SPARQ "Factory" 2nd-Tier Cal Procedure for End-Users

TECHNICAL NOTE

Overview

The following procedure describes how to perform a **Factory Second-tier Calibration.** All SPARQ models that include the internal calibration capability ("E" Series SPARQs) are shipped with a factory 2nd-tier calibration, and the default SPARQ configuration enables the application of this calibration via a checkbox in the **Calibration** tab.

Factory 2nd-tier calibrations are nominally performed on all SPARQ returned for an annual calibration, and on repairs that affect the signal path, including internal switch matrix, pulser/sampler, sampler and/or cable. With the 2nd-tier calibration, the annual calibration is not simply a "performance verification", but is instead a real calibration that corrects for any drift that may have occurred in the SPARQ's signal paths prior to the last factory 2nd-tier calibration.

End-users can also perform a factory 2nd-tier calibration at their discretion, and the scripts described in this document are available via download from the LeCroy website. By performing a factory 2nd-tier calibration, users have the ability to achieve the best performance possible short of a full recalibration of the SPARQ, which can only be done at the factory. A full recalibration includes re-measurement of the internal switch matrix on "E" Series SPARQ models.

The goal of the factory 2nd-Tier calibration is to generate a calibration file that is applied "on top" of the automatic calibration performed by the internal OSLT calibration. The action of the 2nd-tier calibration should be small; the error corrections that applied should act as a fine-tuning of the measurement.

> ***Note**: The Factory 2nd-tier calibration is different than a "User 2nd-tier calibration", which serves a different purpose, and that is described in other application notes.*

This application note lists the required equipment and outlines the procedure for performing, validating and installing the factory 2nd-tier calibration. Please contact your local LeCroy application engineer with any questions.

Preparing for the Calibration

Required Equipment/Files

- In addition to the SPARQ to be calibrated, the cables matched to the user's SPARQ are required.
- A 40GHz calibration kit with female open, short, and load standards, + 2 Thru standards (or 2 of the female-to-female adapters that ship with SPARQ units.)
- Touchstone files for the calibration standards, or a "Standards.cstd" file (see Appendix for CSTD format)
- Latest version of the Factory 2nd-tier calibration scripts. Customers can download the scripts from the LeCroy website.
- PC running latest release version of the SPARQ application, or an approved beta version.

Before the Factory 2nd-tier calibration is performed

- If applicable, all repairs should be completed.
- The SPARQ "port cables" have been measured properly.
- The calibration data of the switch matrix and S2P files for the cables should be loaded onto the SPARQ's SD card with the correct folder structure and filenames (i.e. the SPARQ is otherwise ready for customer use.)
- The SD card should be unlocked so that the result of the calibration can be loaded onto the card as described below.
- The cables supplied with the SPARQ should be attached to the correct ports and properly torqued.

Factory 2nd-tier Calibration Procedure

1. Create a new folder to contain the files used for and created by the 2nd-tier calibration. Include the serial number in the folder name: (e.g. LCRY2402N12345-FactorySecondTierCalibration
2. Copy the calibration scripts to the folder created above.
3. Copy Touchstone files for the calibration standards to the folder created above, OR create a Standards.cstd file for the calibration kit (see Appendix C). Files should be named as follows:
    - Short.s1p
    - Open.s1p
    - Load.s1p
    - Thru.s2p
    - Standards.cstd
4. Get the SPARQ & SPARQ application up and running:
    a. Connect PC to SPARQ
    b. Power up the SPARQ
    c. Run the SPARQ application.
5. Perform a **Recall Defaults**
6. Configure the filename settings in the Instrument Setup tab to match the SPARQ cable S2P files.
7. **Disable** cable de-embedding by **unchecking** the De-embed Cables checkbox in the **Instrument Setup** dialog.
8. **Disable** the Factory and User 2nd-tier calibrations by **unchecking** the **Factory** and **User** checkboxes in the **Calibration** tab.
9. Perform measurements on the short, open and load standards using the scripts as described below. Each script will perform three 1-port measurements, and save three **S1P** and three **.cal** files. *(Note that the filename of the script to run describes the port number used for the standards, with "X" indicating that the corresponding port is not used. E.g., LXSO.vbs has load on 1, nothing on 2, short on 3, open on 4.)*
    a. Attach the S, O, L standards to the ends of the cables connected to ports 1, 2, 3, and torque.
    b. Run script **SOLX.vbs**
    (*Note: the script makes the measurements in reverse order, allowing users to move each*

standard after it has been measured to the port specified in the next step of the procedure while the SPARQ is calculating the result of the last step.)

c. Move the S, O, L standards to end of cables connected to ports 2, 3, 4, and torque.
d. Run script **XSOL.vbs**
e. Move the L, S, O standards to end of cables connected to ports 1, 3, 4, and torque.
f. Run script **LXSO.vbs**
g. Move the O, L, S standards to end of cables connected to ports1, 2, 4 and torque.
h. Run script **OLXS.vbs**
i. Take off O, S, L standards. The 2nd-tier calibration folder will now include S1P files for each standard on each port.

