EPSILOMETER
DIELECTRIC MATERIALS
MEASUREMENT ANALYZER

USER MANUAL

Version 24.1.2

COMPASS
TECHNOLOGY GROUP

COPPER MOUNTAIN
TECHNOLOGIES

RVNA Software Installation

1. Place included USB memory stick into USB port of computer or laptop.
2. File Explorer window showing folder contents of USB drive should open automatically with auto-run feature, but 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 installation files.
4. Run setup application program called "Setup_RVNA v23.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 are not displayed on the right but are described below.
7. Ensure "*Enable Demo Mode*" is **NOT** checked. Click "**Next**".
8. Select a folder destination for RVNA software to be installed on computer and click "**Next**" button.
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 included measurement software *(Figure 2)*.
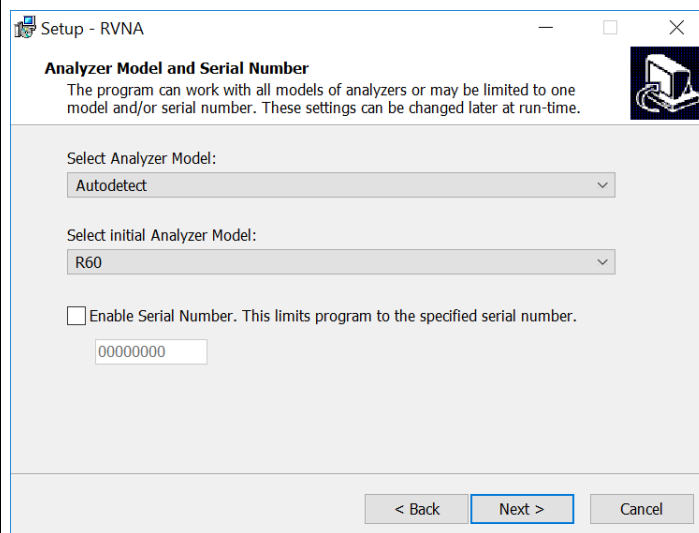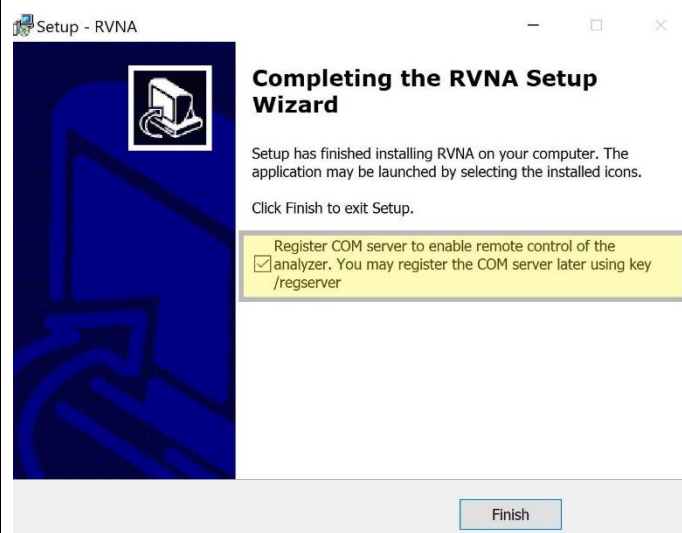

