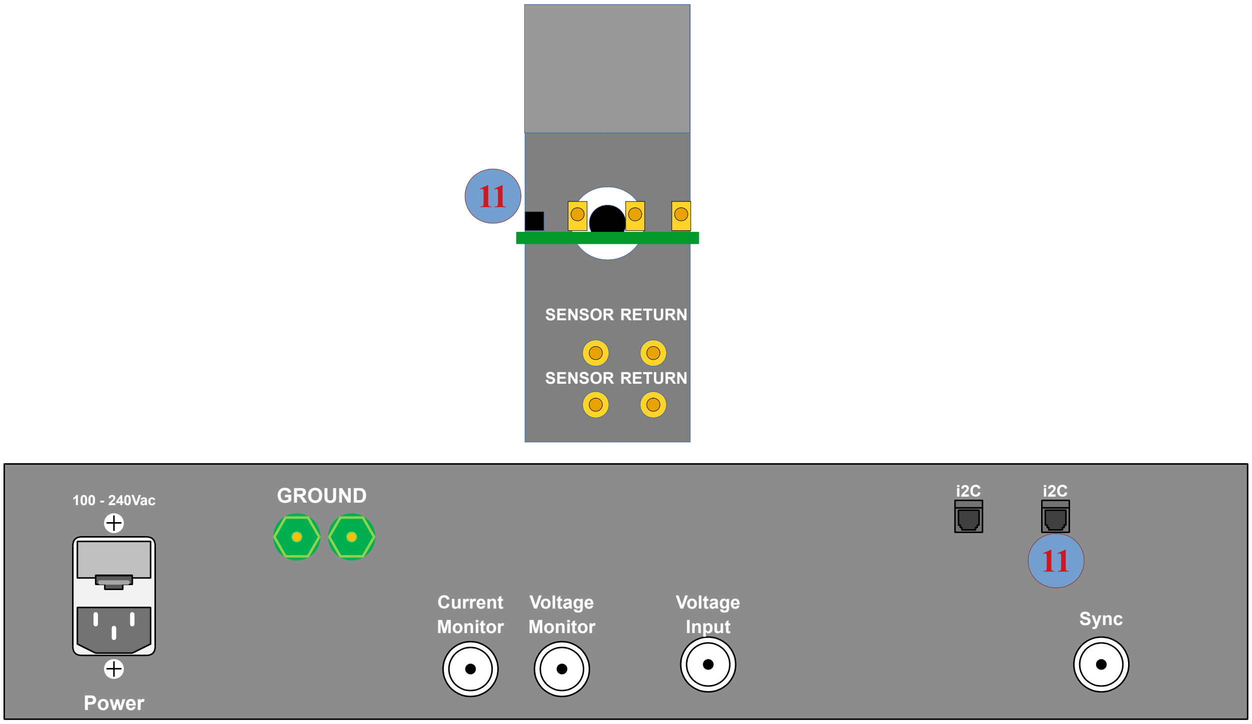
Connection	From	To	Cable Type	Discussion
1	Tester DRIVE Port	CS 2.5 Voltage Input	BNC-to-BNC	Tester DRIVE Voltage scaled to the desired Magnetic Field. It is input to the CS 2.5 Voltage Input port. It is scaled by 0.25 A/V to generate the current out of the CS 2.5 front panel
2	Tester I2C	CS 2.5 I2C	I2C-to-I2C	This cable provides logic communication between the tester and the CS 2.5
3	Tester USB	Vision Host Computer USB	USB-to-USB	This cable provides the logic communication between the tester and the Vision host computer.
4	Tester Ground	CS 2.5 Ground	Banana-to-Banana	This provides a common earth ground to the two instruments.
5	CS 2.5 Current Monitor	Tester SENSOR 1 Port	BNC-to-BNC	This provides a voltage that is a model representation of the actual current being output by the CS 2.5. It allows the tester and Vision to read the exact current.



Tester Rear Panel

Connection Reference Image 2

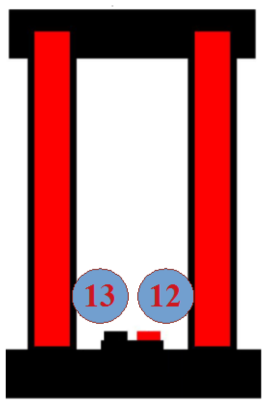
Connection	From	To	Cable Type	Discussion
6	Shield Box Fingerboard (Electronics Board) SENSOR SMA	Shield Box SENSOR SMA	SMA-to-SMA	The selected Hall Effect magnetic field sensor output is passed from the electronics board through the shield box SENSOR connection to provide a ground.
7	Shield Box Fingerboard RETURN SMA	Shield Box RETURN SMA	SMA-to-SMA	The sample polarization response to the magnetic field is passed from the electronics board through the shield box RETURN connection to provide a ground.
8	Shield Box DRIVE SMA	-	SMA-to-Shorting Plug	This is the DRIVE input port of the electronics board. It is not used in a magnetic measurement. It is connected to the shorting plug to ground the DRIVE signal lines.
9	Shield Box SENSOR Port	Tester SENSOR 2 Port	SMA-to-BNC	This provides the Hall Effect magnetic field sensor output to the tester so that it can be used to determine the exact magnetic field applied to the sample.
10	Shield Box RETURN Port	Tester RETURN Port	SMA-to-BNC	This provides the sample polarization response to the tester for capture, integration and conversion.



