VNA4win

User Guide

GM4PMK and GM3SEK

CONTENTS

LEGAL NOTICE

1 INTRODUCTION

Welcome to *VNA4win*, a *Windows* user interface for the N2PK Vector Network Analyser (VNA): www.n2pk.com

VNA4win's 'front panel' emulates a typical hardware VNA, but with extra features that are impossible in hardware.

1.1 Getting Started

Please follow these simple steps:

1. Print this manual, and keep it handy. The dual-standard page layout will print on either International A4 paper or US 8.5x11in.
2. Install *VNA4win* as detailed in Section 2.
3. Next, please take the quick tour in Section 3.
4. Then you'll be ready to explore *VNA4win* in more detail.

1.2 What's New in *VNA4win* v1.3

- Full support for the LTC2440 fast ADC
- Full support for USB interface
- Simplified frequency entry
- Single-frequency mode
- Two pairs of trace markers, with difference (delta) facility
- Centre a new sweep around any marker
- Various minor improvements
- Fixes for problems that you never noticed.

New in *VNAVNA4win* v1.3c:

- Improved manual and auto-scaling
- Support for Correlated Double Sampling (CDS)

CAUTION ***Calibration files from earlier versions will not work with v1.3c !***
From VNA4win v1.3b onwards, the format of calibration files has changed to include the CDS status (see Section 6.4.5).

1.3 Questions?

Most of your questions are answered in this manual… so please read it first.

1.4 Bug Reports

We really would like to hear about any remaining bugs. Please e-mail us at either gm4pmk@marsport.org.uk or gm3sek@ifwtech.co.uk

2 INSTALLATION

1. Unzip the *VNA4win* distribution file into a directory of your choice. If you already have *VNA4win* v1.2b, you can unzip this new version into the same directory.

CAUTION *If you are an existing user, you should configure an entirely new version of* vna.ini *for this new version (Section 4). Rename your existing* vna.ini *file* **before** *unzipping the new distribution file, and let the installer create a new file. Then you can then copy-and-paste your custom settings into the new file. When you run the installer, it will warn you about overwriting existing files.*

If you are using a USB interface, the drivers for this must be installed **before** *proceeding to step 2. You must also edit the* vna.ini *file to include the line* `usb = yes` *(see Section 4).*

If you are using a parallel port interface, the equivalent line in the vna.ini *file must be* `usb = no` (see Section 4)*. You may also need to set the parallel port mode to* `ECP` *in the PC BIOS.*

2. Plug a working N2PK VNA, and power-up.

CAUTION *VNA4win supports only the original N2PK VNA hardware, the LTC2440 fast ADC modification and the USB interface.*

We will not support any hardware variations that we have not personally tested. VNA4win does not support a second detector.

You are now ready to start *VNA4win* – turn to the next page.

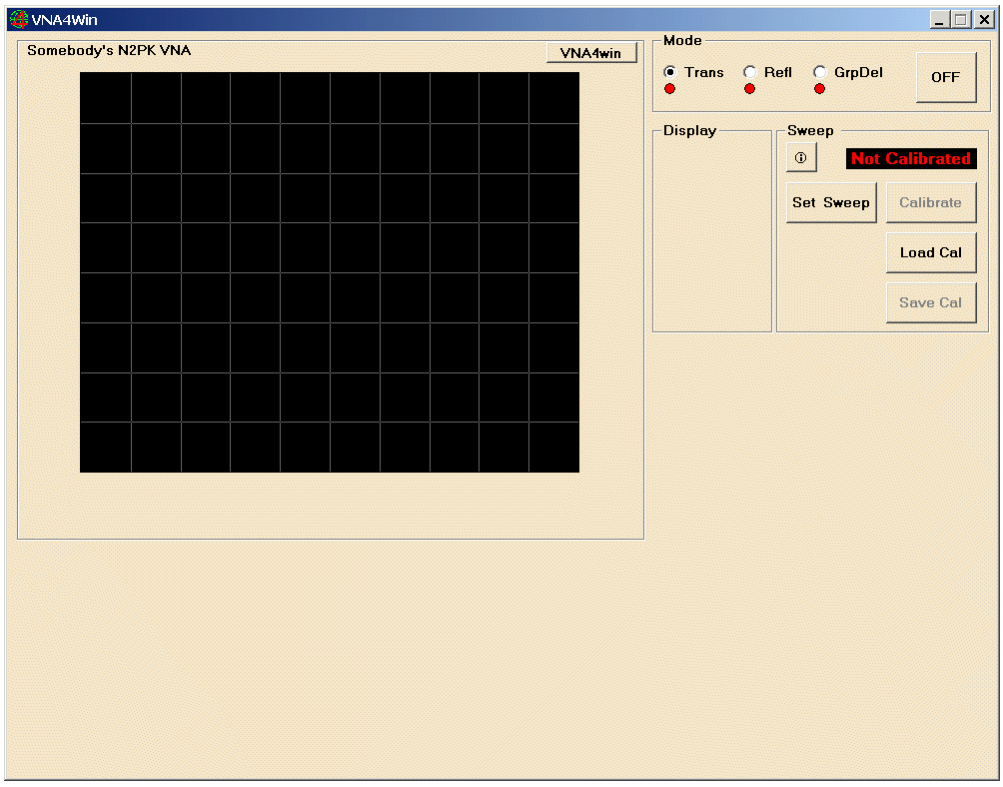
3 THE QUICK TOUR: TRANSMISSION AND REFLECTION

To become familiar with *VNA4win*, please follow through all the numbered steps in this Section of the manual.

3.1 Starting VNA4win

1. Run **VNA4win.exe** You should see the startup screen (some versions of *Windows* support an error message if the program cannot detect the VNA).

   VNA4win runs in a fixed 800x600 window. This is also the required minimum display resolution, and will completely fill the screen on an old 800x600 monitor.[1]



   This startup screen contains very few controls because the VNA is not yet ready for use – it needs to be calibrated.

   Unlike a hardware VNA, *VNA4win* only displays the controls that you can use. At the moment, these are the **Mode**, **Set Sweep** and **Load Cal** buttons (and of course, **OFF**).

[1] To maximise the program's screen area with an 800 x 600 monitor, set the *Windows* Taskbar to **Auto-hide**.

2. At startup, a warning message says **Not Calibrated** in red. Whenever you see this message, no valid measurements are possible.

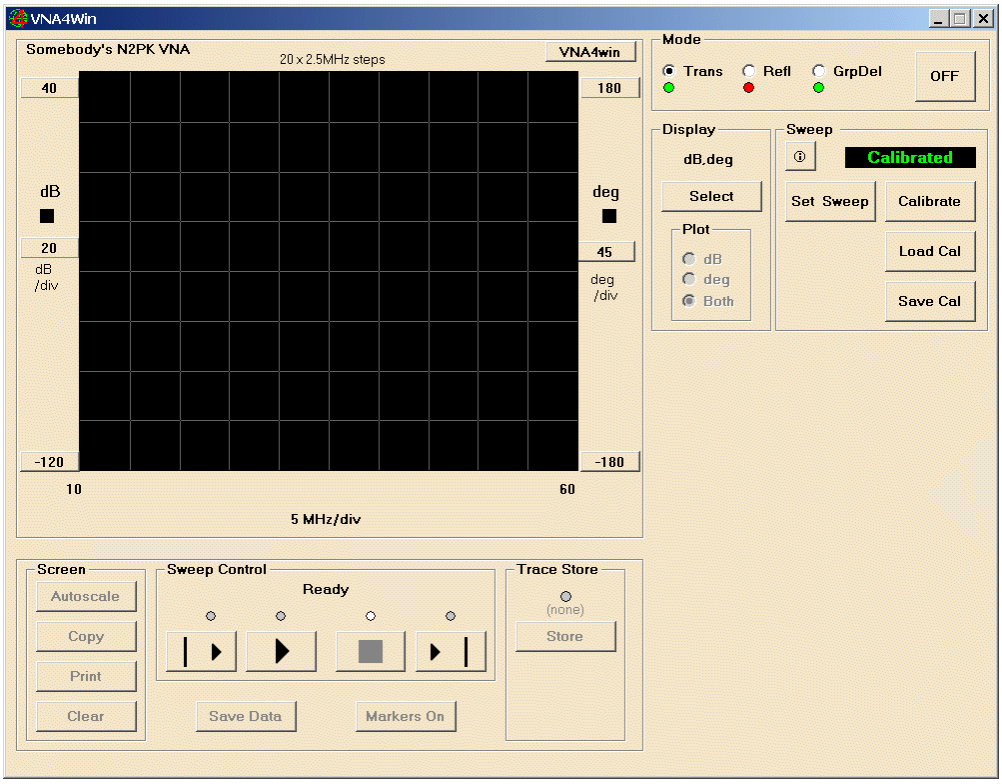
   Before the N2PK VNA can make any measurements, it needs two essential things:

   - A **frequency sweep** setting to specify the range of measurement
   - A **calibration** dataset that is valid for
     - the measurement hardware you will be using
     - the type of measurement you wish to make
     - the specified frequency sweep range.