Figure 1. RVNA Model and Serial Number

Figure 2. Registration of RVNA

CTGEpsilometer™ 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_1.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 CTGEpsilometer 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.
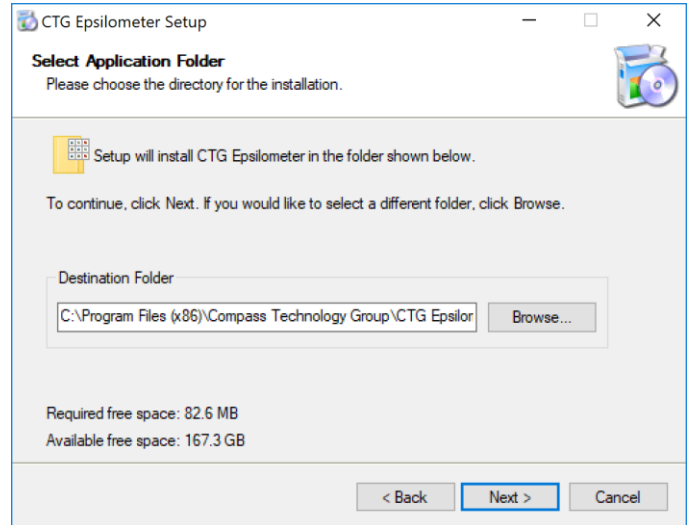8. CTG.Epsilometer icon will be displayed on desktop as symbol.

Figure 3. Selecting Destination Folder

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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 containing two ribbon tabs: "*General*" and "*Analyzer*" (**Figure 4**).

3. Within the "*General*" ribbon tab, 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

6. The "**Enable Banner**" toggle switch allows the user to input

7. Upon CTG Epsilometer application launch, CMT RVNA software is automatically opened in the background. CTG Epsilometer application will then perform a connection to the RVNA software.

8. To verify a successful connection to RVNA, navigate to the grey "*Analyzer*" ribbon tab (Figure 5).

9. Successful connection to RVNA will display a green *plug* icon 🔌 to the user.

10. Upon application launch, the CTG Epsilometer software configures the RVNA software to use the following "*Default*" VNA parameters:
    Start Frequency: 3 MHz   Stop Frequency: 6 GHz
    IFBW (Hz): 100   Num Points: 401
    Power Mode: Manual   Power (dBm): 0.0

11. To create a custom VNA profile with VNA desired parameters, use the "*Create Settings*" fields to create a VNA profile that can be selected by the user at any time by the user.
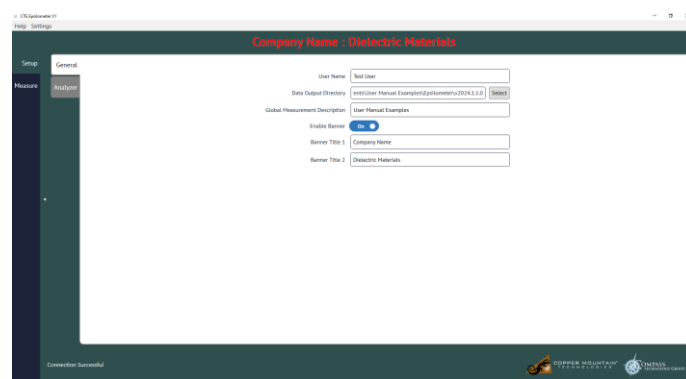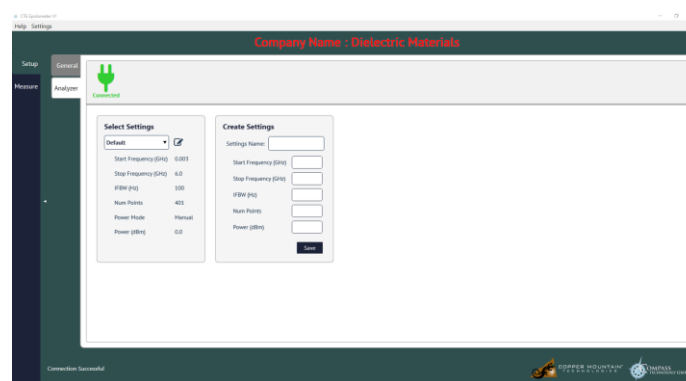

Figure 4. Initial "Setup" Screen

Figure 5. VNA Settings Screen

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Epsilometer Overview

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.

