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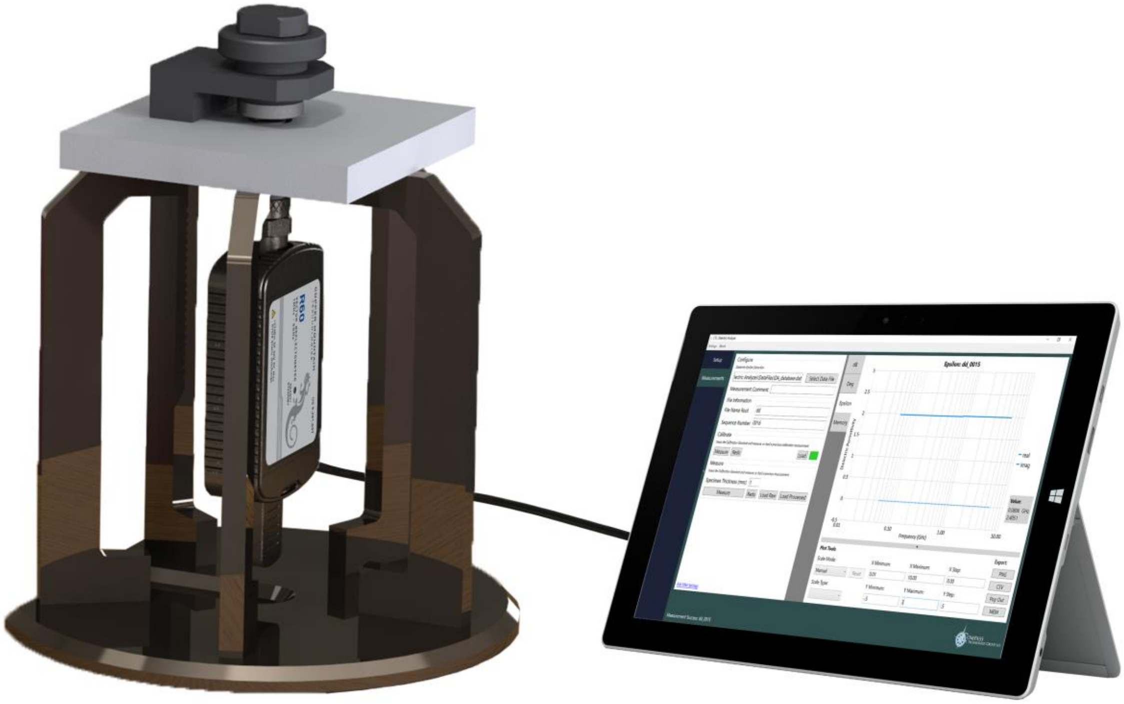
COPPER MOUNTAIN TECHNOLOGIES

COMPASS TECHNOLOGY GROUP, LLC

Epsilometer Measurement System User and Software Guide



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RVNA Software Installation

1. Place included USB memory stick into USB port of computer or laptop.
2. File Explorer window showing contents of USB drive should open automatically with auto-run. If auto-run is disabled, open File Explorer by holding down the ⊞ key + “E” and navigate to USB drive.
3. Double-click “*1) Copper Mountain RVNA Software*” folder to display install files.
4. Run setup program called “Setup_RVNA vx.x.x” by double-clicking on file.
5. Select “**Next**” button to reach “*Analyzer Model and Serial Number*” window. Ensure “**Autodetect**” is selected under “*Select Analyzer Model*” drop-down menu. Under “Select Initial Analyzer Model,” select the correct model number, which can be seen on the Vector Reflectometer. Click “**Next**” button to advance to next window.
6. The next 4 screens to get through involve accepting the defaults and clicking next. These screens described below.
7. Ensure “*Enable Demo Mode*” is **NOT** checked. Click “**Next**”.
8. Select a folder destination for RVNA software to be installed and click “**Next**”.
9. Ensure “**Full Installation**” is selected from drop-down menu of “*Select Components*” window and click “**Next**”.
10. Click on “**Next**” to add RVNA icon shortcuts to Start Bar menu and Desktop.
11. Press “**Install**” button to begin file extraction installing RVNA software onto computer/laptop.
12. Following setup file extraction, a new window will appear with a checkmark option asking to register the COM server to enable remote control of the R60 analyzer. ****IT IS VITAL THAT THIS FEATURE BE ENABLED**** Unchecking this box will require a full reinstallation of RVNA software for successful operation of measurement software. *(Figure 2.)*

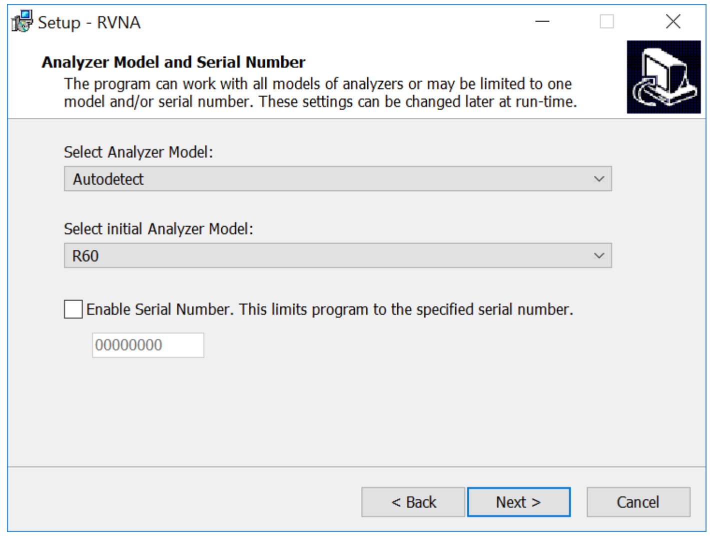


Figure 1. RVNA Model and Serial Number

Figure 2. Registration of RVNA

CTG Epsilometer™ Software Installation

1. Open File Explorer by holding down the key + “E” and navigate to USB Drive.
2. Double-click “*2) CTGCalc Installers*” to display installation files.
3. Run setup application program called “*CTGEpsilometer_x.x*” by double-clicking on file.
4. Click “**Next**”. Select a folder destination for CTGEpsilometer software to be installed on computer and click “**Next**” button. *(Figure 3.)*
5. Click on “**Next**” to add CTG Epsilometer icon shortcuts to Start Bar menu and Desktop.
6. Click “**Next.**” Select a folder destination for the Program shortcuts
7. Once installation files extraction is complete, click “**Finish**” button to complete required software installation.
8. CTG Epsilometer icon will be displayed on desktop as symbol.