3. You could enter a frequency sweep manually, and then go through a calibration procedure. But *VNA4win* has an easier option: you can load a frequency sweep and calibration data from a file.

   Click **Load Cal File**, and then double-click on **demo1.cal** in the file dialog.

   Now the screen is much more interesting!



4. The calibration file contains both frequency sweep data and some calibration data, so the calibration status message now says **Calibrated** in green. Several new features also appear on-screen (we'll get to those in a moment).

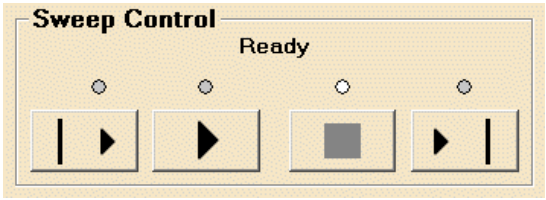
5. Also notice the small LEDs below the three **Mode** buttons for **Transmission**, **Reflection** and **Group Delay**. These show which measurement modes the present calibration is valid for.

At startup, the default **Mode** setting is **Trans** (transmission) and the calibration loaded from *demo1.cal* is valid for that mode. That is why the **Calibration** LED turned green.

6. Click the button to change the mode to **Reflection** (which has a small red LED below it) and note that the calibration status message has changed back to **Not Calibrated** in red. This tells you that the calibration data in *demo1.cal* are not valid for reflection measurements.
7. Before you continue, be sure to change the **Mode** back to **Trans**, so the calibration status message once again says **Calibrated** in green.

3.2 Transmission Measurement

8. Because it is now OK to make measurements, *VNA4win* enables the VCR-style buttons on the **Sweep Control** dialog. When you see these controls, it is OK to make a measurement.



9. Connect any 2-port transmission device to the VNA, and click the ▶| button to start a continuous sweep. You will see amplitude and phase plotted on the 10div x 8div screen.

CAUTION *This example sweep will not be accurate, because the demo1.cal file contains only generic calibration data.* **For a real measurement, you must ALWAYS use calibration data from your individual VNA and hardware setup.**

10. Experiment with the VCR buttons to control the sweep. The small white LEDs show which button you last clicked, and the status caption at top centre shows what is now happening.

|▶	Start a new sweep (after the first sweep is complete, the status changes automatically to **Continuous**).
▶	Continuous sweep. Starts or resumes the current sweep.
■	Pause/stop sweep.
▶|	Stop at end of sweep.

A moving green bar at the bottom of the graphics display will indicate the progress of the sweep.

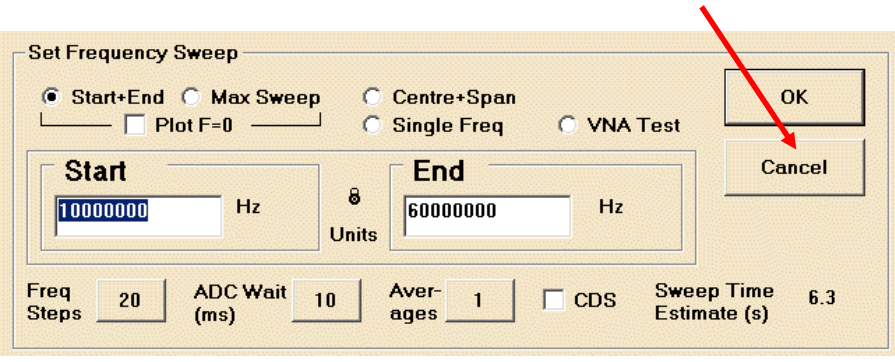
11. You can click the ▶| button at any time during a sweep. The VNA will complete the present sweep, and then stop. Stop ■ will stop the sweep at any time – click one of the other buttons to resume.
12. When you look at the results plotted by *VNA4win*, always remember what you are **really** seeing:
    - *VNA4win* makes measurements at a series of frequency **point**s. The display joins up the plotted frequency points with lines, but remember that these lines are only a visual aid – measurements only exist at the **points**.

- You may see near-vertical jumps on the display where the measured phase appears to switch between –180° and +180°. This is only because the phase display 'wraps around' at ±180°; in reality the phase change is usually quite small (e.g. from 179° to 181°).
- If a trace overwrites itself (which can happen with some types of measurements), it will disappear to black.

3.3 Explore Further

13. With the sweep stopped, several function buttons are enabled. These are described in later Sections:
    - **Autoscale** (Section 11.1) controls the scaling of the display axes
    - Each y-axis has three scale buttons (maximum, minimum and /div) which display the current scale settings. You can also click these buttons to change the scale settings manually (Section 11.2)
    - **Copy** (Section 11.3) copies the 10x8 display to the Windows Clipboard
    - **Print** (Section 11.4) prints the 10x8 display with full details
    - **Clear** (Section 11.5) clears the display
    - **Save Data** (Section 11.6) saves the data to a file that can be read by most spreadsheet programs
    - **Markers** (Section 12) displays frequency markers on the traces, and gives a readout of the data
    - **Trace Store** (Section 13) saves the current trace(s) for future comparison.
14. While the sweep is stopped, you can click **Display** to bring up a list of different display options for the data. The sweep must be repeated to display the results in a different way.
15. While the sweep is stopped, click **Set Sweep**. The **Sweep Control** dialog is replaced by the **Set Frequency Sweep** dialog.

CAUTION *For this quick tour, you should* **only look** *at the features in the* ***Setup Frequency Sweep*** *dialog. Do not click any controls except* **Cancel***!*



The **Set Frequency Sweep** dialog is explained in more detail in Section 6. The features to note during this quick tour are:

- Different modes of sweep – currently we are in **Start+End** mode, but **Centre+Span**, **Max Sweep**, **Single Freq** and **VNA Test** modes are also available
- The two frequency entry fields to specify the sweep range
- Three buttons along the bottom can be used to select:
  - number of **Frequency Steps** in the sweep across the screen
  - **ADC Wait** time after each measurement
  - number of **Averages** at each measurement
- The **CDS** check box can be used to select Correlated Double Sampling, if applicable (more details later)
- At the bottom right, an automatic **Sweep Time Estimate** will respond to your selections on the previous three buttons
- The **OK** button (more details later)
- The **Cancel** button – click this now, and you'll be returned to the **Sweep Control** dialog.

CAUTION *If you accidentally changed something in the* **Set Frequency Sweep** *dialog, you may see the* **Not Calibrated** *warning message, and the* **Sweep Control** *dialog will not open. If this has happened, go back to Step 3 and reload the* **demo.cal** *file, and then you can rejoin the tour from here.*

3.4 Reflection Measurement

The next demonstration is of **Reflection** mode.

16. Connect a reflection bridge and test object to your VNA.
17. Click the **Refl** button on the **Mode** panel. Because the VNA presently has no calibration for this mode, you will see the **Not Calibrated** warning message.
18. Use the **Load Cal** button as detailed in Step 3 to load the cal file **demo2.cal**. The calibration status message now says **Calibrated** in green once again**,** because *demo2.cal* contains valid calibration data for this mode.
19. The sweep facilities available - including scaling, single sweep, save data, trace memory and markers – are the same as for **Transmission** mode.
20. Note that the display initially plots magnitude and phase – the **Display** panel is showing **|Z|, deg**. Clicking the **Display** button will bring up a list of other display options, including a Smith chart. Selecting a different display option will stop the sweep, disable the markers and clear the screen.

3.5 Closedown

21. Click the **VNA4win** button at the top right of the 10x8 display. This shows the current version information and the copyright message. Also, please read the **LEGAL NOTICE** on page iii.
22. To complete the quick tour, click the **OFF** button at the top right. This closes *VNA4win*.

3.6 Read Again

As you begin to use your N2PK VNA, from time to time you will find it useful to read N2PK's documentation again – especially Part 1.

As you become more familiar with *VNA4win*, also please read this manual again.