Torque limiting screw

Top electrode

Specimen under test

Integrated analyzer

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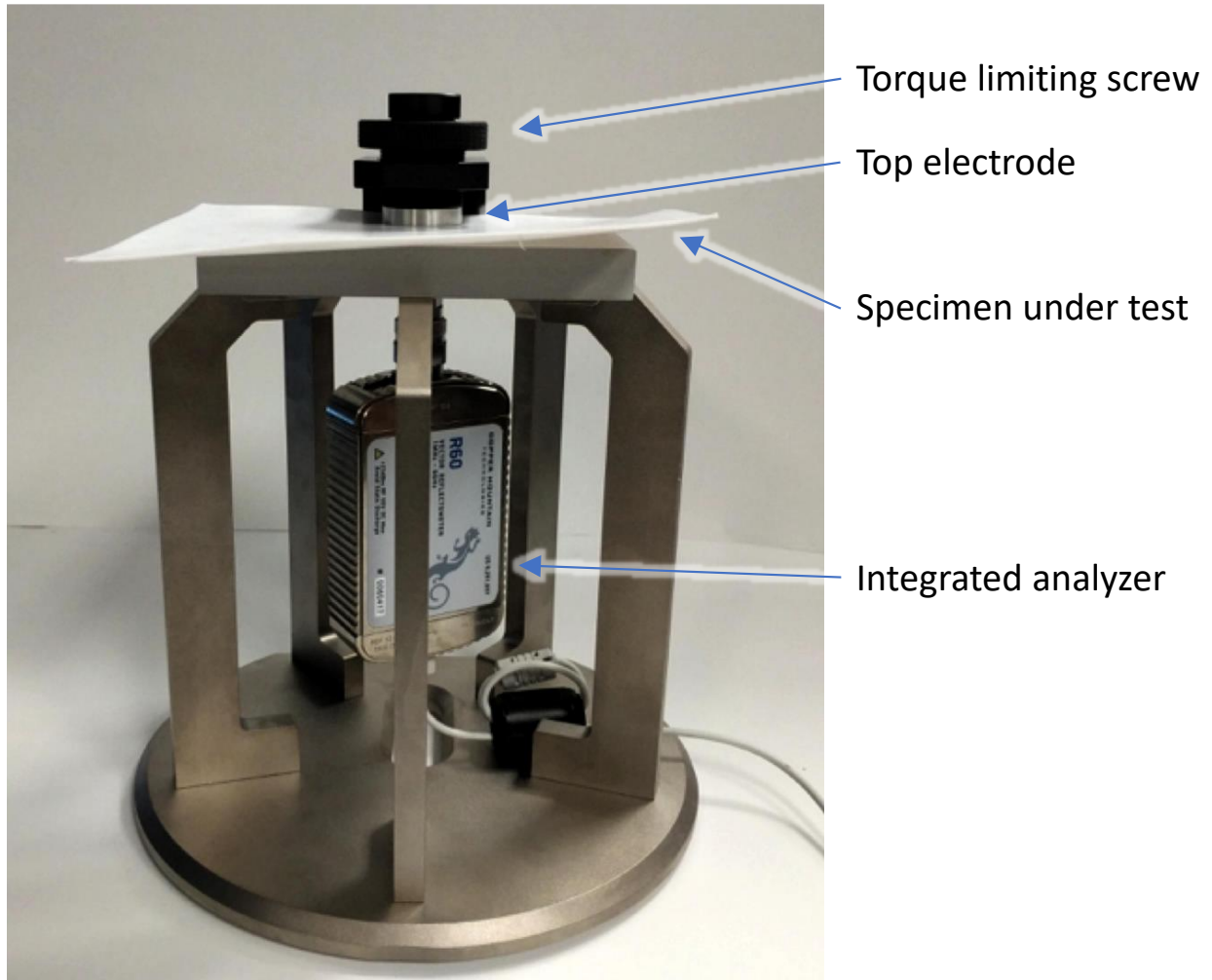
Measurement Screen Items