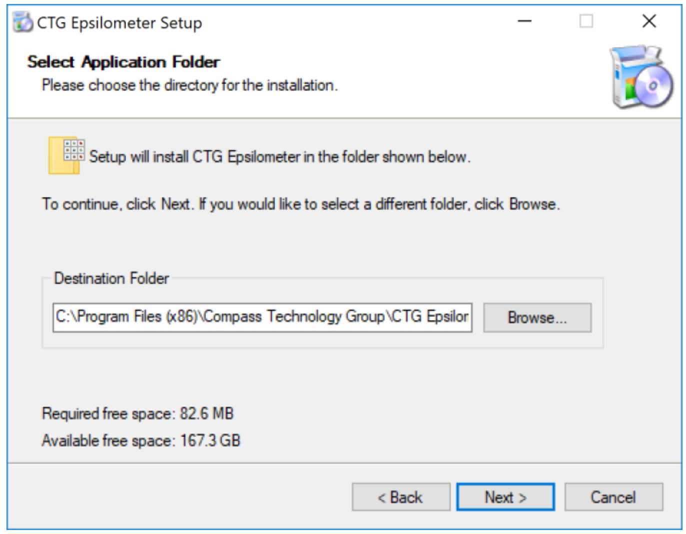
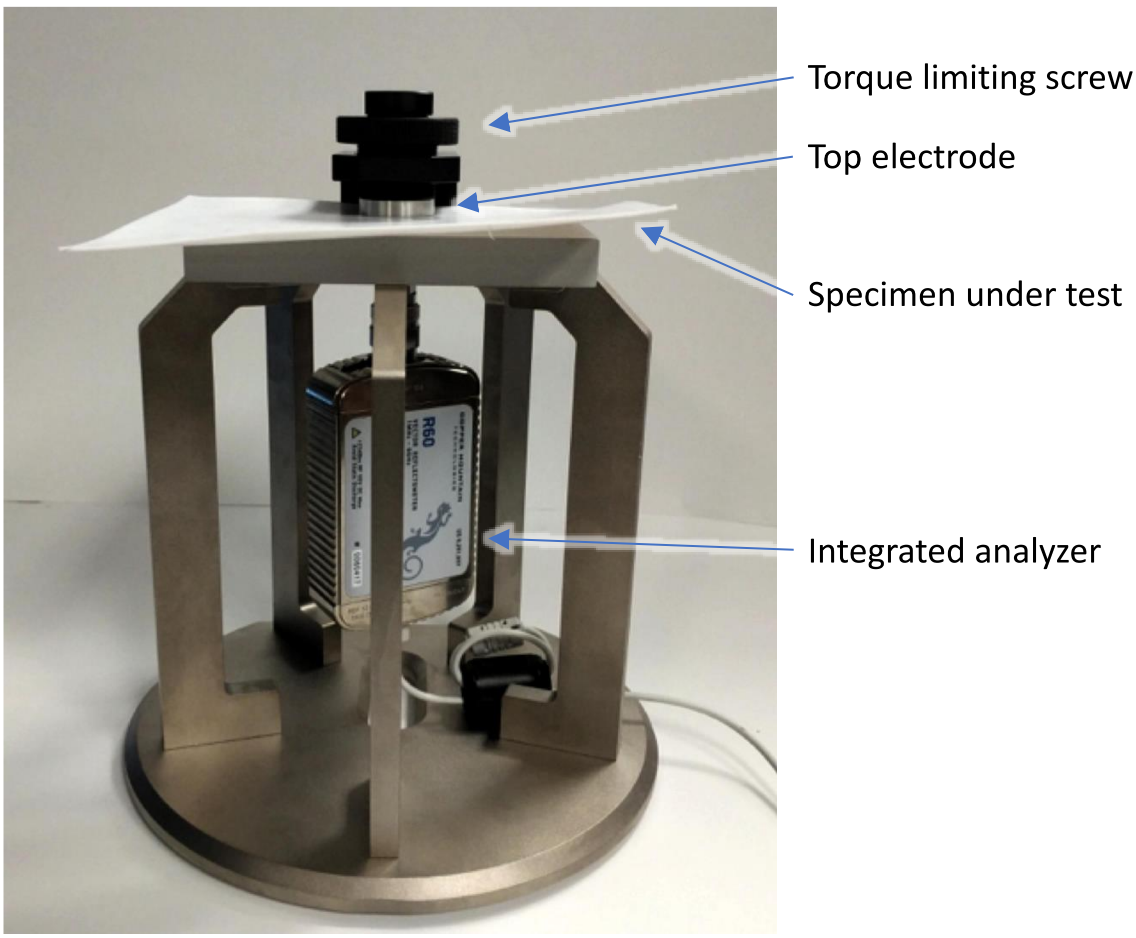


Figure 3. Selecting Destination Folder

Epsilometer Overview & Principle of Operation

The Epsilometer is a device that measures dielectric substrate materials to determine the complex permittivity from 3 MHz to up to 6 GHz. The measurement hardware is pictured below. It represents a new measurement method based on the parallel plate capacitor concept, which determines complex permittivity of dielectric sheets with thicknesses up to about 3 mm. Unlike the conventional capacitive measurement devices, this new method uses a greatly simplified calibration procedure and is capable of measuring at frequencies from 3 MHz to 2 GHz, and in some cases up to 6 GHz. It solves the parasitic impedance limitations in conventional capacitor methods by explicitly modeling the fixture with a full-wave computational electromagnetic code. Specifically, a finite difference time domain (FDTD) code was used to not only design the fixture, but to create a database-based inversion algorithm. The inversion algorithm converts measured fixture reflection (S11) into dielectric properties of the specimen under test.