As you gain more experience, the significance of things you had read before will become *much* clearer!

4 CONFIGURE VNA.INI

Use a text editor to customise the **vna.ini** file. This file has some items in common with N2PK's original **vna.cfg** file, plus other enhancements that are specific to *VNA4win*.

1. Enter your name or callsign in the **`owner =`** field – see below. This will customise the name at the top left of the display. A maximum of 10 characters is allowed.
2. Edit the **`clk =`** field to show the exact frequency of your clock oscillator.
3. If you are using the USB interface, change the **`usb =`** setting to **`usb = yes`**.

   If you are using the parallel port interface, leave that setting as **`usb = no`**. You may also need to set the parallel port mode to `ECP` in the PC's BIOS.
4. Edit the **`graticule =`** field if you wish. This changes the colour of the display graticule, as the standard setting may not be suitable for all types of CRT and LCD display.
5. For other parameters such as the exact resistance of your 50Ω standard load, and the minor parasitic reactances, follow the instructions in N2PK's documentation.

CAUTION *VNA4win will start up without **vna.in**i, because the program incorporates a sensible set of built-in default values… but they won't be **your** values!*

For the most accurate measurements, you must enter the correct data for your specific N2PK VNA, and for the measurement standards that you are currently using.

Here is an example file:

```
' vna.ini
' Setup for VNA4Win software for N2PK VNA

[general information]
'
' Comment markers in this file can be ' # or (
' They can appear anywhere along a line, and the rest
' of that line will be ignored.
' Blank lines are also ignored.
'
' Entries must be of the form:
' variablename=value  'optional comment
'                    ^
' There MUST be at least one space after the variable value,
' and before the (optional) comment marker.
' Spaces before or after the = are also allowed.
'
' Variable names are important - don't change them.
' Errors in variable names will be interpreted as missing data.
'
' Entries can be in any name order.
' For convenience, the ini file is classified into logical Sections,
' each headed by a [Section name] in square brackets.
' [Section name] lines are ignored when reading the file.
'
' WARNING - do not edit this file unnecessarily.
'
' If any entry (or the whole vna.ini file) is missing or
' unreadable, the program will use inbuilt defaults as required.
' Duplicate lines or entries other than those shown will be ignored
'
```

```
[general]
owner = Somebody ' Callsign or name - up to 10 characters, no spaces
                 ' Longer names will be truncated

port = &H378     ' Printer port base address in hex (&H) or decimal
                 ' &H378 = 888 = LPT1
usb = no         ' No if using printer parallel port, yes for usb
clk = 148.33978  ' Actual master oscillator frequency in MHz

graticule = 2    ' Graticule colour: 0 = off (black)
                 ' 1, 2, 3 dark, mid, light grey
                 ' 4 = white

Z0 = 50          ' Ohms, system impedance, normally 50 ohms

npoints = 21     ' Number of sweep points default (steps+1)

[ADC items]

ADCtype = 2440   ' ADC type either 2410 or 2440 ONLY
ADCmode = 0      ' Startup mode for LTC2440: 0-9 or 15. Leave at 0 for LTC2410
ADCavg = 1       ' Default number of readings averaged per point
ADCdel = 10      ' Default ADC settling time in ms

[standards]
[open]
Cop=0.119        ' Fringing C of the Open-circuit standard (pF)
                 ' (0.119 pF for N connector)
[short]
Lsh=0.0          ' Series inductance of the Short-circuit standard (nH)
rsh=0.0          ' Series resistance of the Short-circuit standard (ohms)

[loadstd]
Rld=50.000       ' Series resistance of the Load standard (ohms)
Lld=0.0          ' Series inductance of the Load standard (nH)
Cld=0.00         ' Shunt capacitance of the Load standard
                 ' beyond the reference plane (pF)


# end of vna.ini
```

5 MODE SELECTION

The **Mode** controls are at the top left, alongside the **OFF** button which closes the program.

Mode is the top-level control setting. When you change **Mode**, many other controls and displays will change too.

CAUTION *Whenever you change **Mode**, you **MUST** also:*

1. ***Install or remove the accessory Reflection Bridge, as needed for the new Mode.***
2. ***Recalibrate the VNA** – VNA4win will not allow you to make measurements without a valid calibration for the selected **Mode**, but it cannot check that you are using the correct hardware configuration!*

5.1 Transmission Mode

This is the basic mode of the VNA hardware. **Transmission** Mode measurements are always made on two-port devices, and they measure the gain/loss and the phase shift between the VNA's **RF OUT** and **DETECTOR** ports. See N2PK's hardware documentation for details.

5.2 Reflection Mode

Reflection Mode measures impedance, and related quantities such as return loss and SWR. Reflection measurements are always for a single-port device; they require a bridge accessory connected to the VNA's **RF OUT** and **DETECTOR** ports. See N2PK's hardware documentation for details.

5.3 Group Delay Mode

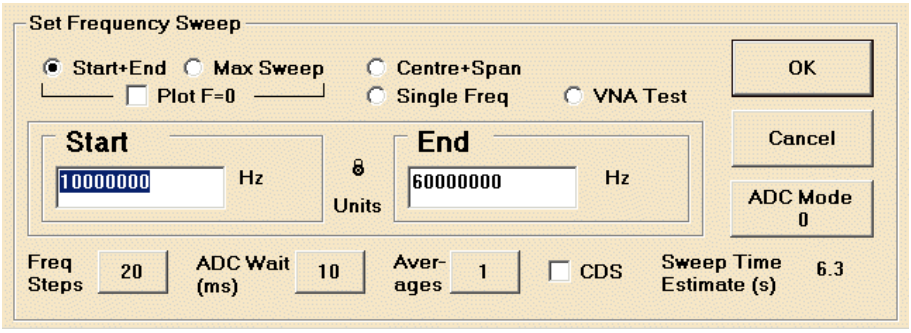
Group Delay Mode is a specialised version of **Transmission** Mode. See Section 14 for more details.

6 SETTING A FREQUENCY SWEEP

This Section describes in more detail how to use the **Set Frequency Sweep** dialog.

To open this dialog, start *VNA4win* and click **Set Sweep**.

The dialog opens with the existing sweep setup already displayed. Default values are loaded at startup, or by loading a calibration file (which includes the related sweep setup).



Note: The **ADC Mode** button will only be visible if you have specified **`ADCtype = 2440`** in *vna.ini* (Section 4).

6.1 Types of Sweep

Radio buttons allow you to choose the type of frequency sweep. The labels on the two frequency entry fields change according to your selection.

- **Start+End** is the default.
- **Centre+Span** is useful for sweeps on either side of a specific frequency. For example, you can reduce the **Span** setting to zoom in on details.
- **Max Sweep** is a **Start+End** sweep that automatically selects the maximum frequency range of the N2PK VNA, 50kHz to 60MHz.
- **Single Freq** selects measurements using the single-frequency display (see Section 8.2).
- **VNA Test** gives direct control of the DDS frequency and phase, and displays the resulting ADC output voltage. See Section 15 and N2PK's hardware documentation for details.

When you change between a **Start+End** sweep and a **Centre+Span** sweep, in either direction, the frequency settings are automatically translated to give the same frequency coverage.

The **Plot F=0** check box makes the frequency axis of a **Start + End** sweep display begin at zero, which often makes the display easier to interpret. See Section 8.1 for an example.

6.2 Frequency Entry Fields

Swept frequency measurements are configured using two frequency entry fields. According to the type of sweep selected above, these are labelled either **Start** and **End**, or **Centre** and **Span**. When **Single Freq** is selected, there is only one frequency entry field.

Simply type a frequency into the appropriate field, and then press **Tab**.

You can use a wide range of number formats, including '1e6' format. You can also use your customary decimal-point character.

The default units of frequency are **Hz**, but you can change these units at any time by adding **MHz** or **kHz** to the number you have typed; or **Hz** to restore the original units. (Units are not case-sensitive, and may also be entered as their first letter, **m**, **k** or **h**.)

The **Units** icon controls what happens to the units in the other frequency entry field when you change units. By default the two fields are 'locked' together – if you change units in either field, the other field will change too. To allow units to be changed independently in the two fields, click the icon and the symbol changes to (unlocked). To return to locked units, click the icon again.

6.3 OK and Cancel Buttons

The **OK** button in the **Setup Frequency Sweep** dialog makes several consistency checks before allowing you to exit the dialog and save your changes. If you see an error message, correct the error and click **OK** again. (Sometimes you have to click **OK** more than once to complete the consistency checks.)

