Welcome to N2PK VNA Software Version 2.01

This README file contains information about the software for the N2PK Vector Network Analyzer. Please read this file in its entirety. It is recommended that it be printed for quick reference to the programs and their features. Also refer to the VNA documents Parts 1 and 2 for VNA hardware details, and Part 3 when it becomes available for additional software and application information.

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1. Release history

Release 2.01

Known problems:
1. Ctrl+C does not work in PARPORT.

Corrections:
1. New calibrations, after the 1st, no longer change the user input frequencies if a CAL file is present.
2. Maximum number of frequencies no longer decreases on subsequent new calibrations - did so in Release 2.00 if a CAL file was present.
3. Relative phase (approx.) is now correct on re-entry to VFO program "S" frequency mode selection.
4. Frequencies stored in CAL data files for real time programs are now the original calibration frequencies, not the last ones used.
5. Corrected some memory allocation errors in DDS.

Changes:
1. Calibration file names are now named *.CAL instead of *CAL.DAT.
2. Frequency in REFLR is now displayed to 8 decimal digits as other programs.
3. Frequency entry in the VFO program is not allowed above 100 MHz.

Additions:
1. Allows user specified data (*.DAT) filenames.
2. Adds 'ADCdel' to *.CAL files.
3. Added the 'Radio' mode to the VFO program, where the RF DDS can be used as a single conversion radio local oscillator and the LO DDS can be used as the radio's BFO.

Release 2.00 (Aug. 24, 2003)

1. Initial common 'look & feel' release of all programs.

2. Hardware requirements

The VNA hardware and software are designed to operate with an IBM compatible PC with:

a) an IEEE 1284 compliant parallel port.
b) a minimum of 1 Mbyte of memory if DOS is used.
c) a monitor and a display adapter capable of VGA 640x480 graphics.
d) minimum of an 80386 processor with an 80287 numeric co-processor

In addition, the 'N2PK VNA' as described primarily in Part 2 of the VNA documentation will be required and additional hardware, as needed, such as impedance bridges, DDS buffer, detector pre-amp, etc. Part 3 will describe additional hardware to extend the 0.05 - 60 MHz frequency range of the VNA to VHF and UHF in narrowband fashion.

Useful accessory: IEEE 1284 compliant parallel port switch, such as the Belkin F1U123. A parallel port switch allows the PC to share one parallel port between the VNA and a printer.

The PC and the software here provide all hardware control functions as well as data transfer, reduction, display and storage of test results.

The VNA hardware and software has been tested on laptop and desktop systems of various speeds, ranging from 75 to 2000 MHz.

An IEEE 1284 compliant parallel port cable with a DB25 connector at each end is recommended, such as the Belkin F2A047-XX, where XX specifies the length. Non IEEE 1284 cables and switch boxes have little signal line impedance and crosstalk control and usage with the VNA may result in software and hardware mal-functions.

It is recommended that the parallel port be capable of 'ECP' or 'EPP' modes for best performance, particularly on the faster real time programs such as the SWPGEN program. However, in some limited testing, it was not found necessary to enable ECP or EPP modes to obtain maximum performance.

3. Operating Systems environments

The VNA programs are all DOS based and will function properly in:

a) MS DOS 5
b) Windows 95
c) Windows 98
d) Windows 2000 (requires a direct parallel port access driver)

The programs may also function in other versions of DOS and Windows, such as ME, NT, and XP, but have not been tested. NT and XP will likely require a direct parallel port access driver, as does Windows 2000.

There are several direct parallel port access drivers available. The only one that has been tested with the VNA is "Direct I/O" at:

http://www.direct-io.com/

As claimed at the above web site, it appears to be quite fast as I see no performance difference between native DOS and Windows 2000.

In Windows, multiple copies of the same VNA program or different ones can be executing simultaneously. However, this will likely introduce errors in most cases and should be generally avoided. The only known exception is simultaneous use of the VFO and ADC programs in the DEBUG directory which interact with different hardware in the VNA. However, even with these two programs, it may be possible for Windows time sharing, combined with VNA operations in the VFO program, to result in ADC time-outs, which will currently abort the ADC program.

