EDGES Receiver Calibration Steps

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This document provides a description of the steps required to calibrate an EDGES receiver. Detailed pictures and instrument settings as well as checklists are provided to help reduce human error in these measurements. The basis for these calibration steps can be found in the calibration paper published by Raul Monsalve in the astrophysical journal: http://iopscience.iop.org/article/10.3847/1538-4357/835/1/49/pdf or on ArXiv https://arxiv.org/pdf/1602.08065.pdf.

Document Organization

Overview of the Calibration Procedure

If the receiver is new, it must be exposed to various temperatures while running for a few days to remove sensitivities to thermal stresses. The receiver should be conditioned for 1 day at 25 C, then 3 days at 35 C, followed by 2 days at 15 C, and finally 1 day at 25 C again. The LNA should be cycling between its three states by means of running the program “pxspec”, which cycles through the three LNA connection positions (ambient noise source, hot noise source, and antenna), is running during conditioning and records the spectra. Recorded spectra from this step can be discarded.

The receiver calibration procedure is performed at specific receiver temperatures of 25C, 35C, and 15C, regulated using a thermal plate and an Oven Industries controller. The receiver is insulated with 3/4” foam on as many sides as possible so that the ambient lab temperature does not compete with the case temperature (see Figure 1). RFI free spectra of several load devices and their S11 curves are needed and described next.

A calibration data set consists of: 1) the spectra and the S11 of four parameter loads; 2) the S11 and spectra of an antenna simulator (for verification of correct parameter extraction); 3) The internal four position switch (SP4T) S11 characterization (S11 measurements of male calibration standards attached to the receiver’s input and the 3 standards attached to the four-position switch via the VNA port); and 4) the S11 of the receiver as measured at the input of the receiver. The S11 measurements of the four loads and the receiver must be made immediately after the LNA cycling/spectra recording is stopped.

Table 1 summarizes the required measurements and Figures 1-2 show the calibration loads. Table 2 lists the frequency range settings and Table 3 lists the SP4T control voltage settings.

Table 1. Calibration Measurements Summary

Task	Duration	Measurements	VNA Settings (Lowband Freq. Range)	Notes
Receiver	N/A	S11	Attach VNA to the receiver input directly using only a Male-Male SMA adapter Use female calibration standards Power -35dBm IF 100 Hz Averaging 30 samples Save the averaged S11 trace by using the Macro "Save to Touchstone" in the "Real and Imaginary" format	1) SMA endcap on the VNA port. 2) Calibrate VNA using female OSL standards.
4 Position Switch	N/A	S11	Connect the VNA to the VNA port Power 0 dBm IF 100 Hz Averaging 10 samples Save the averaged S11 trace by using the Macro "Save to Touchstone" in the "Real and Imaginary" format	Use Male OSL standards on the receiver's input.
Long Cable – Short Termination	24 hrs	Spectra and S11	Connect the VNA to the VNA port Power 0 dBm IF 100 Hz Averaging 10 samples Save the averaged S11 trace by using the Macro "Save to Touchstone" in the "Real and Imaginary" format	1) Use semi rigid cables between the VNA and the VNA port. The measurement is very sensitive to cable disturbances. 2) Use a ferrite choke on the receiver input while taking spectra measurements.
Long Cable – Open Termination	24 hrs	Spectra and S11		
Ambient Load	48 hrs	Spectra and S11		
Hot Load	48 hrs	Spectra and S11		
Antenna Simulator	48 hrs	Spectra and S11		

Table 2. Frequency Range Settings

Range Type	Lower Limit (MHz)	Upper Limit (MHz)	Points	Frequency Step (MHz)
Lowband	40	100	241	0.250
Midband	40	120	321	0.250
Highband	90	190	401	0.250
Full Range	40	200	641	0.250

Table 3. Internal Four Position Switch (SP4T) Voltage Selection Settings

Switch Position	Open	Short	Match	External
Applied Voltage	28 V	31.3 V	34 V	37 V

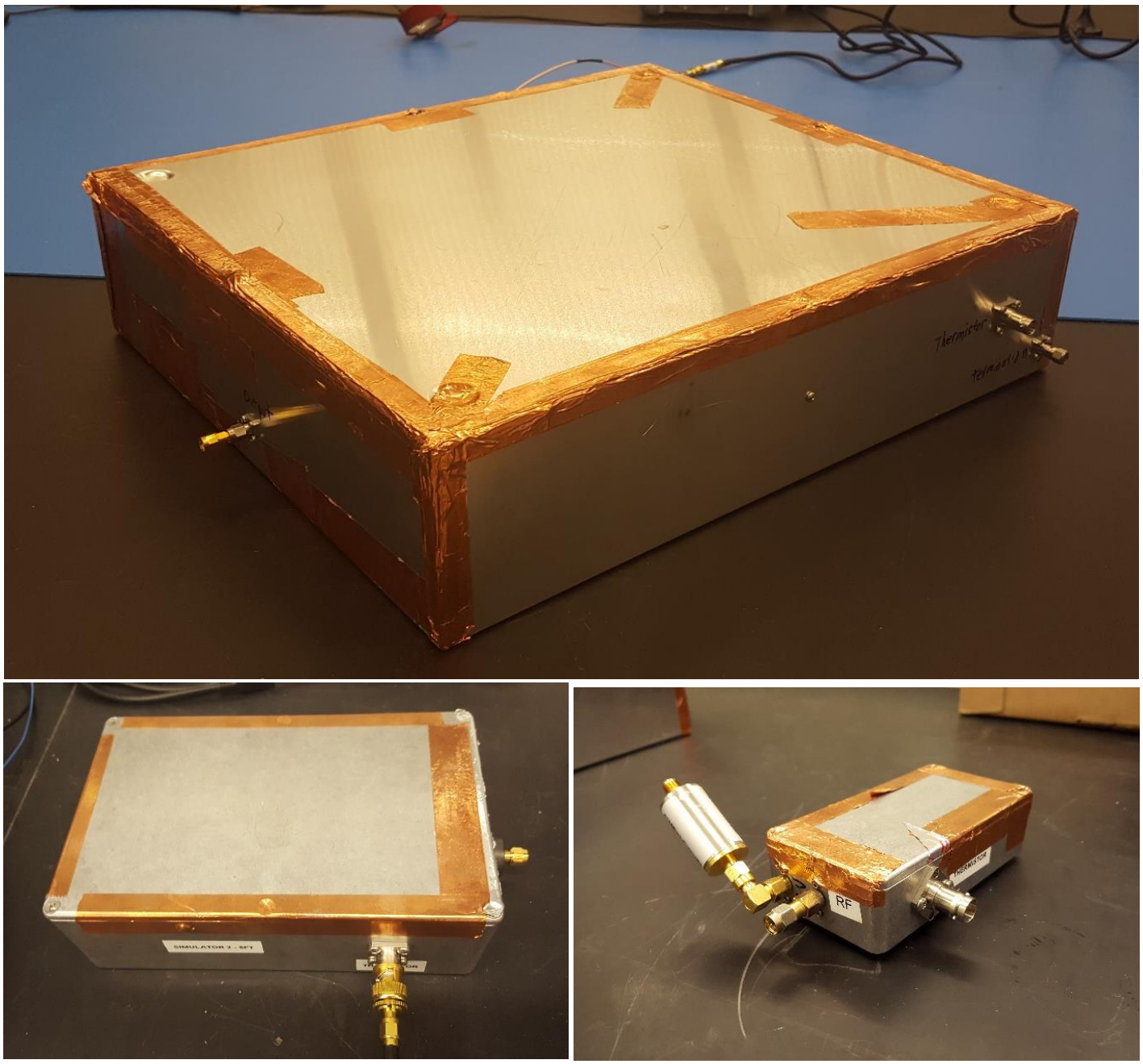


Figure 1. Calibration Loads. (Top) the long cable inside its metallic enclosure with its SMA input on the left and on the front-right are the thermistor BNC and the cable termination SMA connectors. (Bottom left) Antenna simulator 2 (8 foot long cable) showing the thermistor BNC connection at the bottom-right and the SMA input connector at the right. (Bottom right) Ambient and hot load showing the thermistor SMA connector on the right side, the SMA input to the left in the middle and the Voltage input at the far left side of the box going through a low pass filter. Zero V DC is applied to create the ambient load and 12 V DC is applied to create the hot load. It takes 1 to 2 hours to thermally stabilize after changing the voltage to the device.

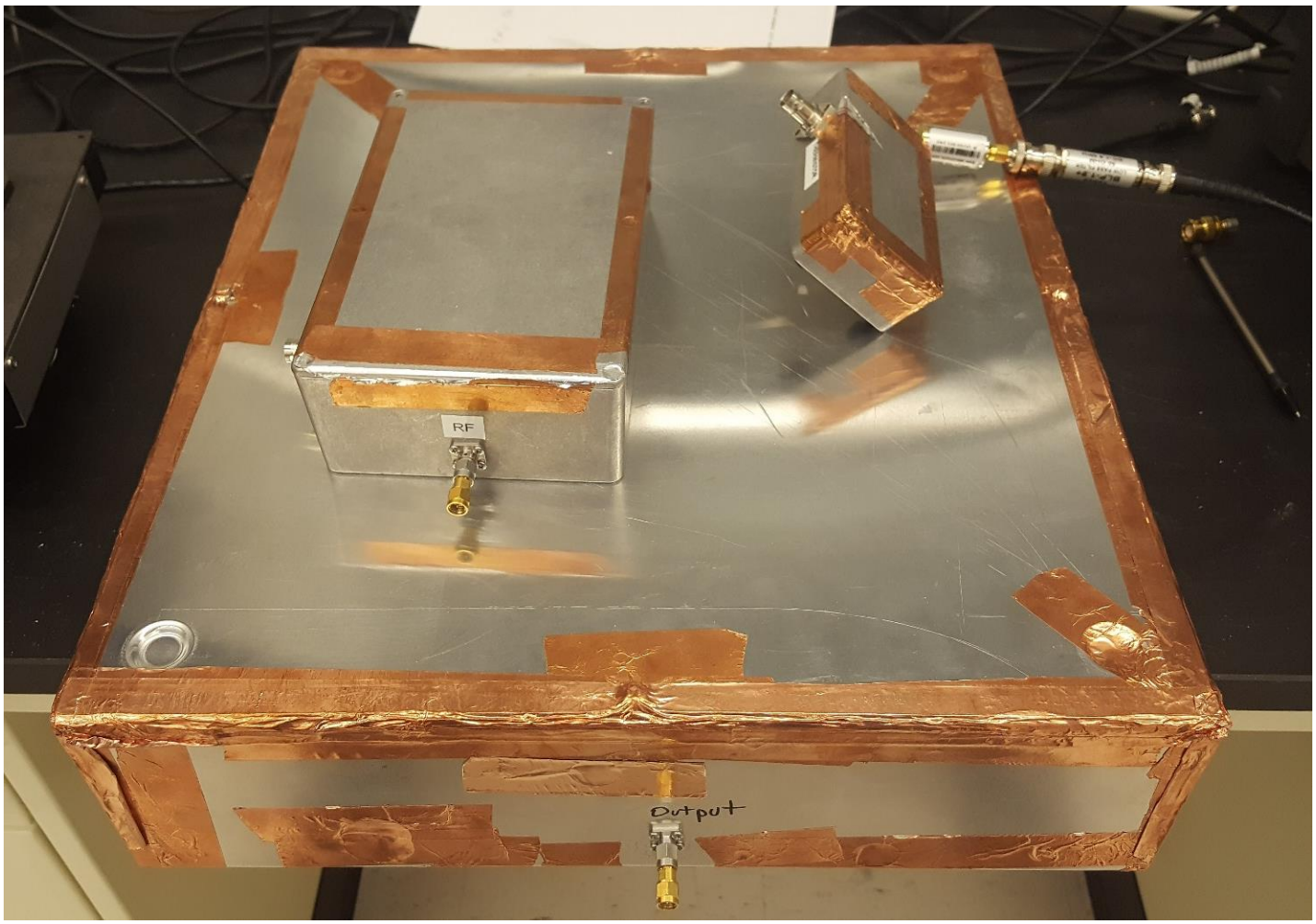


Figure 2. Relative sizes of the calibration loads.

Measuring the S11 of the Receiver

VNA S11 Settings

The VNA power level is -35 dBm and averaging is 30 with the IF set to 100 Hz. See Table 2 for the frequency range settings. The VNA is attached directly to the receiver via one M-M SMA adapter.

Receiver Conditioning Before First Time Measurements

Cycle the LNA at a fixed temperature for 4-6 hrs via the pxspec program. Monitor the thermistors to make sure all of the internal temperatures have stabilized. Put a terminating SMA cap on the VNA port (open, short, or 50 ohm). After stabilization, the spectra that was recorded during LNA cycling can be discarded.

VNA Calibration

Calibrate the VNA using the female calibration standards and the settings as described above, remembering to attach the M-M SMA adapter to the VNA beforehand. This is done to make sure the VNA has reasonable settings and doesn't go so far out of calibration that we can't trust the numbers that it gives. The M-M SMA adapter stays on the VNA the entire time. Save the state of the VNA using the “save state” and file dialog menus.

Measurement Steps

1) Measure the female OSL standards on the VNA. (Use the “Save to Touchstone” program)
2) stop the LNA cycling (i.e., exit pxspec)
3) immediately after pxspec stops, connect the VNA to the receiver and measure the S11
4) disconnect the VNA and restart pxspec
5) remeasure the 3 calibration loads again.
6) stop the LNA cycling
7) immediately reconnect the VNA and measure the S11 of the receiver for the second time.

It is best to do this twice because there is a chance that one of the readings might be corrupted by either human error or something else.
Repeat it 3x if you are pretty sure that one of the readings is faulty. It is good to have 2 sets of readings that you think are good.

Figures 3 – 6 show the S11 traces of the Calibration OSL standards and of the receiver over the range of 40 MHz to 120 MHz.

