User Entry of the Keysight (Agilent/HP) 8510 Calibration Standards Definitions for Millimeter Wave Configuration

The purpose of this procedure is to guide an 8510 millimeter wave user through the completion of the OML Calibration Standards Definition Chart (OML Definitions Chart). The procedure will then address the Keysight 8510 (8510) front panel inputs necessary for entry of the characteristics of Waveguide Standards made up of the components of an OML millimeter wave waveguide Calibration Kit. When the Calibration Standards Definitions have been entered, the 8510 user will then be able to perform a waveguide calibration procedure. Calibrations, based on these Calibration Standards Definitions, are possible for both the "one path-two port" measurement utilizing one OML T/R type module, one OML T type module and the "two path-two port" utilizing two OML T/R type modules. Carefully follow the procedure on a step-by-step basis for maximum user efficiency. This procedure assumes that the users 8510 system has been correctly configured and is operating properly. For reference, the configuration process is described in the OML paper entitled User Control of the HP 8510 for Millimeter Wave Configuration(41-020325) or in the OML millimeter wave module user's manual.

An overview of waveguide calibration process, Calibration Charts and Calibration Kits

This procedure follows closely the Keysight methodology for the calibration process. A calibration kit is composed of several components which are individually or collectively referred to as "Calibration Standards." Keysight has assigned an arbitrary "class" number and a definition methodology to each of these Calibration Standards. The mix of Standards to be used is determined by the calibration method to be performed. A listing of the various type of calibrations typically used for millimeter wave waveguide applications is found in the OML document Most Common Types of Calibration Procedures(4x-xxxxxx_Manual) or in the OML millimeter wave module user's manual.

Included in that document are the types of "Calibration Standards" used in each calibration procedure. Millimeter Wave Waveguide VNA Calibration Procedures vs. OML Cal Kit Components(41-020118) lists the various calibration procedures that can be performed with an OML Cal Kit. An example would be the SSLsT calibration method which is popular as millimeter wave waveguide calibration. It utilizes the following "Calibration Standards": 1) a Short, 3) an Offset Short, 10) a Load (sliding) and 11) a Thru connection.

The number, (x), shown in front of each item is the Class assignment for that Standard as defined by Keysight. OML has chosen to use the same "class assignments" and definition procedure as Keysight with a few minor deviations or amplifications to simplify the process. The OML Definition Chart that follows combines the functions of both the Keysight "Standard Class Assignments Chart" and the Keysight "Calibration Standards Definition Chart." This is possible by the use of the same Standards Class assignments reflected in Keysight's calibration kits as being applicable to the Class assignments for the Standards in the OML calibration kits.

Calibration kits are available from several vendors covering the waveguide bands up through 110 GHz. One of the vendors also has a calibration kit for WR-08 covering up to 140 GHz. OML is the only vendor offering calibration kits for all waveguide bands covering from 33 to 325 GHz. Almost all Cal Kits include the following components: 1) a flush short, 2) a ¼ wavelength section, and 3) a fixed load. Some kits include a precision waveguide section, of known length, to be used as a verification tool for the quality of the calibration, and one or two waveguide sections to be used as "test port adapters" which are to be attached to the waveguide ports of the millimeter wave VNA modules. Typically, all vendors supply these components with precision waveguide flanges. The OML Millimeter Wave VNA Cal Kits are similar to those provided by other vendors but differ in that they include all of the above components plus: an additional flush short, an additional waveguide load and a sliding waveguide load. The OML Cal Kit includes a precision waveguide section, of known length, to be used as a verification tool for the quality of the calibration. The OML Cal Kit provides two precision waveguide shims whose difference is ¼ wavelength instead of a single ¼ wavelength shim. The first shim is arbitrarily 0.1000" thick and the second shim is 0.1000" plus $\lambda/4$ at the geometric mean frequency (GM(Fo)) of the waveguide band being addressed. This results in shims that are more robust (resistant to damage) and are easier to produce accurately up to 325 GHz. All of the components in the OML Cal Kit are produced using electro-forming techniques offering the best in dimensional accuracy and are mechanically traceable to N.I.S.T.