4. File contents

a) VNASOFT.ZIP:

README.TXT
README.PDF
VNA.CFG
VNAREALT.ZIP
VNASTORE.ZIP
VNADEBUG.ZIP

b) VNAREALT.ZIP:

```
VNA.CFG
REFLR.EXE
TRANSR.EXE
GRPDELR.EXE
VFO.EXE
SWPGEN.EXE
```

c) VNASTORE.ZIP:

```
VNA.CFG
EGAVGA.BGI
REFL.EXE
TRANS.EXE
GRPDEL.EXE
```

d) VNADEBUG.ZIP:

```
VNA.CFG
PARPORT.EXE
VFO.EXE
ADC.EXE
DDS.EXE
```

5. Program Installation

The following procedure is recommended for new VNA users and will be assumed in the descriptions that follow. However, the procedure can be modified to suit individual user preferences, as they develop, for programs used, data storage locations, common or isolated copies of the VNA.CFG and *.CAL files, etc.

In what follows, "X" is the hard drive letter of your choice.

a) Create the following directories:

```
X:\VNA
X:\VNA\DL      (Original download files)
X:\VNA\REALT   (Real time programs)
X:\VNA\STORE   (Stored data programs and possibly stored data files)
X:\VNA\DEBUG   (Hardware debug programs)
```

You can also optionally create:
X:\VNA\DATA
This directory can be specified as the 'current working directory', in either DOS or Windows, and will be used to store user data in the CFG, CAL, and DAT files.

b) Copy or move the VNASOFT.ZIP file to X:\VNA\DL. Unzip it there to obtain:

```
X:\VNA\DL\README.TXT
X:\VNA\DL\README.PDF
X:\VNA\DL\VNA.CFG
X:\VNA\DL\VNAREALT.ZIP
X:\VNA\DL\VNASTORE.ZIP
X:\VNA\DL\VNADEBUG.ZIP
```

c) Copy X:\VNA\DL\README.TXT and X:\VNA\DL\README.PDF to X:\VNA for quick reference after installation.

d) Copy VNAREALT.ZIP to X:\VNA\REALT and unzip it there to obtain:

```
X:\VNA\REALT\VNA.CFG
X:\VNA\REALT\REFLR.EXE
X:\VNA\REALT\TRANSR.EXE
X:\VNA\REALT\GRPDELR.EXE
X:\VNA\REALT\VFO.EXE
X:\VNA\REALT\SWPGEN.EXE
```

e) Copy VNASTORE.ZIP to X:\VNA\STORE and unzip it there to obtain:

```
   X:\VNA\STORE\VNA.CFG
   X:\VNA\STORE\EGAVGA.BGI
   X:\VNA\STORE\REFL.EXE
   X:\VNA\STORE\TRANS.EXE
   X:\VNA\STORE\GRPDEL.EXE
```

f) Copy VNADEBUG.ZIP to X:\VNA\DEBUG and unzip it there to obtain:

```
   X:\VNA\DEBUG\VNA.CFG
   X:\VNA\DEBUG\PARPORT.EXE
   X:\VNA\DEBUG\VFO.EXE
   X:\VNA\DEBUG\ADC.EXE
   X:\VNA\DEBUG\DDS.EXE
```

The VNA.CFG file in X:\VNA\DL should not be edited to maintain it for reference and copying to other directories if errors are made to the VNA.CFG files in those directories.

6. Current Working Directory

All programs will read data from file(s) and, in some cases, will write data to files. These files, as used by each program, are located in the 'current working directory' or simply the 'working' directory.

These files include the VNA.CFG, all the *.CAL, and all the *.DAT files.

In DOS or a DOS box/VDM in Windows, the current working directory is the "current path" (in DOS 6.22 parlance) as can be displayed by typing "PROMPT PG" at the command prompt. Normally, it would be preferable to change that directory to the one specifically created for VNA use. That can be any of the directories created in section 5a above.

If the DOS (box or VDM) current path is changed to the VNA program directory using the DOS "CD" command, then the current working directory will be that same directory.

BAT files can also be used to handle directory management as described in DOS documentation.

