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Hermes VNA User Guide

Introduction

This PC software, and associated FPGA code, enables a Hermes board to be used as either a Reflection or Transmission vector network analyser (VNA). VNA measurements can be made over the range 100 kHz to 60 MHz in 1 Hz steps (subject to any frequency limitations of external measurement equipment).

FPGA code

The Hermes board to be used as a VNA must be loaded with FPGA code V1.7 or higher. All previous functions of V1.6 are retained so this code version can be used for either VNA or transceiver use.

PC Code

Code is currently only available in SVN in which case the following does not apply.

[The PC code (VNA.exe) is installed on the PC using an installer which can be obtained here:

http://openhpsdr.org/download.php

in the 'Windows' section.

Installer options enable the default installation drive and directory to be changes as well as the installation of start-up and desk-top icons. Any files that are required to run the code, if not already present e.g. .NET 4.0, will be automatically installed.]

Each time VNA.exe is run and closed the current settings (e.g. Mode, Calibration file and path etc) is saved in a file 'VNA.ini'. This file is save here:

C:\Users\<User Name>\AppData\Roaming\OpenHPSDR\VNA

in order to comply with Windows Vista and Win 7 user file requirements.

Operation

IMPORTANT: The maximum Tx output level from Hermes, Tx level control set to the RHS, is approximately -10 dBm. In which case with the 20dB Attenuator in circuit on the Rx input then it is safe to connect the Tx output directly to the Rx input. If the Attenuator is not selected then the ADC may be overloaded. This will be indicated by the 'ADC Overload' indicator illuminating Red.

DO NOT OPERATE HERMES WITH THE ADC OVERLOAD INDICATOR ILLUMINATED

When used for Transmission or Reflection measurements it is recommended that a 6db attenuator be connected directly to the Tx output of Hermes. Alternative the low level output from Hermes, suitably configured, can be used as the signal source. The attenuator not only prevents possible overload of the ADC but also provides a solid 50 ohm source to the device under test (DUT) or

Reflection Bridge. With a 6dB or higher attenuator in circuit then the 20dB attenuator on Hermes does not need to be selected. Not using the 20dB attenuator is desirable since a larger measurement signal is presented to the Rx input which may increase the measurement accuracy.

If the IP address of the PC Ethernet port that the Hermes is connected to is know then enter it in 'PC IP' in xxx.xxx.xxx.xxx format (e.g. 192.168.1.4). If the IP address is not known then the software will automatically locate the appropriate address.

Before making measurements in transmission mode the VNA needs to be calibrated. Enter the 'Start' Frequency (MHz), 'End' Frequency (MHz) and number of 'Steps' to take. The maximum number of Steps is restricted to 1000. If measurement at only a single frequency is required then leave the End and Steps blank.

If Hermes is currently being used in Transceiver mode then cycle the power to the board before using it in VNA mode. Similarly, cycle the power before using Transceiver mode again.

Power on the Hermes board and click the 'ON' button. If the software locates a Hermes board then the ON button will turn green and the 'PC IP', 'Hermes IP', 'Hermes MAC' and 'Code version' will be filled in. If a Hermes can't be located then a warning will be displayed and the user will need to investigate the cause.

Transmission Mode Measurements:

To make measurements in transmission mode connect the Tx output (via a 6dB attenuator) to the Rx input via a length of coax that represents that which will be used when measuring the DUT.

In the 'Mode' group select 'Transmission' if not already selected.

Enter the 'Start', 'End' and Steps in the 'Calibrate' Group box. Frequencies should be entered in MHz with a 1 Hz resolution e.g. 14.159001 equates to 14.159001 MHz.

NOTE: each frequency Step takes approximately 40 mS, in which case 100 steps will take 4 seconds, 1000 steps 40 seconds etc.

Click 'Calibrate' and the software will collect data that will be used to calibrate the VNA when the DUT is being measured. The progress of the calibration process will be indicated on the progress bar.

At the end of the calibration process you will be prompted to save the Calibration file. If you intend to make the same, or similar, measurements in the future then it will save time if a suitable calibration file is available. Click 'OK' to save the file and 'Cancel' to ignore.

When saving a calibration file it is useful to save the Start, End and Steps, and the fact it is a transmission file, in the file name e.g. 1-10-100-trans.csv. Note that Transmission and Reflection files are not interchangeable.

If you would like to use this same Calibration file the next time the software is run then select the 'Auto Load Calibration' check box. This will automatically load the last used Calibration file when the software is first started.

NOTE: the default directory for Calibration files is :

C:\Users\<user name>\My Documents\openHPDSR\VNA

Replace the direct connection between the Tx output and Rx input with the DUT and then click 'Measure'. The progress of the measurement will be displayed on the progress bar.

Once the Measurement is completed a graph will displayed. The left vertical axis displays the Gain (in dB's) of the DUT and the right vertical axis the Phase (degrees). The horizontal axis will contain the Start and End frequencies.