Initializing CTG Epsilometer™ Software

1. Connect computer to Epsilometer with included USB cable.
2. Open CTG Epsilometer software by double-clicking the CTG Epsilometer icon on your desktop. An initial "Setup" screen will appear.(Figure 4)
3. Type in a preferred name in the "**User Name**" field.
4. Use the "**Data Output Directory**" field to select the appropriate folder to save the data files.
5. Use the "Global Measurement Description" field to describe the data being collected. This information will be included on data file headers.
6. Keep the "**Timeout**" Field to 90 and Click "**Connect**." This time (in seconds) tells the software how long to wait for initialization of the analyzer.
7. Once "**Connect**" is clicked, CTG Epsilometer will connect to the RVNA.
8. RVNA will open and CTG Epsilometer initial "Setup" screen will display the message "VNA *Connection Success!*" (Figure 5)

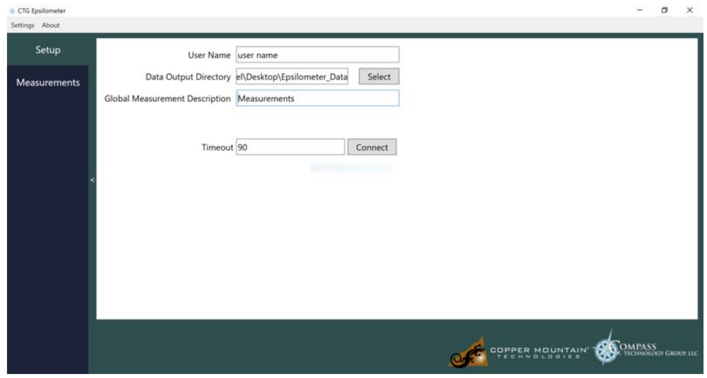


Figure 4. Initial "Setup" Screen

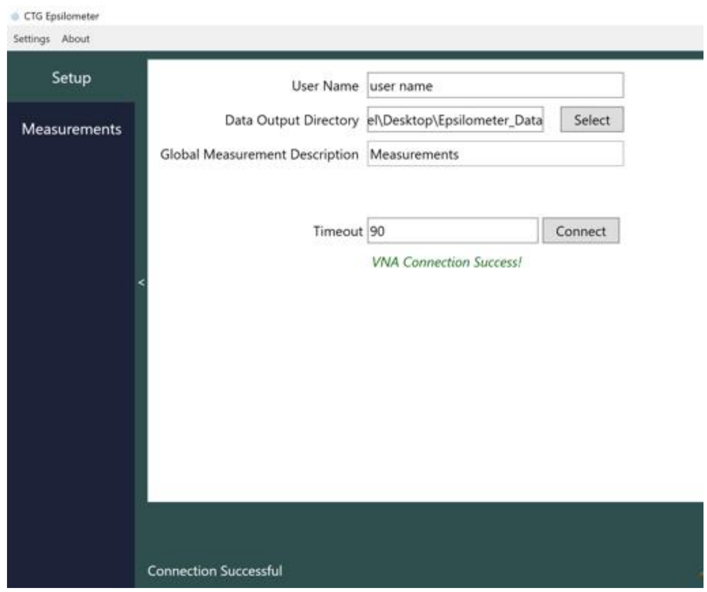


Figure 5. VNA Connection Success.

Measurement Screen Items

After connecting to the analyzer in the Setup tab, select the Measurements tab on the far-left side of the window. The general flow of the Measurement tab is from top to bottom of the group-boxes, with the plot section automatically displaying the most relevant plot after an action. The group-box descriptions can be found in the appendix of this guide.