Current Source CS 2.5 Rear Panel

Connection Reference Image 3

Connection	From	To	Cable Type	Discussion
11	CS 2.5 I2C	Shield Box I2C	I2C-to-I2C	This cable provides logical communication between Vision and the shield box electronics board EEPROM and Hall Effect magnetic field sensors.



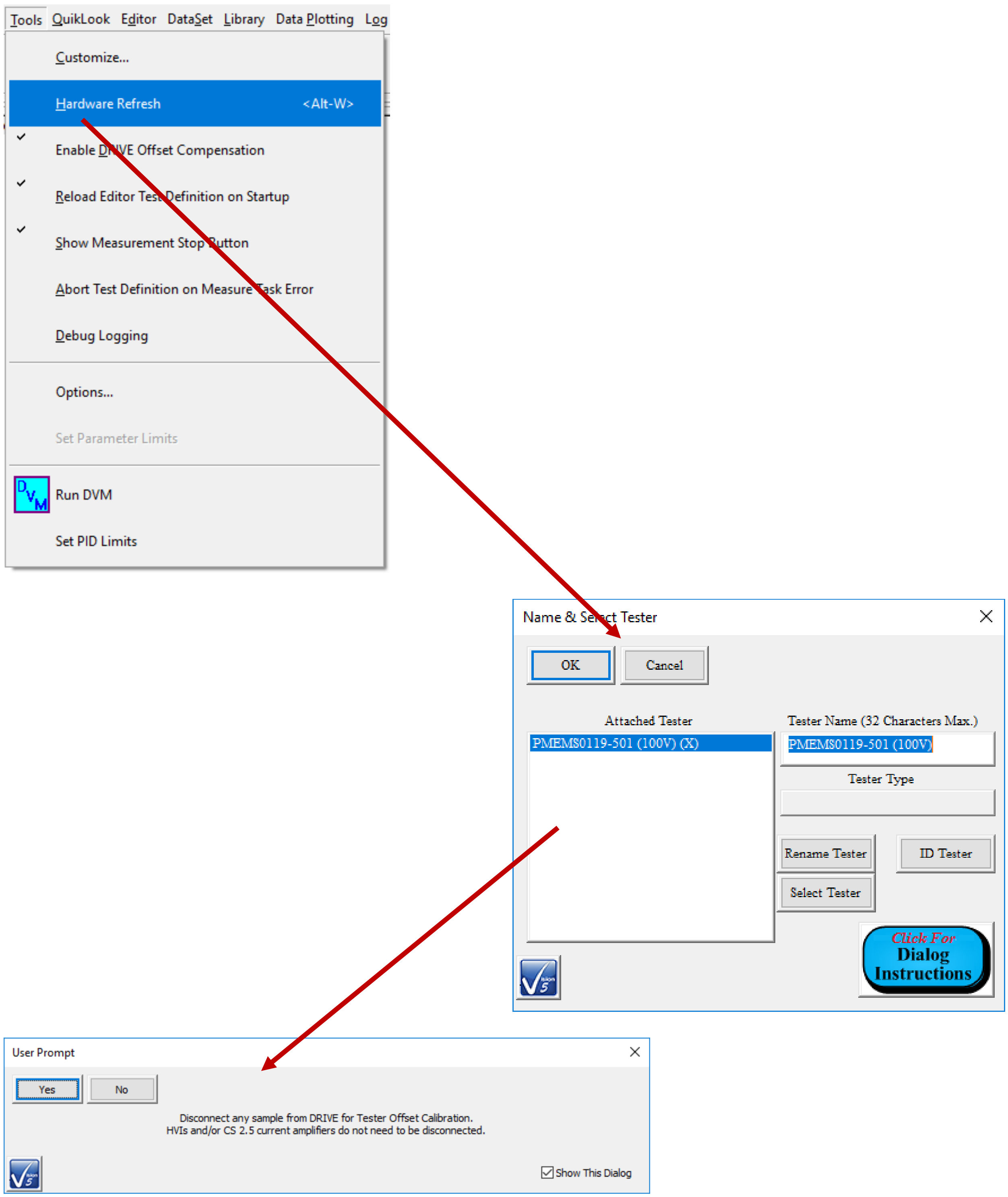
CS 2.Front Panel

Connection Reference Image 4

Connection	From	To	Cable Type	Discussion
12	CS 2.5 Current Output +	Helmholtz Coil Red Connector	Banana-to-Banana	This cable carries the CS 2.5 current output into the Helmholtz Coil input. This current generates the magnetic field
13	Helmholtz Coil Black Connector	CS 2.5 Current Output -	Banana-to-Banana	This cable carries the current output from the Helmholtz Coil back into the CS 2.5 input, completing the current circuit.

