

## Thru-Reflect-Line (TRL) Calibration Using the RO4003C Standards

There are two necessary steps to perform a vector network analyzer (VNA) calibration. The first is to define a calibration kit and the second step is to perform the actual calibration using known standards. The process of defining the calibration kit sets up the VNA to perform the proper set of measurements and to correctly apply these measurements in the calculation of the error correction coefficients. While many standard calibration kits come built-in to the VNA, specific TRL kits are not, though TRL calibration can still be performed with the VNAs in the lab.

The systematic process of defining the TRL calibration kit, as well as performing the TRL calibration itself, is listed in the remainder of this manual. It is assumed that the THRU, REFLECT and LINE standards are those that have been supplied to you for the EE 481 lab. Specifically, all three standards have been fabricated on a single board of RO4003C laminate.

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### Creating the User-Defined TRL Calibration Kit

In order to use the TRL technique, the characteristics of the calibration standards must be entered into the analyzer's user-defined calibration kit.

The following steps show you how to define a calibration kit to utilize a set of TRL standards. This specific TRL kit contains a:

- Zero length THRU,
- Flush short for the REFLECT standard (i.e., 0 second offset from the THRU plane),
- LINE standard with a 49.24-ps offset delay (beyond the THRU) for a 50- $\Omega$  transmission line using the standards which were constructed on RO4003C laminate.

The following designations will be used to help you operate the VNA:

- A front panel button will be depicted by a box outline such as **BUTTON**.
- A softkey on the VNA display will be represented by highlighting the key name as **SOFTKEY**.

### Modify the Standard Definitions

- 1) Attach the grounding wrist strap to yourself and check its proper performance by inserting the banana plug into the SP-300 Wrist Strap Checker located near your work station. Only proceed when the green "OK" LED is lighted. Insert the banana plug into the 8753ES VNA. Make sure the gray work pad is connected to the grounding lug on the VNA. (Note that only the 8753ES VNAs will be used in this course.) You must wear the grounding wrist strap at all times to mitigate the effects of electrostatic discharge, which can easily damage a network analyzer.

- 2) Press **Preset** to place the VNA in the factory present configuration.
- 3) Select the frequency span to measure  $S$  parameters. This is done by pressing **Start**, then entering the starting frequency for the sweep. For example, press **4** **G/n**. Then enter the ending frequency of the sweep, such as **Stop** **6** **G/n**.
- 4) The number of equally spaced frequencies at which to measure the  $S$  parameters is entered by pressing **Sweep Setup** **NUMBER of POINTS** and the number of points, for example **801** **x1**.
- 5) Press the following keys to start modifying the TRL standards definitions: **CAL**  
**CAL KIT MODIFY DEFINE STANDARD**.
- 6) In this cal kit, the REFLECT standard is an OPEN. To select an open for this standard, press **1** **x1**, then **OPEN MODIFY STD DEFINITION SPECIFY OFFSET OFFSET DELAY** **0** **x1** **STD OFFSET DONE STD DONE (DEFINED)**.
- 7) To define the THRU/LINE standard, press:  
**DEFINE STANDARD** **4** **x1** **DELAY/THRU MODIFY STD DEFINITION SPECIFY OFFSET OFFSET DELAY** **0** **x1** **STD OFFSET DONE STD DONE (DEFINED)**.
- 8) To define the LINE/MATCH standard, press:  
**DEFINE STANDARD** **6** **x1** **DELAY/THRU MODIFY STD DEFINITION SPECIFY OFFSET OFFSET DELAY** **0.04924** **G/n** **MAXIMUM FREQUENCY**.  
Enter a frequency greater than the maximum at which you will be measuring  $S$  parameters. For example, press **6** **G/n**, then press **STD OFFSET DONE**.
- 9) For the purpose of this example, change the name of the standard by pressing **LABEL STD** and entering the name "LINE".
- 10) When the title area shows the new label, press: **DONE** **STD DONE (DEFINED)**.

### Assign the Standards to the Various TRL Classes

- 11) To assign the calibration standards to the various TRL calibration classes, press: **CAL** **CAL KIT MODIFY SPECIFY CLASS MORE MORE TRL REFLECT**.
- 12) Since you previously designated standard #1 for the REFLECT standard, press: **1** **x1**.
- 13) Since you previously designated standard #6 for the LINE/MATCH standard, press: **TRL LINE OR MATCH** **6** **x1**.
- 14) Since you previously designated standard #4 for the THRU/LINE standard, press: **TRL THRU** **4** **x1**.
- 15) To complete the specification of class assignments, press: **SPECIFY CLASS DONE**.

