

Wireless Circuits and Systems Laboratory

Procedure #7 Calibrating the HP 8714 Network Analyzer

This procedure describes the different types of calibrations that are available with the HP 8714 vector network analyzer, and how they are performed. The information can be found in more detail in Chapter 6 of the HP8714 (B/C) RF Network Analyzer Users Guide. Since the 8714B and 8714C have slightly different front-panel buttons and menu structures, a separate procedure is included for each.

[This procedure was originally written by Micheal Oldenburg.]

HP 8714B Calibration

Before we start with calibration, however, let's first describe some of the vocabulary associated with the VNA.

Ports: The 8714B VNA has two different “ports”, which are the physical RF connection points on the front of the instrument. **Port 1 is the Reflection Port.** Associated with Port 1 are an RF signal source which is used to excite the device under test (D.U.T.), and a receiver which is used to measure the signal reflected back from the D.U.T. (the source and receiver are, of course, located within the instrument casing). **Port 2 is the Transmission Port.** Associated with Port 2 is a receiver, which is used to measure the signal transmitted through the device. If you are measuring the reflection coefficient (S_{11}) of a 1-port D.U.T., the device must be connected to Port 1. In order to measure the four scattering parameters of a 2-port D.U.T., it is first connected to measure S_{11} and S_{21} , and is then physically turned around (i.e., the connections to Port 1 and Port 2 of the VNA are reversed) to measure S_{22} and S_{12} .

Measurements: There are 5 primary types of measurements which can be made using the 8714B. The two types which will be used in the WAMI laboratory are “reflection” and “transmission.” The other three types are power, conversion loss, and detection. When you select channel 1 or channel 2 (see below) from the Meas menu on the front panel of the VNA, you will then select one of these types of measurements. While making a measurement, it can be displayed on the screen in several different **formats**, e.g., log magnitude, linear, phase, and Smith chart. The format is chosen from the Configure menu on the front panel.

Channels: The 8714B VNA has two different “channels”, which are not fixed physical entities. A channel can be considered as a type of measurement which you define; by switching between channel 1 and channel 2 you can have the VNA display two different types of measurements on your device (either alternately, or simultaneously using a split-screen display). For example, you may “define” channel 1 to be a measurement of the reflection coefficient (from Port 1), and channel 2 as the transmission coefficient (from Port 2). It is important to keep in mind that any calibration you perform can only be associated with one channel. If you want to use both channels to characterize the D.U.T., you must therefore calibrate on each channel separately. A channel is defined by choosing either CHAN 1 or CHAN 2 from the Meas menu on the front panel, and then selecting the desired type of measurement.

Calibrations: There are three different types of calibration procedures which may be used in the WAMI laboratory: Normalization, Transmission and Reflection. If a “transmission” measurement is assigned to a given channel, then either a normalization or a transmission calibration can be performed. If a “reflection” measurement is assigned to a given channel, then either a normalization or a reflection calibration can be performed. Typically, however, reflection coefficients are easier measure using a reflection calibration. It is important to be aware that there are measurements and calibrations of the same name (reflection and transmission), so that you don't get confused in the following. A possible fourth type of calibration (AM Delay) will not be described here.

1. Normalization Calibration

This is the simplest type of calibration. The analyzer stores measured data taken without the D.U.T. into memory, and divides subsequent measured data by the stored data in order to remove frequency response errors. The

procedure below assumes that a transmission measurement is being performed, although in some instances a normalization calibration could also be used for a reflection measurement.

1. Set up the analyzer for your measurement:
 - a. select **CHAN 1** or **CHAN 2** -> **Transmissn**
 - b. enter any other operating parameters as needed, e.g., the start and stop frequencies and the number of points. Unless specified otherwise, use 201 frequency points.
2. Connect the equipment as you would for the actual measurement, but omit inserting the D.U.T. This will generally mean connecting a cable between ports 1 and 2 of the VNA.
3. Press **CAL** -> **Normalize**. The CAL button is found in the Configure menu on the front panel of the VNA.
4. You may now insert the D.U.T into the measurement setup. The data that is displayed is the transmission coefficient for the D.U.T. including all the connectors and cables, divided by the transmission coefficient for the connectors and cables alone.
5. Notice that the top of the display now shows the type of measurement followed by “/M” to indicate the displayed data is actually the measurement divided by memory.

NOTE: The normalization will be invalidated if any frequency settings are changed after calibration.