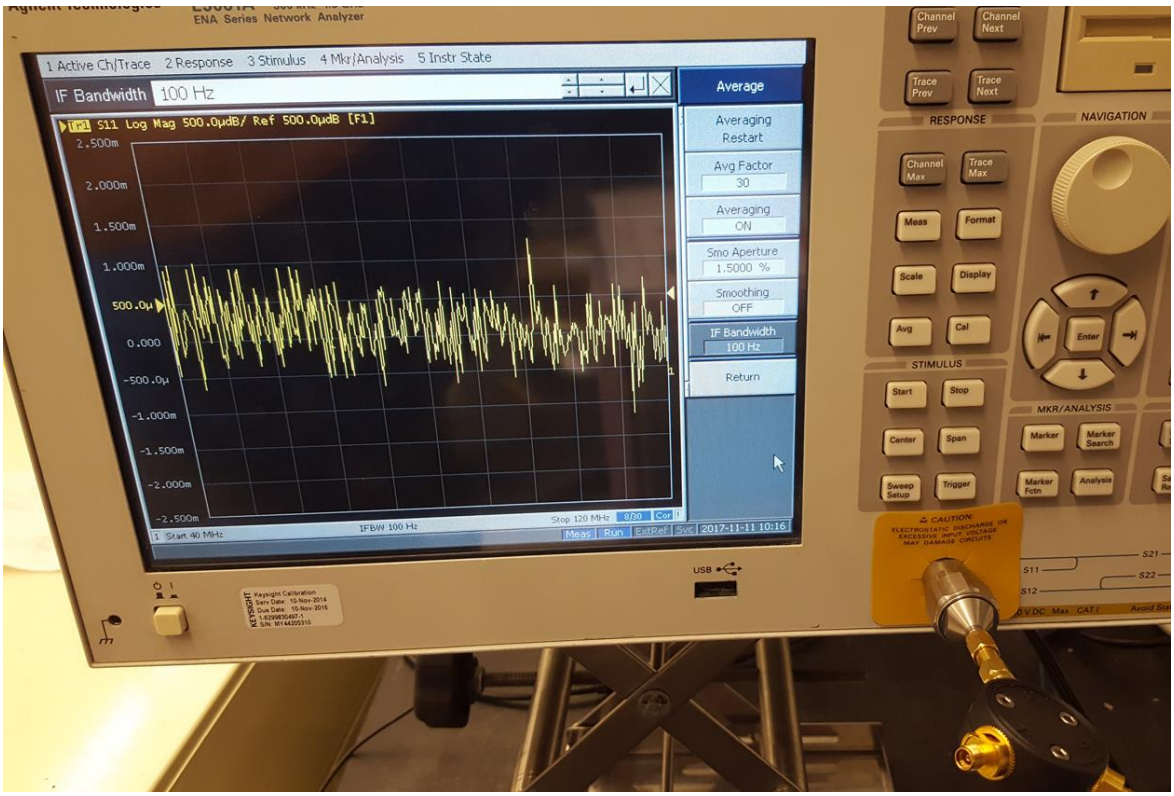


Figure 3. S11 of the Female Calibration “Open” Standard

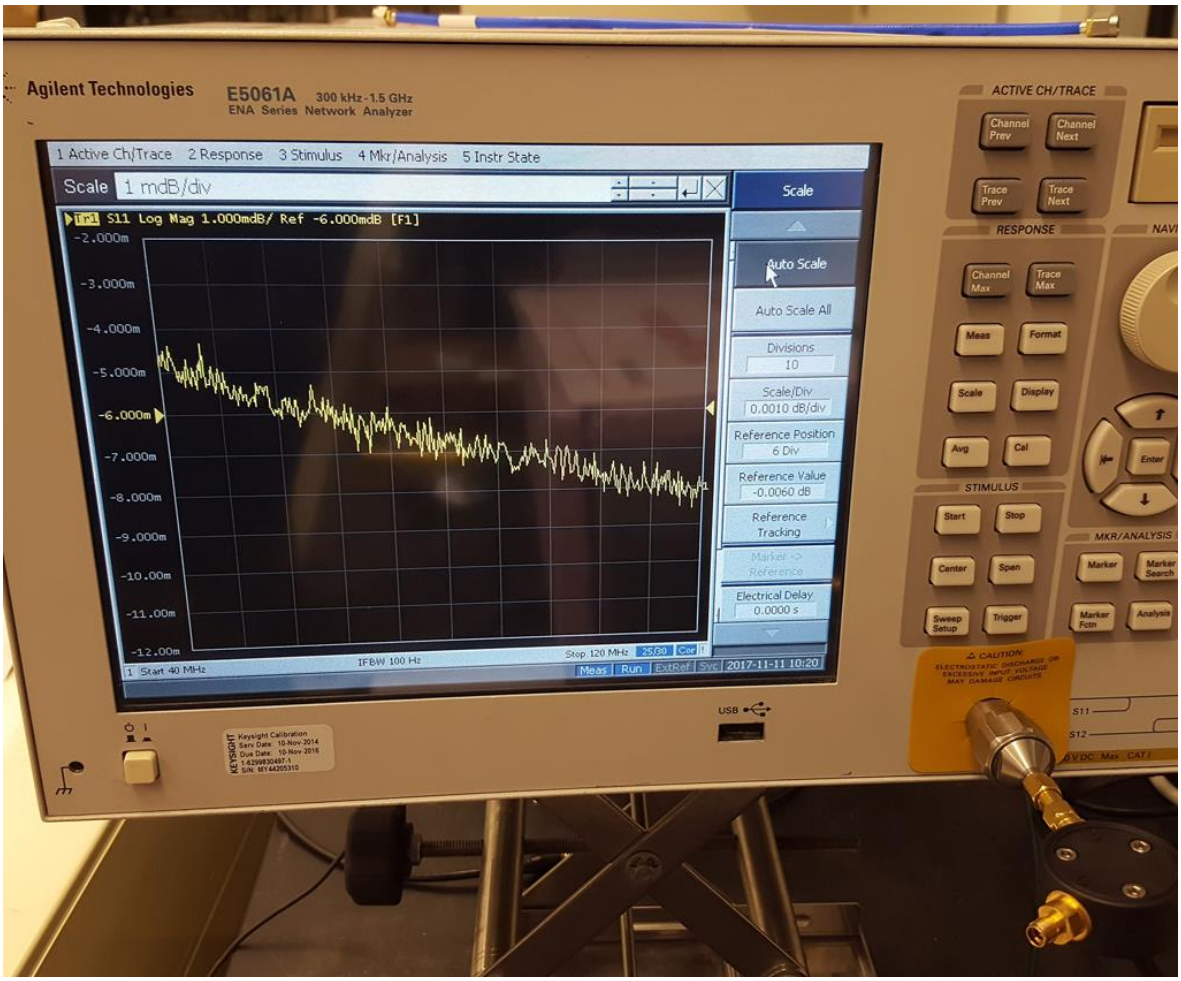


Figure 4. S11 of the Female Calibration “Short” Standard

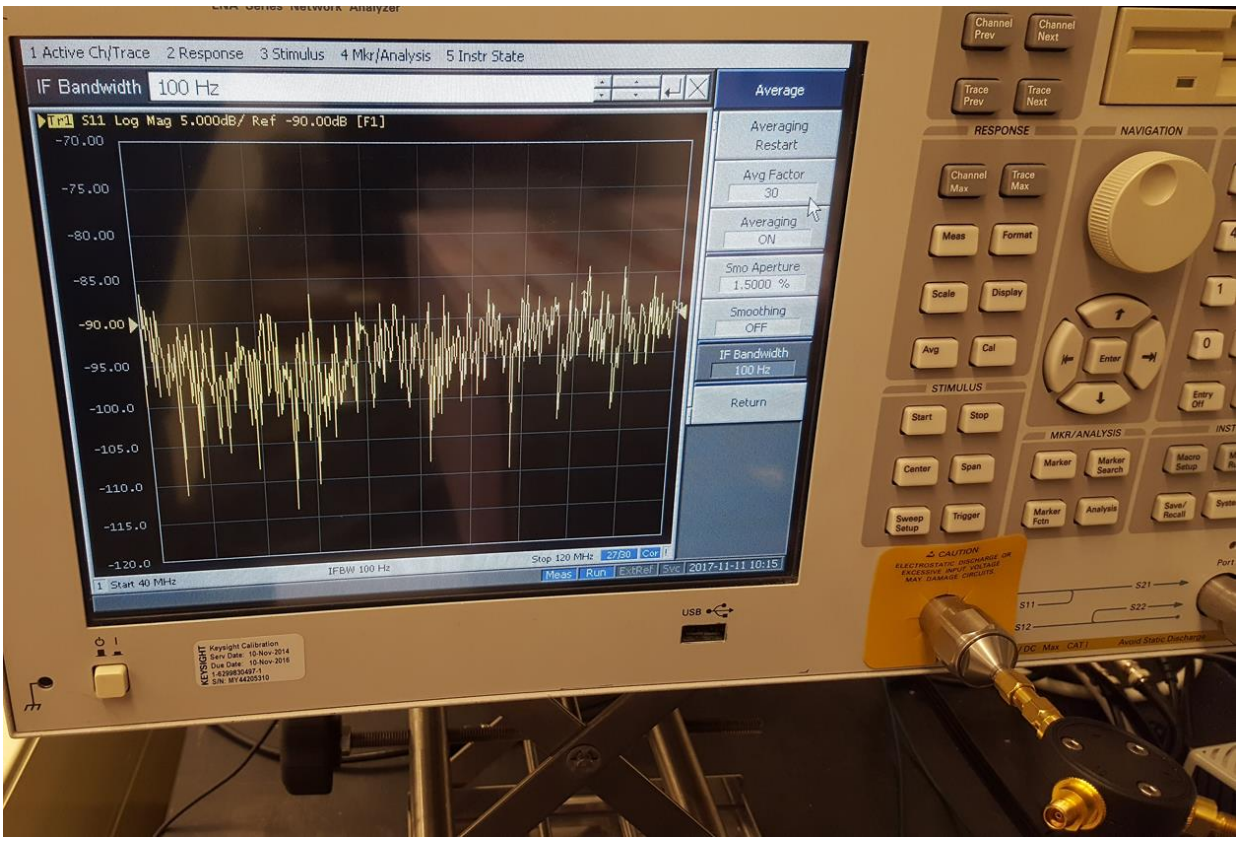


Figure 5. S11 of the Female Calibration “Match” Standard

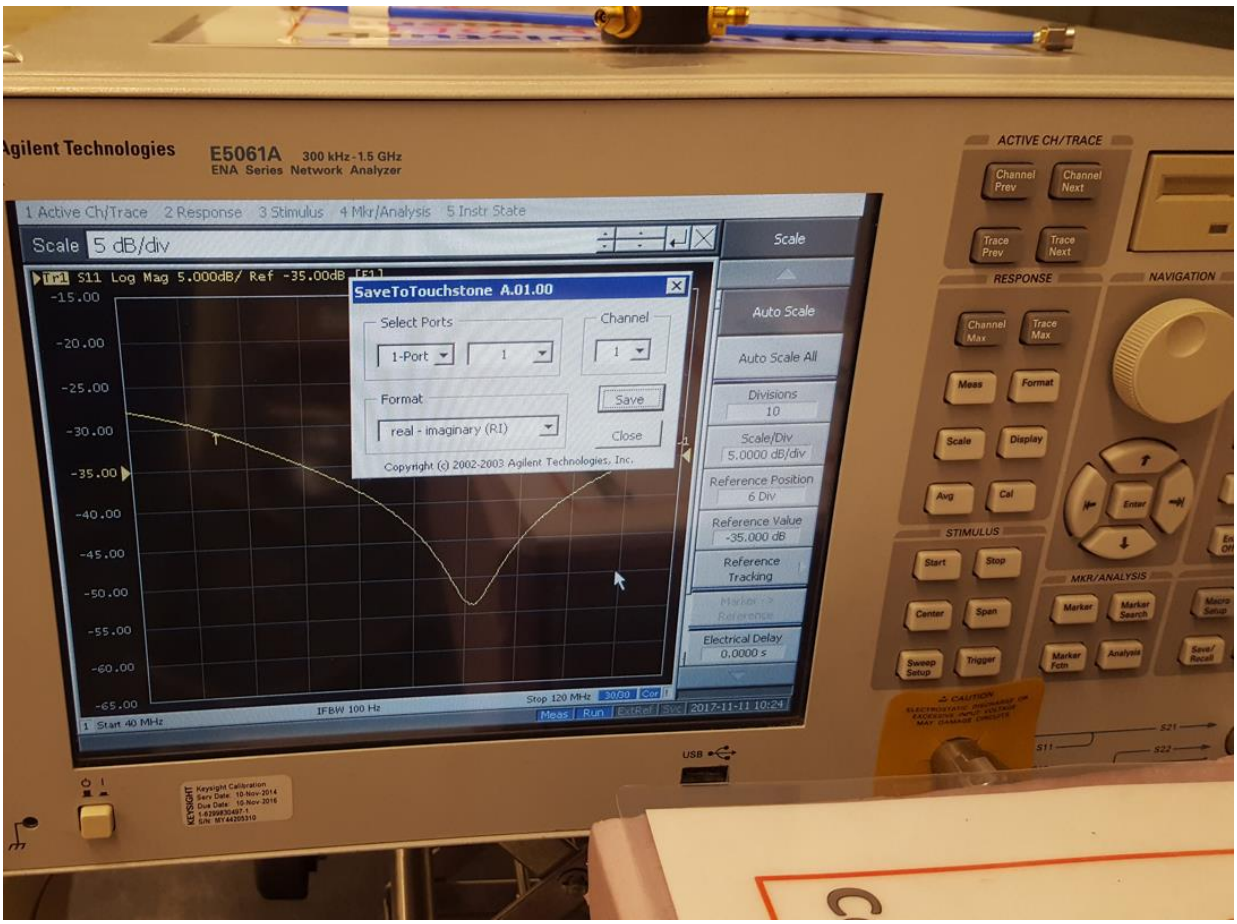


Figure 6. Typical receiver S11 trace. SaveToTouchstone Macro dialog box can be seen.

Measuring the S11 of the Internal Four Position Switch (SP4T)

VNA S11 Settings

The VNA power level is 0 dBm and averaging is 10 with the IF set to 100 Hz. See Table 2 for the frequency range settings. The VNA is attached to the VNA port using a cable that must not be disturbed or allowed to sag during measurements (see Figure 7).

Receiver Conditioning Before First Time Measurements

Cycle the LNA at a fixed temperature for 4-6 hrs via the pxspec program. Monitor the thermistors to make sure all of the internal temperatures have stabilized. Put a terminating SMA cap on the VNA port (open, short, or 50 ohm). After stabilization, the spectra that was recorded during LNA cycling can be discarded.

VNA Calibration

Calibrate the VNA using the male calibration standards and the settings as described above. This is done to make sure the VNA has reasonable settings and doesn't go so far out of calibration that we can't trust the numbers that it gives. Save the state of the VNA using the "save state" and file dialog menus.

Measurement Details

Allow the receiver's internal temperature to stabilize, meaning pxspec is not running and the internal voltage to the VNA switch disabled. Leave the receiver's input open.

Do these measurements shortly after calibrating the VNA as described above.
Connect the VNA to the VNA port.
VERY IMPORTANT: Make sure the connection does not move at all. the S11 changes drastically if you bump the cable.

Do not attach the external standard to the Receiver's input yet as the case temperature may affect the temperature of the calibration devices.

Measure the internal standards on the switch:
1) 28 V applied = internal Open
2) 31.3 V applied = internal Short
3) 34 V applied = internal Match

Now attach the male match calibration standard

4) 37 V applied = external match
change the male standard to the short standard
5) still 37 V applied = external short
change the male standard to the open standard
6) still 37 V applied = external open

disconnect the male standard
Repeat steps 1-6.

Collecting Calibration Data: Load Spectra and Load S11

Spectra of the five loads listed in Table 1 (shown in Figure 1) must be collected and the corresponding S11 waveforms must be measured for each load device immediately after stopping the spectra collection via the VNA port and the internal four position switch (SP4T) set to the “external position”, along with the S11 of the internal four position switch positions 1-3 (Open – Short – Match).

VNA S11 Settings

The VNA power level is 0 dBm and averaging is 10 with the IF set to 100 Hz. See Table 2 for the frequency range settings. The VNA is attached to the VNA port using a cable that must not be disturbed or allowed to sag during measurements (see Figure 7). During spectra recording, the VNA is not attached to the VNA port (see Figure 8).

Receiver Conditioning Before First Time Measurements

Cycle the LNA at a fixed temperature for 4-6 hrs via the pxspec program. Monitor the thermistors to make sure all of the internal temperatures have stabilized. Put a terminating SMA cap on the VNA port (open, short, or 50 ohm). After stabilization, the spectra that was recorded during LNA cycling can be discarded.

VNA Calibration

Calibrate the VNA using the male calibration standards and the settings as described above. This is done to make sure the VNA has reasonable settings and doesn't go so far out of calibration that we can't trust the numbers that it gives. Save the state of the VNA using the “save state” and file dialog menus.