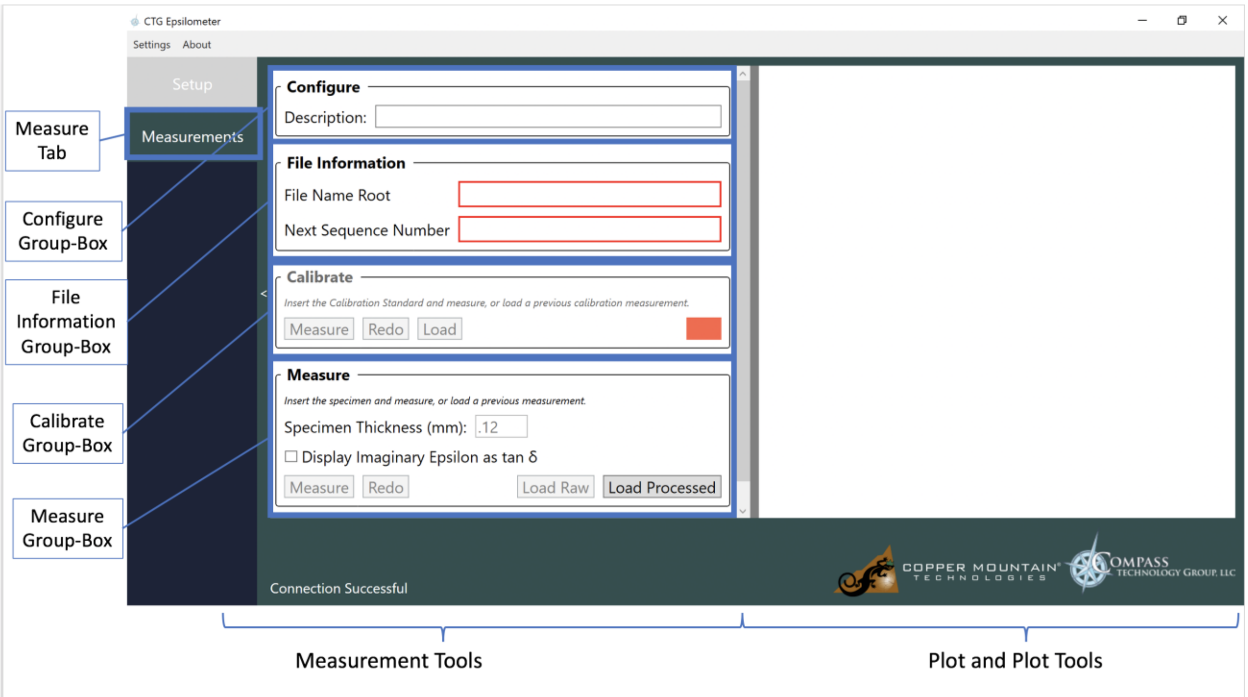


Figure 6. Measurement Tab

The Measurements screen is divided into an action pane on the left and a plotting pane on the right as shown in **Figure 6**. The action pane sections are set up in the order to be performed from top to bottom. Note the red border rows in file information Group-Box. This is an indication that the field is required before further action can be performed.

The techniques used in this guide, which are also displayed with screenshots, are critical to measure the correct epsilon. User errors such as having air gaps between the electrodes and material can create significant errors in the data (> 15% error). Other errors include input of the incorrect thickness.

Important Procedures for Ensuring Accurate Measurement

1. Be careful to not have your hand or any other foreign metallic materials near the top, electrode area of the Epsilometer during measurement
2. Also during measurement, ensure the top electrode lowered flush against the specimen. Turn top knob clockwise to lower the electrode until tightens.
3. Note the knob includes a special secondary knob for limiting the torque of the electrode against the specimen. Use the torque-limiting knob (Figure 7) to achieve final tightness so that the same torque/force is used for both the calibration measurement and the unknown specimen measurement
4. Be sure to have an accurate specimen thickness – the measurement error is directly related to the thickness uncertainty.
5. Input the correct thickness in the “**Measure**” Group Box

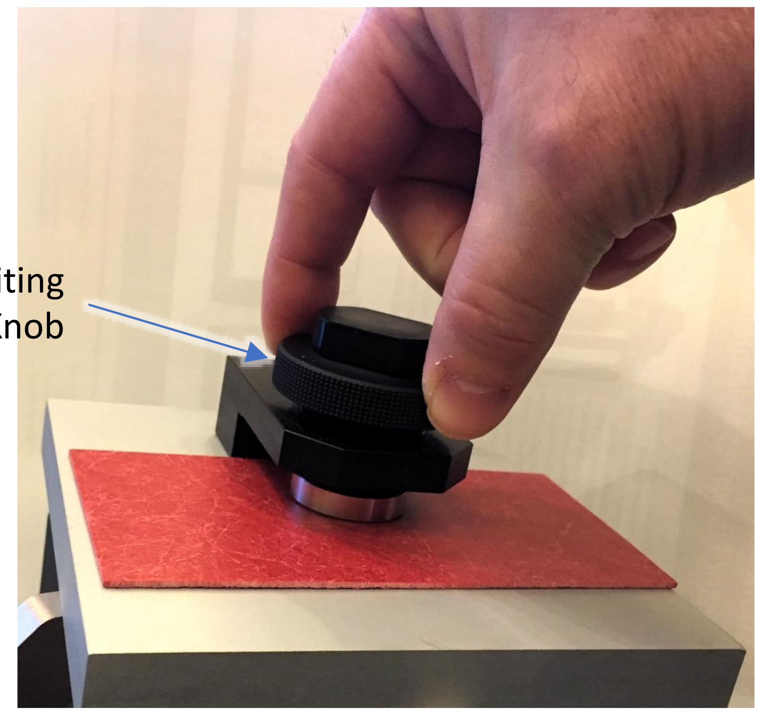


Figure 7. Photograph of torque-limiting knob

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Calibration Procedure

*****Calibration must always be performed prior to taking specimen data*****

A special Teflon calibration specimen is supplied with the epsilometer. Maintain this calibration standard so that is remains clean and undamaged. If you lose or otherwise need a replacement calibration standard, contact Copper Mountain Technologies to obtain a new one.

1. Select the measurement tab on the far-left side of the window. The program will then display that specific measurement window. (Figure 8)
2. Describe the material in the “Description” field in the “**Configure**” Group-Box (optional). (Appendix 1.1 for more detail)
3. Under the “**File Information**” Group-Box enter a name in the “File Name Root” field. Notice the “Next Sequence Number” automatically populates. (Appendix 1.2 for more detail)
4. Turn the top knob counter-clockwise to raise the top electrode. (Figure 9) Place the approximately 1mm Teflon Calibration Sample between the two electrodes. Turn the top knob clockwise to lower the top electrode (Figure 10) until it is snug but not over-tight. then use the torque-limiting knob to lower the top electrode to its final force.
5. Click “Measure” in the “**Calibrate**” Group Box. Notice the box turned from red to green. (Figure 11). (Appendix 1.3 for more detail). Make sure the plot appears and the tab on the left is “Deg.” The plot should look similar to the right side of Figure 11. The Teflon calibration specimen may now be removed.
6. Note that a calibration measurement is recommended at least once every few hours, in case there is temperature drift.