Note that there are no connections to or from the Precision tester front panel. The DRIVE and RETURN ports on the tester front panel are electrically identical to the DRIVE and RETURN ports on the rear panel. All connections should be made to the rear panel.

Please note that if you make any changes to hardware configuration after Vision is running – for example, if you turn on the CS 2.5 – you must select Tools->Hardware Refresh… or press <Alt=W>. The Vision startup procedures will repeat.



Hardware Refresh.

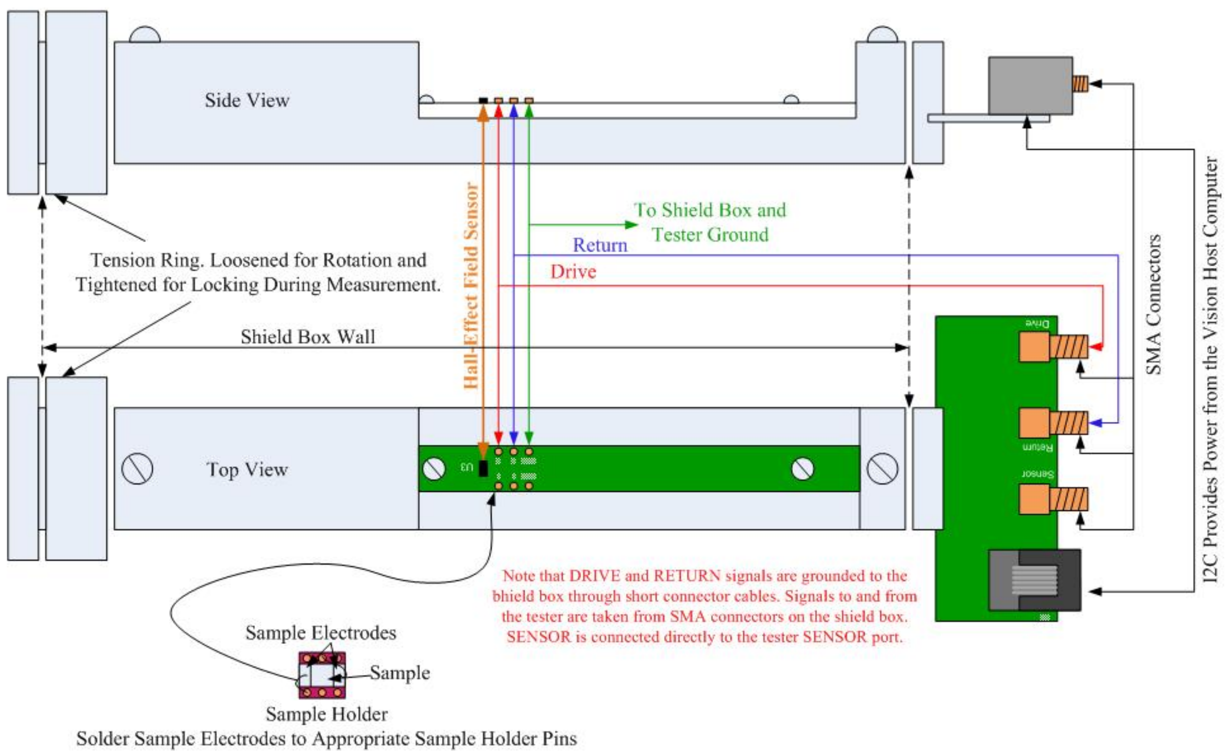
The magnetic field output by the Helmholtz coil is given in G/Amp. The Task generates the field by:

Magnetic Field (G) = DRIVE Voltage x *Current Amplifier Amps/Volt Ratio* x *Field (G)/Amp Ratio* (1)

Vision actually works backwards through this. The user specifies the intended magnetic field and Vision computes:

DRIVE Voltage = Magnetic Field (G) x 1/(*Current Amplifier Amps/Volt Ratio*) x 1/(*Field (G)/Amp Ratio*) (2)

This figure, taken from the Task Instructions, shows how the sample socket board connects to the shield box electronics board.