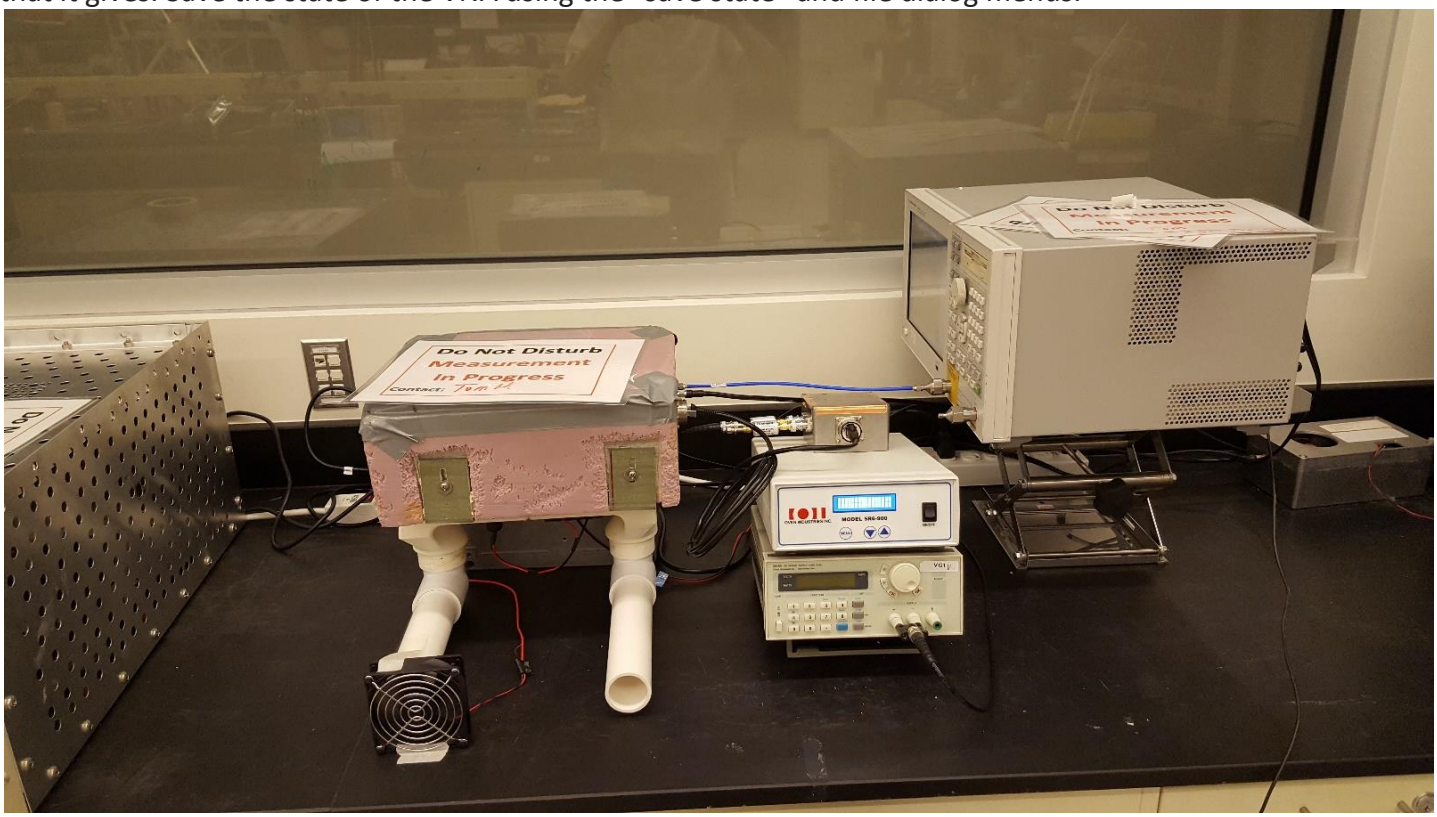


Figure 7. VNA attached to the VNA port using a short rigid cable only when measuring the S11 of a calibration load. Note: In this picture, the S11 has already been measured and the calibration load device has been disconnected from the receiver. The Faraday cage is seen to the left.

Measurement Details

General Settings

Set the thermal plate set to one of three temperature values: 15 C, 25 C, or 35 C. Allow the receiver's internal temperature to stabilize while running pxspec. The internal voltage to the VNA switch must be disabled, and the VNA port on the receiver is capped with an SMA open, short, or 50 Ω termination. The load calibration device is attached to the receiver's input using a ferrite core to reduce stray RFI (see Figure 9). Temperature readings are collected for each of the available thermistors (load device and the various internal thermistors) at least every 2 minutes, but not more than every 30 seconds.

Load Device Thermistor Connections

The thermistor BNC connector on the load device is connected to a labjack device or logging resistance meter that records the resistance value every 60 seconds. The same is done for the receiver's internal thermistors, which exit via the 8P8C (often incorrectly called RJ-45) connector (see Figure 8).

Spectra Measurements

Spectra is collected for each load for the given amount of time as indicated in Table 1. Usually the "long cable" load is placed inside a faraday cage because it seems to be most susceptible to RFI pickup. One should examine the waveform from the pxspec program on the monitor when beginning these measurements to make sure there is no visible sign of RFI. If there is RFI, further shielding must be done, or perhaps there is a source of RFI running in the lab, which must be identified and quieted.

When enough spectral data has been collected, the pxspec program is exited and the VNA should be connected to the VNA port as quickly as possible (< 15-30 seconds) after the program stops running.

S11 Measurements

The first S11 measurement should be of the load device, meaning that the SP4T control voltage is set to 37 V (see Table 3). Then the other S11 measurements should be made in the order of internal Match (34 V), internal Short (31.3 V), and internal Open (28 V). These 4 measurements should be then repeated for the sake of reproducibility and to be able to recover from a faulty measurement.

Storing the readings

After the S11 measurements are made, rename the spectra data files. There may be several files as a new one is started each day at 5:00 pm Arizona time. A description of the load should be appended to the beginning of the native file name such as 2017_307_03.acq → AmbientLoad_15C_2017_307_03.acq.

The temperature readings are stored in a .csv file and need to be stored in a central location on the enterprise server under /data5/edges/data/. Typically there is a directory tree whose top directory is the description of the calibration such as Lowband3_January_2018. Then there are subfolders for Resistance, S11, and Spectra readings. Under these are three temperature sub-directories for the three temperatures 15C, 25C, and 35C. Permissions must be set such that others on the team can be able to write into the directory and are able to read every file.

Figures 9 and 10 show the Hot/Ambient loads connected to the receiver and Figure 11 shows the antenna simulator #2 connected to the receiver. Figures 12-14 show the S11 waveforms of the internal SP4T "open", "short", and "match" connections. Figures 15-18 show typical waveforms of the Ambient Load, the Antenna simulator load, and the long cable open and long cable shorted loads.

Correcting and storing the S11 measurements and column headers

The measured S11 of the external loads will be corrected using the measurements of the internal OSL standards that are on the four position switch. The function used is either "High_band_Switch_correction" or

“low_band_Switch_correction”. For the LNA S11 correction, the correction is made using the measurements made with the external OSL standards and the correction function used is “rc.dembed”.

The corrected S11 results are stored in the top level S11 directory and the naming convention follows this example format:

Directory example:

/data5/edges/data/Receiver01_2018_01_08_040_to_200_MHz/25C/S11/

Filename example:

“ s11_calibration_low_band_LNA_25_degC_50_100MHz_2018.txt”.

The columns of the file follow this format:

1	2	3	4	5	6	7	8	9	10	11	12	13
Freq (MHz)	LNA Real	LNA Imag	Ambient Load Real	Ambient Load Imag	Hot Load Real	Hot Load Imag	Open Cable Real	Open Cable Imag	Shorted Cable Real	Shorted Cable Imag	AntSim Real	AntSim Imag

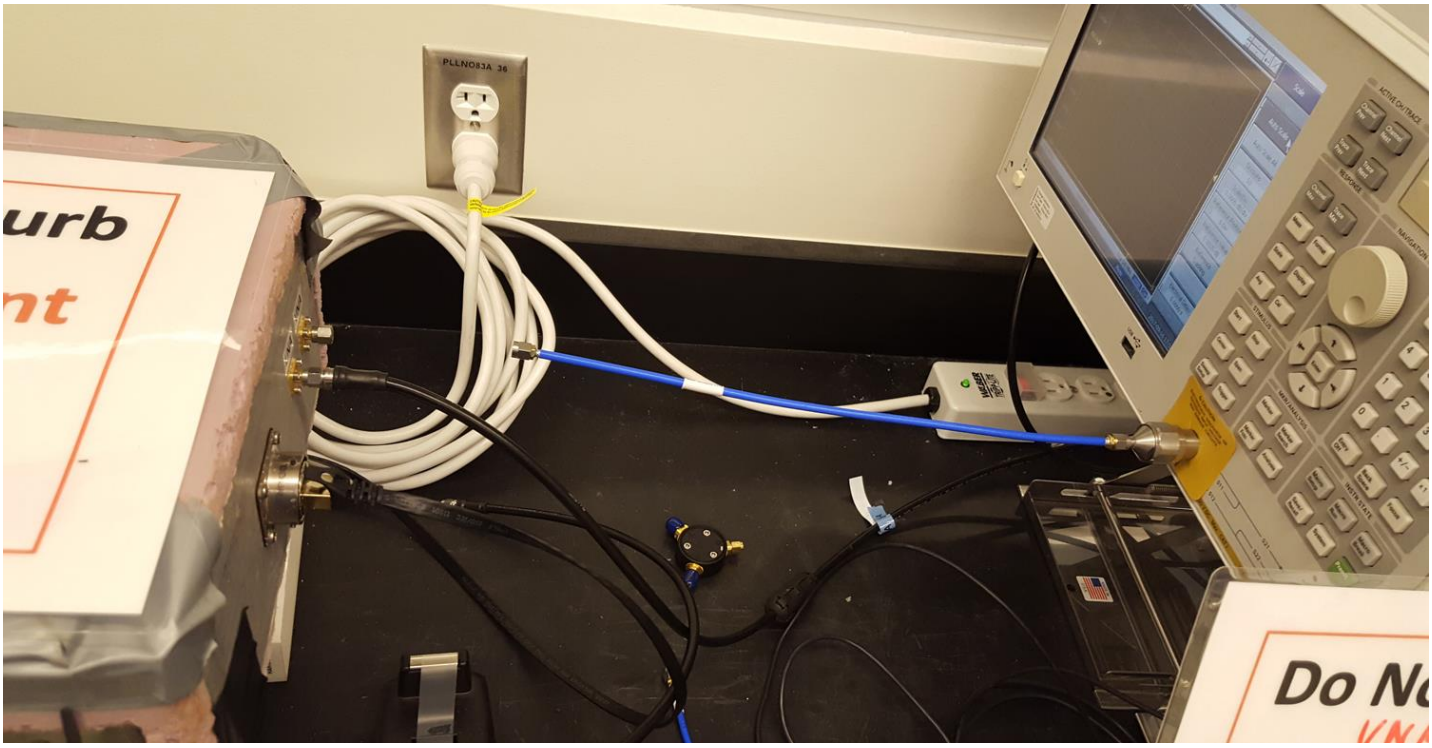


Figure 8. Configuration of the receiver while spectra is being collected. Shown are the locations of the VNA port, the LNA output, whose connection also includes DC power to the LNA, and the 8P8C connector which contains voltage input signals to the SP4T as well as LNA and SP4T thermistor output connections.

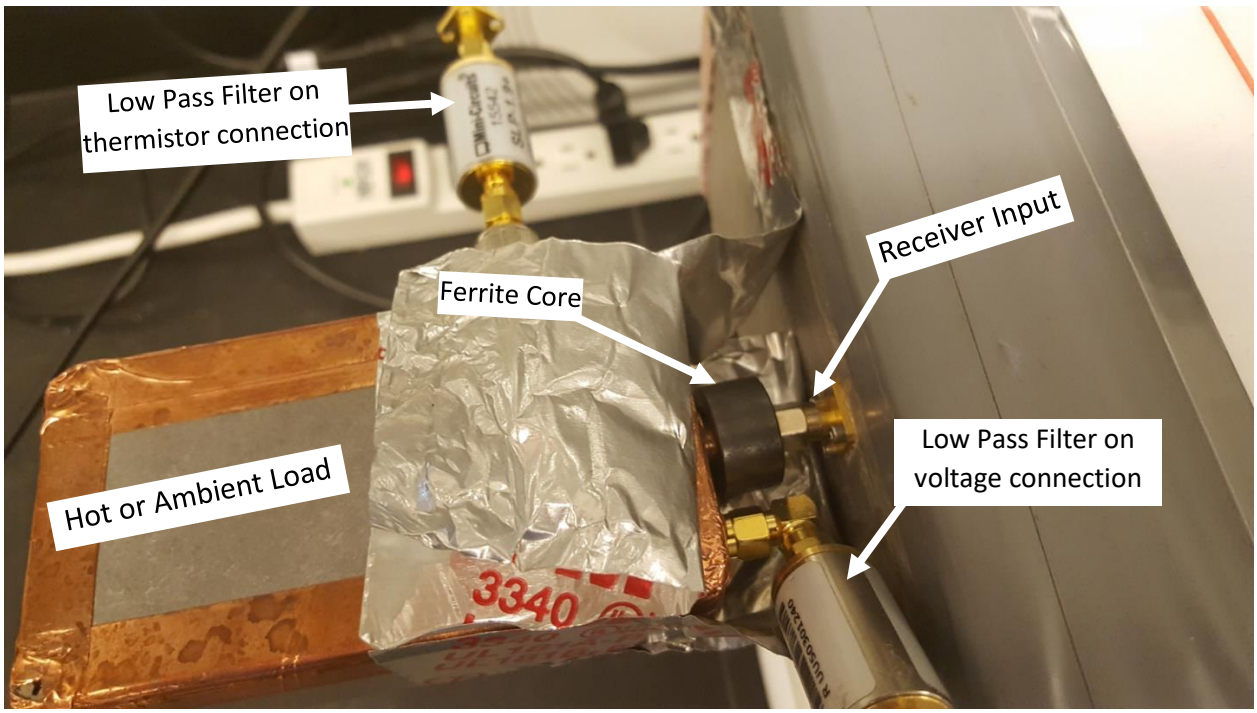


Figure 9. Close up view of the Hot/Ambient Load showing the ferrite core and the filters on the thermistor and voltage input connections.

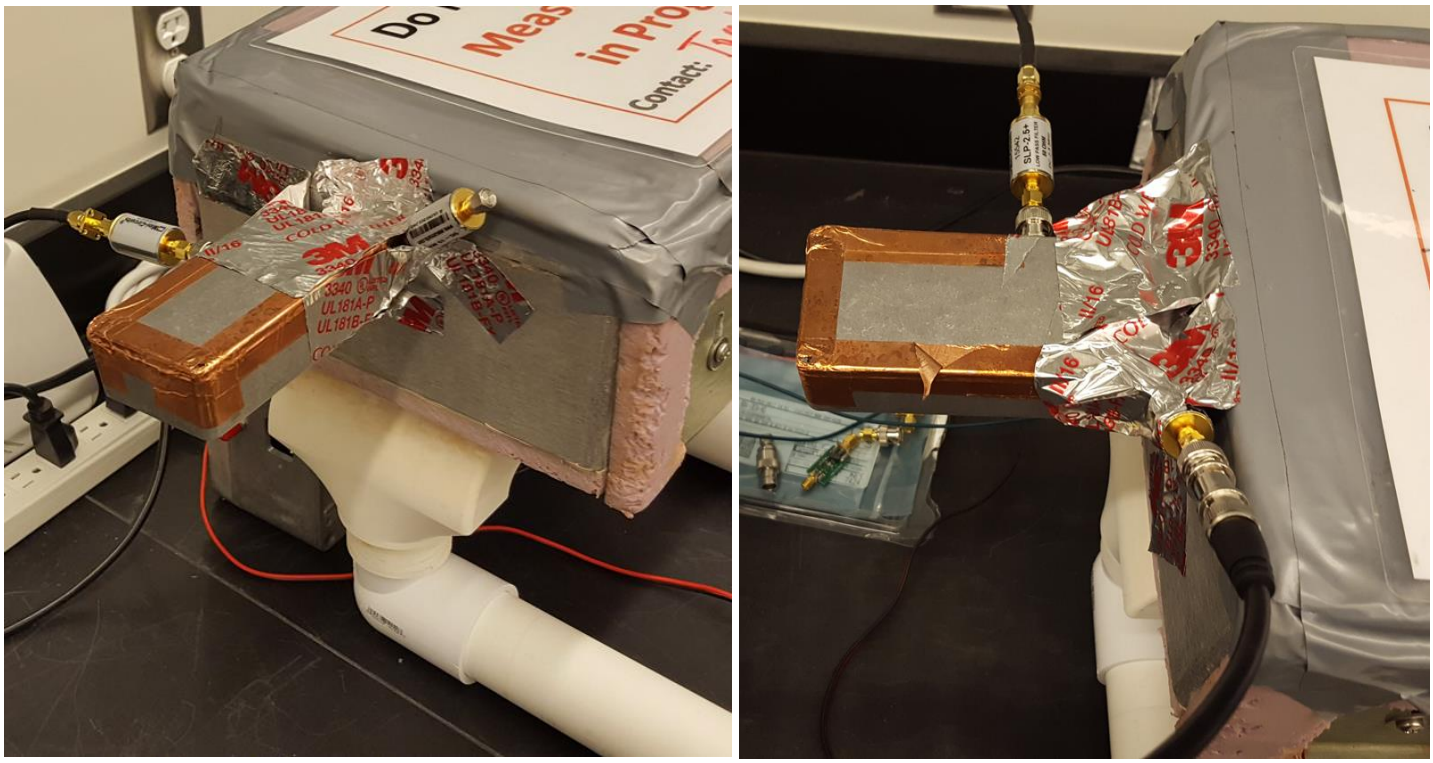


Figure 10. Metallic tape from the Hot/Ambient load to the metal receiver box. (Left) 0 V (short) applied to the voltage input to create the ambient condition. (Right) A connection to a power supply to enable 12 V operation to create the hot condition.