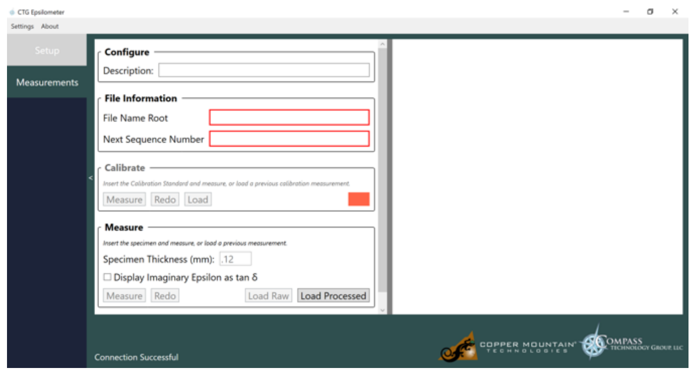

Figure 8. Measurement Screen

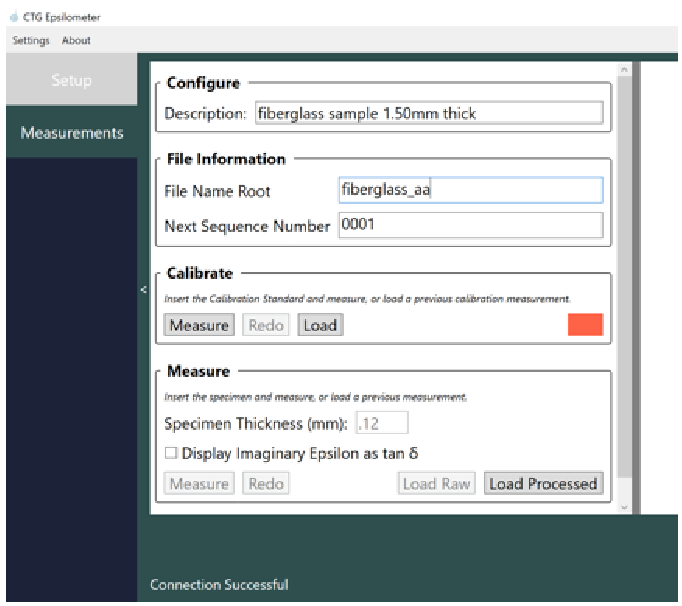

Figure 9. Description and File Information

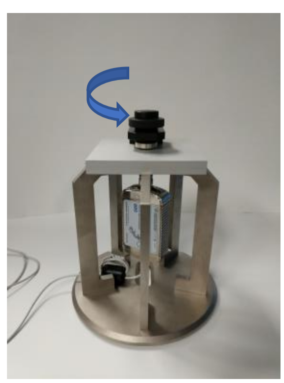

Figure 9. Raise Electrode

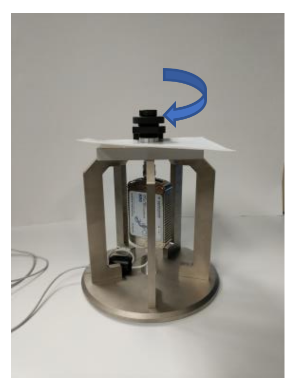

Figure 10. Lower Electrode

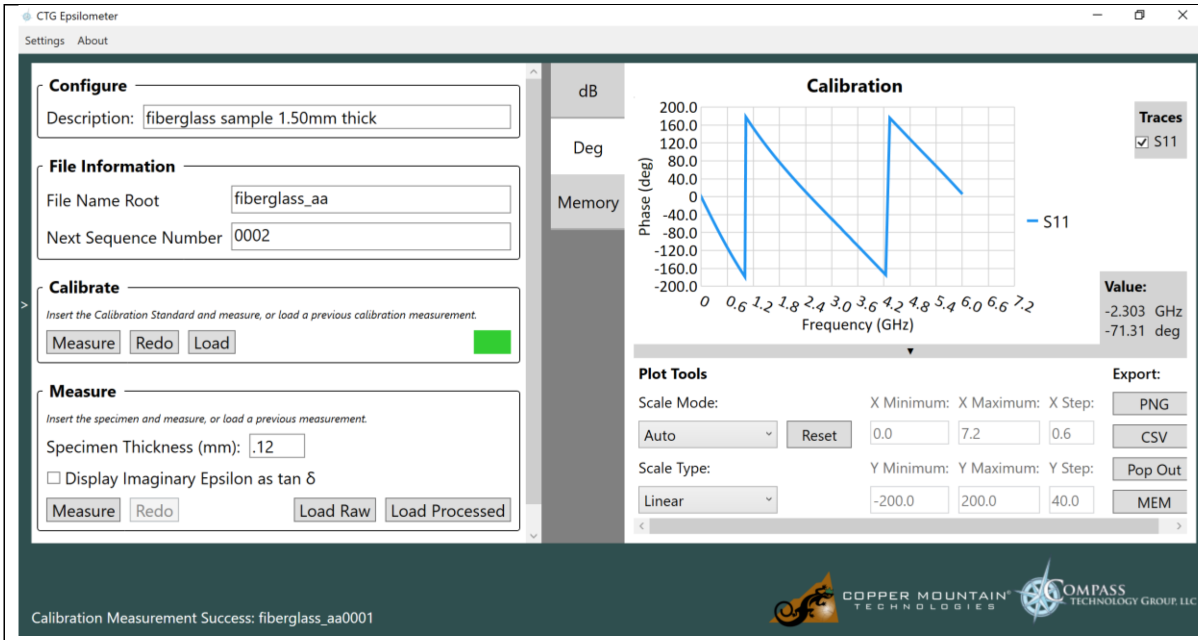

Figure 11. Calibration Success (Deg Tab)