When using Windows PIFs or shortcuts, the current working directory will default to the program file directory. There is also an option using the program information file, or 'PIF' as it was called in the early versions of Windows, to define a different working directory. The PIF can be accessed in later versions of Windows by right clicking on the icon or words for a shortcut to each progam or a copy of the program. Then left click on 'Properties', left click on the 'Program' tab, and finally enter the name of the desired directory next to 'Working.'

Of course, the working directory must be created and the files needed or used by that progam must be transferred there. In the case of files written by that program, they will automatically be placed in the designated directory.

There are doubtless many different ways that the DOS or Windows directory management tools can be used with the VNA and its files.

7. VNA.CFG file

Each program requires a copy of the VNA.CFG file in its current working directory. This file contains information that can be customized by each VNA user. It is an ASCII file that can be viewed, modified, and saved by any text editor, such as Notepad and Wordpad in Windows or EDIT in DOS.

A sample VNA.CFG file, without the optional comments, is shown here:

```
---
Port=0x378
Clk=148.340
ADCdel=100
```

```
cfp=1
ZØ=5Ø
Cop=Ø.Ø39
Rsh=Ø
Lsh=Ø.Ø
Rld=5Ø.Ø13
Lld=Ø.15
Cld=Ø.23
Raw=Ø
---
```

Here's a description of the parameters:

```
Port    - The address of the parallel port used by the VNA in hex. Keep
          the 'Øx' prefix - only the following three digits may be
          different. This value can be obtained from the PC's CMOS
          memory for DOS, or using Device Manager in Windows.
Clk     - The actual VNA master oscillator frequency in MHz. It can be
          adjusted from the sample value by either direct measurement
          of the master oscillator or indirectly by measuring a DDS
          frequency using the VFO program and correcting the Clk
          parameter until the measured frequency matches the programmed
          frequency within acceptable limits. To correct the Clk
          parameter, multiply the last Clk value by the ratio of the
          measured to the programmed DDS output frequency. This may
          have to be repeated depending on the number of digits used
          in the calculations.
ADCdel  - delay in ms between a frequency/phase program and the first
          ADC read that follows. '1Ø' is recommended for the real time
          programs for improved performance with the possibility of
          some degradation in accuracy. '1ØØ' is recommended for best
          accuracy for any test or debug program.
cfp     - continuous frequency programming: if set to '1', there will
          be no 'holes' or interruption in the DDS outputs due to
          re-initialization between different frequencies, 'Ø' if
          otherwise. Use '1' as a default.
ZØ      - Basis in ohms for measured reflection coefficients and the
          center of Smith Chart displayed in REFL, generally 5Ø ohms.
          This can be different than the resistance of the load
          standard.
Cop     - Excess shunt (fringing) capacitance in pF of the Open
          calibration standard beyond the reference plane. Ø.Ø39 pF
          represents a flush ground female SMA chassis connector.
          Lacking a better value, use Ø.
Rsh,Lsh - Series resistance in ohms and inductance in nH for the Short
          calibration standard. Both are essentially close to zero thru
          6Ø MHz for a well constructed flat plane short over the back
          of a flush ground emale SMA chassis connector. Lacking a
          better value, use Ø for each.
Rld     - Series resistance in ohms of the Load calibration standard,
          usually about 5Ø ohms. Use an accurately (4 point Kelvin
          probe) measured value, if possible. Lacking a better value,
          purchase precision 1% or Ø.1% meatl film resistor(s) and use
          the nominal value(s).
Lld,Cld - Series inductance in nH and excess shunt capacitance in pF
          of the Load calibration standard beyond the reference plane.
          The values shown are estimates for a four Ø8Ø5 2ØØ ohm Ø.1%
          surface mount resistors, mounted E-W-N-S fashion, between the
          center pin and outer conductor of a flush ground female SMA
          chassis connector. Lacking values for other terminations,
          use Ø for each.
Raw     - Set to '1' to append raw data to *.RAW files, 'Ø' if not. For
          general usage, 'Ø' is recommended to avoid accumulation of
          unused data.
```

The values needed for the open, short, and load calibration standards will depend on the connectors and standards being used. If you use multiple calibration standard sets, a VNA.CFG file can be saved for each set using some descriptive file name and each changed to VNA.CFG as needed prior to testing using them.