10. Perform measurements with the thru standards (or F-F adapters) connected between the cables as described below. Each script will perform two 2-port measurements, and save two S2P and two .cal files.
    a. Cable 1 ← T → Cable 2, Cable 3 ← T → Cable 4
    b. Run script **12_34.vbs**
    c. Cable 1 ← T → Cable 3, Cable 2 ← T → Cable 4
    d. Run script **13_24.vbs**
    e. Cable 1 ← T → Cable 4, Cable 2 ← T → Cable 3
    f. Run script **14_23.vbs**
    g. Take off the thru standards. The 2nd-tier cal folder will now include S2P files for each pair of ports.
11. Run **ApplySOLT.vbs**.
    a. This script outputs the 2nd-tier calibration files, including the **L12T** file which is the file that will be used by the SPARQ when implementing the Factory 2nd-tier calibration, along with a ConversionLog, and 4 "S8P" files.
    b. This script also copies the S2P files configured in the Instrument Setup tab into the Factry 2nd-tier cal folder, naming them *cable[x].s2p*
    c. This script can take several minutes to run. The SPARQ application will indicate "Converting…" during the conversion process, potentially along with other messages in the lower left corner of the application window.
    d. The steps below described how to verify and install the L12T file. If the conversion fails, the ConversionLog.txt file will include lines beginning with an exclamation point.

Validating the Calibration

12. View the **ConversionLog.txt file**. This file includes information about the files that were read from the factory 2nd-tier calibration folder. Errors in reading a file or creating the L12T output will be shown with an exclamation point at the beginning of the line.
13. Run **CalculateResiduals.vbs.** This script is the first step in verifying that the Factory 2nd-tier cal created above only creates a small change. It re-runs a 2nd-tier cal using the L12T calibration file created above, while also de-embedding the cables as would be done in a standard measurement. Files created in this step are placed in a subfolder called **residual**, and are used below.
14. Analyze the elements of the **SecondTier_x.s8p** files resulting from the CalculateResiduals.vbs script, and that reside in the **residuals** subfolder. The application SParameterViewer, (free download from www.lecroy.com) can be used for this analysis. Figure 1 shows several examples; Appendix B shows the structure of the SecondTier_x.s8p files.
    a. View the ED_m, ES_m, and EL_im elements of SecondTier_x.s8p (in blue). These should be small, less than -20dB at 40GHz.
    b. View the ER_m, and ET_im (in green). These should be close to unity, +/- 2dB at 40GHz, including any spikes.
    c. View the phase of the ER_m, and ET_im terms. These should be close to 0; +/- 20 degrees at40GHz, with no wrapping.