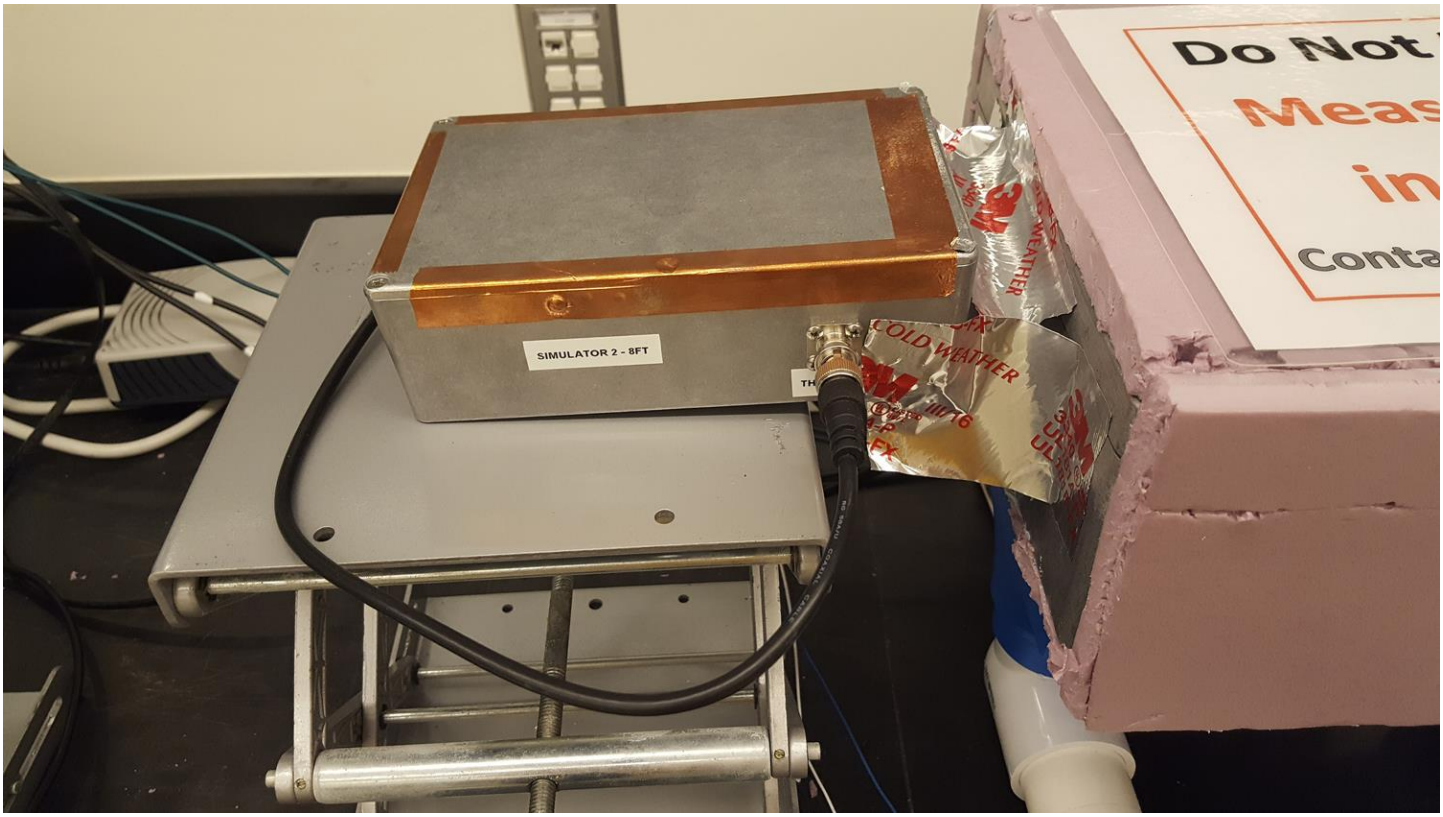


Figure 11. The Antenna Simulator 2 load device connected to the receiver.

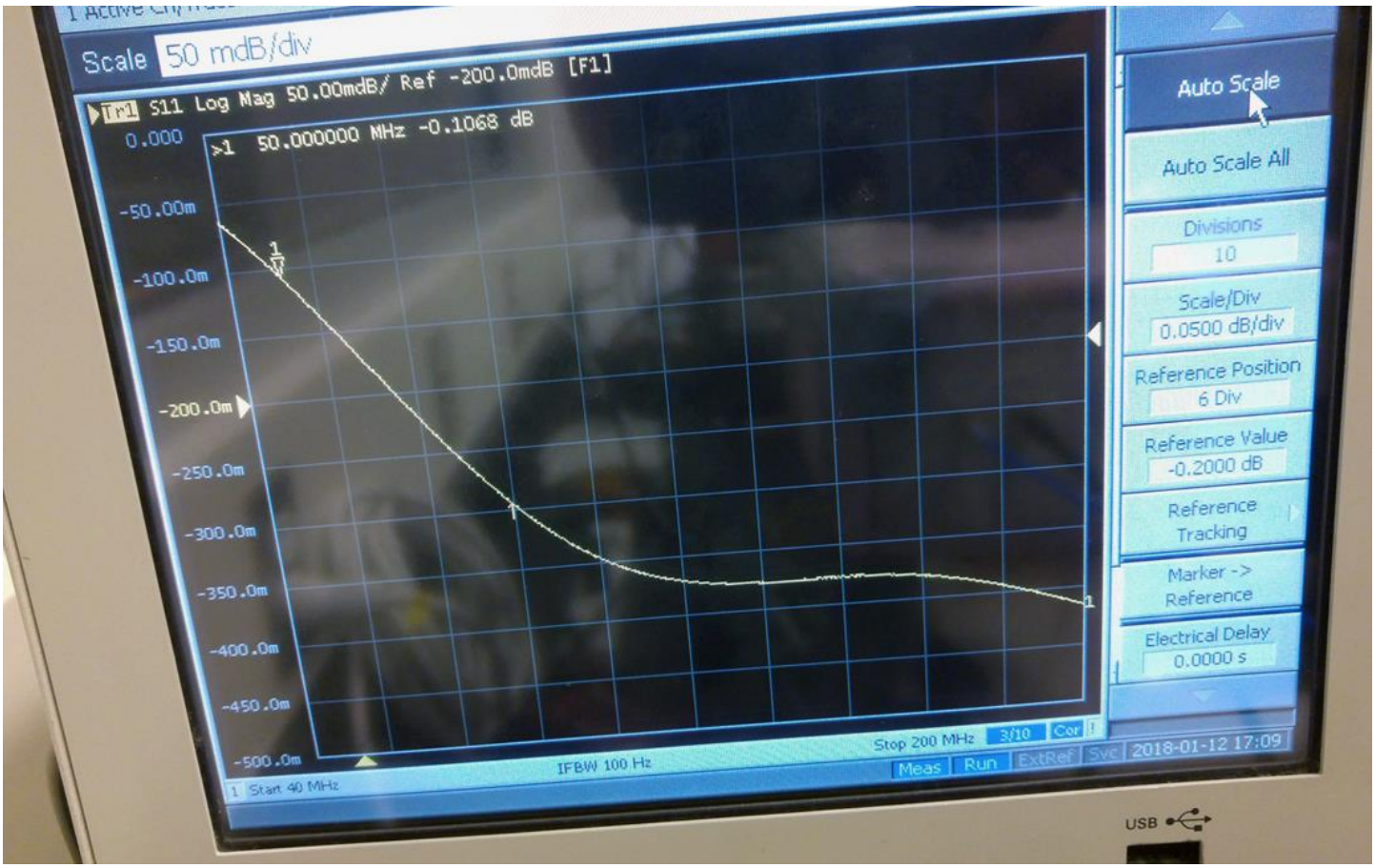


Figure 12. Internal “Open” S11 waveform.

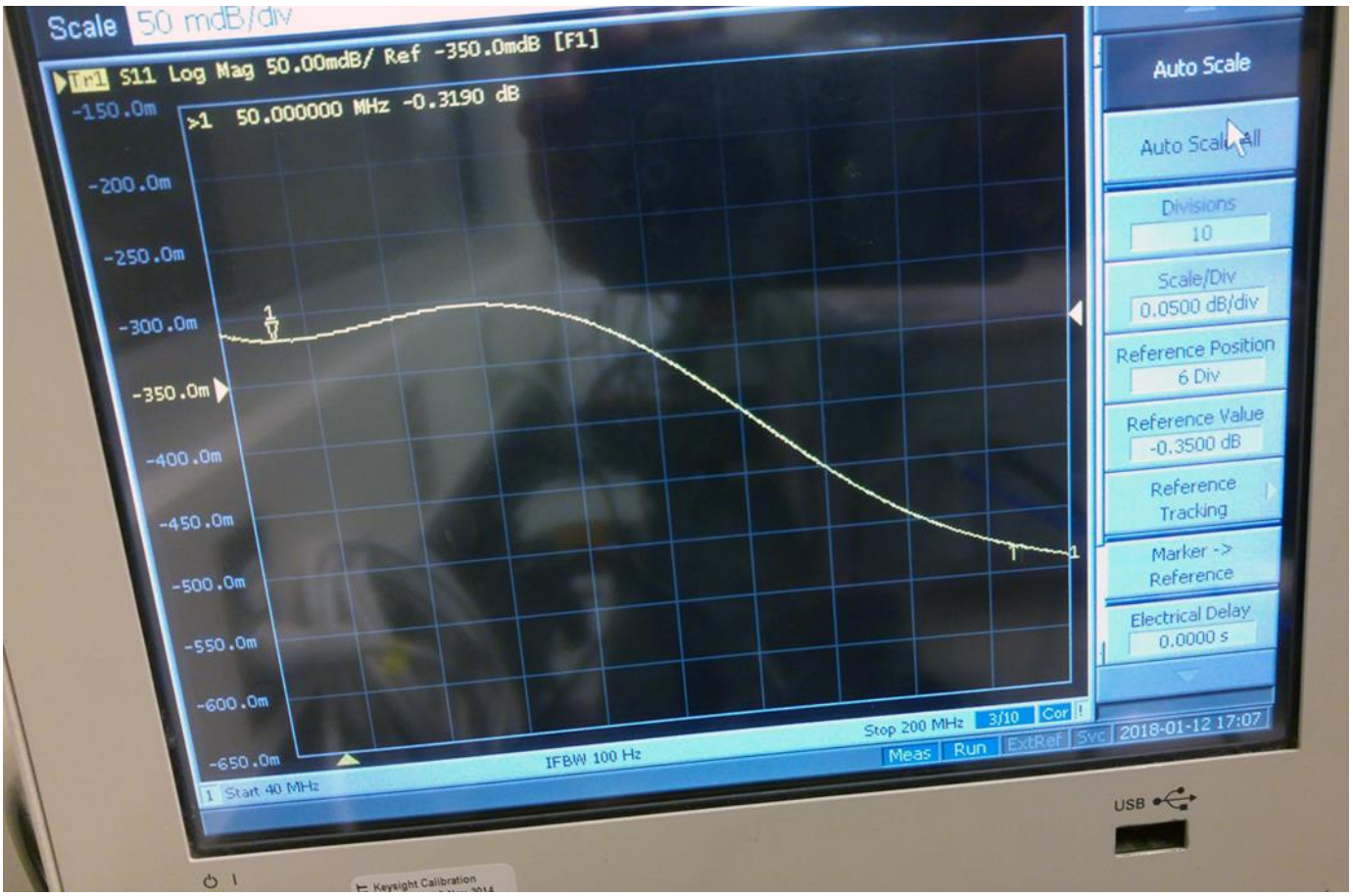


Figure 13. Internal “Short” S11 waveform

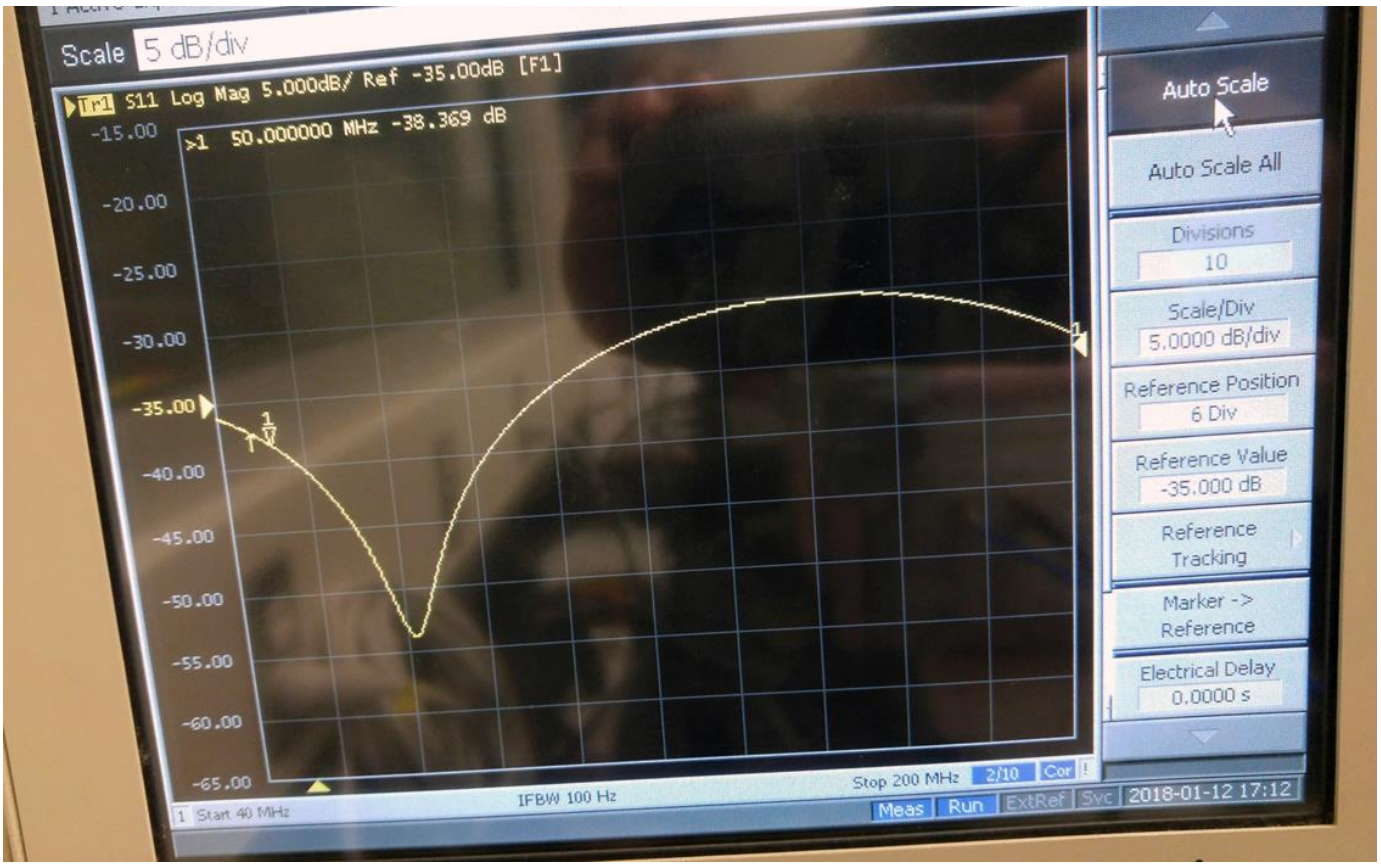


Figure 14. Internal “Match” S11 waveform.