2. Transmission Calibration

This calibration procedure is necessary for obtaining accurate measurements of the transmission coefficient of a D.U.T. which is to be connected between Ports 1 and 2 of the VNA.

1. Set up the analyzer for your measurement:
 - a. select **CHAN 1** or **CHAN 2** -> **Transmissn** to assign the transmission type of measurement to the channel
 - b. enter any other operating parameters as needed, e.g., the start and stop frequencies and the number of points. Unless specified otherwise, use 201 frequency points.
2. Press **CAL** -> **Transmissn**. The CAL button is found in the Configure menu on the front panel of the VNA. At this point you need to select the appropriate type of transmission calibration. A complete list of the options is:
 - a. **Restore Defaults**. This installs a calibration array measured and stored in the analyzer at the factory. Typically, you should NOT use this option.
 - b. **Response**. A response calibration prompts you to connect a through cable as the calibration standard, and then measures it across the frequency band you have defined, using the number of frequency points you have defined. Typically, there will be one coax cable connected to each port of the VNA. Using a female-to-female adaptor, connect the two cables together and then perform the measurement. Changing the frequency range or number of points after calibration will either reduce the accuracy of the cal or invalidate it. Make sure that you have these parameters set correctly before the calibration is performed.
 - c. **Response and Isolation**. This type of calibration is only necessary when trying to achieve a very large dynamic range (> 100 dB) and will most likely not be used for the WAMI lab.

For the Wireless Circuits and Systems Design Lab, you will typically choose the **Response** option.

3. A “C” will appear in the upper right hand corner of the display when the calibration is complete. You can now connect the D.U.T. to port 1 of the VNA and obtain corrected measurements of the reflection coefficient.

3. Reflection Calibration

This calibration procedure is necessary for obtaining accurate measurements of the reflection coefficient of a D.U.T. which is connected to Port 1 of the VNA.

1. Set up the analyzer for your measurement:
 - a. select **CHAN 1** or **CHAN 2** -> **Reflection** to assign the reflection type of measurement to the channel
 - b. enter any other operating parameters as needed, e.g., the start and stop frequencies and the number of points. Unless specified otherwise, use 201 frequency points.
2. Press **CAL** -> **Cal Kit**. The CAL button is found in the Configure menu on the front panel of the VNA. At this point you need to select the appropriate calibration “kit” from the list. A cal kit is a collection of standards (open, short, load, etc.), for which the characteristics are known and can be supplied to the VNA. For the WAMI laboratory we will use SMA standards; the necessary information for these pieces has already been determined, and is contained within a file that is loaded into the 8714B. Select **User Defined** from the list.
3. Press **Prior Menu** -> **Reflection** to return to the main calibration menu and to begin the Reflection Calibration sequence. A complete list of the options is:
 - a. **Restore Defaults** - This installs a calibration array measured and stored in the analyzer at the factory. Typically, you should NOT use this option.
 - b. **One Port** - A one-port calibration will prompt you to connect three measurement standards: an open, a short, and a load. The standards should be connected at the same point at which the D.U.T. will be connected after calibration. Generally, this will be at the end of a coaxial cable which is connected to Port 1 of the VNA. The analyzer will measure each standard across the frequency band using the number of points you have defined. Changing these parameters after calibration will either reduce the accuracy of the calibration or invalidate it. Make sure you have these parameters set correctly before beginning the calibration sequence.

For the Wireless Circuits and Systems Design Lab, you will typically choose the **One Port** option.

4. A “C” will appear in the upper right hand corner of the display when the calibration is complete. You can now connect the D.U.T. to port 1 of the VNA and obtain corrected measurements of the reflection coefficient.

HP 8714C Calibration

Before we start with calibration, however, let's first describe some of the vocabulary associated with the VNA.

Ports: The 8714C VNA has two different “ports”, which are the physical RF connection points on the front of the instrument. **Port 1 is the Reflection Port.** Associated with Port 1 are an RF signal source which is used to excite the device under test (D.U.T.), and a receiver which is used to measure the signal reflected back from the D.U.T. (the source and receiver are, of course, located within the instrument casing). **Port 2 is the Transmission Port.** Associated with Port 2 is a receiver, which is used to measure the signal transmitted through the device. If you are measuring the reflection coefficient (S_{11}) of a 1-port D.U.T., the device must be connected to Port 1. In order to measure the four scattering parameters of a 2-port D.U.T., it is first connected to measure S_{11} and S_{21} , and is then physically turned around (i.e., the connections to Port 1 and Port 2 of the VNA are reversed) to measure S_{22} and S_{12} .