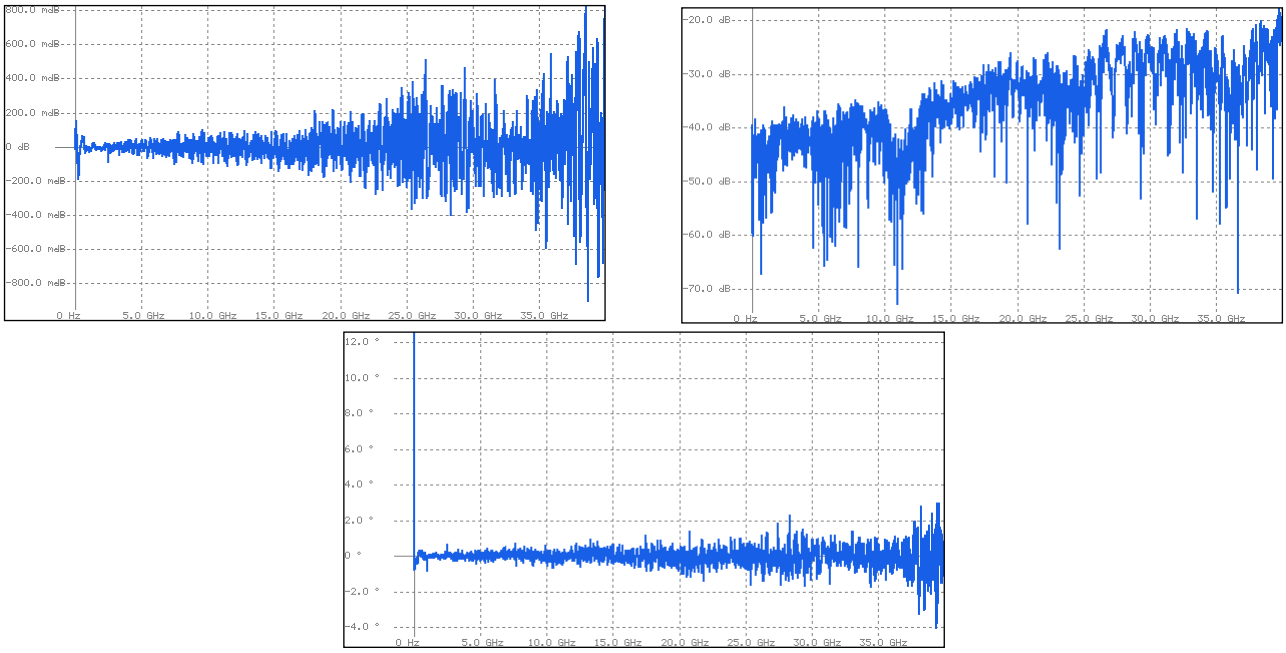

Figure 1: Residual Error Term examples; ER_1, ED_1 and ER_1 phase.

Installing the Calibration

15. Transfer the L12T file and residual folder/contents to SPARQ SD card, into the **Caldata.zip** file. Any older version should be removed or overwritten. The L12T filename should have the structure:
    [model_ID]_[serial_number]_FactorySecondTierCalibration.L12T

    Note: the model_ID might include a suffix, such as "4004Ea" rather than "4004E".

16. Lock the SD card. This isn't required for SPARQ operation, but is recommended in order to prevent accidental loss of information.

17. When ApplySOLT.vbs runs (described in a previous step), the L12T file is automatically copied to the correct folder on your PC. (C:\LeCroy\SPARQ\Calibration\SPARQ) No other action is required to begin using the 2nd-tier calibration.

Appendix A: Files Used and Created by the Procedure

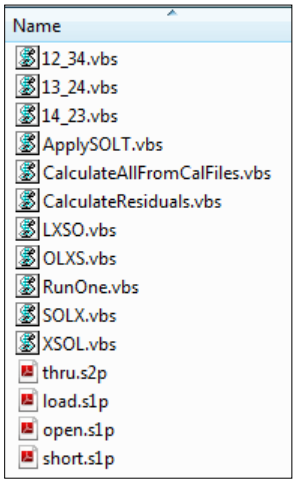

Figure 2: Scripts and Touchstone files for the calibration standards that are used to measure the standards