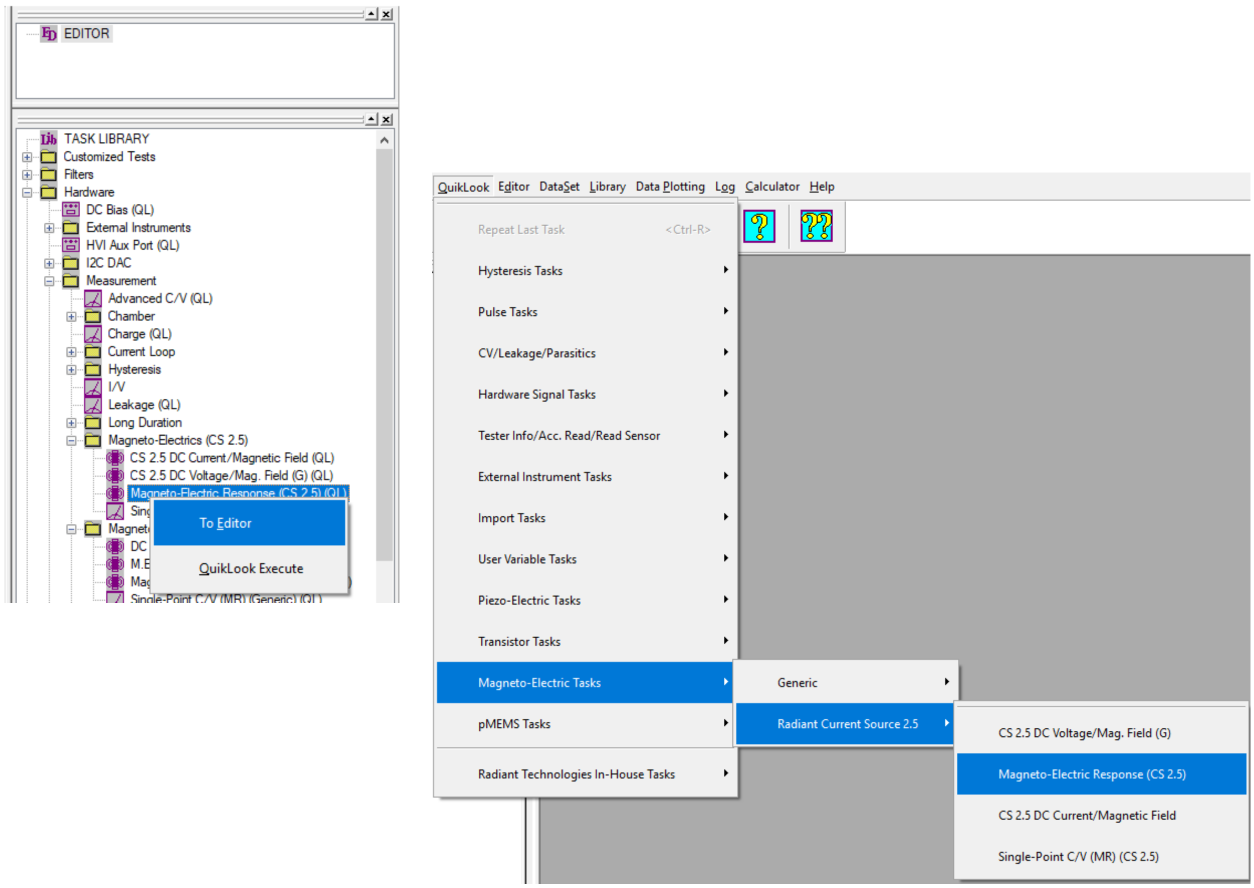


Aside - You might ask the question: Why is there an SMA connector on the shield box electronics board labeled "Drive"? The answer is that, by swapping just a few cables, the sample's polarization response to an electric field can be measured using the Hysteresis Task. To make that measurement, disconnect cables 1 and 9 from the figures and tables above. You will not be generating voltage into the CS 2.5, so cable 1 is removed. You will not be reading the Hall Effect magnetic field sensor response at the SENOR 2 port, so cable 9 is removed. Cable 9 is an SMA-to-BNC, so use it to connect the Precision Tester DRIVE Port (1) at the BNC end.

Then disconnect the shorting plug from 8 on the Helmholtz Coil electronics board and connect the SMA of cable 9 to that connector (8). The Precision tester will now be able to drive a voltage directly into the sample installed in the Helmholtz Coil electronics board socket.

Magneto-Electric Task Configuration

The Magneto-Electric Task is access through the TASK LIBRARY at Hardware->Measurement->Magneto-Electric Response (CS 2.5). It is also found under the QuikLook menu at QuikLook->Magneto-Electric Tasks->Radiant Current Source 2.5.



Accessing the Magneto-Electric Response Tasks.