Make sure that the common parameters, such as Port, Clk, & cfp, are updated in all the various copies of the VNA.CFG as needed.

8. Data Averaging

Averaging of measured data is provided in all of the VNA programs that collect data.

Since each data point is a vector (i.e. magntude & phase on the complex plane), averaging the readings collected for each component of each vector can result in signal to noise ratio (S/N) improvements when the S/N is low.

The maximum improvement is when there is essentially no signal. For example, the noise floor in a transmission test can be typically lowered (improved) by about 7 dB when ten readings are averaged. The degree of improvement with averaging will vary as it depends on a variety of factors, including the drift in the VNA.

However, since averaging increases the test time in nearly direct proportion, averaging should be used only in those cases where it can actually improve accuracy.

High insertion loss transmission measurements and group delay measurements significantly off the 'nose' of a filter are two test examples that may benefit from averaging. Only the most critical of impedance measurements will benefit from averaging.

9. Re-usable calibration

The real time and stored data reflection, transmission, and group delay programs all provide the user with the option of saving a calibration just performed for later re-use. On subsequent entry, each program will offer the user the option of re-using the previously saved calibration data. If the subsequent DUTs are to be tested over the same frequency range and would utilize the same calibration standards, this can be a significant time saver particularly for the OSL reflection calibration where the calibration consumes 75% of the total test time needed for a single DUT.

Each program will search its current working directory for a previously saved calibration file. It will also optionally write new calibration data in the current working directory. Note that each calibration save will over-write the previously saved data.

However, care must be taken to ensure that the original test set-up is replicated prior to subsequent measurements. It is also important that the VNA be warmed up sufficiently prior to all measurements to minimize drift induced errors. Periodic re-test is recommended to verify that the set-up is correct and that drift has not introduced an unacceptable level of error.

The calibration files are named REFL.CAL, TRANS.CAL, and GRPDEL.CAL. They are all ASCII text files that can be viewed to verify contents and saved under a new name by any text editor, such as Notepad & Wordpad in Windows or EDIT in DOS. They can also simply be copied or re-named as desired. In this way, multiple calibration files can be stored and re-used.

10. Programs & Features

On entry, each program displays a description of what it does. Here is a summary of each by directory:

X:\VNA\REALT directory programs

This is a collection of real time VNA test programs, as denoted by the "R" suffix, that display reflection, transmission, and group delay data to the user as it is being collected at selected frequencies. In addition, there are two programs, VFO and SWPGEN, that collect no data, but provide real time interaction with the VNA RF and LO DDS signal sources.

Each program requires a valid VNA.CFG file in its current working directory. It may be desirable to set the ADCdel parameter in the the real time VNA.CFG files to 1 (ms) to provide the best possible performance. While there can be accuracy losses by doing so, they may not be important to some real time applications, such as adjustments.

The real time programs can also be used to perform preliminary measurements in preparation for more extensive and time consuming stored data collection. Using the generic VFO capability of all of the real time programs, parameters like crystal resonant frequencies, filter 3 dB frequencies, and group delay peaks can be quickly found and then used as the basis for more detailed measurements.

REFLR.EXE

This program measures the complex reflection coefficient from 5Ø kHz to 6Ø MHz for one port and multi-port networks, such as antennas, amplifiers, and components. A variety of directly measured & derived test data will be continuously updated on screen at 1 to 7 frequencies. Each frequency can be independently controlled while DUT data is displayed. No DUT data will be written to a file. Calibration data in REFL.CAL can be used and this file can also be written using calibration done here.

TRANSR.EXE

This program measures the complex transmission gain from 5Ø kHz to 6Ø MHz for multi-port networks, such as filters, matching networks, and amplifiers. If care is taken to ensure the source and load match required by the DUT, the measured complex transmission gain will closely approximate S21 or S12. A variety of directly measured & derived test data will be continuously updated on screen at 1 to 7 frequencies. Each frequency can be independently controlled while DUT data is displayed. No DUT data will be written to a file. Calibration data in TRANS.CAL can be used and this file can also be written using calibration done here.