Specimen Measurement Procedure

*****Measurement must be done with no hand or other extraneous material nea and with top electrode flush against specimen*****

1. Once Calibration is completed, measurement of the specimen may be done.
2. Measure the thickness of the specimen in millimeters (mm), using an accurate measurement tool, preferably a micrometer.
3. Turn the top knob counter-clockwise to raise the top electrode. (Figure 13). Place the measurement specimen between the two electrodes and turn the top knob clockwise to lower the top electrode until it is snug. (Figure 14). Then use the

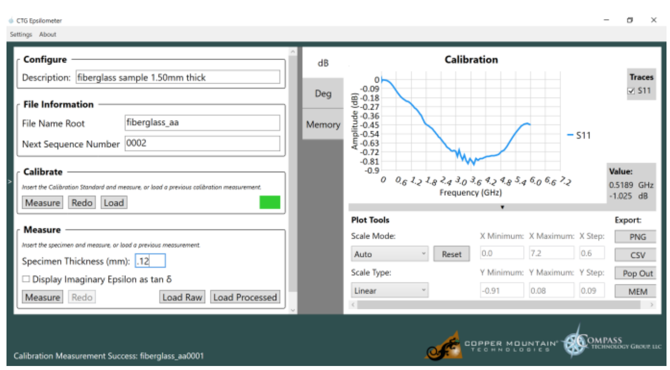

Figure 12. Calibration Success (dB Tab)

torque-limiting knob to lower the top electrode to its final force.

4. Use the "Measure" Group-Box and the "Specimen Thickness (mm)" field to type in the correct thickness that was measured in Step 2
5. Click "Measure" in the "**Measure**" Group Box to measure the dielectric permittivity of the specimen. (Figure 15)
6. Note the check box "Display Imaginary Epsilon as tan" displays the loss tangent instead of the imaginary permittivity if desired. (Appendix 1.5)

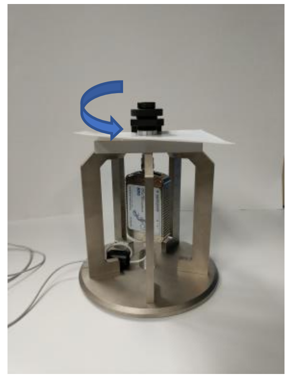

Figure 13. Raise Electrode

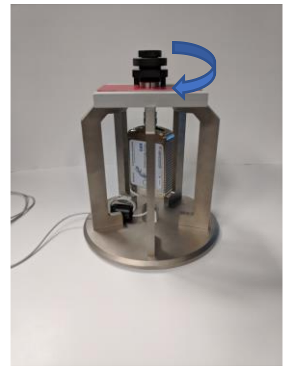

Figure 14. Lower Electrode

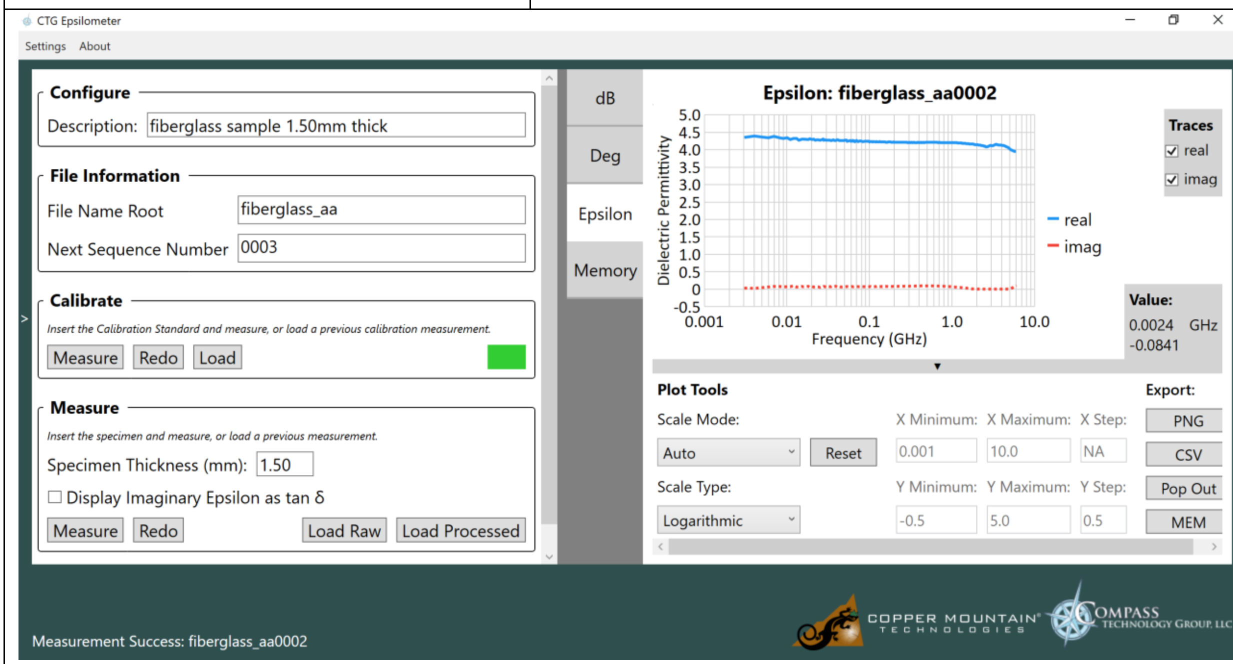

Figure 15. Measure Epsilon

Memory Tab (Optional)