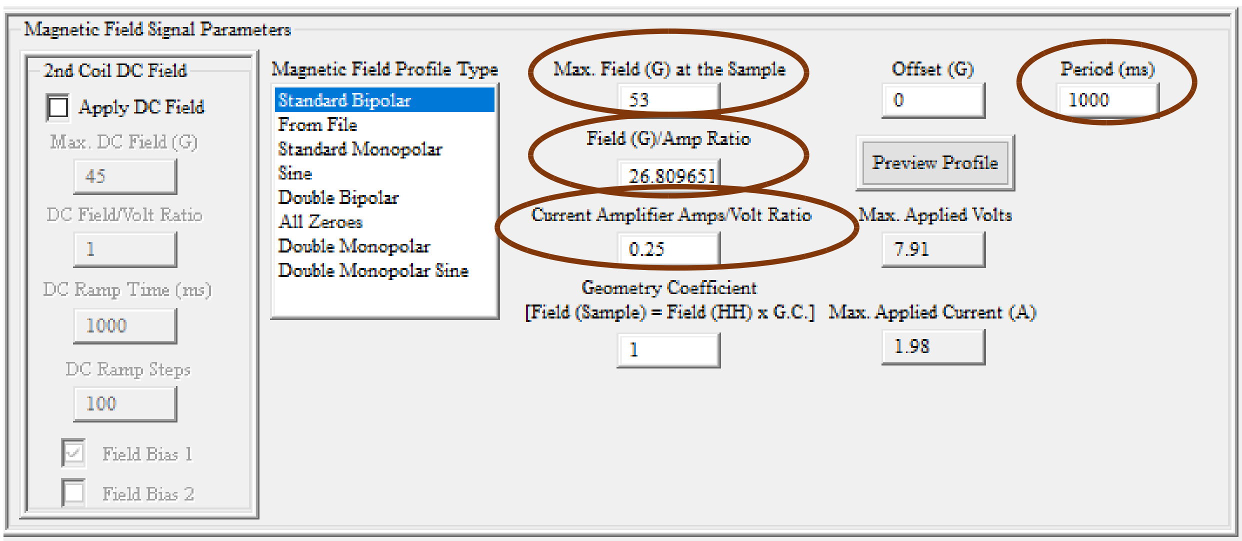
Conversion equations (1) and (2), from above, are reiterated here for convenience:

Magnetic Field (G) = DRIVE Voltage x *Current Amplifier Amps/Volt Ratio* x *Field (G)/Amp Ratio* (1)

DRIVE Voltage = Magnetic Field (G) x 1/(*Current Amplifier Amps/Volt Ratio*) x 1/(*Field (G)/Amp Ratio*) (2)

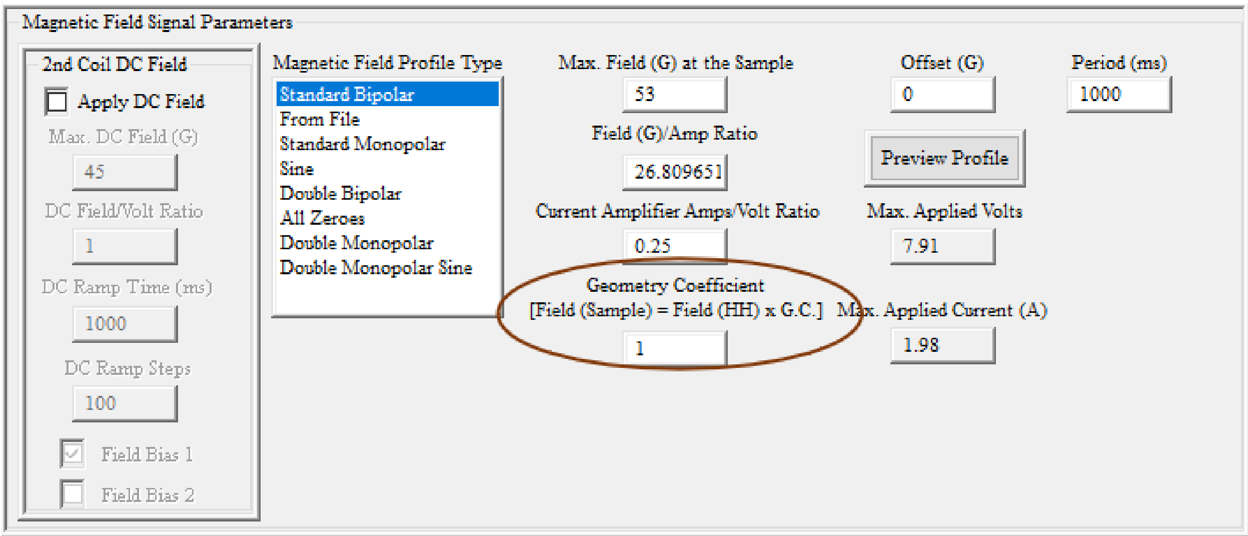
The four primary parameters to be configured are:

- *Max. Field (G) at the Sample*: This is the maximum magnetic field to apply, in Gauss, over the magnetic field profile. It is equivalent to Max. Volts in a Hysteresis measurement.
- *Period (ms)*: This is the duration, in milliseconds, of the application of the magnetic field profile for a single measurement. For the default "Standard Bipolar" (as well as the "Sine") profile, it is equivalent to 1000/Frequency (Hz).
- *Field (G)/Amp Ratio*: This is the field (G) response of the Helmholtz coil to a 1.0-Amp input current. This ratio is found on a label on the Helmholtz coil.
- *Current Amplifier Amps/Volt Ratio*: This value represents the current, in Amperes, out of the CS 2.5 Current Source for a 1.0-Volt input. This value is calibrated at Radiant Technologies, Inc, stored in the CS 2.5 EEPROM and read from the EEPROM automatically by the Task. The user may adjust this value, but should not.