GRPDELR.EXE

This program measures group delay from 5Ø kHz to 6Ø MHz for multi-port networks, such as filters, matching networks, and amplifiers. You will need to enter a 'frequency aperture' which is centered on each nominal test frequency. Typical apertures are 1-1Ø% of the DUT BW. This program can be useful in determining an optimal aperture. Measured group delay is continuously updated on screen at 1 to 7 frequencies. Each frequency can be independently controlled while DUT data is displayed. No DUT data will be written to a file. Calibration data in GRPDEL.CAL can be used and this file can also be written using calibration done here. The user can specify either a two or four frequency aperture to be used for the group delay calculation. The four frequency aperture is slower, but may help the user determine the optimum aperture width for a given DUT.

VFO.EXE

This program provides independent or coupled frequency control of the RF & LO DDS sources. There are two coupled modes. One provides the same frequency and relative phase control of the LO DDS phase, in 11.25 degree increments. The second coupled mode controls the RF DDS frequency and the offset of the LO DDS from the RF DDS. The frequencies and phase are initially entered numerically and can then be changed using the cursor control (arrow) keys.

This program can also be used to enable the VNA's RF DDS as a local oscillator (LO) for a superhet radio where the indicated frequency is actually the radio's tuned frequency. The RF DDS is automatically offset on the high side by the intermediate frequency (IF). The LO DDS can also be used as the radio's beat frequency oscillator (BFO).

The decimal frequency is directly controlled, but the DDS hex tuning words are also displayed.

The VNA's ADC will not be used. There will be no data on screen or to a file. There will be no program feedback that the DDS's have properly received or executed their commands. The user can do that by independent measurements of frequency and relative phase.

The VNA test programs are typically limited by distortion in the RF DDS output transformer for frequencies below 5Ø kHz. However, the LO DDS outputs are capacitively coupled and negligible distortion occurs below 5Ø kHz. The primary limitation is amplitude loss, but this can also be minimized by high impedance loading which may be desirable at audio or near audio frequewncies.

SWPGEN.EXE

This program sweeps the DDS sources and permits real time return loss and insertion gain/loss measurements, and adjustment if desired, of one port and multi-port networks, such as antennas, amplifiers, and other components. The program assumes that the user will supply an external bridge, a log amp, a scope, and trigger or DAC connections from the VNA, as needed, to perform the desired measurements. The sweep center frequency, deviation from the center frequency, the number of frequencies per sweep, the LO DDS phase, and re-trace time are all controllable while sweeping. There will be no data on screen or written to a file. The VNA's ADC will not be used during frequency sweeps. An AD83Ø7 log amp with output offset control can be a useful RF detector when connected to the scope vertical input. A calibrated 5Ø ohm step attenuator is also useful for setting vertical calibration. Pin 14 of the parallel port DB25, at the VNA, can be used for external scope sync and also beam blanking during frequency re-trace, if desired. In addition, a DAC will be available on the fast detector board to permit horizontal deflection of a scope in X-Y mode.

X:\VNA\STORE directory programs

This is a collection of stored data VNA test programs designed to collect reflection, transmission, and group delay data and store the data in files. The user can then view, copy, or import data into other programs, such as MathCAD, spreadsheets, word processors and e-mail.

Each program requires a valid VNA.CFG file in its current working directory. While it may also be desirable to set the ADCdel parameter in the stored data VNA.CFG files to 1 (ms) to provide the best possible performance, the best accuracy here may be more useful as provided with the default value for ADCdel of 1ØØ (ms). It is difficult to provide specific guidelines for setting ADCdel. The user can experiment with various values of ADCdel ranging over a suggested range of 1 to 1ØØ ms to determine the value that provides the desired balance of accuracy and test time for the DUTs of interest.