The **Cancel** button allows you to exit the **Setup Frequency Sweep** dialog at any time, but no changes are saved.

6.4 Steps, ADC Wait, Averages and CDS

These controls are along the bottom of the **Setup Frequency Sweep** dialog. If you need to make any changes, do so before clicking **OK**.

6.4.1 Button operation

The labels on the **Steps**, **ADC Wait** and **Averages** buttons show the current settings. When you click any button, a drop-down list of alternative settings appears. You can also type in a value.

When you have selected or typed a value, click **OK** or click on any other control. This closes the drop-down list and redisplays the button, which now shows the updated value.

6.4.2 Number of frequency steps

Options are **10**, **20**, **50**, **100**, **200** and **400**. These values fit nicely onto the 10-division display grid, and also fit well with one another (see Section 7.4).

Note: The **Plot F=0** option can often make frequency sweeps easier to interpret (Section 6.1).

The actual number of measurement points is 1 more than the number of steps. The maximum of 400 steps represents about 1 pixel per frequency step in the display area.

6.4.3 ADC wait time

The output voltage of the detector is smoothed by RC lowpass filters before being presented to the ADC – see N2PK's documentation for details. As each measurement will produce a different voltage, **ADC Wait** is a delay time to allow the capacitors to charge or discharge accurately to their new voltage before starting the ADC conversion. The optimum **ADC wait** time is normally based on a worst-case jump in detector output voltages between successive amplitude and phase measurements.

Options for **ADC Wait** (in ms) are **0**, **1**, **2**, **5**, **10**, **20**, **50**, **100** and **200**. (The default value is selected using `ADCdel` in *vna.ini*. You can also type in a value manually.)

6.4.4 Number of averages

The **Averages** control sets the number of successive voltage measurements that will be averaged before further output processing. More averaging will increase the accuracy of calibration measurements, and will reduce display jitter in measurements where the signal/noise ratio is poor. The time for each measurement will be proportional to the number of averages selection.

Averages is also a useful way to control the refresh rate for continuous single-frequency measurements (Section 10.2).

Options for **Averages** are **1**, **2**, **4**, **5**, **10** and **16**. (The default value is selected using `ADCavg` in *vna.ini*. You can also type in a value manually.)

6.4.5 Correlated Double Sampling (CDS)

As you already know[2], the N2PK VNA makes two measurements at each frequency point, first with the DDS phase set to 0° and then with the phase set to 90°. The **CDS** check-box enables Correlated Double Sampling, an advanced measurement method that compensates for detector offset voltages by making four measurements at each frequency, with the DDS phase successively set to 0°, 180°, 90° and 270°.

Effects of drift, RF leakage and offsets can be mostly cancelled by subtracting the ADC output voltages for 0° and 180°, and likewise subtracting the 90° and 270° readings. Instead of simple measurements of V_0 and V_{90}, CDS uses:

$$V_0' = (V_0 - V_{180})/2 \quad \text{and} \quad V_{90}' = (V_{90} - V_{270})/2$$

CDS can extend the VNA's dynamic range downward by at least 20-30dB, but it is only needed for measurements of the highest accuracy, or where the through or return loss is very high, which means that the signal level at the Detector is very low. Since four measurements per frequency point are being made, instead of the normal two, the sweep time is approximately doubled.

The CDS selection that you make here will also be used for single-frequency measurements (Section 8.2).

CAUTION ***The same calibration cannot be used for both CDS and non-CDS measurements.***
Whenever you use the **CDS** *check-box, a message will warn that the existing calibration will no longer be valid.*

Calibration files from earlier versions will not work with v1.3c!
From VNA4win v1.3b onwards, the CDS status is saved in each calibration file, and is updated automatically when that file is re-loaded.

Also note that when CDS is enabled, the Transmission calibration procedure (Section 7.1) does not require an open-circuit frequency sweep.

---

[2] If you didn't already know this, please re-read N2PK's documentation.

6.5 Sweep Time Estimate

The **Steps**, **ADC Wait**, **Averages** and **CDS** controls will all affect the sweep time. At the bottom right, the **Sweep Time Estimate** will respond automatically to your selections.

6.6 ADC Mode Selection

This Section only applies if your VNA uses the LTC2440 ADC, often called the *fast detector*.

The conversion rate of the LTC2440 ADC can be set via the **ADC Mode** button. Whenever this button is visible, all sweep rates and sweep time estimates will depend on the mode selection. (The **ADC Mode** button will only be visible if *VNA4win* has been started from a *vna.ini* file that specifies `ADCtype=2440` – see Section 4.)

Available modes are 0 to 9 and 15 (as defined in the LTC2440 data sheet) and are shown in the table below. The conversion rate affects the available resolution, because of conversion noise. There is a trade-off between speed of conversion – and hence sweep rate – and accuracy. Mode 0 is the default mode which maintains compatibility with the slower 2410 ADC, and is in fact the same as mode 3. Mode 15 offers the highest resolution and also 50/60Hz rejection, but with the penalty of less than 7 conversions per second.

ADC Mode	Conversion Rate	Time per conversion	RMS Noise
0	880Hz	1.13ms	2.0µV
1	3.52kHz	0.28ms	23µV
2	1.76kHz	0.57ms	3.5µV
3	880Hz	1.13ms	2.0µV
4	440Hz	2.27ms	1.4µV
5	220Hz	4.54ms	1.0µV
6	110Hz	9.10ms	750nV
7	55Hz	18.2ms	510nV
8	27.5Hz	36.4ms	375nV
9	13.75Hz	72.7ms	250nV
15	6.875Hz	145ms	200nV

7 CALIBRATION – FILES AND INTERPOLATION

VNA4win has the very useful facility to save and load calibration files. This means you do not have to repeat the whole calibration procedure for routine measurements where you only need moderate accuracy. You only need to recalibrate when you need the highest accuracy.

7.1 Manual Calibration

1. Select **Mode** for the type of measurement you wish to calibrate.
2. Click **Set Sweep** to open the **Setup Frequency Sweep** dialog, and enter up a frequency range, number of steps etc. (see Section 6).
3. Exit the dialog by clicking **OK** (possibly more than once).
4. Click **Calibrate** and follow the on-screen instructions. Until the calibration is complete, the status message will say **Calibrating** in white.
5. When calibration has been completed, several things happen:
   - The calibration status message now says **Calibrated** in green. The small LED below your selected **Mode** also turns green, meaning that you now have a valid calibration for this mode.
   - The **Sweep Control** panel appears below the screen – because you have a valid calibration, measurements are now allowed.
   - The **Save Cal File** button is enabled, so can now save this frequency sweep and calibration data to a file (if you wish).

7.2 Save Calibration File

A *VNA4win* calibration file contains the entire sweep setup that you were using at the time of calibration, plus the frequency-stepped calibration results that will be used to correct your future measurements.

Transmission and **Group Delay** modes share the same calibration (because group delay is a special kind of transmission measurement), so a calibration made with **Mode** set to either **Transmission** or **Group Delay** will be valid for both modes. **Reflection** mode always requires its own separate calibration.

A single calibration file can save the data for all three modes, provided that the sweep setup remains the same. If you wish, you can repeat the manual calibration procedure (Section 7.1 above) for a different **Mode** setting before saving all the data in a single calibration file.

To save a calibration file:

1. Click **Save Cal File** (only enabled when at least one valid calibration exists).
2. Use the *Windows* file dialog to save the calibration data as a file (the **.cal** extension will be added automatically if you don't include it).

7.3 Load Calibration File

1. Click **Load Cal File**.
2. Use the *Windows* file dialog to choose the calibration data file.
3. When you click **OK** to load the file, *VNA4win* checks which mode(s) the calibration data is valid for. A small LED beneath each **Mode** button shows either green (valid calibration for this mode) or red (no calibration for this mode). The small LED below your selected **Mode** also turns green, meaning that you now have a valid calibration for this mode
4. If the currently selected **Mode** has a valid calibration, the calibration status message will say **Calibrated** in green. You can now make measurements, and the **Sweep Control** panel appears below the display.

   If the currently selected **Mode** does not have a valid calibration, the calibration status message will say **Not Calibrated** in red. No measurements will be allowed.

CAUTION *There is no guarantee that a stored calibration will still be valid when you re-load it later. It is* **your** *responsibility to make sure that exactly the same conditions still apply, in the entire measurement setup.*

Accuracy will also be affected by thermal drift in the VNA circuits. For the greatest possible accuracy, the VNA must be in the same state of warmup as it was when the calibration was made… which is never completely possible.