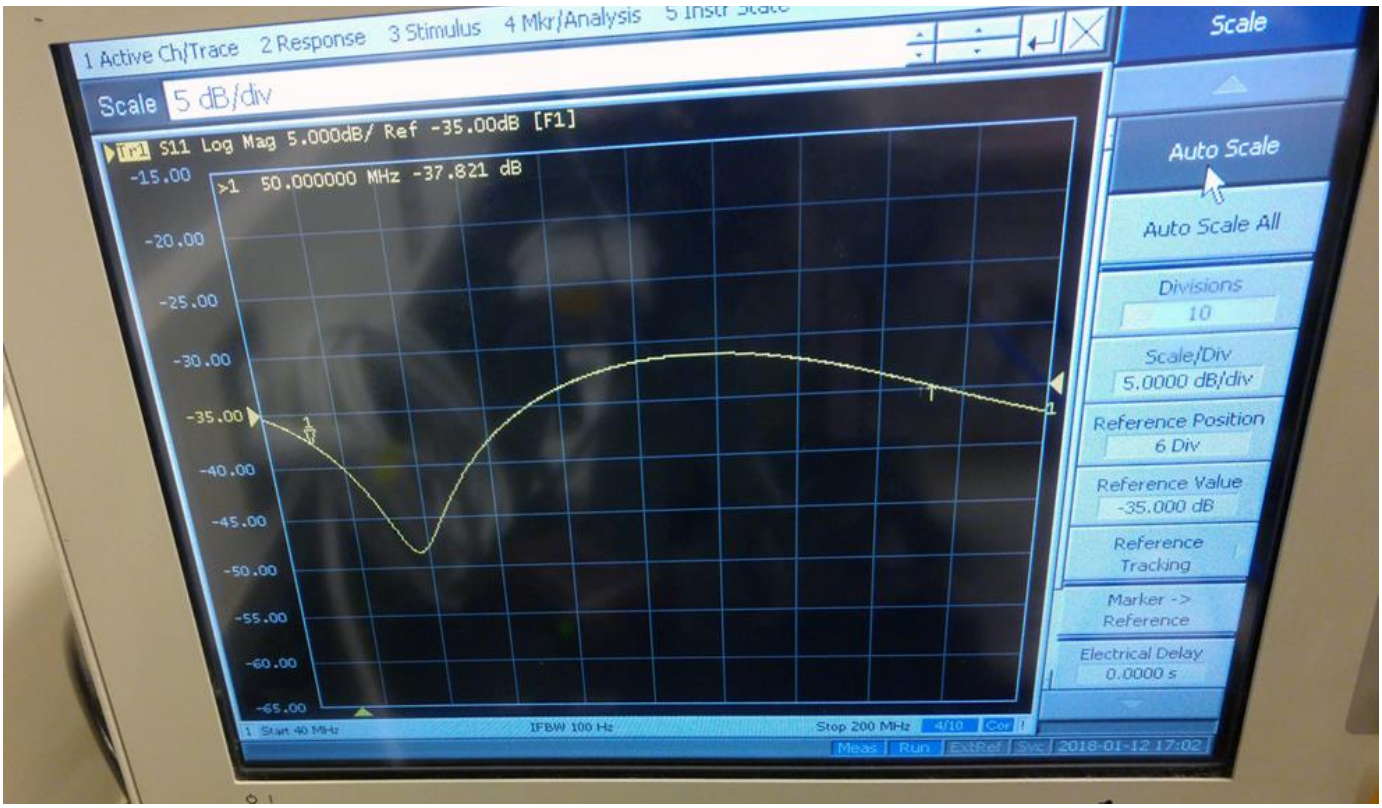


Figure 15. “Ambient” load device S11 waveform.

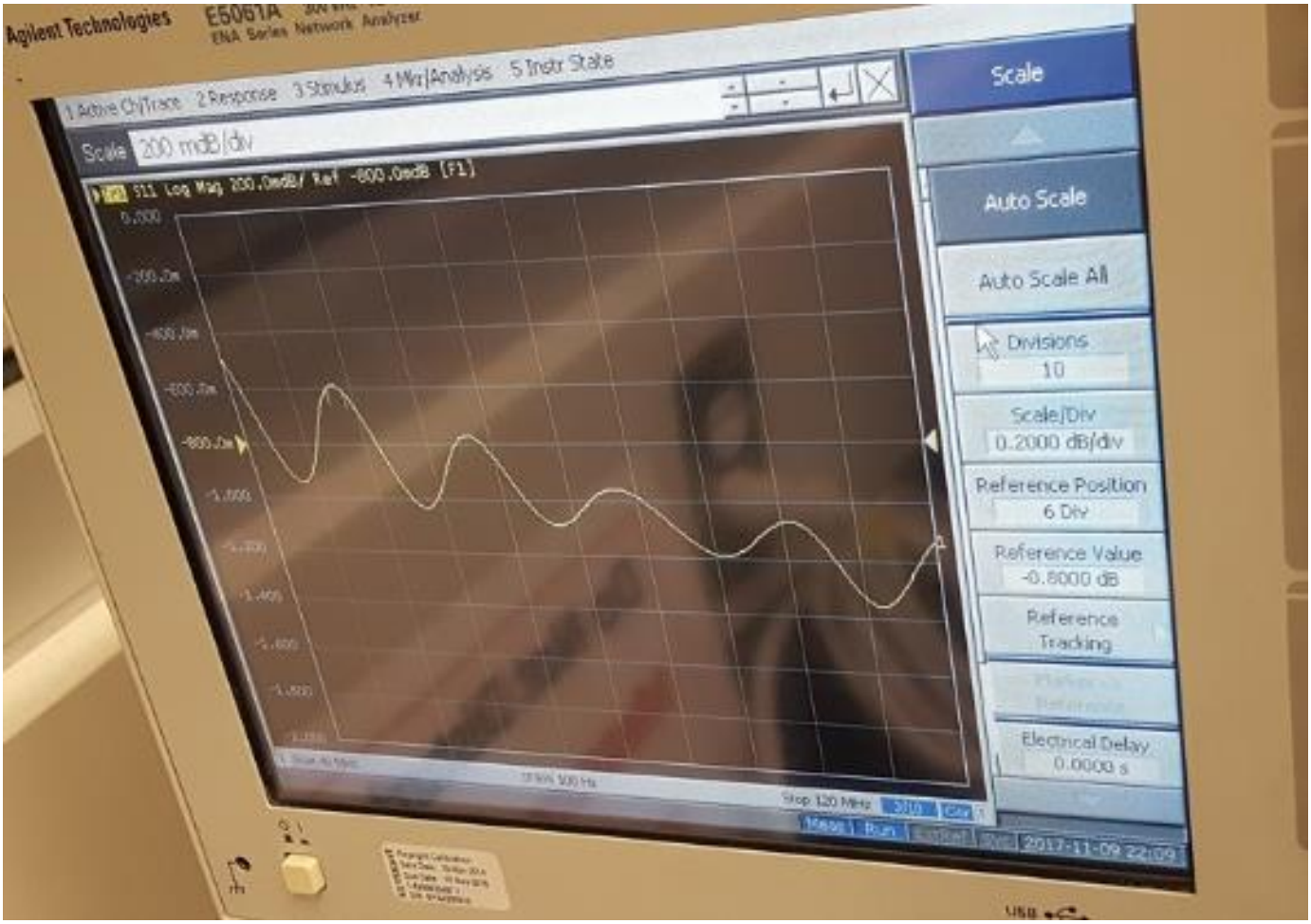


Figure 16. “Long cable shorted” load device S11 waveform.

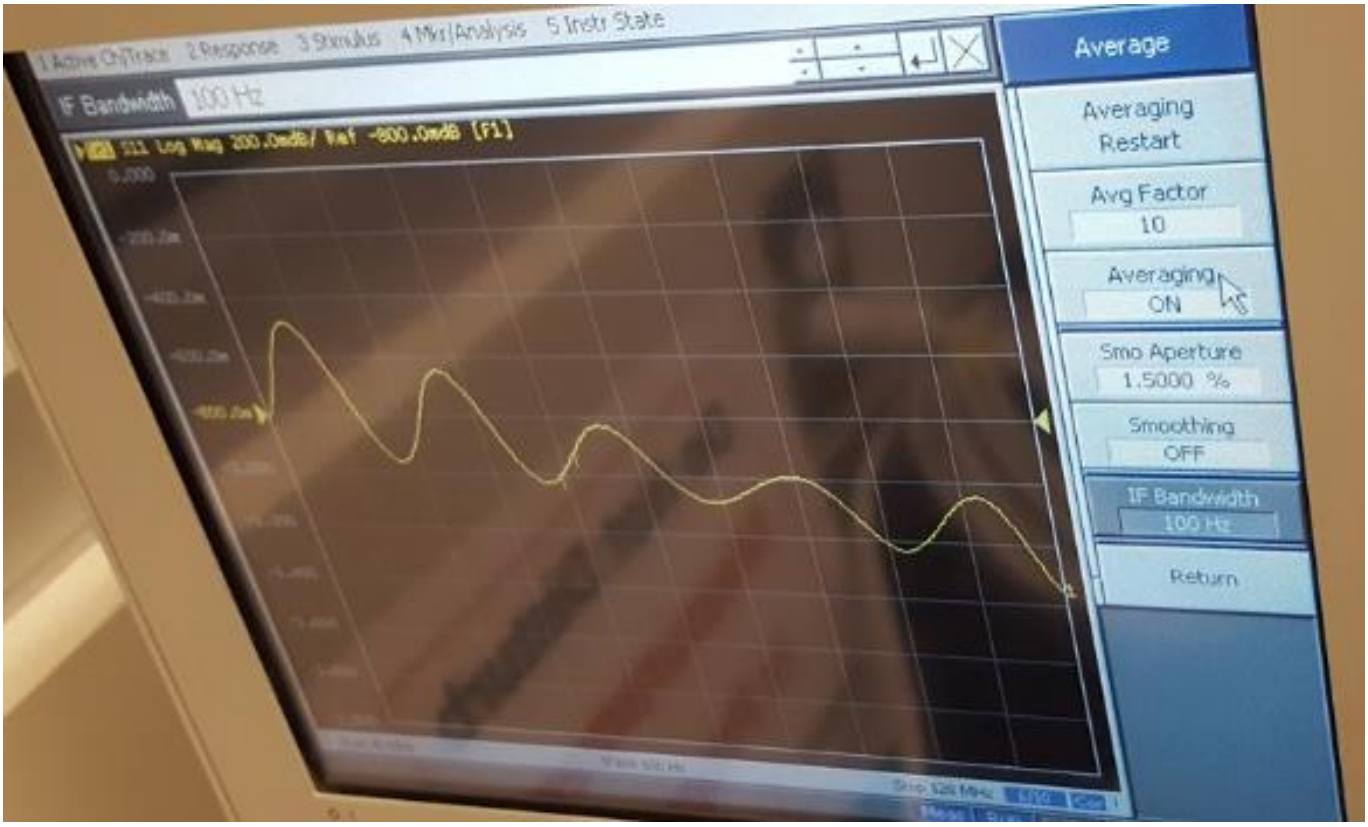


Figure 17. “Long cable open” load device S11 waveform.

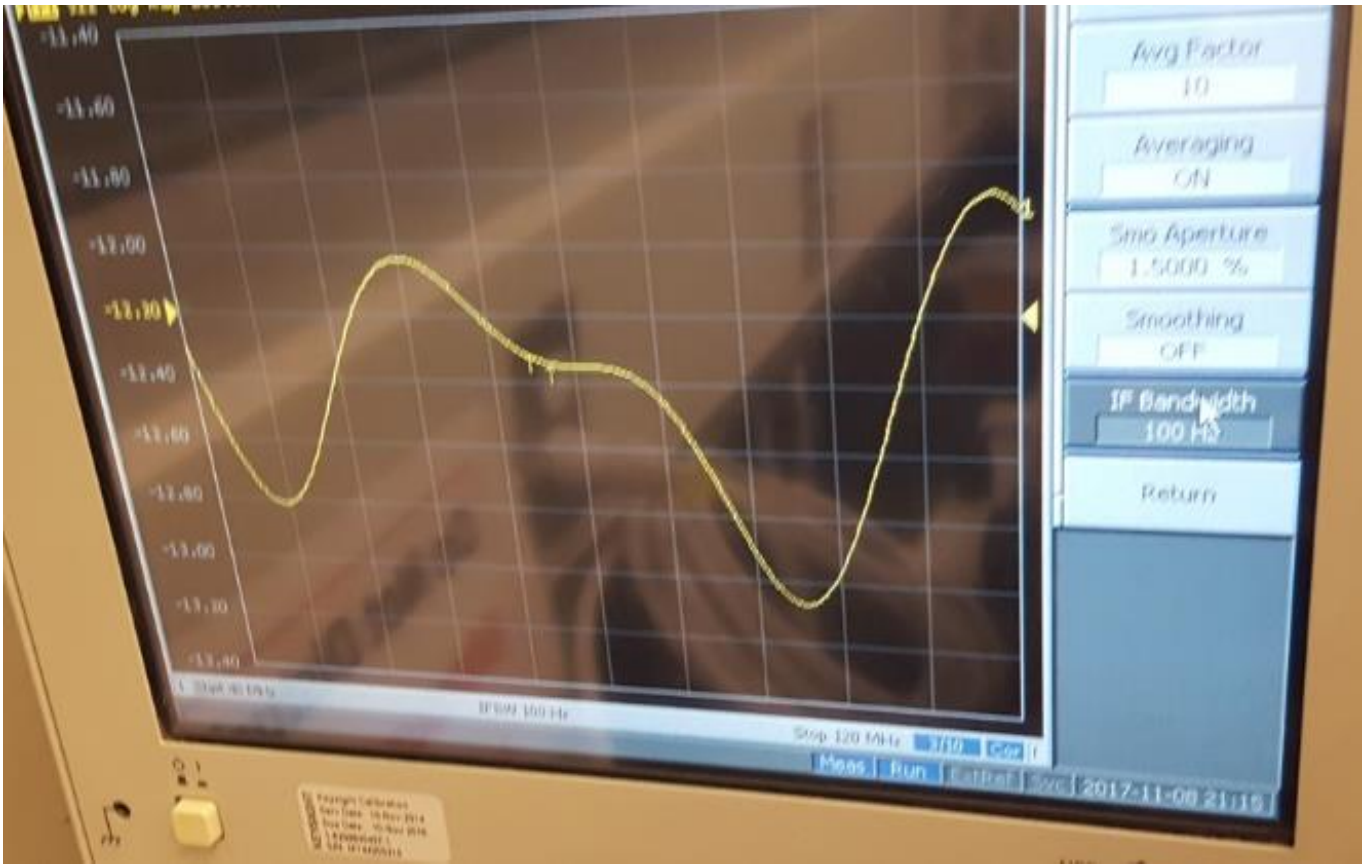


Figure 18. “Antenna Simulator” load device S11 waveform.

Calibrating the VNA

The VNA should be calibrated before making S11 measurements of the receiver and before making S11 measurements of the calibration loads through the VNA port. The only difference in settings is the Power Level and the number of samples to use in the average.

Setup

1) Enter the appropriate settings on the VNA before calibrating.
    a. Set the Number of samples to average and the IF frequency setting via the “Average” button on the VNA.
    b. Enter the frequency start, stop, and number of points under “Sweep Setup”
        i. Number of points = (Freq. Stop – Freq. Start)/(Freq. resolution) +1
        ii. Example: 40MHz to 120MHz with 250kHz resolution = (120-40)/(0.25) + 1 = 321
    c. Enter the power level under “Sweep Setup” → “Power” menu
        i. Pick a power range that places the desired power level in the middle of a range and not on the min or max of a range.
2) If measuring the Receiver’s S11, attach the M-M SMA adapter and use the female cal standards.
3) If measuring the calibration loads through the VNA port, use the male cal standards.