To illustrate the "Calibration Standards Definitions" process let us look at typical data and walk through the necessary steps. The OML Cal Kit includes eight components which used either individually, or in combination with another component, compose a Standard. Included with each OML Calibration Kit is a chart (see pdf flie "Table 1). Example “OML VNA Calibration Kit" data sheet) listing the pertinent properties of each of the Standard components. The accuracy of the mechanical measurement of dimensional properties is traceable to N.I.S.T. The "delay" of each of the Standards is calculated from the length dimension.

These components include (the example shown is for a WR-12 60 to 90 GHz Cal Kit): a) a waveguide termination (labeled "T-12 Precision Term"), b) a second waveguide termination (also labeled "T-12 Precision Term"), c) a flush short (labeled "S-12 Precision Short"), d) a second flush short (also labeled "S-12 Precision Short"), e) a 0.1000" waveguide shim (labeled "OS-12 Precision Insert B"), f) a 0.1000" plus λ/4 waveguide shim (labeled "OS1/4-12 Precision Insert A"), g) an adjustable waveguide load (labeled "AL-12 Adjustable Load") and h) a waveguide section of precisely known length (labeled "W/G-12 Precision Section"). An example situation: a "one path-two port" calibration of a WR-12 system using an OML V12VNA-T/R module (T/R), with its test port adapter waveguide section attached, and an OML V12VNA-T module (T), with the supplied waveguide attenuator attached. An SSL(s)T calibration would make use of either the first or second flush short (no difference exists) in combination with the 0.1000" waveguide shim to form the Standard for the Short, the first "S" in SSL(s)T. Either the first or second flush short in combination with the 0.1000" plus λ/4 waveguide shim would be used to form the Standard for the Offset Short, the second "S" in SSL(s)T. The sliding load will be used as the L(s) Standard for the SSL(s)T. A connection of the T/R module test port (with the Test Port Adapter attached) to the test port of the T module input of the waveguide attenuator (attached to the input of the T module form the Thru, the T in SSL(s)T.

OML Calibration Standards Definitions Chart use

The OML Definitions Chart was intentionally made similar to the Keysight version so as to allow the user ease of transition back and forth between the OML and Keysight versions. As the OML Definitions Chart is concerned only with millimeter wave waveguide calibration, all of the items on the Keysight Definitions Chart relevant to coaxial calibrations were excluded. Again the Keysight "Class" assignments used for their calibration kits were adopted by OML.

For the discussion of the OML Definitions Chart the WR-12 Cal Kit example above (pdf file Table 1) will be used. The pdf file Table 2 is an example of an OML Definitions Chart with the data from a typical OML WR-12 Cal Kit inserted. Starting from the left of the OML Definitions Chart the first column is divided into two sub-columns. The "Class #" column is used to determine the Class # assignment and replaces the Keysight "Standard Class Assignment Chart" for our purposes. The "Type" column is used to identify which of the three waveguide calibration standard type is assigned to that Class #. The three type of Standards are Short, Load and Delay/Thru. The term Short can represent flush short, an offset short or a sliding short (typically not used in waveguide calibration). The term Load can represent a fixed load, an offset load and a sliding load. The term Delay/Thru recognizes that a through connection will exhibit some delay property. The direct interface of the test ports of two millimeter wave modules will have be a Thru connection of zero delay. The waveguide shims or the "known length" waveguide section will each have a different delay property and can be used as part of the "Thru" calibration. The choice of which "Type" of standard is assigned to which "Class #" is arbitrary.