Magneto-Electric Response Task Primary Configuration Parameters.

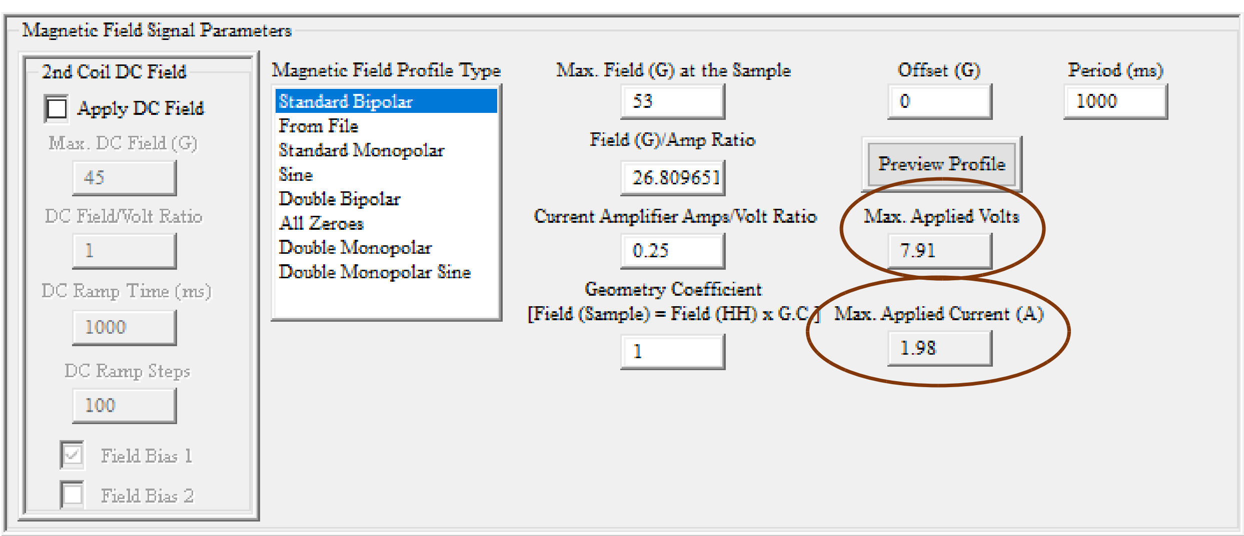
A *Geometry Coefficient*, less than or equal to 1.0, may also be introduced to the calculation of equation (2). This allows for the user to provide an estimate of the loss of magnetic field at a sample that, for reasons of position and/or rotation, is not receiving the full magnetic strength. Equation (2) is divided by this term to increase the voltage, and therefore magnetic field, so that the sample is in a field of maximum strength defined in *Max Field (G) at the Sample*. This value should not normally be adjusted from 1.0.



Magneto-Electric Response Task Geometry Coefficient Parameter.

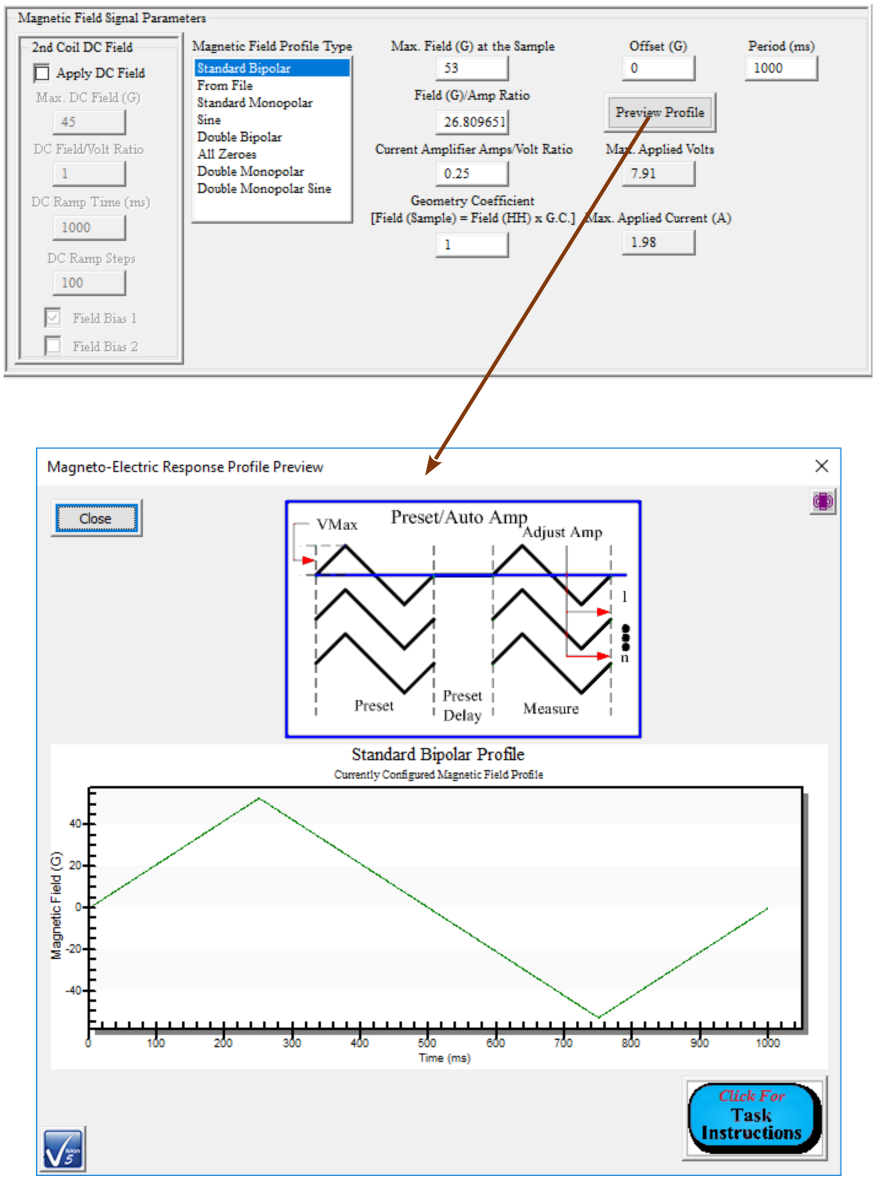
Two terms are computed automatically and are presented in read-only controls for the user's information. These are:

- *Max. Applied Volts*: This is the voltage to be applied at the Precision tester DRIVE port as a result of the calculation of equation (2).
- *Max. Applied Current (A):* this is the current out of the CS 2.5 and into the Helmholtz coil given by *Max. Applied Volts* x *Current Amplifier Amps/Volt Ratio*.



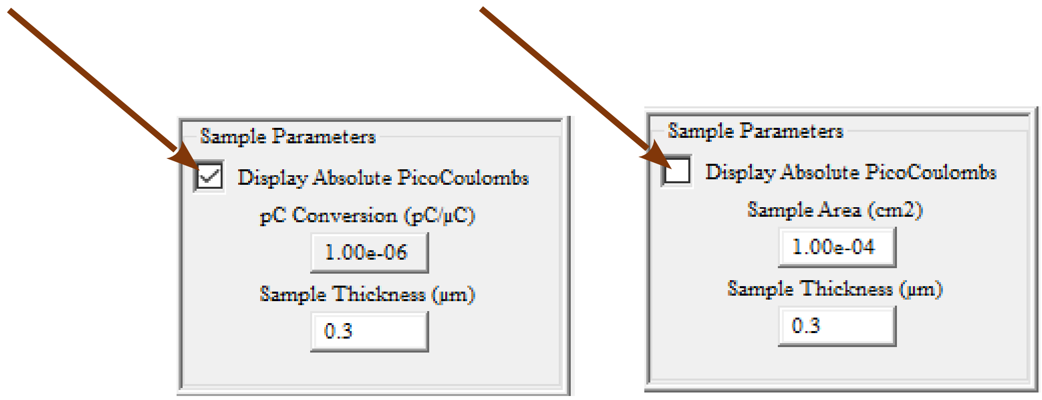
Magneto-Electric Response Task Derived Electrical Parameters.

The magnetic field profile that will be applied given the current configuration parameters can be reviewed by click the *Profile Preview* button. The graphic above the profile plot refers to enabling or disabling of the measurement preset and automatic amplification. Please see the Task instructions for more detail.