After connecting to the analyzer in the Setup tab, select the "*Measure*" tab on the far-left side of the window. The general flow of the "*Measure*" 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.
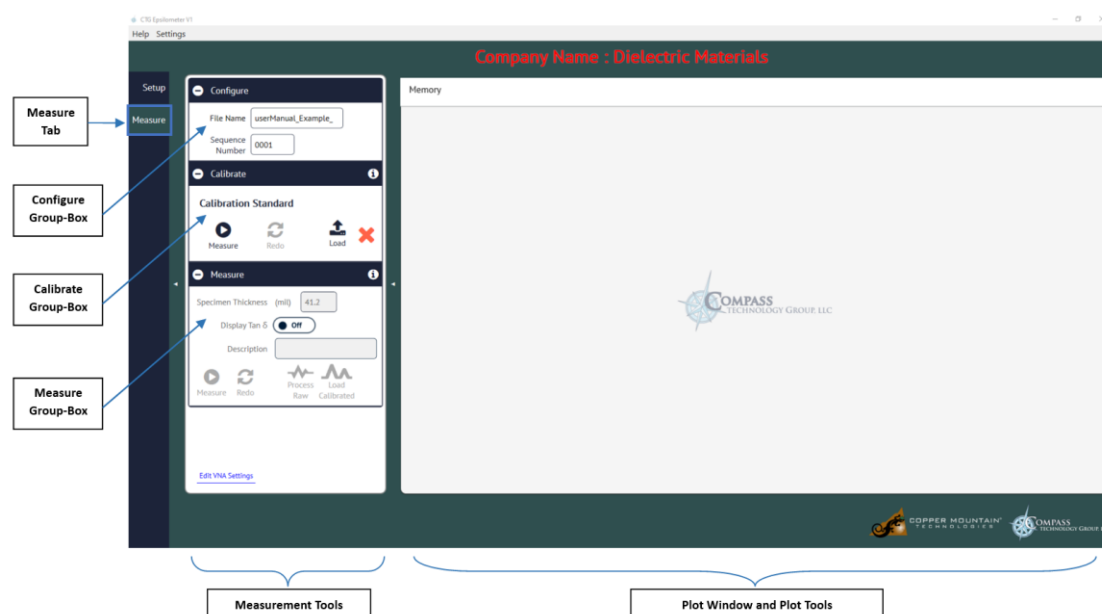

Figure 6. Measure Tab

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 ✖ in "*Calibrate*" group box. This is an indication that a calibration measurement 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.

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Important Environmental and User Procedures for Accurate Measurement

1. It is recommended before beginning measurements to have the CMT R60 reflectometer powered on for approximately 15 minutes to achieve temperature equilibrium.
2. Be careful to not have your hand or any other foreign metallic materials near the top, electrode area of the Epsilometer.
3. During measurement, ensure the top electrode lowered flush against the specimen. Turn top knob clockwise to lower the electrode until tightens.
4. Note the knob includes a special secondary knob for limiting the torque of the electrode against the specimen. Use 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.
5. Be sure to have an accurate specimen thickness – the measurement error is directly related to the thickness uncertainty.
6. Input the correct thickness in the "**Measure**" Group Box.
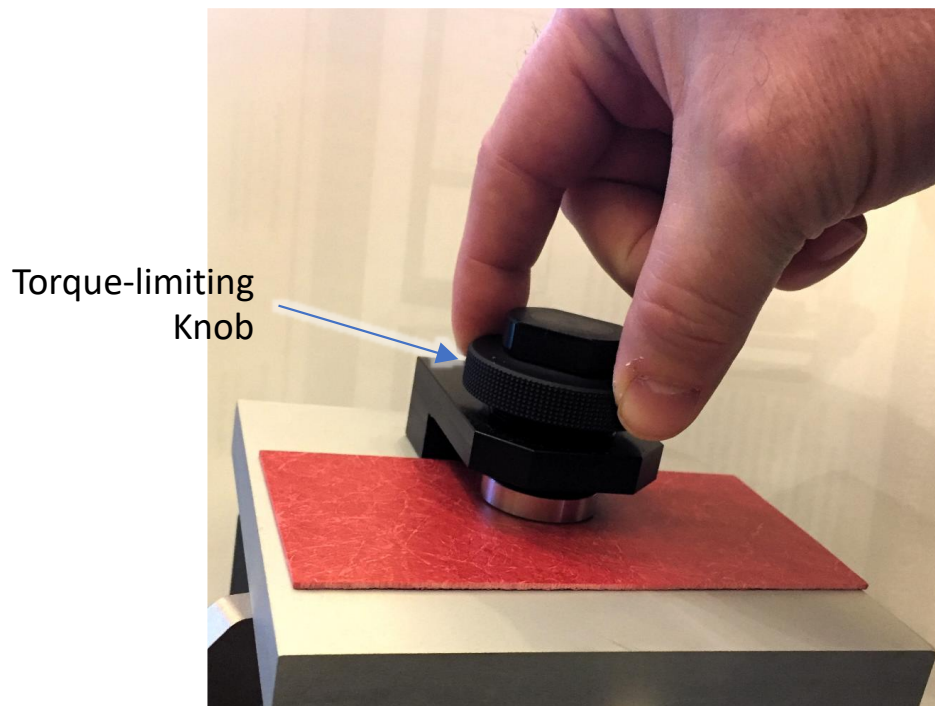