*****The memory tab is used to keep and compare plots of previous measurements*****

1. Once a measurement is finished, the plots can be saved into the "**Memory**" Tab to compare results from more than one measurement
2. Click the "**MEM**" button on the right hand bottom corner of the plot panel under the "Export" title (Figure 16)
3. A box should pop out giving you an option to add any series to the "Memory" Tab (Figure 17)
4. From the drop-down menu, select a "Series" and enter a name
5. Click "add" to add the plot to the screen
6. The resulting plot should appear on the “Memory” tab. For demonstration purposes, the figure below are the real and imaginary parts of "Epsilon" from to a single measurement. To add more plots, measure another specimen and follow steps 2-5

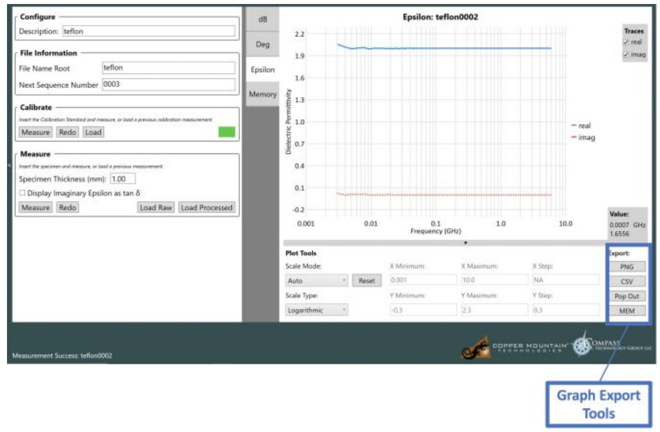

Figure 16. Graph Export Tools

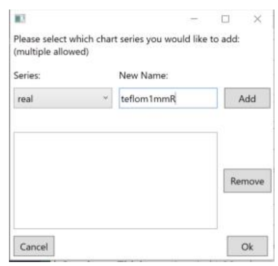

Figure 17. Add Real Line

Figure 18. Add Imag Line

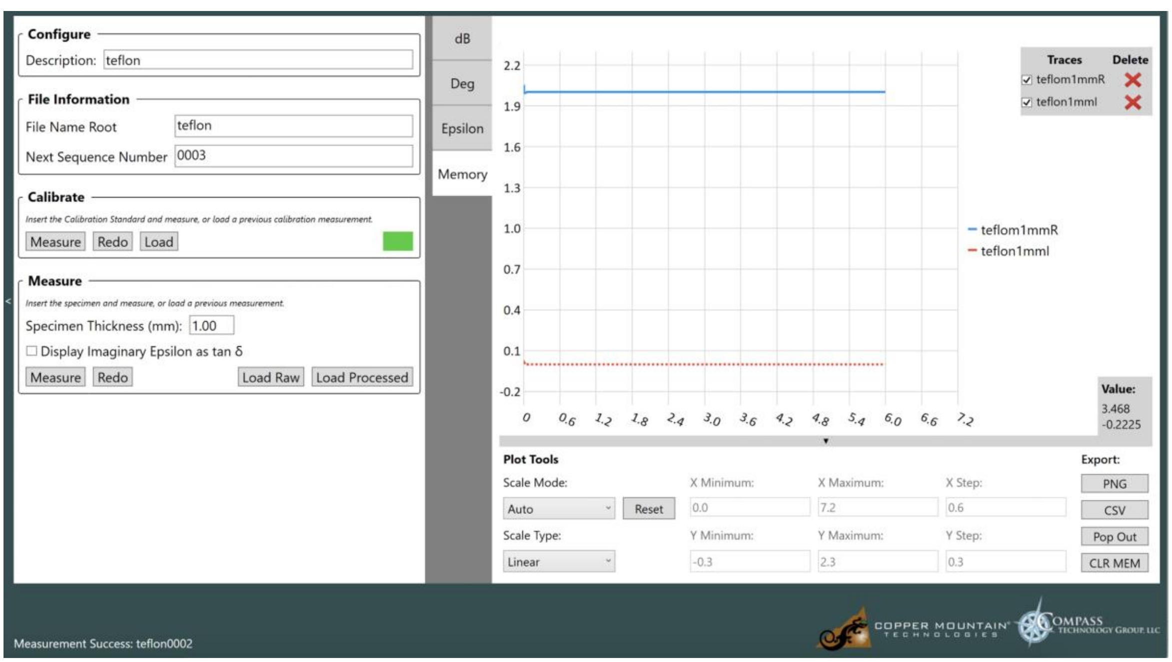

Figure 19. Memory Tab

Plot Tools

The plot views and plot tools are a powerful means of manipulating the data measured with this software. This section briefly overviews the options within the Plot Area are provided. **Figure 20** illustrates the plot tools layout.