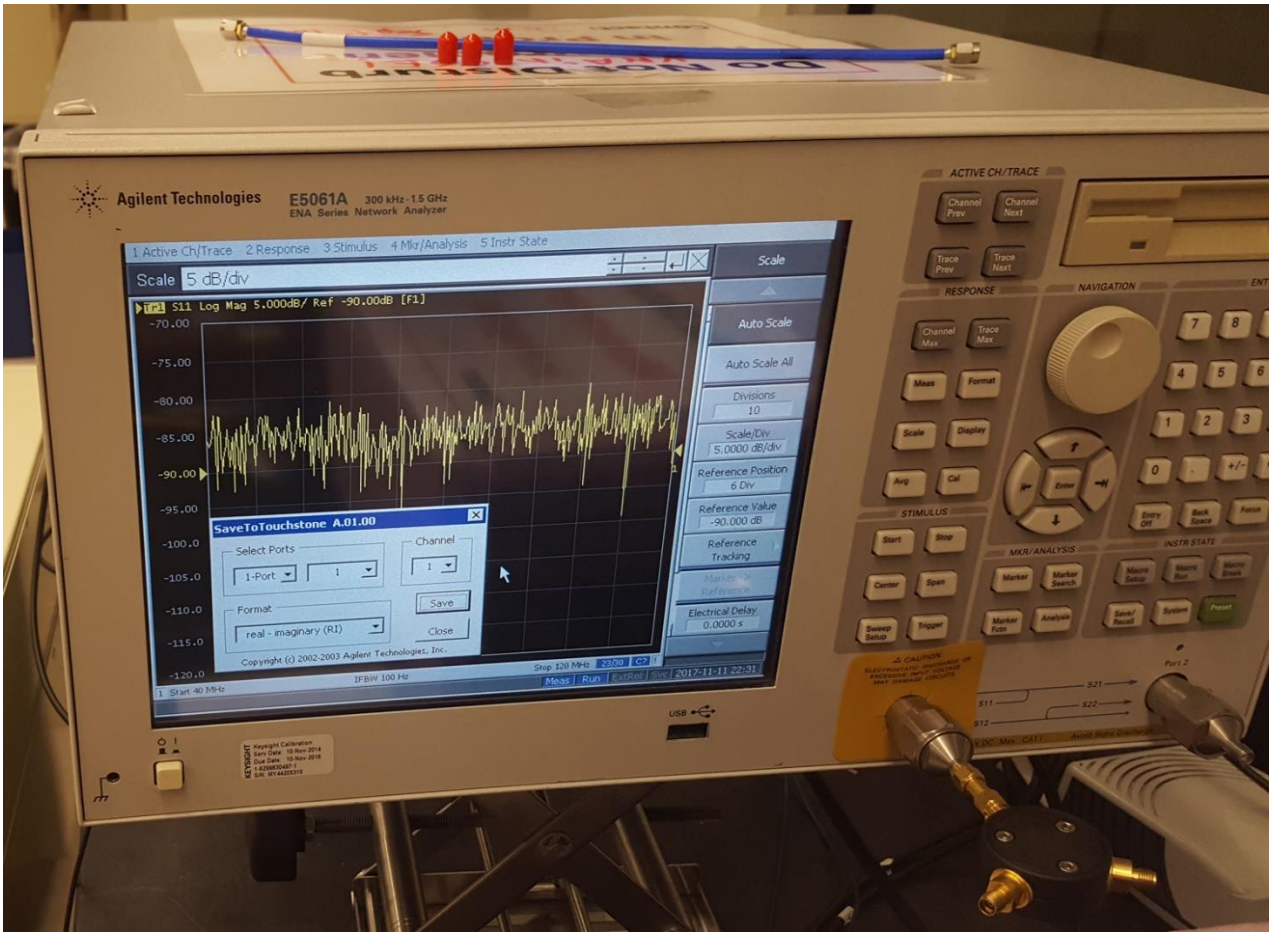
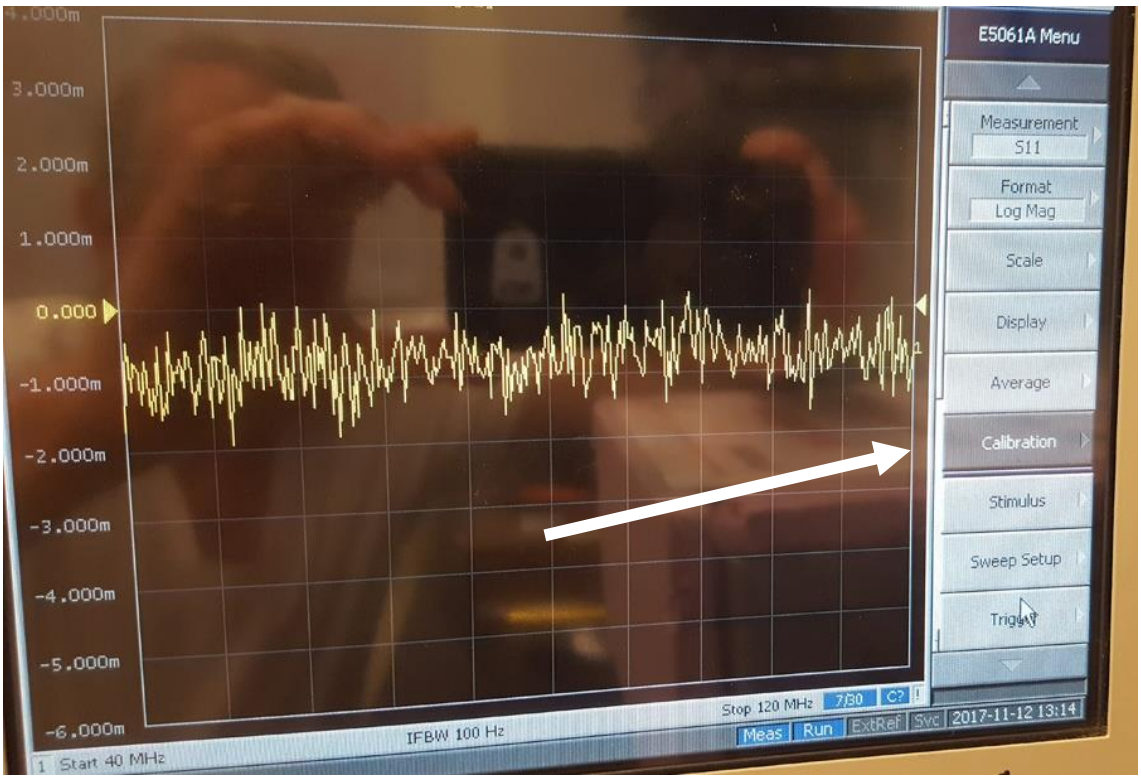


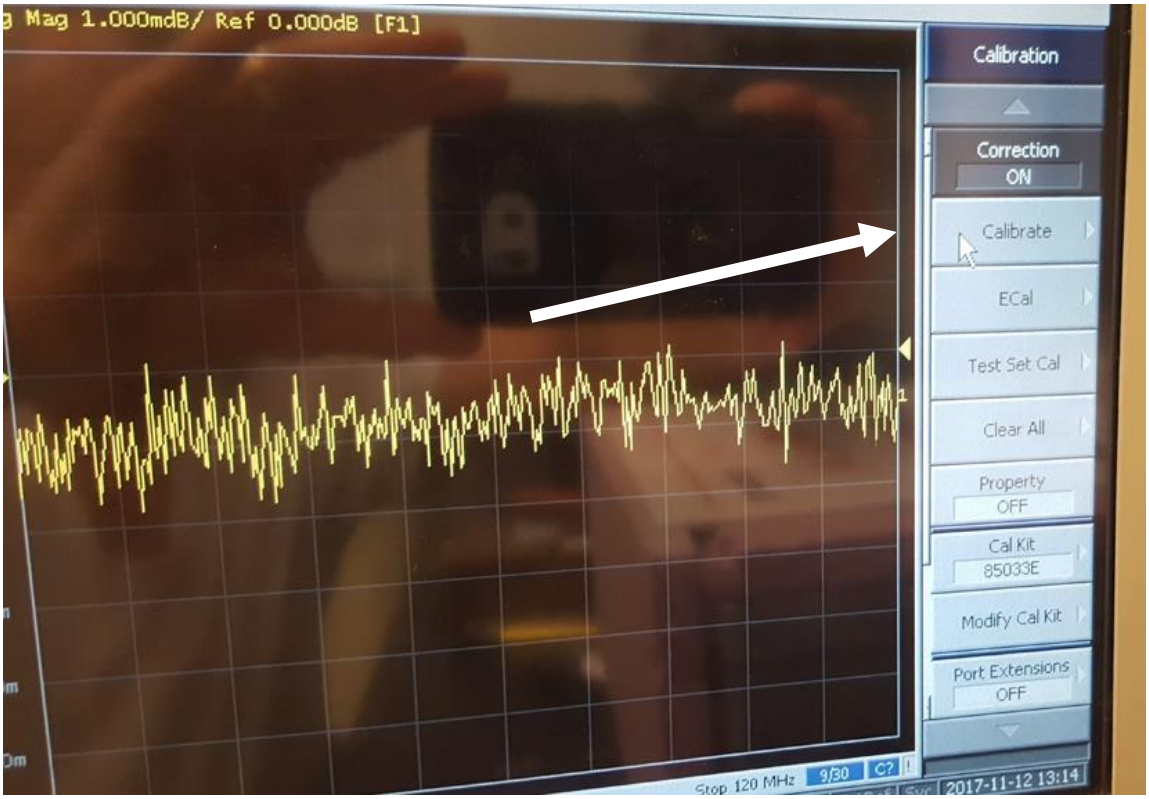
Figure 19. Example of the female calibration “match” (“load”) connected via an SMA M-M adapter.

Calibration Process on the VNA

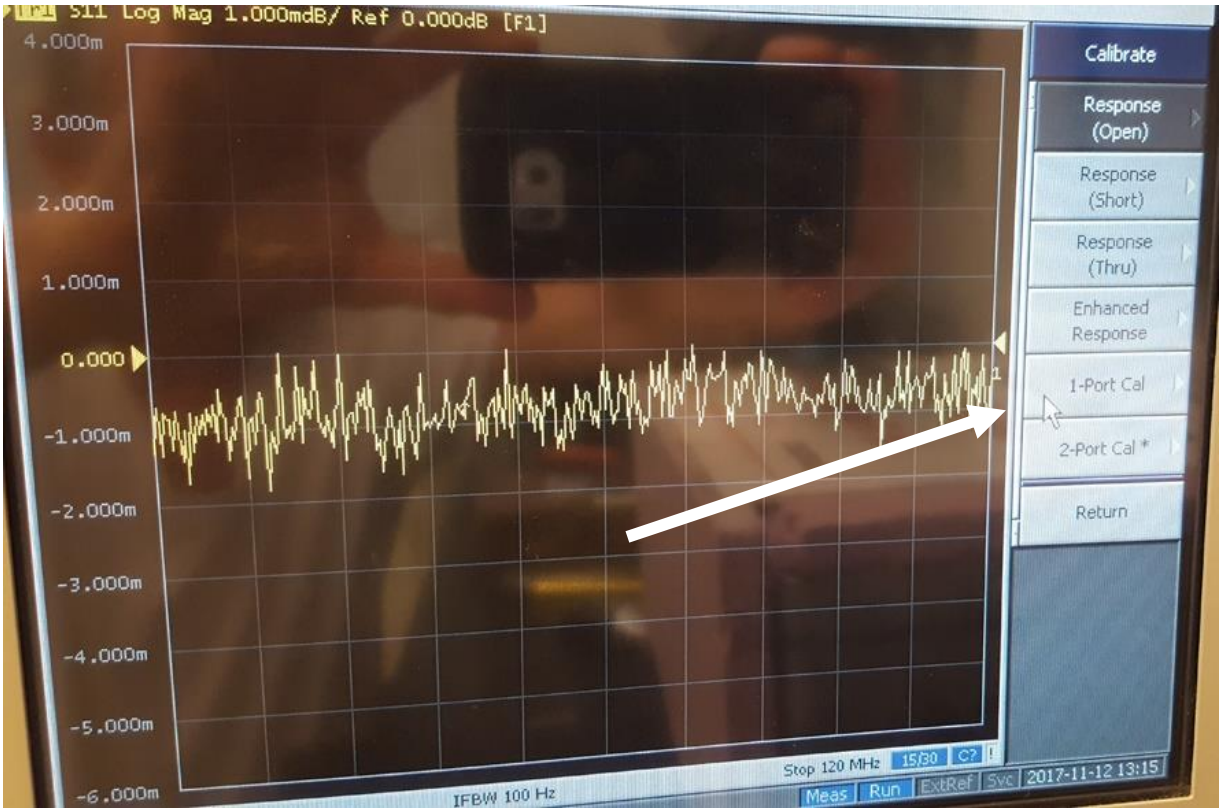
1) Select the “Calibration” menu item



2) Select “Calibrate”

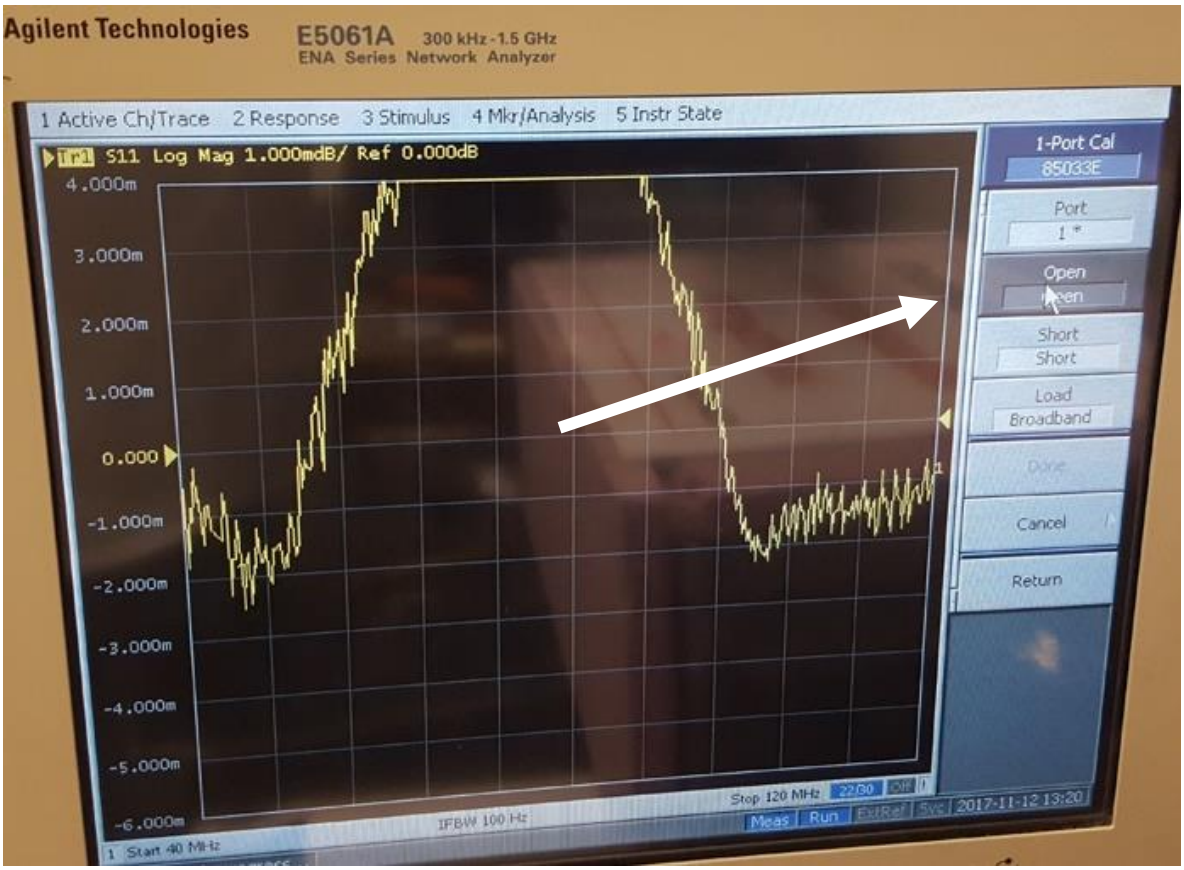


3) Select “1-Port Cal”