Measurements: There are 7 primary types of measurements which can be made using the 8714C. The two types which will be used in the WAMI laboratory are “reflection” and “transmission.” The other five types are fault location, SRL, power, conversion loss, and detection. When you select MEAS 1 or MEAS 2 (see below) from the Meas menu on the front panel of the VNA, you will then select one of these types of measurements. While making a measurement, it can be displayed on the screen in several different **formats**, e.g., log magnitude, linear, phase, and Smith chart. The format is chosen from the Configure menu on the front panel.

MEAS 1 and 2: The 8714C VNA has two different “measurements” which can be defined by the user at any given time; by switching between MEAS 1 and MEAS 2 you can have the VNA display two different types of measurements on your device (either alternately, or simultaneously using a split-screen display). For example, you may “define” MEAS 1 to be a measurement of the reflection coefficient (from Port 1), and MEAS 2 as the transmission coefficient (from Port 2). It is important to keep in mind that any calibration you perform can only be associated with one “measurement”. If you want to use both MEAS 1 and MEAS 2 to characterize the D.U.T., you must calibrate for each measurement separately. A measurement is defined by choosing either MEAS 1 or MEAS 2 from the Meas menu on the front panel, and then selecting the desired type of measurement.

Calibrations: There are three different types of calibration procedures which may be used in the WAMI laboratory: Normalization, Response and One Port. If a “transmission” measurement is assigned to a given MEAS, then either a normalization or a Response calibration can be performed. If a “reflection” measurement is assigned to a given MEAS, then either a normalization or a One Port calibration can be performed. Typically, however, reflection coefficients are measured using a One Port calibration. The 8714C is capable of performing other types of calibrations which are not defined here.

1. Normalization Calibration

This is the simplest type of calibration. The analyzer stores measured data taken without the D.U.T. into memory, and divides subsequent measured data by the stored data in order to remove frequency response errors. The procedure below assumes that a transmission measurement is being performed, although in some instances a normalization calibration could also be used for a reflection measurement.

1. Set up the analyzer for your measurement:

a. select **MEAS 1** or **MEAS 2** -> **Transmissn**

b. enter any other operating parameters as needed, e.g., the start and stop frequencies and the number of points. Unless specified otherwise, use 201 frequency points.

2. Connect the equipment as you would for the actual measurement, but omit inserting the D.U.T. This will generally mean connecting a cable between ports 1 and 2 of the VNA.

3. Press **CAL** -> **Normalize**. The CAL button is found in the Configure menu on the front panel of the VNA.

4. You may now insert the D.U.T into the measurement setup. The data that is displayed is the transmission coefficient for the D.U.T. including all the connectors and cables, divided by the transmission coefficient for the connectors and cables alone.

5. Notice that the top of the display now shows the type of measurement followed by “/M” to indicate the displayed data is actually the measurement divided by memory.

NOTE: The normalization will be invalidated if any frequency settings are changed after calibration.

2. Transmission Calibration

This calibration procedure is necessary for obtaining accurate measurements of the transmission coefficient of a D.U.T. which is to be connected between Ports 1 and 2 of the VNA.

1. Set up the analyzer for your measurement:

- a. select **MEAS 1** or **MEAS 2** -> **Transmissn** to assign the transmission type of measurement to the measurement
- b. enter any other operating parameters as needed, e.g., the start and stop frequencies and the number of points. Unless specified otherwise, use 201 frequency points.

2. Press **CAL**. The CAL button is found in the Configure menu on the front panel of the VNA. At this point you need to select the appropriate type of transmission calibration. A complete list of the options is:

- a. **Defaults**. This installs a calibration array measured and stored in the analyzer at the factory. Typically, you should NOT use this option.
- b. **Response**. A response calibration prompts you to connect a through cable as the calibration standard, and then measures it across the frequency band you have defined, using the number of frequency points you have defined. Typically, there will be one coax cable connected to each port of the VNA. Using a female-to-female adaptor, connect the two cables together and then perform the measurement. Changing the frequency range or number of points after calibration will either reduce the accuracy of the cal or invalidate it. Make sure that you have these parameters set correctly before the calibration is performed.
- c. **Response and Isolation**. This type of calibration is only necessary when trying to achieve a very large dynamic range (> 100 dB) and will most likely not be used for the WAMI lab.
- d. **Enhanced Response**. This type of calibration requires additional standards to be used, and will most likely not be used for the WAMI lab.
- e. **Normalize**. This is the same calibration explained above.