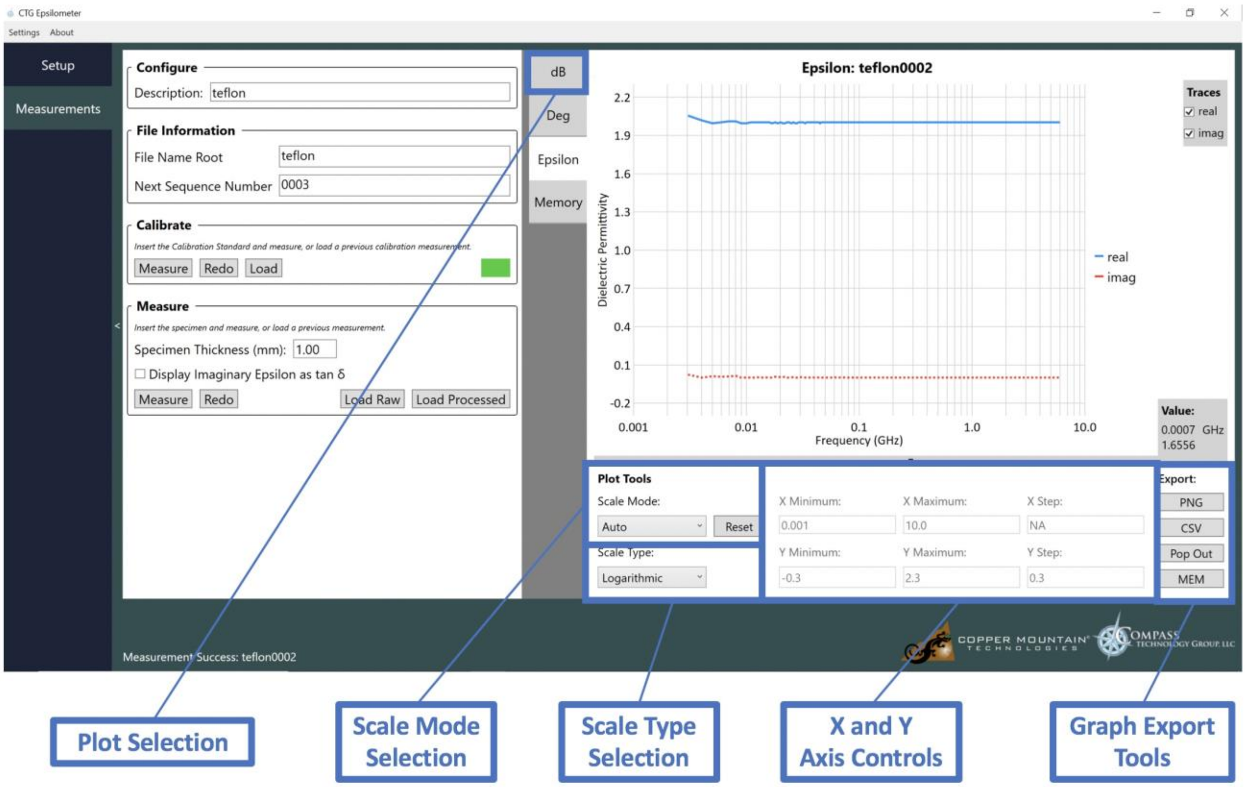

Figure 10: Plot Tools on the Measurement Screen

Plot Selection

The tabs along the left side of the data plot in **Figure** 1**20** allow the user to navigate between the different data displays from a single measurement. In this example, addition to displaying data as extracted Epsilon, you can also select dB, degrees, or a set of data you have loaded in Memory for comparison. Generally speaking, the plot will come up on the same plot tab for the previous measurement.

Scale Mode Selection

The default behavior of plotted data is to autoscale based on the measured data. However the user may override the default axes limits by selecting manual mode and then inputting the desired minimum, maximum, and step limits in the X and Y Axis Controls area.

Scale Type Selection

A drop-down selector allows the user to switch between a linear and logarithmic frequency scale. Because data is taken over several orders of magnitude, the default behavior is to plot as a functno of logarithmic frequency.

Graph Export Tools

The measured data and inverted permittivity results are automatically saved as text files (*.s1p and *.epsmu) in the default data directory. In addition to this, graph export tools enable the user to output results in a number of other formats. Clicking the PNG button will save the current plot as a *.png file. Clicking the CSV button will save the data in the current plot as a *.csv file. Clicking the Pop Out button will create a new window that contains the current plot. Clicking the MEM button enables the user to populate the Memory plot tab with current data for later comparison to other measurements.

Appendix

Section 1.1: "Configure" Group-Box

The Description field is optional and should contain information about the material. This could include external properties, such as color, type, shape, thickness. Information typed in this box is then included in the output file headers.

Section 1.2: "File Information" Group-Box

This field identifies how the output data will be labelled. The "File Name Root" dialogue box identifies the label that will be used for all output filenames until the field is changed. The "Sequence Number" dialogue box identifies the unique sequential ID number that refers to the measurement instance within a session. This number is embedded in the name of the output data file after the "File Name Root." The sequence number is auto-incremented to minimize the risk of accidentally overwriting previously measured data.

Section 1.3: "Calibrate" Group-Box

The Epsilometer utilizes a 1mm Teflon sample for calibration, which is supplied with the unit. To ensure accurate measurements, only a Teflon calibration specimen supplied by Copper Mountain Technologies should be used.

To calibrate, the calibration sample is placed between the top and bottom electrode. The top knob is turned clockwise to lower the top electrode onto the surface of the Teflon until it is snug. The second torque-limiting knob is used to secure the sample with a consistent force for each measurement.

The "**Measure**" button obtains the calibration data from the system, which is also stored in a file that can be loaded later. The indicator box tursn from red to green when valid calibration data is in memory.

The "**Redo**" button is the same as the "**Measure**" button except the sequence number is not incremented. Note that selecting redo will overwrite the previous measurement.

The "**Load**" button is used to load calibrations that have been previously saved.

Section 1.4: "Measure" Group-Box

The "Measure" group-box includes a text-box to specify specimen thickness. Dielectric property inversion requires accurate measurement of the specimen thickness. Specify the thickness in the "**Specimen Thickness**" text-box in millimeters.

The "**Redo**" button is the same as the "**Measure**" button except the sequence number is not incremented resulting in overwriting the previous measurement.

The "**Load Raw**" button loads previously measured raw data.

The "**Load Process**" button is used to load measured processed data.

Section 1.5: "Loss Tangent" Check Box

The 'loss tangent' is associated with the energy absorption of a material and is equal to the imaginary permittivity divided by the real permittivity

$$tan\ \delta = \frac{\epsilon''}{\epsilon'}$$

The loss tangent is a convenient way to compare the relative dielectric loss of materials that have different real permittivities.