However, for a given calibration kit, once the data is entered into the 8510, the "Class #" of a standard "Type" cannot be changed. There are two "Offset" columns, one for the waveguide length (delay) data of a particular Standard, and one to indicate that the is system mode is waveguide. The "Delay pS" of a Standard is derived from its insertion length. *). Side note, the delay data must be entered into the 8510 in "nS" but all of the Keysight charts and the 8510 display will show the delay in "pS" for the waveguide bands covered by OML.* Each of the Standards will have a length entry ranging from "0" (no length) to that of the longest Standard to be used. The entry for Standard 1, representing the Short of a Short/Offset Short pair, will be that of the combination of a OML "S-12" flush short and the OML "OS-12" 0.1000" waveguide shim which will have a delay of 0.008475 pS (the delay of the 0.1000" waveguide shim only). Likewise, the entry for Standard 3, representing the Offset Short of a Short/Offset Short pair, will be that of the combination of a OML "S-12" flush short and the OML "OS-1/4-12" 0.1000" plus λ/4 waveguide shim which will have a delay of 0.012993 pS (the delay of the 0.1000" plus λ/4 waveguide shim only). The Offset column labeled "Zo Ω" is concerned with the 8510 front panel entry used to denote the system test port impedance, i.e., coax or waveguide mode. A value of "1" should be entered for each Standard indicating that the system is in the waveguide mode.

There are two entries necessary for "Frequency (GHz)". The first is for the TE 1,0 cutoff frequency and is labeled "Min". The TE 1,0 cutoff frequency, 48.362 (GHz), of the WR-12 waveguide is indicated in our sample chart. The second is for the TE 2,0 cutoff frequency and is label "Max". This is also known as the "mode" frequency and is twice the TE 1,0 frequency. The entry on our sample chart is 96.724 (GHz). These two entries must be a very precise entries as the VNA uses this data for a number of its algorithms in the calibration process. This is especially true as the user goes higher in frequency above 110 GHz (WR-10) as waveguide vendors do not guarantee their waveguide dimensions for WR-08 and above. The use of the commonly published waveguide cutoff frequencies can cause potentially fatal errors in the calibration. Use the OML Cal Kit data chart TE 1,0 and TE 2,0 frequency data for the precision components in the OML Cal Kit. For more information see the OML paper "Millimeter Wave Vector Analysis Calibration and Measurement Problems Caused by Common Waveguide Irregularities" that is on the OML web site or in the OML VNA modules users manual.

The formal description of the Standard is entered in the column "Standard Label". This is also description that is entered into the 8510. In the following list the **Standard Labels** is shown along with the Standard Class #, The Standard Type and the OML Cal Kit Components used to assemble each Standard. The Standards possible with the components of an OML WR-12 Cal Kit are used as examples.

Standard Class	Standard Type	**Standard Label**	OML Components
1	Short	**SHORT**	S-12 + OS-12
3	Short	**/OFFS**	S-12 + OS1/4-12
9	Load	**FIXED**	T-12
10	Load	**SLIDING**	AL-12
11	Delay/Thru	**THRU**	none
13	Delay/Thru	**THRU W/G**	W/G-12
14	Delay/Thru	**THRU .1**	OS-12
15	Delay/Thru	**THRU.1+/4**	OS-12
20	Load	**OFFS LOAD**	T-12 + OS-12
21	Load	**/4OFFS LD**	T-12 + OS1/4-12

OML has made use of the latitude in labeling that is available in the 8510 "LABEL STD" function to make the labels more meaningful. Standards 13 through 21 are typically not possible with other vendor's Cal Kits. An OML paper entitled "Millimeter Wave Waveguide VNA Calibration Procedures vs. OMLCal Kit Components" can be found in the OML millimeter wave module user's manual. This paper details which of the OML Cal Kit components are used as, or used to make up the Standards required for the various calibration procedures.

The next two columns are used by the user for "record keeping" and are not for data to be entered into the 8510. The OML Cal Kit components that make up each Standard are identified in the column labeled "OML Components". For WR-12 the Standard 1 consists of the combination of an OML "S-12" short and the OML "OS-12" 0.1000" waveguide shim. The "Comments" column is provided for notation of a verbal description of the Cal Kit components or combination thereof used for a given Standard or for specific calibration conditions to be utilized, etc.

OML has chosen to list, on the example OML Definitions Chart, all of the Standards possible with the components of the OML Cal Kit. These were also listed in the above discussion of "Standard Labels". With this data entered into the 8510 Standards Definitions the user can try other calibration techniques requiring different sets of Standards without stopping to reenter different or additional Calibration Standards Definitions. A blank pdf copy of Table 2 is available for the user to copy and enter his own data.