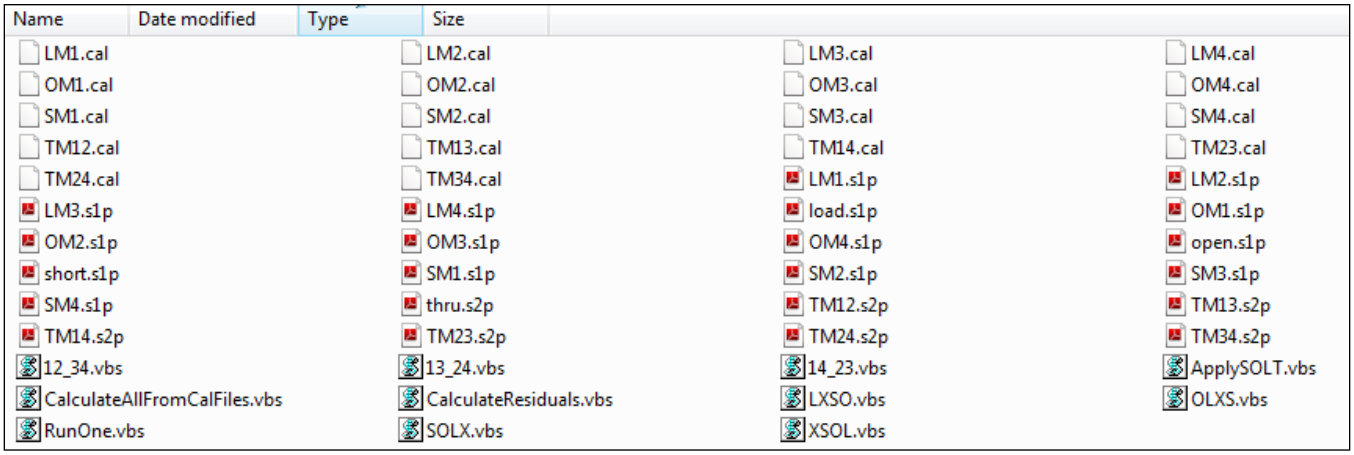

Figure 3: Files after running scripts to measure the calibration standards

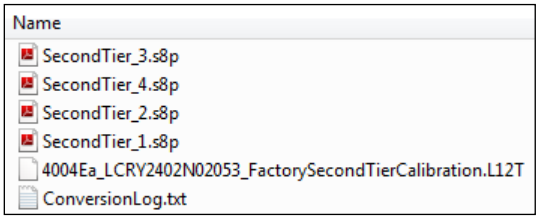

Figure 4: Files created by ApplySOLT.vbs

Appendix B: CSTD File Structure

The calibration constants can be represented as S-parameter files or using a “CSTD” calkit file. This file includes a model of the calibration kit, using polynomials to mode the open and short. Copy the lines beginning with “%” to a text file, and enter the values for each item immediately following.

```
% DESCRIPTION [Enter manufacturer and model number of calkit]
%
%       C0 (fF) - OPEN
%       C1 (1e-27 F/Hz) - OPEN
%       C2 (1e-36 F/Hz^2) - OPEN
%       C3 (1e-45 F/Hz^3) - OPEN
%       offset delay (pS) - OPEN
%       real(Zo) of offset length - OPEN
%       offset loss (GOhm/s) - OPEN
%       L0 (pH) - SHORT
%       L1 (1e-24 H/Hz) - SHORT
%       L2 (1e-33 H/Hz^2) - SHORT
%       L3 (1e-42 H/Hz^3) - SHORT
%       offset delay (pS) - SHORT
%       real(Zo) of offset length - SHORT
%       offset loss (GOhm/s) - SHORT
%       load resistance (Ohm) - LOAD
%       offset delay (pS) - LOAD
%       real(Zo) of offset length - LOAD
%       offset loss (GOhm/s) - LOAD
%       offset delay (pS) - THRU
%       real(Zo) of offset length - THRU
%       offset loss (GOhm/s) - THRU
63.170000
-1178.000000
109.600000
-2.146000
14.490000
50.000000
1.300000
0.000000
0.000000
0.000000
0.000000
16.684000
50.000000
1.300000
50.000000
0.000000
50.000000
1.300000
57.960000
50.000000
0.000000
```

Appendix C: Layout of the 2nd-Tier Calibration Error Term S-param Files

An N port measurement will generate N s8p files containing error terms as shown below. (Cells with no entry are 0; “n” maps to index number of the s8p file.)

- ED_n: Directivity error term when pulsing from port n
- ER_n: Reflection error terms when pulsing from port n
- ES_n: Source match error term when pulsing from port n
- ET_in: Transmission error term from port i when pulsing from port n
- EL_in: Load match error term from port i when pulsing from port n

SecondTier_1.s8p	1	2	3	4	5	6	7	8
1	ED_1				ER_1			
2						ET_21		
3							ET_31	
4								ET_41
5	1				ES_1			
6						EL_21		
7							EL_31	
8								EL_41

SecondTier_2.s8p	1	2	3	4	5	6	7	8
1					ET_12			
2		ED_2				ER_2		
3							ET_32	
4								ET_42
5					EL_12			
6		1				ES_2		
7							EL_32	
8								EL_42

SecondTier_3.s8p	1	2	3	4	5	6	7	8
1					ET_13			
2						ET_23		
3			ED_3				ER_3	
4								ET_43
5					EL_13			
6						EL_23		
7			1				ES_3	
8								EL_43

SecondTier_4.s8p	1	2	3	4	5	6	7	8
1					ET_14			
2						ET_23		
3							ET_34	
4				ED_4				ER_4
5					EL_14			
6						EL_24		
7							EL_24	
8				1				ES_4