Therefore stored calibrations are only ever a shortcut – but a very useful one where speed is more important than ultimate accuracy.

For any critical measurement, there is no substitute for allowing the VNA to warm up thoroughly, and then making a calibration immediately before the meassurement.

CAUTION Calibration files from earlier versions will not work with v1.3c!
From VNA4win v1.3b onwards, the format of calibration files has changed to include the CDS status (see Section 6.4.5). This should not be a problem, because you should not make a habit of using old calibration files.

7.4 Interpolated Calibrations

As another useful shortcut for faster measurements, you can change the frequency sweep settings within the calibrated range. This allows you to:

- 'Zoom' into an existing sweep, to examine an area of special interest; and/or
- Increase the number of steps to give better measurement resolution.

This facility is called **interpolated calibratio**n. *VNA4win* creates a temporary 'working' calibration for the new sweep, based on the original calibration data. The ⓘ panel (Section 7.5 below) will summarise what is happening.

Whenever you are using interpolated calibration, the calibration status message will say **Interpolated** in yellow. But take care…

CAUTION *When you are using interpolated calibration, true calibration only exists at the original calibration frequencies.*

Only* you *can determine if an interpolated calibration will be sufficiently accurate for* your *particular measurements.

Interpolated calibration relies on the assumption that measurement hardware has no significant frequency/phase variations between the frequency points of the original calibration. With the current VNA hardware, interpolated calibration is unlikely to be useful for accurate measurements above 50MHz.

7.4.1 Frequency Sweep

To change the frequency sweep within the calibrated range, click **Set Sweep** and change the settings as described in Section 6.

You can change the frequency sweep (using **Start+End** or **Centre+Spa**n), the number of steps, or both.

Any time that you are not using the exact frequency sweep for which the calibration was made, the calibration status message will say **Interpolated**.

CAUTION *You can only use interpolated calibration **inside** the existing calibrated frequency range.*

If you try to extend the frequency sweep outside of the calibrated range, the calibration status message will change to **Not Calibrated** *when you exit from the **Frequency Sweep** dialog. Measurements will not be allowed. Go back into the **Frequency Sweep** dialog and correct the error.*

You can click the ⓘ button (Section 7.4.3) to see a summary of the new situation; or if the ⓘ panel, is already visible, it will automatically be updated. The **Present Setup** column will now be different from the **Calibration** column.

7.4.2 ADC Wait and Averages

You can also go into the **Frequency Sweep** dialog to change the **ADC Wait** time and the number of **Averages** at any time. If the ⓘ panel is displayed (Section 7.5 below), this will update the **Present Setup** column.

Changes to **ADC Wait** and/or **Averages** will not create an interpolated sweep (unless of course you also changed the frequencies and/or number of steps).

Also, changes to **ADC Wait** and/or **Averages** will not be stored as part of the calibration setup unless you use **Save Cal** (Section 7.2).

7.4.3 CDS

See Section 6.4.5 for information about Correlated Double Sampling.

CAUTION ***The same calibration cannot be used for both CDS and non-CDS measurements.*** *Whenever you use the* **CDS** *check-box, a message will warn if the calibration is no longer valid.*

From VNA4win v1.3b onwards, the CDS status is saved in each calibration file, and is updated automatically when that file is re-loaded.

When CDS is enabled, the Transmission calibration procedure (Section 7.1) does not require an open-circuit frequency sweep.

7.4.4 Single Frequency Mode

Single Frequency mode (Section 8.2) cannot be accessed unless there is a valid calibration covering the selected frequency and the selected **Mode** of measurement. Also calibration procedures are not allowed while in **Single Frequency** mode – you must calibrate over a frequency *sweep* that covers the wanted frequency.

7.5 Calibration Information

When you make a manual calibration or load a **.cal** file, you can see a summary of the current setup by clicking the ⓘ button. This opens the **Sweep/Calibration Information** panel (which is simply labelled ⓘ).

The ⓘ panel is divided into two columns. The **Calibration** column shows the conditions under which the currently valid calibration was made. The **Present Setup** column shows where these may have been altered since the calibration was made (or re-loaded from file).

These two columns can be different – see Section 7.4 on **Interpolated Calibrations** above – but whenever the calibration still applies, the **Present Setup** column simply says **Same** against each setting.

To close the ⓘ panel, either click its **Close** button or click the ⓘ button again.

8 MEASUREMENT DISPLAYS

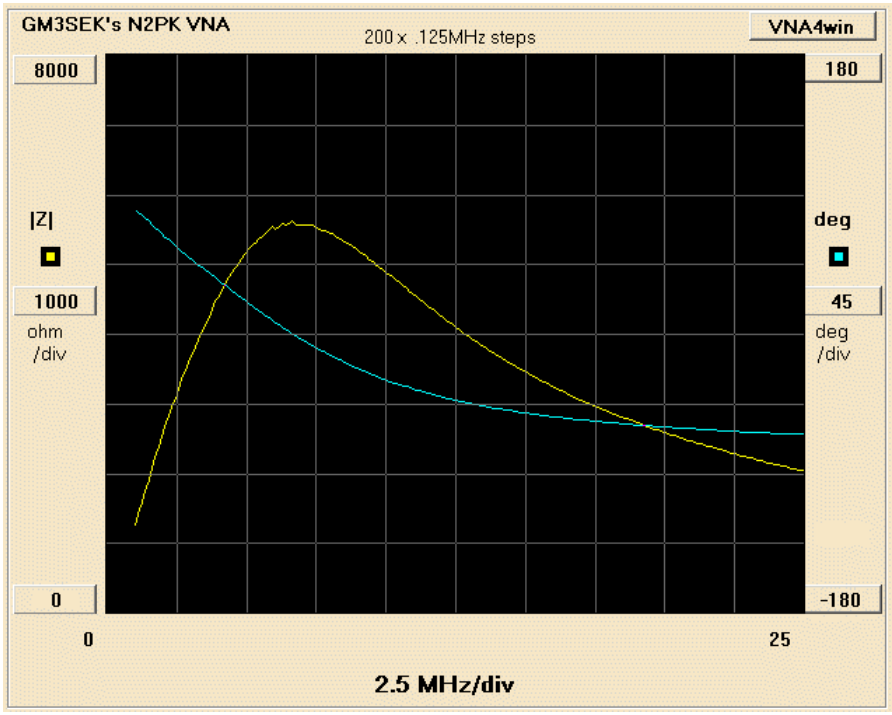
VNA4win v1.3 offers two different kinds of measurement displays, which are selected in the **Set Frequency Sweep** dialog (Section 6):

- Swept-frequency displays, in either **Start + End** mode (including **Max Sweep**) or **Centre + Span** mode, as described in Section 6.1. See Section 8.1 below for further details about swept measurement displays.
- Single-frequency displays, by selecting **Single Freq** mode as described in Section 6.1. See Section 8.2 below for further details about single-frequency measurement displays.

The **Sweep Control** buttons that select these functions are described in Section 10.

8.1 Swept-frequency Displays

Here is a typical example of a swept-frequency display.



This particular display has the following features:

- **Frequency range** is 1MHz to 25MHz, selected using the **Set Sweep** button to open the **Set Frequency Sweep** dialog (Section 6.1).

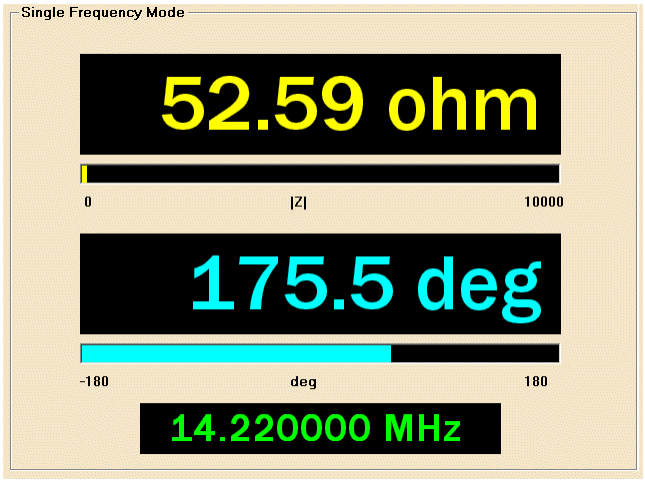
  Note: Although the frequency sweep in this example starts at 1MHz, the display is plotted from 0MHz (by checking the **Plot F=0** option). The frequency scaling then becomes 2.5MHz/division, a nice round number which makes the display much easier to read.