Torque-limiting Knob

Figure 7. Photograph of torque-limiting knob

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Calibration Procedure

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

1. Select the "*Measure*" tab on the far-left side of the window. The program will then display that specific measurement window. (Figure 8)
2. Under the "**Configure**" Group-Box enter a name in the "File Name" input field. The complete file name of each measurement will consist of the "**File Name**" and "**Sequence Number**" concatenated together. Note that the "**Sequence Number**" will automatically populate between measurements (Appendix 1.2 for more detail).
3. Turn the top knob counter-clockwise to raise the top electrode of the Epsilometer (**Figure 9**). Place the Teflon Calibration Sample between the two electrodes. Turn the top knob clockwise to lower the top electrode until lightly snug (**Figure 10**). Then use the torque-limiting knob by applying downward pressure while turning clockwise to lower the top electrode to its final force.
4. Click "Measure" in the "**Calibrate**" Group Box. Notice the red 'X' turned into a green checkmark. (**Figure 11**). (Appendix 1.3 for more detail). Make sure the plot appears and the tab on the left is "dB." The plot should look similar to the right side of Figure 11. The Teflon calibration specimen may now be removed.
5. Note that a calibration measurement is recommended at least once a measurement session, in case there is temperature drift. It can also be good practice to take a calibration measurement at the end of a measurement session to compare the calibration files if data anomalies exist.
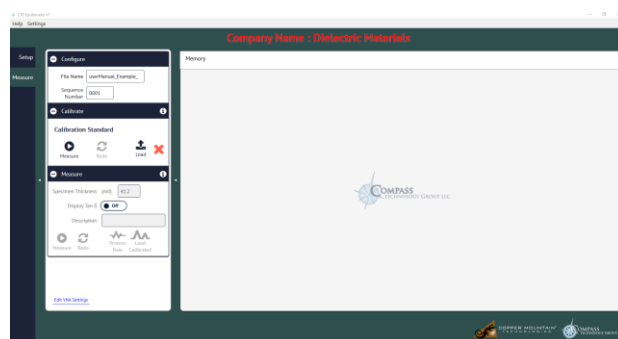