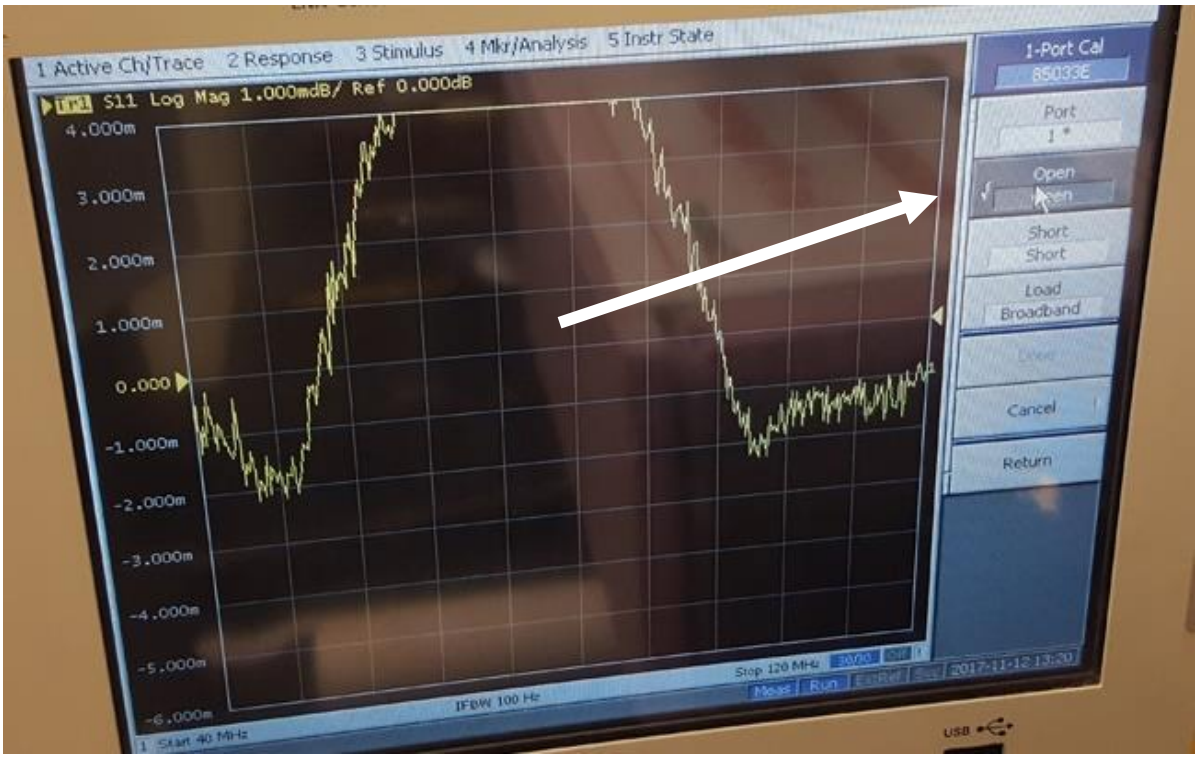


4) Select “Port 1”

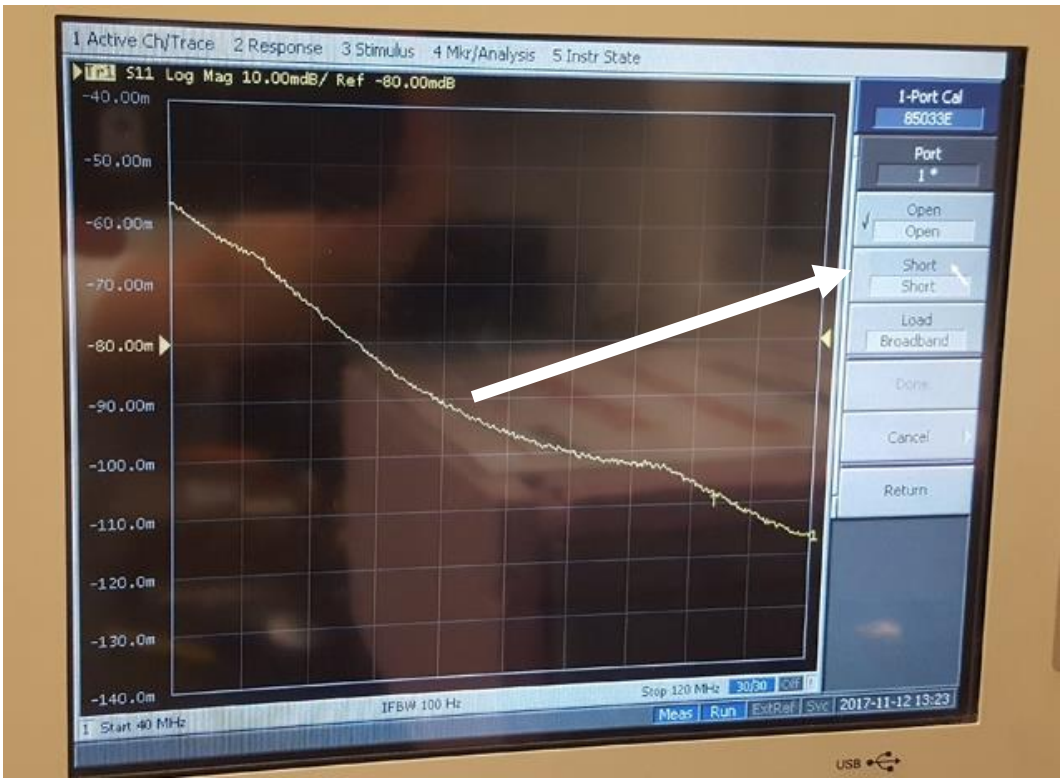
5) **Attach the Open calibration standard** and click the “Open” tab. You may go to the “Autoscale” menu to see the waveform, but then go back to the calibration menu. Wait for the checkmark to appear before disconnecting the Open and connecting the “Short” next.



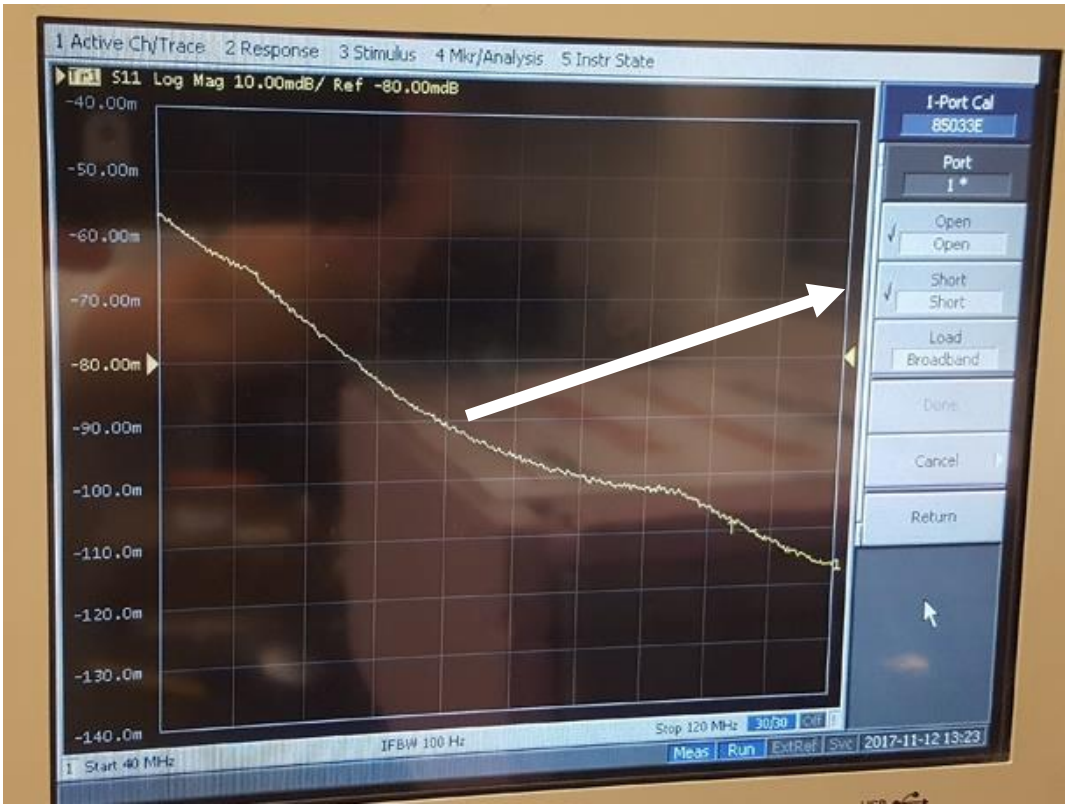
a. Checkmark appears after averaging is complete for the standard.



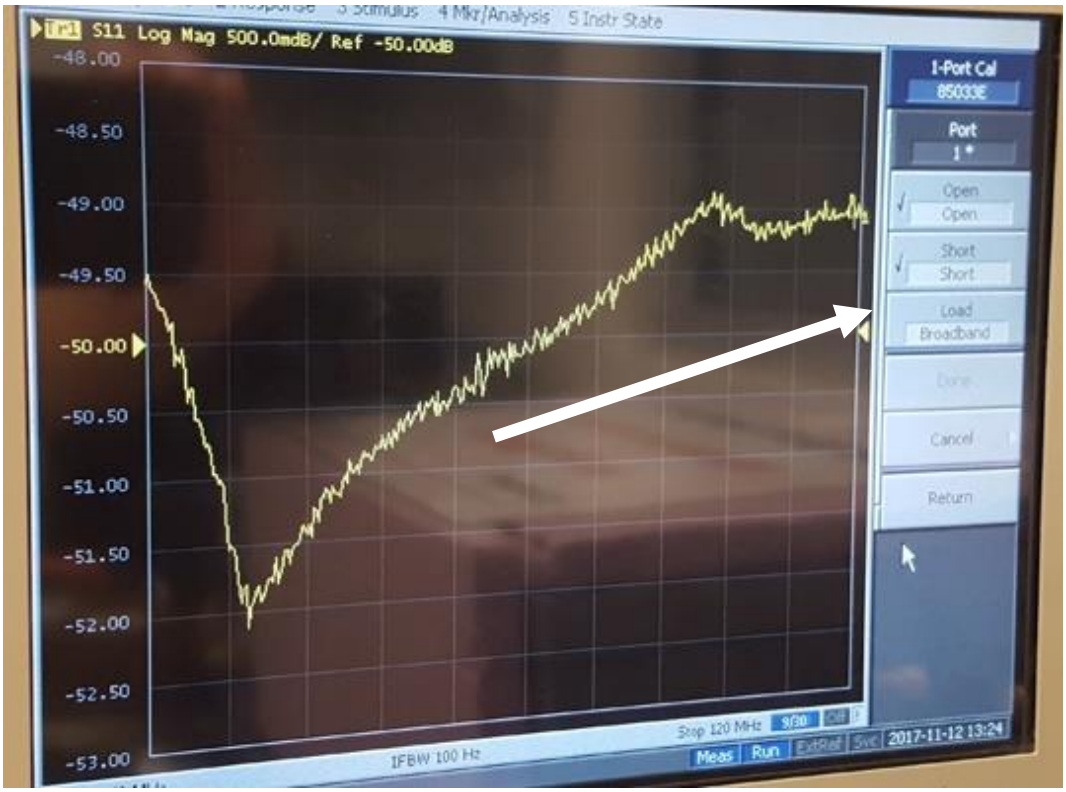
6) **Attach the Short calibration standard** and click the “Short” tab. You may go to the “Autoscale” menu to see the waveform, but then go back to the calibration menu. Wait for the checkmark to appear before disconnecting the Open and connecting the “Match” next.



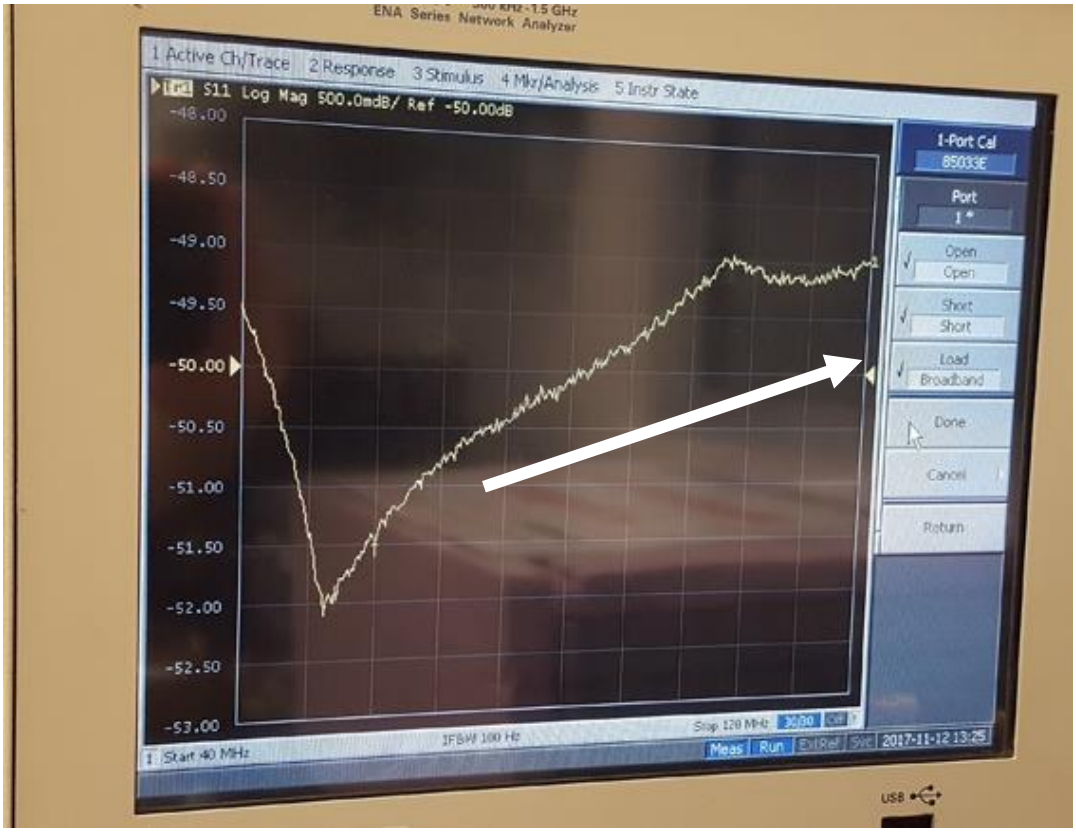
a. Checkmark appears after averaging is complete for the standard.



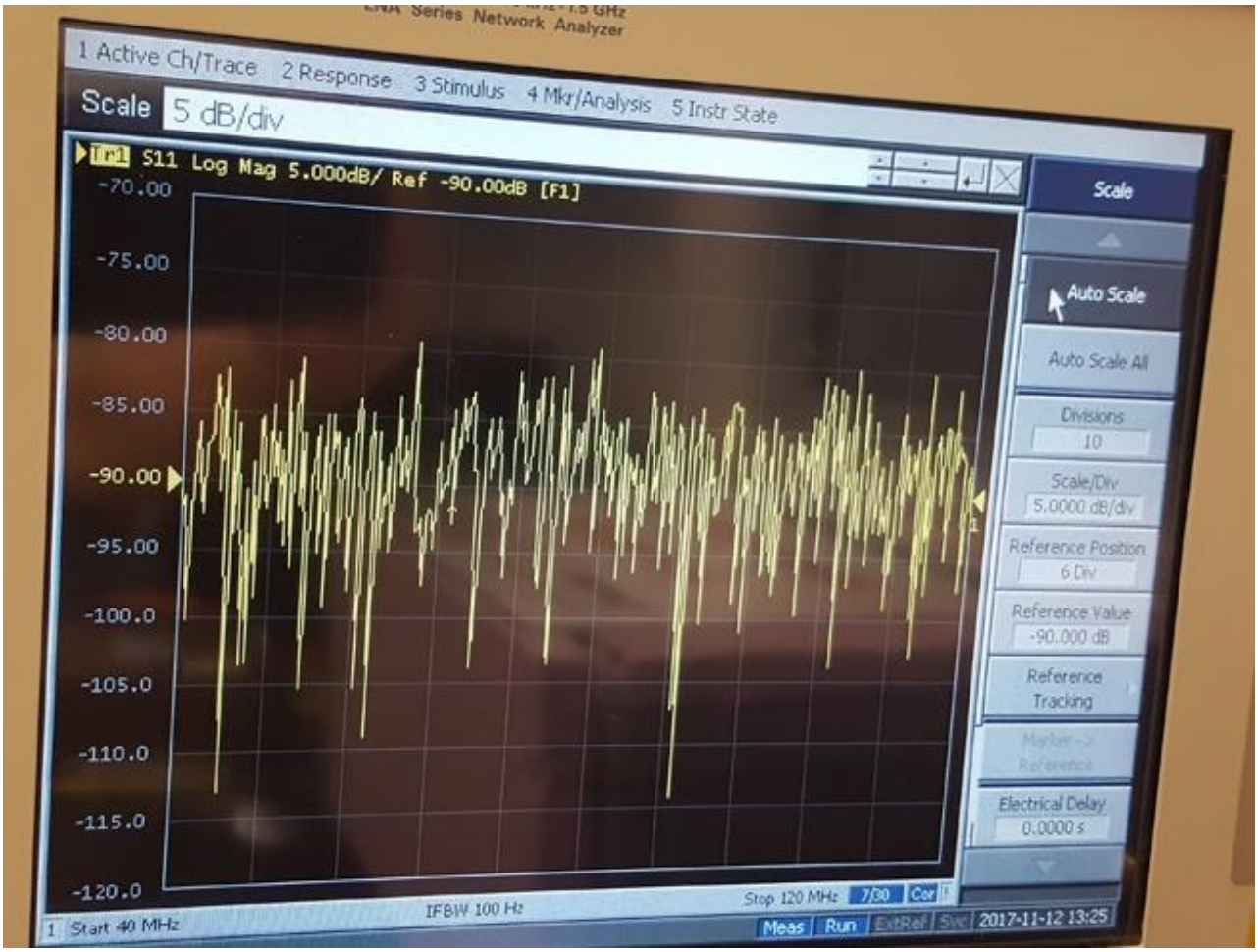
7) **Attach the Match calibration standard** and click the “Load” tab (also called “Match”). Wait for the checkmark to appear.



a. Checkmark appears after averaging is complete for the standard. **Very Important: click the “Done” button. The calibration will be lost unless you click “Done”.**



8) Autoscale the screen and it should look something like this: (flat response near -80 dB)



Calibration is now complete.