The horizontal axis can be changed to a log scale by checking the 'Log x Axis' box. The vertical axis can be auto ranged by checking the 'Auto Range' box. The points on the graph can be displayed in Line, Dot or Spline format by selecting the appropriate button.

If a Transmission Calibration has already been made then previously saved calibration files can be selected using the File > Load Calibration File menu item at the top left of the screen.

Similarly, the current calibration data can be saved at any time using the File > Save Calibration File menu.

The current setting of the '20dB Attenuator' is saved in the Calibration file and set to the saved value when the file is loaded.

Reflection Mode Measurements:

To make measurements in reflection mode connect the Tx output (via a 6dB attenuator) and Rx input to a Reflection Bridge. See Appendix A for information regarding constructing a suitable Reflection Bridge.

In the 'Mode' group select 'Reflection Smith' if not already selected.

Insert the 'Start', 'End' and number of 'Steps' required. See the Transmission Mode Measurements section regarding these settings.

Click 'Calibrate' and the software will collect data that will be used to calibrate the VNA. Calibration in Reflection mode is done using three different loads individually connected to the measurement port on the Reflection Bridge (or at the end of a length of coax cable if the load to be measured is remote from the Bridge). The loads are 'Open', 'Short' and 'Load'. The first two are self explanatory whilst the 'Load' is a resistance corresponding to the Impedance at which the VNA is to be operated - typically 50 ohms. The quality, and accuracy, of these three loads will directly affect the accuracy of the measurements.

Once 'Calibrate' has been clicked the software will prompt you to connect the relevant load and then take the necessary measurements. The procedure for saving and restoring Reflection Calibration data is the same as that for Transmission - please refer to that section for additional information.

Connect the load to be measured to the measurement port on the Reflection Bridge and then click 'Measure'. The progress of the measurement will be displayed on the progress bar.

Once the measurement is completed a Smith Chart will be displayed that shows the variation of measured impedance with frequency. The Smith Chart is normalised to the Load value used to calibrate the VNA - typically 50 ohms.

If the measurement was done at a single frequency then the Impedance in R +/-jX format will be displayed on the Chart. Note this is the actual rather than the normalised Impedance.

The Impedance at the final frequency step (or measurement frequency if no steps) along with other derived values will be displayed in the 'Results' area of the display.

A graphical display of various measured and derived values can be displayed by selecting the 'Reflection Chart' button. It is not necessary to re-measure in order to display this data and you can switch between Graph and Smith Chart as desired.

The Graph will initially display the SWR of the load Impedance over the frequency range. Drop down menus are provided at the top of the graph such that other measured and derived results can be displayed independently on the left and right Y axis.

The horizontal axis will contain the Start and End frequencies. The 'Display' controls operate in the same manner as described in the Transmission section.

Saving Results for External Evaluation

The results of a *Reflection* measurement can be saved to a file and exported for further analysis in an external program. Presently the VNA software saves files in Zplot format (see http://ac6la.com/zplots.html). Once a Reflection measurement has been made select the 'File' menu at the top left of the screen and select 'Save Zplot File'.

Saving and Retrieving Measurements

Measurements can be saved and retrieved using the 'File' menu at the top left of the screen. Select 'Load Measure File' to load a previous saved file and 'Save Measure File' to save current results.

Once loaded, a saved file will display in the mode that was used to take the measurements e.g. Transmission or Reflection. If the latter then the data can be displayed using either the Smith Chart or Graph.

A Measurement file can be loaded without a Hermes being connected or the 'ON' button being selected.

The path and name of the Calibration file in use when the Measurement file was saved is attempted to be opened when reading the Measurement file. If the file exists the user will be prompted to open it. In which case the VNA software can be run and additional measurements made.

If the associated calibration file cannot be found then a warning message will be displayed.

Note that should a Measurement file be received from another user, or using different hardware, then the associated Calibration file will most likely not be usable. In which case click the 'Calibration' button to generate a new Calibration file based on the Start, End and Steps read from the Measurement file.

General Information

Measurements taken during development indicate that using Hermes as a VNA can result in very accurate and repeatable results. Like any other VNA the accuracy and quality of the Open, Short and Load devices is critical in order to ensure accurate and repeatable results. Since measurements to less than 0.1 ohm are possible the use of high quality connectors and leads etc is recommended. The contact resistance of a worn BNC plug and socket is very evident when taking measurements.

Preliminary test results indicate accuracy in the order of 0.5% and in many cases 0.1%.

Measured values do change as the Hermes board heats up once initially powered. For the most accurate results it is recommended that the board be powered for 15 minutes before taking measurements.

Immediately after running a Calibration it is informative to do a measurement and display the results of the direct connection or load. Typically the Transmission display will be very close to 0dB and 0 degrees and the Reflection display very close to the Load resistance used.

Appendix A

If a suitable Bridge is not available, and the user wishes to construct one, then these designs are recommended:

http://www.wetterlin.org/sam/Reflection/3BeadBalunBridge.pdf

http://hiqsdr.finken-net.de/html/rf-cir.htm

Sam's web site at:

http://www.wetterlin.org/sam/

contains a wealth of useful information relating to VNAs.