For the Wireless Circuits and Systems Design Lab, you will typically choose the **Response** option.

3. A “C” will appear in the upper right hand corner of the display when the calibration is complete. You can now connect the D.U.T. to port 1 of the VNA and obtain corrected measurements of the reflection coefficient.

3. One Port Calibration

This calibration procedure is necessary for obtaining accurate measurements of the reflection coefficient of a D.U.T. which is connected to Port 1 of the VNA.

1. Set up the analyzer for your measurement:

- a. select **MEAS 1** or **MEAS 2** -> **Reflection** to assign the reflection type of measurement to the measurement
 - b. enter any other operating parameters as needed, e.g., the start and stop frequencies and the number of points. Unless specified otherwise, use 201 frequency points.
2. Press **CAL** -> **Cal Kit**. The CAL button is found in the Configure menu on the front panel of the VNA. At this point you need to select the appropriate calibration “kit” from the list. A cal kit is a collection of standards (open, short, load, etc.), for which the characteristics are known and can be supplied to the VNA. For the WAMI laboratory we will use SMA standards; the necessary information for these pieces has already been determined, and is contained within a file that is loaded into the 8714B. Select **User Defined** from the list.
3. Press **Prior Menu** to return to the main calibration menu and to begin the Reflection Calibration sequence. A complete list of the options is:
- a. **Restore Defaults** - This installs a calibration array measured and stored in the analyzer at the factory. Typically, you should NOT use this option.
 - b. **One Port** - A one-port calibration will prompt you to connect three measurement standards: an open, a short, and a load. The standards should be connected at the same point at which the D.U.T. will be connected after calibration. Generally, this will be at the end of a coaxial cable which is connected to Port 1 of the VNA. The analyzer will measure each standard across the frequency band using the number of points you have defined. Changing these parameters after calibration will either reduce the accuracy of the calibration or invalidate it. Make sure you have these parameters set correctly before beginning the calibration sequence.
 - c. **Normalize** - As described above.
For the Wireless Circuits and Systems Design Lab, you will typically choose the **One Port** option.
4. A “C” will appear in the upper right hand corner of the display when the calibration is complete. You can now connect the D.U.T. to port 1 of the VNA and obtain corrected measurements of the reflection coefficient.

Appendix: Checking and Installing the SMA Calibration Kit

1. The calibration standards file must be loaded from a floppy disk into the analyzer if it is not already loaded as a user-defined kit. For the lab, it will most likely already be stored in the analyzer. To verify that it is already loaded.

Select **CHAN 1** (or **CHAN 2**) -> **Reflection**
 Select **CAL** -> **Cal Kit** -> **User Defined**.

If you are using the 8714C, use **MEAS 1** or **MEAS 2** instead of **CHAN**.

2. If the analyzer reports that a User Defined kit is not installed, you have to load the ASCII calibration file (see below) from a 3.5" floppy disk. In order to do this, you must first create the following file using Notepad or some other text editor. Then save the file to a floppy disk. Insert the disk into the analyzer and perform the following:

Select **SAVE/RECALL**. (Make sure the internal 3.5" floppy drive is active. If the floppy's directory does not appear press **Select Disk->Internal 3.5" Disk**.)

Highlight the file using the cursor -> Select **Recall State**.
 Select **CAL** -> **Cal Kit** -> **User Defined**.

3. Once the Cal Kit is selected, the calibration is performed as described above.

Contents of the ASCII file:

```

10 !$ SMA Calibration Kit Definitions
20 !$ See page 6-19 of the HP8714 User's Guide
30 ! OPEN:
40 ! Z0 50.0
50 ! DELAY 0.0
60 ! LOSS 0.0
70 ! C0 50.008E-15
80 ! C1 -1.969E-27
90 ! C2 592.05E-36
100 ! C3 -55.651E-45
110 !
120 ! SHORT:
130 ! Z0 50.0
140 ! DELAY 13.06E-12
150 ! LOSS 0.0
160 !
170 ! LOAD:
180 ! Z0 50.0
190 ! DELAY 0.0
200 ! LOSS 0.0
210 !
220 ! THRU:
230 ! Z0 50.0
240 ! DELAY 0.0
250 ! LOSS 0.0
260 END

```