Receiver S11 Sensitivity to VNA Power Levels Measurements

The S11 of the receiver will be measured with various VNA power levels. The LNA must be powered up, but it is not cycling (switching) between receiver input, hot noise source, and ambient noise source. The VNA port is capped. The VNA is connected directly to the receiver via a M-M SMA adapter.

Day 0

a) Set the Oven-industries Controller to 25 C.
b) The 4 position switch has no voltage applied.
c) pxspec is not running – i.e., no 3 position switch cycling & no spectra.
d) The VNA port has an SMA cap on it: open, short, or 50 ohm termination.
e) Attach an SMA M-M adapter to the VNA. The adapter is part of the VNA now.
f) Let the receiver sit for 8 hours to stabilize for 8 hours

Day 1 (all measurements done twice)

VNA preparation:

a) Set the VNA to
    a. 30-trace average,
    b. 40-120 MHz, 50-200 MHz, or broadspectrum 40 – 200 MHz
    c. 250 kHz frequency steps (The number of frequency points is $(f_{max}-f_{mix})/250$ kHz + 1
    d. IF = 100 Hz
    e. Power level = -35 dBm
b) Calibrate the VNA with the female OSL standards.

Each measurement is 4 readings: the OSL female standards (1-3), and then the Receiver(4).

-25dBm:

a) Measure the S11 of the 3 OSL standards **before** connecting the receiver to the VNA
b) Connect the VNA to the receiver input, and measure the receiver S11 at -25 dBm
c) disconnect VNA from receiver input, and wait for 30 to 60 minutes.

-30dBm:

a) Measure the S11 of the 3 OSL standards **before reconnecting** the receiver to the VNA
b) re-connect VNA to receiver input, and measure the receiver S11 at -30 dBm
c) disconnect VNA from receiver input, and wait for 30 to 60 minutes.

-35dBm:

a) Measure the S11 of the 3 OSL standards **before reconnecting** the receiver to the VNA
b) connect VNA to receiver input, and measure the receiver S11 at -35 dBm
c) disconnect VNA from receiver input, and wait for 30 to 60 minutes.

-40dBm:

a) Measure the S11 of the 3 OSL standards **before reconnecting** the receiver to the VNA
b) connect VNA to receiver input, and measure the receiver S11 at -40 dBm
c) disconnect VNA from receiver input, and wait for 30 to 60 minutes.

-45dBm:

a) Measure the S11 of the 3 OSL standards **before reconnecting** the receiver to the VNA
b) connect VNA to receiver input, and measure the receiver S11 at -45 dBm

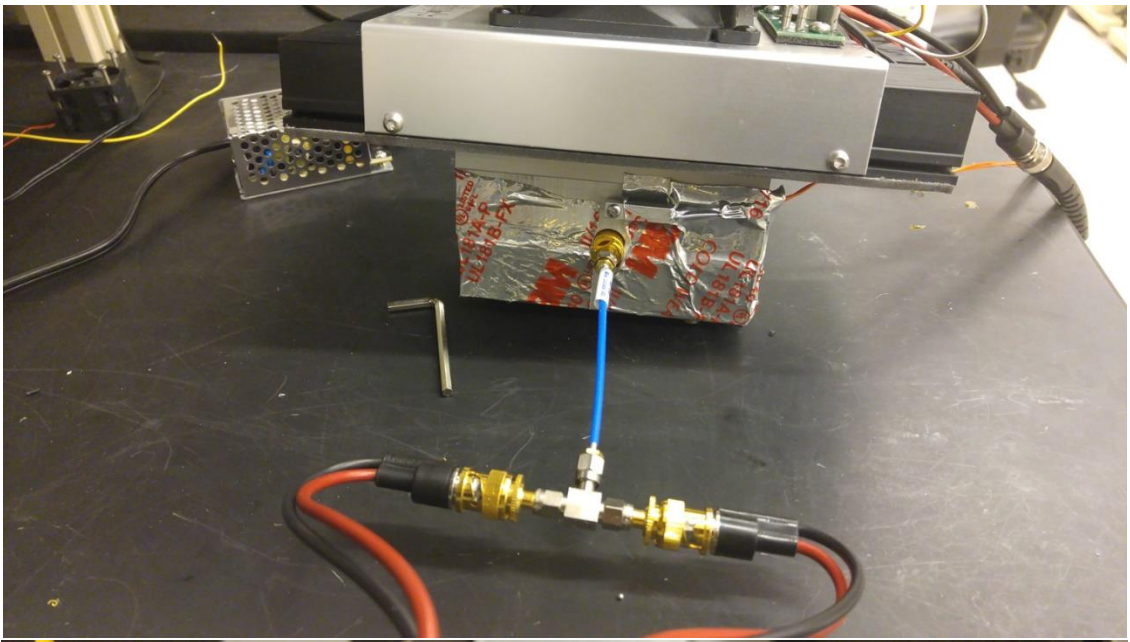
DC Resistance Measurement of Calibration Match Standards at Three Temperatures

Measure the DC resistance of the calibration match standards (male and female) using the thermal plate and the four-wire mode with the Keithly Multimeter. Resistance values are needed at the temperature of the Receiver's calibration temperatures, normally 15 C, 25 C, and 35 C. Example recordings are shown below.

February 2018

Temperature	Phil's Male Match	EDGES (Maury) Male Match	EDGES (Keysight) Female Match
15 C	50.099	50.225	50.361
25 C	50.027	50.177	50.009
35 C	50.002	50.124	49.986

Store these values in a text file in /data5/edges/CalKitMatchResistances/CalibrationMatchResistanceValues.txt. Be sure to include the date of the measurement. If new measurements or standards are made, append the measurements to the end of the list.



Hot-Load Internal Cable Measurements and Storage Location

The description of the measurements and the raw data is located in this enterprise directory:

/data5/edges/data/CalHotLoadCableData

The file “semi_rigid_s_parameters_WITH_HEADER.txt” contains the S11 parameters of the semi rigid cable.

The contents of the readme.txt file are:

##################
Description recorded on 3/13/2018
by Tom Mozdzen given to him by Raul Monsalve
##################

These files are measurements of the Keysight standards at the VNA input:
open.S1P
short.S1P
load.S1P

These files are measurements of the Keysight standards at the far end of the semi-rigid cable:
open_sr.S1P
short_sr.S1P
load_sr.S1P

Each of the 6 raw measurements listed above corresponds to 500 traces averaged automatically by the VNA.
The VNA used was the E5072A and were done at lab room temperature (~ 22.5 degrees C).

Two resistance values were measured for the Keysight 50-ohm calibration load: 50.118, and 50.132 ohm.
We are not sure if one of the values or the average was used.
Since they are very close in value, the results should turn out the same.

Using the above files, we produce the calibrated S-parameters contained in file:
"semi_rigid_s_parameters_WITH_HEADER.txt"

The calibrated file has the following columns:

frequency [MHz], real(S11), imag(S11), real(S12S21), imag(S12S21), real(S22), imag(S22)

The S-parameters correspond to the semi-rigid cable PLUS the male-to-male adapter at the input of the hot load box (i.e., outside the box).

The ports corresponding to these S-parameters are:

Port 1: male connector accessible from the outside of the box.
Port 2: female connector, to which 50-ohm termination is attached, insulated inside the box.

Checklist for Load Spectra and S11 Measurements

Before measuring a new load:

- ☐ If a previous load had been running, remember to complete the "After spectra collection" tasks for that load. Meaning: before you begin these new load tasks, finish the the old load tasks first.
- ☐ Set the oven industries controller to the desire temperature 4 to 6 hrs before collecting spectra
- ☐ Calibrate the VNA if it hasn't been calibrated within two weeks or if its settings have changed
- ☐ Attach the load device to the receiver using a ferrite core
    - Make sure both ends of the SMA adapter are torque-wrench tight
- ☐ Use the faraday cage if using the long cable load
- ☐ Put metallic tape between the load device's case and the metal part of the receiver
- ☐ Support the load device with books or a jack so that stress isn't placed on the receiver's input
- ☐ Make sure the load device has a low pass filter on its thermistor connection at the case of the load device, or at the entrance to the faraday cage
- ☐ Voltage supply going to the internal VNA switch should be in the disabled state
- ☐ VNA should be disconnected from the VNA port
- ☐ The VNA port be capped with an SMA short or 50 ohm terminated end cap
- ☐ Start the pxspec program
- ☐ Start the resistance tracking program

After spectra collection:

- ☐ Save a test file in the folder on the VNA in the folder you are going to save results. This saves time by eliminating navigation to a new folder.
- ☐ Set the switch voltage to 37 V, but do not enable the output yet.
- ☐ Connect the VNA cable to the VNA, but not to the receiver's VNA port.
- ☐ Connect the VNA cable to the VNA port.
- ☐ Exit the pxspec program.
- ☐ Stop the resistance / temperature monitoring program
- ☐ When the spectra collection stops (pxspec exits), enable the 37 V output to the internal switch
- ☐ Restart averaging on the VNA
- ☐ After the proper number of traces have been averaged, save the S11 under the name External01
- ☐ Change the switch voltage to 34 V
- ☐ Restart averaging
- ☐ After averaging has completed save the S11 under the name Match01
- ☐ Change the switch voltage to 31.3 V
- ☐ Restart averaging
- ☐ After averaging has completed save the S11 under the name Short01
- ☐ Change the switch voltage to 28.0 V
- ☐ Restart averaging
- ☐ After averaging has completed save the S11 under the name Open01
- ☐ Repeat the 4 S11 measurements above but save them using 02 instead of 01

File Folder Organization and Naming Conventions

It is important to follow these naming conventions exactly, using identical capitalization so that the scripts, which access these files, do not need to be continually edited to match stored data names.

The top-level folder which contains receiver characterization and calibration data for each receiver should be named as follows:

ReceiverXX_YYYY_MM_DD_LLL_to_HHH_MHz ,

where

- XX is a two digit code for the receiver's build number.
  - Example: the third receiver built should use the numbers 03 (not just plain 3).
- LLL is the start frequency in MHz and HHH is the end frequency in MHz.
  - Example: 40 to 200 MHz should be indicated by 040_to_200_MHz
- YYYY_MM_DD is the beginning date of data taking
  - Example: a start date of December 18th, 2017 would be 2017_12_18

Thus, the top-level directory folder would be named:

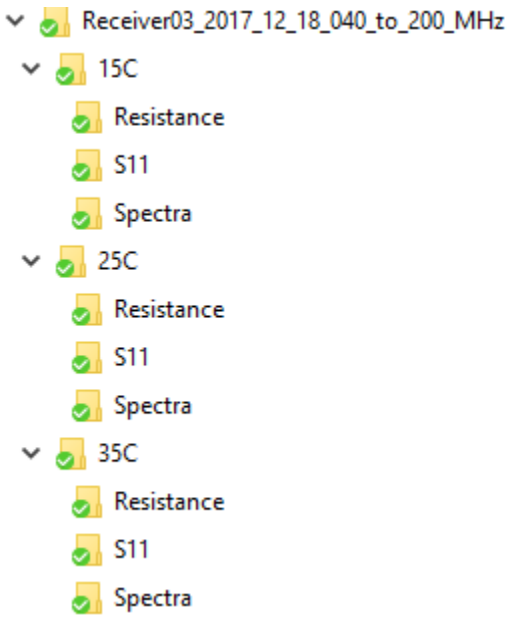
Receiver03_2017_12_18_040_to_200_MHz

The next sub-levels consist of three temperature folders 15C, 25C, and 35C.

Under each of the temperature folders should be the three types of stored data:

Spectra, Resistance, and S11

The results will look like this:



S11 Naming Conventions

S11 data will be collected for the Receiver, the 5 calibration loads and the internal SP4T switch.

The folders under the S11 directory will be named

AntSim3 (or which ever Antenna Simulator is being used)
AmbientLoad
HotLoad
LongCableShorted
LongCableOpen
InternalSwitch
ReceiverReading01
ReceiverReading02 (if a second reading is made)
ReceiverReading03 (if a third reading is made)

The S11 readings for the 5 loads will be named:

Open01.s1p Short01.s1p Match01.s1p External01.s1p
Open02.s1p Short02.s1p Match02.s1p External02.s1p

The Internal Switch S11 readings will be named:

Open01.s1p Short01.s1p Match01.s1p ExternalOpen01.s1p ExternalShort01.s1p ExternalMatch01.s1p
Open02.s1p Short02.s1p Match02.s1p ExternalOpen02.s1p ExternalShort02.s1p ExternalMatch02.s1p

The Receiver S11 readings will be named:

Open01.s1p Short01.s1p Match01.s1p Receiver01.s1p
Open02.s1p Short02.s1p Match02.s1p Receiver02.s1p

If attenuators are used in measurements, the designation Attenuator_XXdB, where XX is the value of the attenuation, shall be included in the FileFolder name or the measurement name: Attenuator_03dB, Attenuator_06dB, Attenuator_10dB, Attenuator_12dB, etc. Since this is not that common a measurement, this document will be updated with specific examples.

Corrected S11 file

s11_calibration_"band_name"_LNA_"temperature"_C_"fstart"_"fstop"MHz_"year".txt

Example:

s11_calibration_low_band_LNA_25deg_C_50_190MHz_2018.txt

This file is stored at the top level of the S11 directory.

Spectra Naming Conventions

The spectra collected for the 5 calibration loads will have the following information appended to the beginning of the default file name that the pxspec program produces:

Load Name	Example Original Name	Example Renaming Result
HotLoad	2017_139_19.acq	HotLoad_2017_139_19.acq
AmbientLoad	2017_141_17.acq	AmbientLoad_2017_141_17.acq
AntSim2	2017_143_12.acq	AntSim2_2017_143_12.acq
LongCableShorted	2017_146_00.acq	LongCableShorted_2017_146_00.acq
LongCableOpen	2017_148_00.acq	LongCableOpen_2017_148_00.acq

Resistance Naming Conventions

The thermistor resistance information collected for the 5 calibration loads will follow this format:

It will contain the date, hour, minute and second of the start time

The name of the load

The temperature of the receiver

Examples of proper usage:

LongCable_Shorted_15C_2_9_2018_16_2_46.csv

LongCable_Open_15C_2_9_2018_16_2_46.csv

AmbientLoad_25C_2_2_2018_18_7_58.csv

HotLoad_25C_2_2_2018_18_7_58.csv