- **Display option** is **|Z|, deg**, selected using the **Display** list (Section 9).

- **|Z| trace** (yellow) has a scale of 0 to 8000Ω. This is configured by clicking **Autoscale** after the sweep has finished, and then making final adjustments by clicking on the maximum value and /division buttons. You can either choose values from the drop-down lists, or type in your own numbers.
- **Deg (phase angle) trace** (blue) has a scale of -180° to +180°. Other options are configurable by clicking on the maximum value and /division buttons. You can either choose values from the drop-down lists, or type in your own numbers.

8.2 Single-frequency Displays

Here is a typical example of a single-frequency display.



The single-frequency display has the following features:

- Large numerical and bar-graph displays, clearly visible at a distance.
- The single measurement frequency is displayed in green. To change the frequency, you can either click the **Set Sweep** button in the usual way, or click directly on the frequency display area; both actions will re-open the **Set Frequency Sweep** dialog (Section 6).

CAUTION *Calibration procedures are not allowed while in single-frequency mode – you must always calibrate first, or load a calibration file. The calibrated frequency* **range** *must include the wanted frequency.*

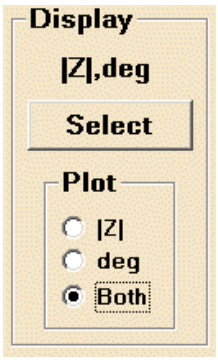
When making single-frequency measurements, functions that are only valid for a frequency sweep are disabled (functions in the **Screen** *panel, markers etc).*

Single-frequency measurements take all their parameter settings from the **Set Frequency Sweep** dialog (Section 6) including **ADC Wait**, **Averages**, **CDS** and **ADC Mode**.

The scale ranges of the two bar-graph displays are the same as the two y-axis scales in the swept display. To change the scaling of the bar-graph displays, go back to a swept display and use the y-axis scale buttons and the **Autoscale** / **Max Range** button as described in Section 11.1. Then return to single-frequency mode.

9 DISPLAY PANEL

The **Display** panel controls how the output data is plotted on the screen.



9.1 Select Button

The **Select** button opens a drop-down list containing the data plotting options that are appropriate for the selected **Mode** (Section 5).

Note: Any change that you make here will clear the display. You will need to make a new sweep to re-plot the data.

9.1.1 Transmission Mode

Option	**Description**	**Magnitude axis** (RH, yellow trace)	**Phase axis** (LH, blue trace)
dB, deg	Gain/loss in dB, and phase shift (both relative to calibration)	Gain/loss, dB	Phase shift (deg)
Mag, deg	Gain/loss in magnitude (not dB), and phase shift (both relative to calibration)	Gain/loss (linear scale)	Phase shift (deg)

9.1.2 Reflection Mode

Option	**Description**	**Magnitude axis** (RH, yellow trace)	**Phase axis** (LH, blue trace)
|Z|, deg	Magnitude and phase angle of impedance	Magnitude (Ω)	Phase (deg)
Rho, deg	Reflection coefficient and phase angle of impedance	Rho (0–1)	Phase (deg)
Rs, Xs	Equivalent series resistance and reactance	R (Ω)	X (Ω)
Rp, Xp	Equivalent parallel resistance and reactance	R (Ω)	X (Ω)

more…

SWR	Standing Wave Ratio of impedance	SWR (1–)	(nothing)
RL, deg	Return loss and phase angle of impedance	Return loss (dB)	Phase (deg)
Smith	Smith chart	Circular Smith chart	

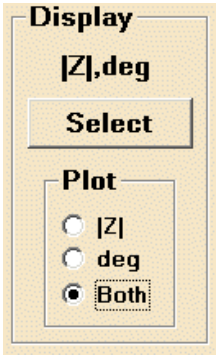
9.1.3 Group Delay Mode

There is only one option:

Option	Description	**Magnitude axis** (RH, yellow trace)	**Phase axis** (LH, blue trace)
dB, µs	Gain/loss in dB, and group delay in microseconds (both relative to calibration)	Gain/loss (dB)	Group delay (µs)

9.2 Plot Options

After at least one sweep has been completed, and the sweep is then stopped, you can then use the **Plot** controls. These select which of the two traces will be displayed – the default is to display both traces.



The trace labels for the **Plot** controls will change according to the type of display you chose using the **Select** drop-down list (Section 9.1 above).

Note: In **Reflection** mode, the **SWR** and **Smith Chart** options only display one trace, so these **Plot** controls are disabled.

The **Autoscale** functions (Section 11.1) apply only to the trace(s) that **Plot** has selected to be visible on-screen. To apply autoscaling to one trace only:

1. Use **Plot** to select only that trace (the other trace disappears)
2. Click **Autoscale**
3. Return to **Plot** and re-select **Both**.

10 SWEEP CONTROL BUTTONS

The **Sweep Control** panel appears whenever measurements are allowed – see Section 7 on **Calibration**. These controls disappear when there is no valid calibration, or when you choose some unrelated function.

The **Sweep Control** panel contains four VCR-style control buttons. The white LEDs show which button you last clicked, and the status caption at top centre shows what is now happening.

10.1 Swept-frequency Measurements

|▸	Start a new sweep (after the first sweep is complete, the status changes automatically to Continuous).
▸	Continuous sweep. Starts or resumes the current sweep.
■	Pause/stop sweep.
▸|	Stop at end of sweep.

You can click the ▸| button at any time during a sweep. The measurements will continue until a complete sweep has been obtained.

The ■ button will halt the sweep at any time – click any of the other buttons to resume.

CAUTION *When you stop a sweep with the intention of using* **Save Data**, *the* **Markers** *functions or* **Trace Store**, *make sure that you have a meaningful set of data to save. Avoid saving data from incomplete sweeps, or from sweeps made while the device under test is changing.*

10.2 Single-frequency Measurements

|▶	Start continuously updated measurements.
▶	Start continuously updated measurements.
■	Pause/stop measurements.
▶|	Make a single measurement.

Single-frequency measurements take all their parameter settings from the **Set Frequency Sweep** dialog (Section 6) including **ADC Wait**, **Averages**, **CDS** and **ADC Mode**.

When making continuous repeated measurements, a good way to control the rate of updating is by varying the number of **Averages**. Averaging over a larger number of measurements gives a longer interval between updates, while also giving more accurate readings with less display flicker.

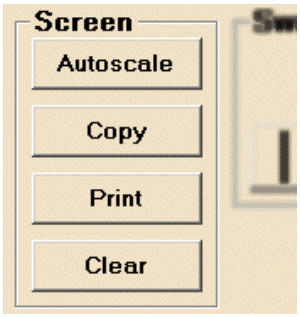
The scale ranges of the two bar-graph displays are the same as the two y-axis scales in the swept display. To change the scaling of the bar-graph displays, go back to a swept display and use the y-axis scale buttons and the **Autoscale** / **Max Range** button as described in Section 11.1. Then return to single-frequency mode.

CAUTION *Calibration procedures are not allowed while in single-frequency mode – you must calibrate over a frequency* **sweep** *that covers the wanted frequency.*

Functions that are only valid for a frequency sweep are disabled when making single-frequency measurements (functions in the **Screen** *panel, markers etc).*

11 SCREEN PANEL BUTTONS

The **Screen** panel appears to the left of the **Sweep Control** panel (Section 10). Its control buttons are enabled only after at least one sweep has been completed, and sweeping has been stopped.



11.1 Autoscale / Max Range Button

This button changes its label between **Autoscale** and **Max Range** according to the next possible function.

Because the potential range of a new measurement is unknown, all measurements are initially plotted using the maximum possible vertical range. For example, transmission measurements are initially plotted on an amplitude scale of +40dB to -120dB, phase +180° to -180°. Other types of measurements default to similarly large maximum ranges.

The **Autoscale** button will redefine the vertical scaling so that the data fills the display better. After you have made the first sweep, and stopped the sweep, click **Autoscale**. The program chooses the best available range, while still keeping easy round numbers for the /**div** scaling.

When you click **Autoscale**, the button label changes to **Max Range** – if you click again, the display changes back to what you saw previously.

Note: The **Autoscale** and **Max Range** functions apply only to the trace(s) that are visible on-screen. To apply these functions to only one trace, use the **Plot** buttons to make the other trace invisible (Section 9.2).