Magnetic Field (G) Vs Time (ms) *Profile Preview.*

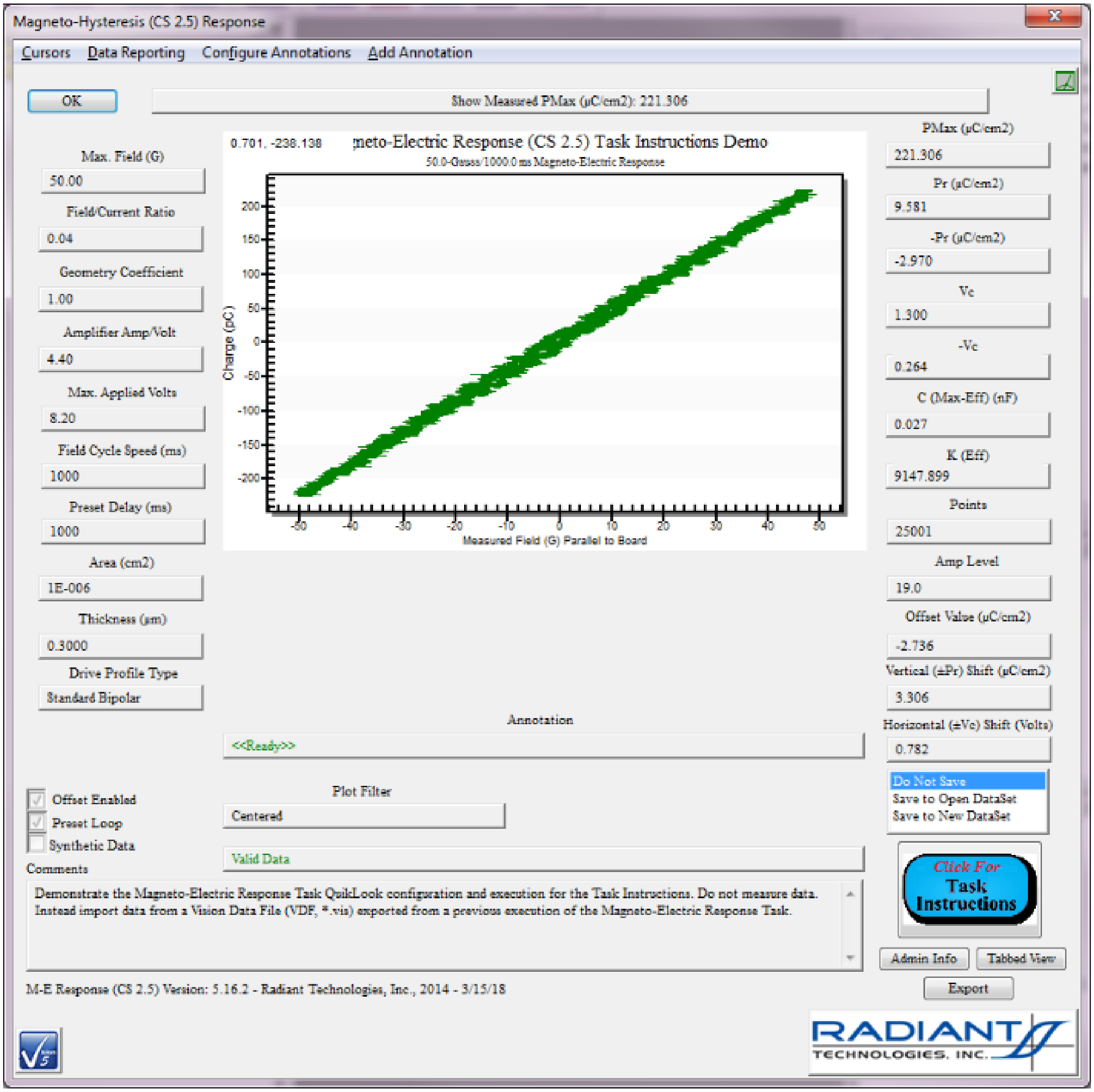
The user has the option of plotting the charge response of the sample in units of PicoCoulombs or the standard ferroelectric response in units of $\mu C/cm^2$. Checking *Display Absolute PicoCoulombs* labels the control *pC Conversion (pC/µC)*, forces the value to 1.00^{-6} and disables the control. Unchecking Display Absolute PicoCoulombs sets the control label to *Sample Area (cm2)* and enables the control. It is important to enter the correct sample electrode area (cm^2). Note that *Sample Thickness (µm)* is provided simply for sample documentation.



Select Response Data Representation.

Most of the remaining controls are common to all Measurement Tasks. Please see the Task Instructions for complete details.

The figure below shows the appropriate ±220 pC response to ±50.0 Gauss of a Radiant Technologies standard thin-film reference sample. The sample is not ferroic. Instead a thin-film piezoelectric sample has a cantilever with magnets attached glues to its surface. As the magnetic field causes the magnets to move the cantilever flexes inducing a piezoelectric charge response in the sample that is captured by the Magneto-Electric Response Task.



±220.0 pC Thin-Film Piezoelectric Sample Response to ±50.0 Gauss.

All of the above information is amplified in the Magneto-Electric Response Task Instructions and other documents distributed with this bundle. Other documents discuss magnetic and ME-response theory. In a video at https://www.youtube.com/watch?v=77BkGWbOvDk I also guide the viewer through the experiment assembly. Much of the video remains relevant to the current generation of Magneto-Electric Test Bundle. However, the video represents an older generation of the distribution. It replaces the Radiant Technologies CS 2.5 Current Source with a Kepco BOP 36 current amplifier. The Kepco amplifier does not provide the complete capabilities of the CS 2.5. As a result there are several additional instruments and accessories discussed in the video that no longer pertain to the Magneto-Electric bundle.

With this document, the Magneto-Electric Task Instructions and the other Magneto-Electric documents in this distribution you should be able to assemble, configuration and execute valid Magneto-Electric Response measurements using both the RTI reference sample (thin-film or bulk) and your own ferroic samples. Please let me know immediately if you have questions, comments or difficulties.

Good luck in your research.

Sincerely,

Scott

Scott P. Chapman
Digital Engineer
Radiant Technologies, Inc.