Figure 8. Measurement Screen

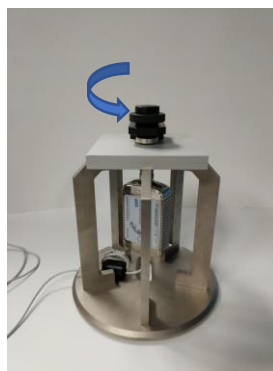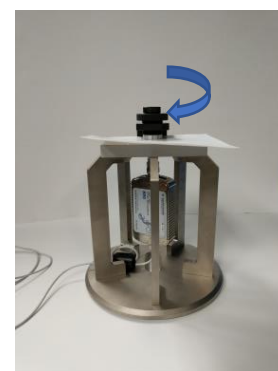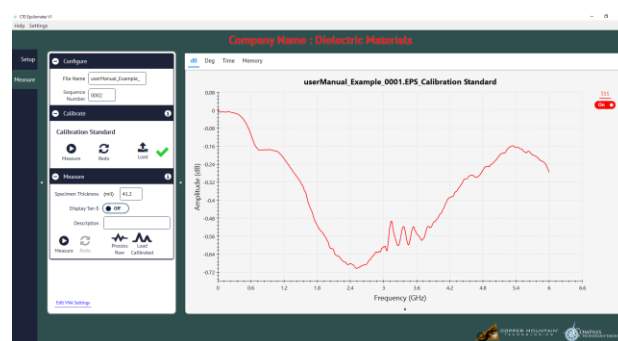Figure 9. Raise Electrode

Figure 10. Lower Electrode

Figure 11. Calibration Success (dB Plot Tab)

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Measurement Procedure

Measurement of Specimen

Measurement must be done with no conductive material nearby and with top electrode flush against specimen

1. Once Calibration has been completed, measurement of the specimen may be performed.
2. Measure the thickness, in inches (mils), of the specimen using a precise measurement tool, preferably a micrometer.
   Note: Measurement units can be changed to metric by clicking the "Settings" menu drop-down (see Appendix 1.4).
3. Turn the top knob counter-clockwise to raise the top electrode. (**Figure 12**). Place the measurement specimen between the two electrodes and turn the top knob clockwise to lower the top electrode until it is snug. (**Figure 13**). Then use downward pressure on the torque-limiting knob while turning clockwise to lower the top electrode to its final force.
4. Use the "*Measure*" Group-Box and the "**Specimen Thickness (mil)**" field to type in the correct thickness that was measured in Step 2
5. Click the "**Measure**" button within the "*Measure*" Group Box to measure the permittivity of the specimen (**Figure 14**).
6. The plotting window will default to the **dB** data display. To see the permittivity data across the selected frequency band, click on the **"Epsilon"** option at the top of the plot window (Appendix 1.7).
7. Note the toggle bar "*Display Imaginary Epsilon as tan*" can display the loss tangent instead of the imaginary permittivity if desired (Appendix 1.6).
8. For a full explanation of the plotting window features, please refer to Appendix 1.7.
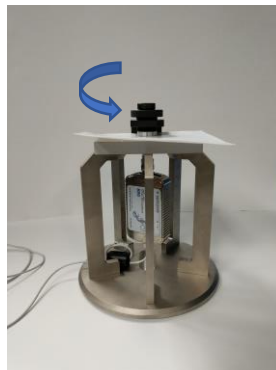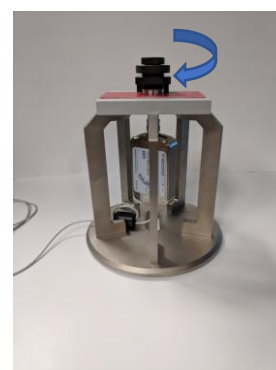

Figure 12. Raise Electrode
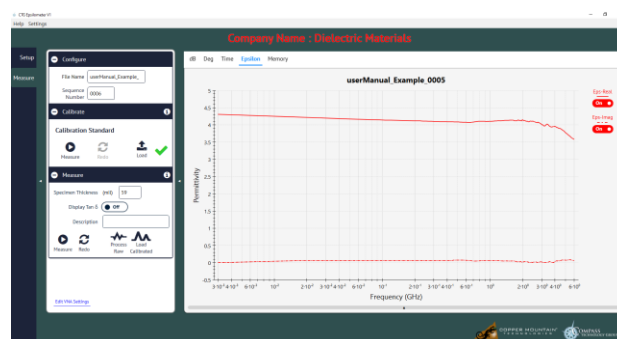

Figure 13. Lower Electrode

Figure 14. Measure Epsilon

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Appendix

Section 1.1: Output File Structure, Format, and Naming
CTG Epsilometer software uses the industry standard *Touchstone SnP* file format for various saved files.