11.2 Manual Scaling

Alternatively, you can re-scale the magnitude and phase axes manually. Like **Autoscale** and **Max Range**, this function is only available after you have made at least one complete sweep, and have stopped the sweep.

The left-hand and right-hand y-axes each have three clickable labels:

- Maximum value, at the top of the axis
- Units/div value, half-way down
- Minimum value, at the bottom of the axis.

To change any of these values, click on its label to see a drop-down list of suitable settings (you can also type in a value, then press **Enter**). The list will change back into a label showing your selected value.

When two labels have been changed, the value on the third label will be recomputed automatically. If you want to keep an existing value, click on its label but don't change anything – click immediately on the next label that you do want to change.

When you change any y-axis scale, the on-screen data are re-plotted. The new scaling will also apply to the bar-graphs in single-frequency measurements (Section 8.2).

Your manually selected scaling will continue to apply until you do one of the following:

- Select different manual scaling, as above
- Click **Autoscale** or **Max Range** (Section 11.1)
- Select a new **Mode** (Section 5).

11.3 Copy Button

Copies the current screen to the *Windows Clipboard*, from which it can be pasted into another *Windows* application. Only the graphics screen itself is copied, without any accompanying information.

11.4 Print Button

Sends a black-on-white image of the screen and all the surrounding information to the printer. A dialog appears where you can type in some text which will accompany the output, e.g. test details or a title.

CAUTION *If the printer is normally routed to the same port that is being used for the VNA (usually LPT1:), you cannot use this facility without switching that port from the VNA to the printer. You can successfully switch devices if you do not try to use either the printer or the VNA when that device is not connected.*

11.5 Clear Button

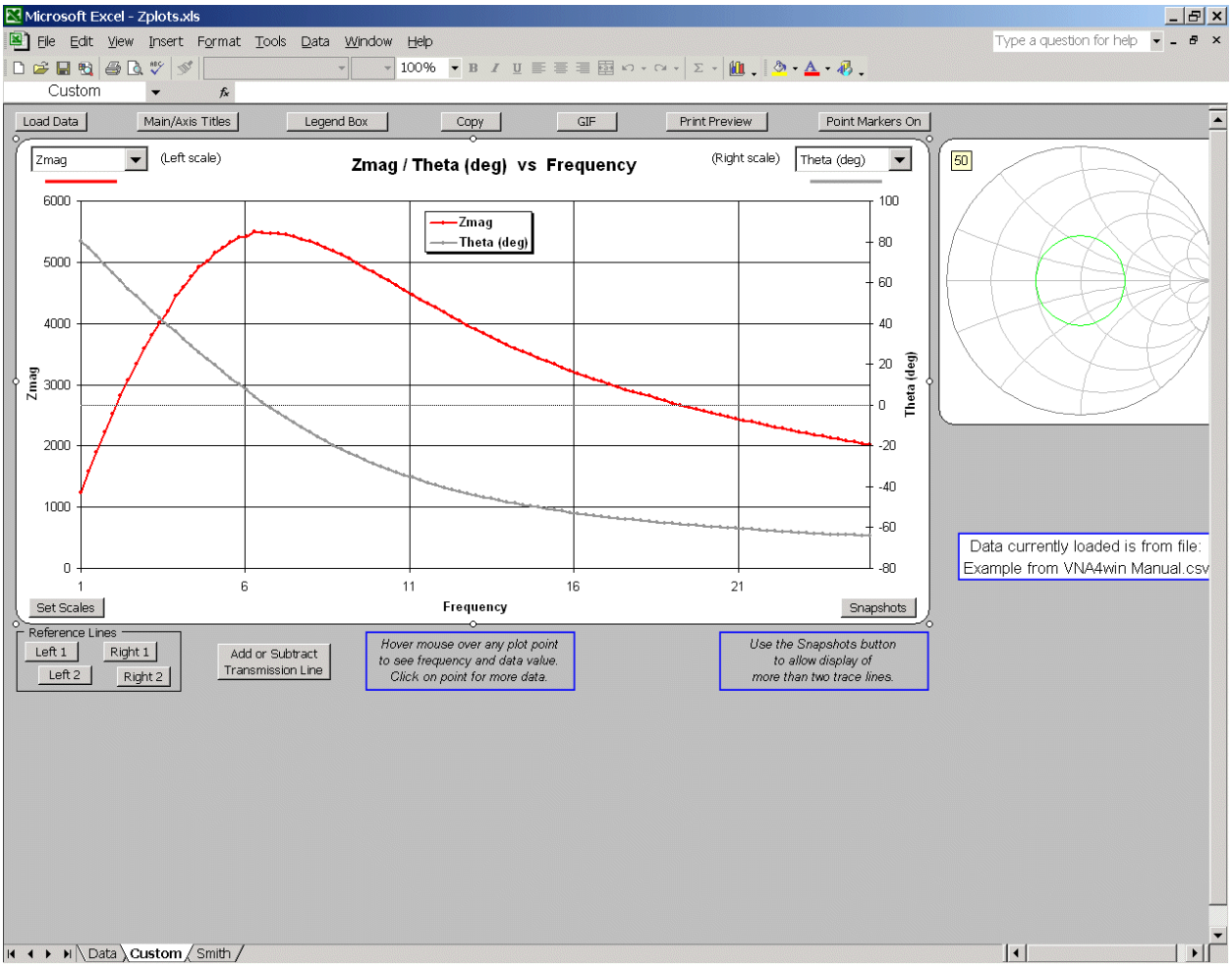
Deletes the trace(s) that are currently visible on the graphics screen. Until the screen is overwritten, you can recover the deleted trace(s) by changing the **Plot** option (Section 9.2) and then changing it back.

11.6 Save Data Button

After at least one sweep has been completed, the **Save Data** button will appear when the sweep is stopped. Clicking **Save Data** opens a Windows file dialog to allow you to save the measurement results as a **.csv** file.

The **.csv** suffix means 'comma-separated variables', a standard format that most spreadsheets can read directly. For example, open *Windows Explorer* and try double-clicking on the file **demo.csv** – quite possibly it will automatically open your existing spreadsheet program and read the file.

The format of *VNA4win*'s .csv files is now compatible with AC6LA's versatile impedance plotting utility *Zplots*. For details, see http://www.ac6la.com/zplots.html



12 MARKERS BUTTON

After at least one sweep has been completed, the **Markers On** button will appear when the sweep is stopped. If you click this button, the **Markers** panel will appear (and the button caption changes to **Markers Off** – click to close).

12.1 Marker Functions

Markers allow you to identify a selected point on each trace, and read off its exact numerical data.

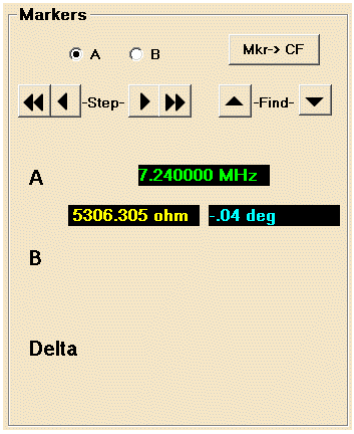
Most display modes have a pair of markers, one for each visible trace. The two markers are always on the same frequency, so they are always vertically in-line.

Initially, the marker is always at the beginning of the sweep. A green dot (or red in Smith Chart mode) shows the position of the marker on each trace. The numerical data for that sweep point are displayed in the **Marker** panel. If markers are on and continuous sweep is selected, the current marker values will be updated every sweep. *VNA4win* v1.3 has two pairs of markers, individually controllable with a difference (delta) function. The first pair of markers is called **Marker A** and the second pair is called **Marker B**.

Section 12.2 explains the basic marker controls when only **Marker A** is selected, and Section 12.3 identifies the differences when the **Marker B** is activated as well.

12.2 Marker Controls

The **Marker** panel initially opens with only **Marker A** selected and active.



The **Marker** panel has two sets of VCR-style control buttons. These buttons are only active when the sweep is paused. The four **Step** buttons move the markers to the left or right, in jumps of 1 frequency step point (◀ ▶) or 10 frequency step points (◀◀ ▶▶). The two **Find** buttons move the markers to the maximum or minimum measured value along the traces (▲ ▼).