Entering the Cal Standards Definitions into the 8510

The proper operation of the millimeter wave 8510 VNA system should confirmed prior to the beginning of any calibration effort. The OML document "User Control of the HP 8510 for Millimeter Wave Configuration" should be followed precisely in setting up the 8510 system. Upon completion of "set-up" the user should examine the output signal of each downconverter channel. Using the "MENU" under "PARAMETERS" the module Reference signal output can be viewed by pressing the "A1" or "A2" buttons depending on the system configuration. Likewise, the module Test signal output can be viewed by pressing the "B1" or "B2" buttons. When the user is satisfied that the system is performing properly the Calibration Standards Definitions can be entered.

Entry of SSL(s)T related Calibration Definitions (other calibration methodologies are similar in the entry of the definitions)

The Cal Kit data that has been entered by the user on to the "Calibrations Standards Definitions" chart supplied in the OML Millimeter Wave VNA Module Users Manual (the data found on the Calibration Kit data sheet) is to be entered into the Keysight 8510 using the following steps.

1) Press the “CAL” button in "MENUS" (lower left corner of the 8510 under the CRT)

2) Press the “MORE” soft key

3) Press the “MODIFY 1" soft key (MODIFY 2 can be used if preferred).

The data for the following steps is that associated with Standard 1, the "OS-xx Precision Insert B" offset shim (0.1000") component of the OML Calibration.

1) Press the “DEFINE STANDARD" soft key

2) Press the "1" key on the "ENTRY" Keypad followed by “X1".

3) Press the “SHORT” soft key

At this point entries for Short properties "L0" through "L3" appear adjacent to soft keys. These are coaxial properties and do not apply to waveguide "Short" Standards. Simply make sure that "0" in each of these entries. If the entry is other than "0" perform the following steps.

4) Press the "L0" soft key and enter "0" using the "ENTRY" keypad followed by "x1".

5) Press the "L1" soft key and enter "0" using the "ENTRY" keypad followed by "x1".

6) Press the "L2" soft key and enter "0" using the "ENTRY" keypad followed by "x1".

7) Press the "L3" soft key and enter "0" using the "ENTRY" keypad followed by "x1".

8) Press the “SPECIFY OFFSET” soft key

9) Press the “OFFSET DELAY” soft key

10) Convert the data listed in picoseconds for Standard 1 (OS-xx Precision Insert B) on the “Calibrations Standards Definitions" chart to nanoseconds and enter that number followed by “G/n" using the "ENTRY" keypad. Example: ".008475" and "G/n" (8.475 pS) for a typical OML WR-12 Cal Kit.

11) Ignore the “OFFSET LOSS” soft key, it is not relevant as the entries are for the waveguide mode.

12) Press the “OFFSET Zo Ω” soft key and enter "1" followed by "x1" using the "ENTRY" keypad.

13) Press the "MINIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

14) Press the "MAXIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

15) Press the "WAVEGUIDE" soft key.

16) Press the "STD OFFSET DONE" soft key.

17) Press the LABEL STD" soft key.

18) If the label shown is "SHORT" proceed, if not enter "SHORT".

19) Press the "TITLE DONE" soft key.

20) Press the "STD DONE" soft key.

The data for the following steps is that associated with Standard 3, the "OS1/4-xx Precision Insert A" offset shim (0.1000" plus 1/λ) component of the OML Calibration Kit.

1) Press the “DEFINE STANDARD" soft key

2) Press the "3" key on the "ENTRY" Keypad followed by “X1".

3) Press the “SHORT” soft key

At this point entries for Short properties "L0" through "L3" appear adjacent to soft keys. These are coaxial properties and do not apply to waveguide "Short Standards. Simply make sure that "0" in each of these entries. If the entry is other than "0" perform the following steps.

4) Press the "L0" soft key and enter "0" using the "ENTRY" keypad followed by "x1".