## Label the Classes

- 16) Press **LABEL CLASS MORE MORE**.
- 17) Change the label of the “TRL LINE OR MATCH” class to “LINE”, then press **DONE LABEL CLASS DONE**.

## Label the Calibration Kit

- 18) Press **LABEL KIT** and create a label up to eight characters long. For this example, enter “TRLKIT1” **DONE**.
- 19) You may find occasionally that the VNA seems to “hang” at this point or in similar situations. This likely happened because the VNA trigger was inadvertently placed in the “hold state” by the machine. To reactivate the trigger, press **Sweep Setup TRIGGER MENU CONTINUOUS**.
- 20) To save the newly defined kit into nonvolatile memory, press: **KIT DONE (MODIFIED) SAVE USER KIT**.

You may wish to save your cal kit to the nonvolatile memory of the VNA or to a diskette for future use. To do this, you first should select the medium to store the data. Press **Save/Recall** then **SELECT DISK**. For storage in the VNA’s nonvolatile memory, select **INTERNAL MEMORY** or to the floppy diskette select **INTERNAL DISK**. Finally, press **SAVE STATE**.

Once you have saved a cal kit, you can use it over and over again. Its “performance” does not degrade over time. Conversely, you should perform a new VNA calibration, described next, whenever the cables have been moved significantly (or reconnected), the environmental conditions have changed significantly (temperature and humidity), or a significant amount of time has elapsed. Generally speaking, recalibrating the VNA once per day is quite common.

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## Performing a TRL Calibration

- 1) Attach the grounding wrist strap to yourself and check its proper performance by inserting the banana plug into the SP-300 Wrist Strap Checker located near your work station. Only proceed when the green “OK” LED is lighted. Insert the banana plug into the 8753ES VNA. Make sure the gray work pad is connected to the grounding lug on the VNA. You must wear the grounding wrist strap at all times to mitigate the effects of electrostatic discharge, which can easily damage a network analyzer.
- 2) Select the frequency span over which to measure the  $S$  parameters. Press **Start** then enter the starting frequency for the sweep. For example, press **4** **G/n**. Then enter the ending frequency of the sweep, such as **Stop** **6** **G/n**. This frequency span should correspond to that specified in your cal kit.

- 3) The number of frequencies at which to measure the  $S$  parameters is entered by pressing **Sweep Setup** **NUMBER of POINTS** and entering the number of points, for example **801** **x1**. This number should correspond to that specified in your cal kit.
- 4) Press **CAL** **CAL KIT** **SELECT CAL KIT** **USER KIT** **RETURN** **RETURN** **CALIBRATE MENU** **TRL\*/LRM\* 2-PORT**.
- 5) To measure the “TRL THRU”, connect the “zero length” THRU standard between the two test ports.
- 6) Press **THRU THRU**.
- 7) To measure the “TRL OPEN”, connect the OPEN standard to PORT 1, and press: **S11 REFL: OPEN**.
- 8) Similarly, connect the OPEN standard to PORT 2 and press **S22 REFL: OPEN**.
- 9) To measure the “TRL LINE”, disconnect the OPEN and connect the LINE standard between the two test ports.
- 10) Press **LINE/MATCH** **DO BOTH FWD + REV**.
- 11) The LINE standard data is now measured and the **LINE/MATCH** softkey label should be underlined.
- 12) For the “ISOLATION”, press **ISOLATION** **OMIT ISOLATION** to choose not to perform the isolation measurement.
- 13) You may repeat any of the previous steps. Your new calibration measurements will simply overwrite the corresponding old ones. Furthermore, there is no requirement to proceed in the order of these steps for a calibration.
- 14) All of the standards measurement softkeys will be underlined on the display when you have completed these measurements. Then press **DONE** **TRL/LRM**. The message COMPUTING CAL COEFFICIENTS will appear, indicating that the analyzer is performing the numerical calculations for the error coefficients.
- 15) You can now save or store the measurement correction for use in later measurements by pressing **Save/Recall** **SAVE STATE**.
- 16) You may find occasionally that the VNA seems to “hang” at this point or in similar situations. This likely happened because the VNA trigger was inadvertently placed in the “hold state” by the machine. To reactivate the trigger, press **Sweep Setup** **TRIGGER MENU** **CONTINUOUS**.
- 17) Connect the device under test. The  $S$  parameters of the device can now being measured with the effects of systematic errors largely removed from the measurements.