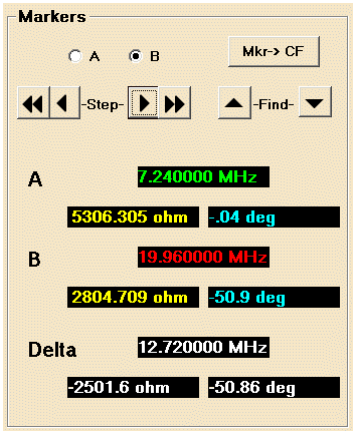
Below the controls, the **A** marker displays show the detailed values for the selected point. No rounding is attempted – you see the detailed raw data.

Note: The **Find** buttons (▲ ▼) operate only on those trace(s) that are currently selected and visible (see **Plot**, Section 9.2). If both traces are selected, the **Find** buttons will search only the magnitude trace (yellow, left-hand scale). You can use those features to make the **Find** facility identify the points you wish to select.

The **Mkr-> CF** button opens the **Set Frequency Sweep** dialog in **Centre+Span** mode, with the new **Centre** frequency set to the active marker. If the existing **Span** is less than 10% of the new **Centre** frequency, the sweep will only be re-centred; in all other cases, the **Span** will initially be set to 10% of the new **Centre** frequency. If you wish, you can still edit **Centre** and/or **Span** manually in the usual way.

12.3 Marker B and Delta Functions

When the radio button is clicked to the **B** position, Marker **A** remains as before and two additional features appear: **Marker B** and the **Delta** function.

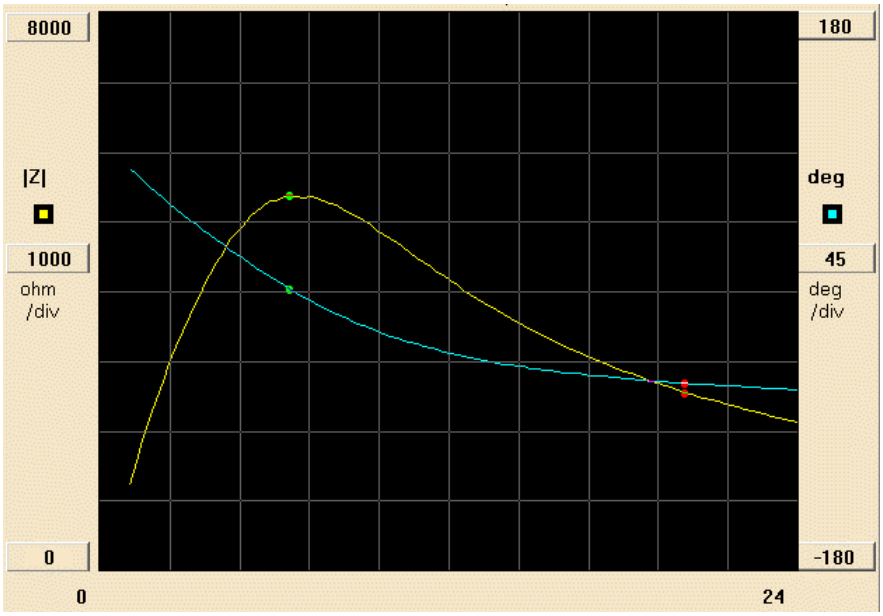


When **Marker B** is selected, the marker controls will now act on **Marker B** only (**Marker A** remains where it is).

In this example of a trace with two sets of markers, **Marker A** (green dots) had first been placed at the peak of the yellow |**Z**| trace, by using the **Find** ▲ button.

Marker B (red dots) was then activated, and moved manually to approximately 20MHz.

The **Delta** displays now show the differences between the corresponding values for the two markers. This difference is always the algebraic value (**B** minus **A**).



13 TRACE STORE

VNA4win has a simple trace memory, which can store a selected trace for later comparison. The **Trace Store** controls are only available after at least one sweep has been completed and the sweep has been stopped.

To save a trace, click **Save Trace**. The **Trace On** button then appears – when you click this button, the stored trace is displayed on-screen (the button changes to **Trace Off**, and also a small indicator shows that a trace is stored).

To differentiate between the 'live' trace and the stored trace, different colours are used. Where traces overlap the colour again changes to show this:

Trace Type	Channel A (Magnitude)	Channel B (Phase)
Normal trace	Yellow	Cyan
Stored trace	Red	Green
Overlapping traces	Green	Blue
Smith chart trace	Green	
Smith chart stored	Red	
Smith chart overlapping	Yellow	

CAUTION *The trace store is strictly temporary. Changing the sweep or display mode will erase the stored trace. Also the stored trace cannot be saved as a file;* ***Save Data*** *will store* data *from a trace (Section 11.6) but this data cannot be loaded back into the program. For that kind of analysis, we recommend that you use an offline utility such as* Zplots*.*

14 GROUP DELAY MEASUREMENTS

14.1 More about Group Delay

Group delay is a specialised form of Transmission measurement – the rate of change of phase with frequency:

$$\tau = d\Phi / d\omega \qquad \text{Units are: (radians)/(radians/sec) = sec}$$

Group delay measurements are important in devices such as filters, because they indicate the amount of phase distortion and probable 'ringing'. This is most likely to occur in the transition regions at the edges of the passband, where the phase-shift through the device may be changing very rapidly.

In this frequency-stepped VNA, group delay is approximated by making *two* phase measurements for each frequency point, at frequencies that are automatically offset slightly below and above the specified frequency.

To measure Group Delay, set the **Mode** to **GrpDe**l. Calibration validity for Group Delay is always the same as for Transmission Mode.

The only **Display** option in Group Delay Mode is **dB, μs** – Magnitude in dB, Group Delay in microseconds.

14.2 Group Delay Aperture

The difference between the two measurement frequencies is called the **Group Delay Aperture**. Choosing the optimum aperture value is critical to a good group delay measurement. The aperture must be small enough to give good resolution in areas where the phase and group delay are changing rapidly. But the aperture must also be large enough to create an accurately measurable difference between the results for the two frequencies.

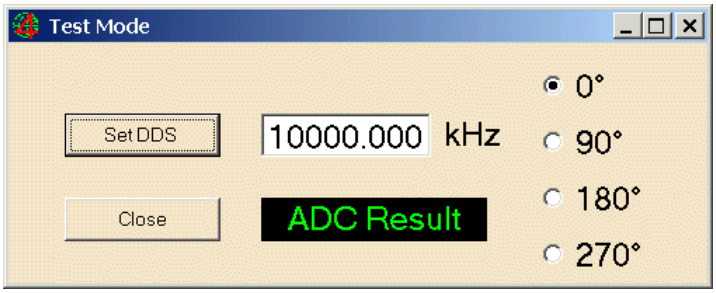
To set the aperture, click the **GrpDel Aperture** button (which is only active in Group Delay mode). This opens the **Group Delay Aperture** dialog. The options are:

- **0.5% of Span** – often a good value, but obviously depending on the selected sweep width and the characteristics of the device being measured
- **1 Step** – may be too coarse, unless the step size is small and the device is not frequency-critical
- **User specified (Hz)** – always displays the currently selected aperture value when the dialog opens. If you click to select this field, you can then edit it to a new value. (Values less than 1Hz or greater than 1 Step are out of range, and will be ignored.)

Click **OK** to exit the **Group Delay Aperture** dialog and save the new setting (or click **Cancel** to exit without changing).

15 VNA TEST

The **VNA Test** facility is selected by a radio button from the **Set Frequency Sweep** dialog. This opens a separate **VNA4win Manual Control** window that gives direct access to DDS and ADC functions.



These facilities can be useful for hardware debugging, or when using the VNA as a signal generator.

15.1 DDS Frequency and Phase

Enter a frequency (note: only in **k**ilohertz). This will set both DDSes to that single frequency, with no stepping.

The **0°**, **90°**, **180°** and **270°** options control the phase difference between the RF DDS and the Detector DDS:

- **0°** sets both DDSes to the same phase (as VNA4win would do automatically for the 'real' part of a measurement).
- **90°** offsets the phase of the Detector DDS by 90° from the RF DDS (as VNA4win would do automatically for the 'imaginary' part of a measurement).
- The additional phase settings of **180°** and **270°** allow you to emulate and test the effects of Correlated Double Sampling (CDS, Section 6.4.5).

Your frequency and phase selections are not applied until you click **Set DDS**. The DDS settings then remain the same until you click **Set DDS** again.

After the **Set DDS** button is clicked**,** a single ADC reading is automatically taken, and the display will hold that result until you click the **Set DDS** button again.

The ADC reading (in green) is in the VNA's 'raw' output, in units of volts and to the maximum precision available.

15.2 Exit

To exit from the **VNA4win Test Mode** window, click the **Close** button.