5) Press the "L1" soft key and enter "0" using the "ENTRY" keypad followed by "x1".

6) Press the "L2" soft key and enter "0" using the "ENTRY" keypad followed by "x1".

7) Press the "L3" soft key and enter "0" using the "ENTRY" keypad followed by "x1".

8) Press the “SPECIFY OFFSET” soft key

9) Press the “OFFSET DELAY” soft key.

10) Convert the data listed in picoseconds for Standard 1 (OS1/4-xx Precision Insert A) on the "Calibrations Standards Definitions" chart to nanoseconds and enter that number followed by "G/n" using the "ENTRY" keypad. Example: ".012993" & "G/n" (12.993 pS) for the sample.

11) Ignore the “OFFSET LOSS” soft key, it is not relevant as the entries are for the waveguide mode.

12) Press the “OFFSET Z0” soft key and enter "1" followed by "x1" using the "ENTRY" keypad.

13) Press the "MINIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

14) Press the "MAXIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

15) Press the "WAVEGUIDE" soft key.

16) Press the "STD OFFSET DONE" soft key.

17) Press the LABEL STD" soft key.

18) If the label shown is "/4 OFFS" proceed, if not enter "/4 OFFS".

19) Press the "TITLE DONE" soft key.

20) Press the "STD DONE" soft key.

The data for the following steps is that associated with Standard 9, one of the "T-xx Precision Term" waveguide load components of the OML Calibration.

1) Press the “DEFINE STANDARD" soft key

2) Press the "9" key on the "ENTRY" Keypad followed by “X1".

3) Press the “LOAD” soft key

4) Press the "FIXED" soft key

5) Press the “SPECIFY OFFSET” soft key

6) Press the “OFFSET DELAY” soft key and enter "0" followed by "x1" using the "ENTRY" keypad.

7) Ignore the “OFFSET LOSS” soft key, it is not relevant as the entries are for the waveguide mode.

8) Press the “OFFSET Z0” soft key and enter "1" followed by "x1" using the "ENTRY" keypad.

9) Press the "MINIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

10) Press the "MAXIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

11) Press the "WAVEGUIDE" soft key.

12) Press the "STD OFFSET DONE" soft key.

13) Press the LABEL STD" soft key.

14) If the label shown is "FIXED" proceed, if not enter "FIXED".

15) Press the "TITLE DONE" soft key.

16) Press the "STD DONE" soft key.

The data for the following steps is that associated with Standard 10, the "AL-xx Adjustable Load" sliding waveguide load component of the OML Calibration Kit.

1) Press the “DEFINE STANDARD" soft key

2) Press the "10" key on the "ENTRY" Keypad followed by “X1".

3) Press the “LOAD” soft key

4) Press the "SLIDING" soft key

5) Press the “SPECIFY OFFSET” soft key

6) Press the “OFFSET DELAY” soft key and enter "0" followed by "x1" using the "ENTRY" keypad.

7) Ignore the “OFFSET LOSS” soft key, it is not relevant as the entries are for the waveguide mode.

8) Press the “OFFSET Z0” soft key and enter "1" followed by "x1" using the "ENTRY" keypad.

9) Press the "MINIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

10) Press the "MAXIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

11) Press the "WAVEGUIDE" soft key.

12) Press the "STD OFFSET DONE" soft key.

13) Press the LABEL STD" soft key.

14) If the label shown is "SLIDING" proceed, if not enter "SLIDING".

15) Press the "TITLE DONE" soft key.

16) Press the "STD DONE" soft key.

The data for the following steps is that associated with Standard 11, a "DELAY/THRU". This is a zero delay, direct connection of two OML Millimeter Wave VNA Modules with the Test Port Adapters (the input attenuator for a "T" module) in place and no other devices inserted.

1) Press the “DEFINE STANDARD" soft key

2) Press the "11" key on the "ENTRY" Keypad followed by “X1".

3) Press the "THRU" soft key

4) Press the “SPECIFY OFFSET” soft key

5) Press the “OFFSET DELAY” soft key and enter "0" followed by "x1" using the "ENTRY" keypad.