The saved files come in multiple formats which include s1p and epsMu. The files start with header lines started with either an exclamation point or a percent symbol, followed by the data and associated information in column format. Header lines allow easy loading into Octave/Matlab. Listed below describe how the files are named by the CTG Epsilometer software:

File Format:

Calibration Files   // *[FileNameRoot] [SequenceNumber] [.EPS_Calibration Standard] [.s1p]*

Raw Specimen File   // *[FileNameRoot] [SequenceNumber] [.EPS_raw] [.s1p]*

Calibrated Specimen File // *[FileNameRoot] [SequenceNumber] [.EPS_cal] [.s1p]*

Extracted Material Properties File // *[FileNameRoot] [SequenceNumber] [.epsmu]*

Section 1.2: "Settings" Menu Options
The user is able to modify the UI display and outputs by clicking on the Settings button located at the top-left of the main software window. Once clicked, CTG Epsilometer will display the following list of options to the user as seen below:

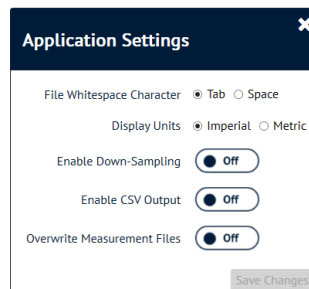**File Whitespace Character**: This field makes the spaces seen in the measurement generated files either a *Tab* or *Space* (single)
Display Units: The user can choose whether the display and input measurements are *Metric* or *Imperial*
Enable Down Sampling: Toggle *ON* or *OFF*
Enable CSV Output: Toggle *ON* or *OFF*
Overwrite Measurement Files: Toggle *ON* or *OFF.* When this setting is *OFF*, CTG Epsilometer will always display a dialogue box to the user asking the user for confirmation to overwrite a data file that already exists (same *File Name* and *Sequence #* in the selected data file path).

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Section 1.3: "Configure" Group-Box

The File Information input field identifies how the output data will be labelled. The "File Name" 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 1.4: "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 turns 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 1.5: "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 inches (mils).

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, generates a new calibrated S1P data file, and then runs the calibrated data through the inversion lookup table to generate an "Epsmu" file containing the permittivity of the sample across the selected frequency band.

NOTE: The generated calibrated S1P data file uses the currently selected "Calibrate" source in memory. If the user wishes to load a raw measurement from a previous session, it is recommended to also load the CALIBRATION STANDARD file from that previous measurement session.

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

Section 1.6: "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 permittivity.

Section 1.7 "Plot Tools" Menu

The "Plot Tools" are a powerful means of viewing and manipulating measurement data in CTG Epsilometer. This section briefly overviews the options within the Plot Area. **Figure 15** illustrates the plot tools in CTG software.

Figure 15

1. **Plot Window Display Options** – Select the type of measurement to be displayed by clicking on the appropriate label

2. **S-Parameter Trace** – Click on the *ON/OFF* toggle switch to view/hide that trace

3. **Plot Window Scale Mode** – Select "*Manual*" from the *Scale Mode* drop-down menu to change the axis limits and steps. Use the *Scale Type* drop-down menu to change the x-axis plot scale from *Logarithmic* to *Linear*

4. **Plot Window Scale Parameters** – This plot tool allows the user to set the domain, range, and respective step values for the data plot when the "*Scale Mode* selection is set to "**Manual**"

5. **Collapsable Plot Tools Arrow** – Different areas of the CTG application windows can be collapsed or expanded by clicking the small black/white triangles. The Plot window is collapsed by default.

6. **Plot Window Export Buttons** – To create a PNG screenshot of the displayed plot, click the **"PNG"** button. The **CSV** button will export the plot traces to a text file. **Pop Out** will open the currently selected plot in a separate window. The **MEM** button / window is a plot comparison tool that allows the user to add traces from a measurement plot into the **Memory** plot associated with the selected measurement tab. The user may change trace labels before loading trace data into memory.

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