6) Ignore the “OFFSET LOSS” soft key, it is not relevant as the entries are for the waveguide mode.

7) Press the “OFFSET Z0” soft key and enter "1" followed by "x1" using the "ENTRY" keypad.

8) Press the "MINIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

9) Press the "MAXIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

10) Press the "WAVEGUIDE" soft key.

11) Press the "STD OFFSET DONE" soft key.

12) Press the LABEL STD" soft key.

13) If the label shown is "THRU" proceed, if not enter "THRU".

14) Press the "TITLE DONE" soft key.

15) Press the "STD DONE" soft key.

The following entries, for Standards 13 through 21, are optional. These describe advanced Standards that it is possible to configure using the components of the OML Cal Kit. The user should consult the OML document "Most Common Types of Calibration Procedures" available at *http//www.omlinc.com/vna_cal.htm* or in the OML millimeter wave module user's manual. Additional information can be found in the other Keysight documents referenced at the end of this document. The question of does the application require these additional calibration delays should be considered before undertaking calibrations using these Standards.

The data for the following steps is that associated with Standard 13, a "DELAY/THRU". This is the Precision Section (known length) inserted between two OML Millimeter Wave VNA Modules with the Test Port Adapters (the input attenuator for a "T" module) in place.

1) Press the “DEFINE STANDARD" soft key

2) Press the "13" key on the "ENTRY" Keypad followed by “X1".

3) Press the "THRU" soft key

4) Press the “SPECIFY OFFSET” soft key

5) Press the “OFFSET DELAY” soft key and enter delay of the precision waveguide section (converted to nS) followed by "nS" using the "ENTRY" keypad.

6) Ignore the “OFFSET LOSS” soft key, it is not relevant as the entries are for the waveguide mode.

7) Press the “OFFSET Z0” soft key and enter "1" followed by "x1" using the "ENTRY" keypad.

8) Press the "MINIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

9) Press the "MAXIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

10) Press the "WAVEGUIDE" soft key.

11) Press the "STD OFFSET DONE" soft key.

12) Press the LABEL STD" soft key.

13) Enter "THRU W/G" using the wheel and soft keys.

14) Press the "TITLE DONE" soft key.

15) Press the "STD DONE" soft key.

The data for the following steps is that associated with Standard 14, a "DELAY/THRU". This is the 0.1000 waveguide shim inserted between two OML Millimeter Wave VNA Modules with the Test Port Adapters (the input attenuator for a "T" module) in place.

1) Press the “DEFINE STANDARD" soft key

2) Press the "14" key on the "ENTRY" Keypad followed by “X1".

3) Press the "THRU" soft key

4) Press the “SPECIFY OFFSET” soft key

5) Press the “OFFSET DELAY” soft key and enter delay of the 0.1000" waveguide shim (converted to nS) followed by "nS" using the "ENTRY" keypad.

6) Ignore the “OFFSET LOSS” soft key, it is not relevant as the entries are for the waveguide mode.

7) Press the “OFFSET Z0” soft key and enter "1" followed by "x1" using the "ENTRY" keypad.

8) Press the "MINIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

9) Press the "MAXIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

10) Press the "WAVEGUIDE" soft key.

11) Press the "STD OFFSET DONE" soft key.

12) Press the LABEL STD" soft key.

13) Enter "THRU .1" using the wheel and soft keys.

14) Press the "TITLE DONE" soft key.

15) Press the "STD DONE" soft key.

The data for the following steps is that associated with Standard 15, a "DELAY/THRU". This is the OS-xx 0.1000 + λ/4 waveguide shim inserted between two OML Millimeter Wave VNA Modules with the Test Port Adapters (the input attenuator for a "T" module) in place.

1) Press the “DEFINE STANDARD" soft key

2) Press the "15" key on the "ENTRY" Keypad followed by “X1".

3) Press the "THRU" soft key

4) Press the “SPECIFY OFFSET” soft key

5) Press the “OFFSET DELAY” soft key and enter delay of the 0.1000" + λ/4 waveguide shim (converted to nS) followed by "nS" using the "ENTRY" keypad.

6) Ignore the “OFFSET LOSS” soft key, it is not relevant as the entries are for the waveguide mode.

7) Press the “OFFSET Z0” soft key and enter "1" followed by "x1" using the "ENTRY" keypad.

8) Press the "MINIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

9) Press the "MAXIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

10) Press the "WAVEGUIDE" soft key.

11) Press the "STD OFFSET DONE" soft key.

12) Press the LABEL STD" soft key.

13) Enter "THRU.1+/4" using the wheel and soft keys.

14) Press the "TITLE DONE" soft key.

15) Press the "STD DONE" soft key.

The data for the following steps is that associated with Standard 20, a "LOAD". This is the OS-xx 0.1000" waveguide shim inserted between a T-xx Precision Term" waveguide load and the Test Port Adapter attached to an OML Millimeter Wave VNA T/R Module.

1) Press the “DEFINE STANDARD" soft key

2) Press the "20" key on the "ENTRY" Keypad followed by “X1".

3) Press the "LOAD" soft key

3a) Press the "OFFSET" soft key

4) Press the “SPECIFY OFFSET” soft key

5) Press the “OFFSET DELAY” soft key and enter delay of the 0.1000" waveguide shim (converted to nS) followed by "nS" using the "ENTRY" keypad.

6) Ignore the “OFFSET LOSS” soft key, it is not relevant as the entries are for the waveguide mode.

7) Press the “OFFSET Z0” soft key and enter "1" followed by "x1" using the "ENTRY" keypad.

8) Press the "MINIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

9) Press the "MAXIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

10) Press the "WAVEGUIDE" soft key.

11) Press the "STD OFFSET DONE" soft key.

12) Press the LABEL STD" soft key.

13) Enter "OFFS LOAD" using the wheel and soft keys.

14) Press the "TITLE DONE" soft key.

15) Press the "STD DONE" soft key.

The data for the following steps is that associated with Standard 21, a "LOAD". This is the OS1/4-xx 0.1000 + λ/4 waveguide shim inserted between a T-xx Precision Term" waveguide load and the Test Port Adapter attached to an OML Millimeter Wave VNA T/R Module.

1) Press the “DEFINE STANDARD" soft key

2) Press the "21" key on the "ENTRY" Keypad followed by “X1".

3) Press the "LOAD" soft key

3a) Press the "OFFSET" soft key

4) Press the “SPECIFY OFFSET” soft key

5) Press the “OFFSET DELAY” soft key and enter delay of the 0.1000" + λ/4 waveguide shim (converted to nS) followed by "nS" using the "ENTRY" keypad.

6) Ignore the “OFFSET LOSS” soft key, it is not relevant as the entries are for the waveguide mode.

7) Press the “OFFSET Z0” soft key and enter "1" followed by "x1" using the "ENTRY" keypad.

8) Press the "MINIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

9) Press the "MAXIMUM FREQUENCY" soft key and enter that frequency followed by "G/n" using the "ENTRY" keypad.

10) Press the "WAVEGUIDE" soft key.

11) Press the "STD OFFSET DONE" soft key.

12) Press the LABEL STD" soft key.

13) Enter "/4OFFS LD" using the wheel and soft keys.

14) Press the "TITLE DONE" soft key.

15) Press the "STD DONE" soft key.

The next step will be to enter the Calibration Standards Definitions data into the 8510. The OML procedure "XXXXX" will detail this process. The following documents will aid the user in implementing this procedure and for developing greater insight into 8510 calibration: 1) HP Product Note 8510-5B (5C coming soon), Network Analysis, "Specifying calibration standards for the HP 8510 network analyzer", 2) HP Product Note 8510-8A, Network Analysis, "Applying the HP 8510 TRL calibration for non-coaxial measurements", 3) HP Product Note 8510-12. Millimeter-Wave Measurements, "Using the HP 8510 Network Analyzer", 4) HP 11644A Series Waveguide Calibration Kits Operating and Service Manual, 5) The flow charts for the calibration procedures found in the 8510C Operating Manual.