REFL.EXE

This program measures the complex reflection coefficient from 5Ø kHz to 6Ø MHz for one port and multi-port networks, such as antennas, amplifiers, and components. A variety of directly measured & derived test data will be displayed on screen, and can also be written to the REFL.DAT file in the current working directory, where 'REFL' can be changed by the user. Raw test data can also be optionally written to the REFL.RAW file. Calibration data in REFL.CAL can be used and this file can also be written using calibrations done here.

TRANS.EXE

This program measures the complex transmission gain from 5Ø kHz to 6Ø MHz for multi-port networks (DUTs), such as filters, matching networks, and amplifiers. If care is taken to ensure the source and load match required by the DUT, the measured complex transmission gain will closely approximate S21 or S12. A variety of directly measured & derived test data will be displayed on screen, and can also be written to the TRANS.DAT file in the current working directory, where 'TRANS' can be changed by the user. Raw test data can also be optionally written to the REFL.RAW file. Calibration data in REFL.CAL can be used and this file can also be written using calibrations done here.

GRPDEL.EXE

This program measures the group delay from 5Ø kHz to 6Ø MHz for multi-port networks, such as filters, matching networks, and amplifiers. If care is taken to ensure the source and load match required by the DUT, the measured complex transmission gain will closely approximate S21 or S12. You will need to enter a 'frequency aperture' which is centered on each nominal test frequency. There is a balance to be found between resolution and noise in the measured group delay. Typical frequency aperture values are 1 - 1Ø% of the DUT BW. Measured group delay will be displayed on screen and can also be written to the GRPDEL.DAT file in the current working directory, where 'GRPDEL' can be changed by the user. Raw test data can also be optionally written to the GRPDEL.RAW file. Calibration data in GRPDEL.CAL can be used and this file can also be written using calibrations done here.

This program only uses a two frequency aperture. Use the real time GRPDELR program to aid in determining the optimum aperture width for a given DUT.

X:\VNA\DEBUG directory programs

This is a collection of VNA hardware debug programs that may be helpful in the event of apparent hardware and/or software mal-functions. In addition, the DDS program can be used for various hardware performance testing.

Each program requires a valid VNA.CFG file in its current working directory.

PARPORT.EXE

This program assists in verifying the parallel port connections between the PC and the VNA. Connect the VNA, if desired, to the appropriate parallel port to facilitate probing of the port pins & verification of connections. The VNA can be powered ON while outbound pins are toggled by the program. During inbound pin sensing, the VNA is powered off and all connectors to the VNA PCB(s) are removed to permit external forcing of voltages on the inbound pins. Parallel port pins will be referenced here to the DB25 connector. Refer to VNA documentation for internal pinouts. Each outbound pin can be toggled between logical 1 (+5V) and logical Ø (Ground) continuously and can be monitored on an oscilloscope. Outbound pins will generally be at a logical Ø state with no program activity. Pins 1, 14, and 16 are typically at a logical 1 state and one can be used as an aid in inbound pin forcing to that state, if needed. Each inbound pin logical state can be sensed and displayed continuously while the corresponding pin can be forced to Ground or +5V to observe the effect. Inbound pins will generally be at a logical 1 state with no external forcing. A series 22Ø ohm resistor between an inbound pin and either a ground pin or one of pins 1,14, or 16, if needed, is recommended to minimize the potential for damage by inadvertently grounding outbound pins. In general, avoid shorting parallel port pins unless you know what you're doing.

VFO.EXE

The VFO program was described above with the real time programs. But, since it exercises only the VNA RF and LO DDS signal sources and does not exercise the ADC, it can be useful in hardware debug as well.

ADC.EXE

This program exercises only the ADC in the VNA without programming the DDS's. Connect the VNA to the appropriate parallel port and power it on now. You will be prompted for an integer to be used to average ADC readings. If this value is greater than 1, then the mean and standard deviation will be displayed. If the DDSs are functional, they can be programmed using one of the other programs

such as VFO prior to starting this program. Connecting the DDSs to the detector will, in turn, affect the ADC readings here.

DDS.EXE

This program is intended to be a general purpose hardware diagnostic tool, a vehicle for non-VNA uses for the hardware, and evaluation of new test sequences. Arbitrary frequency and phase programming can be done for each of the RF & LO DDSs from 5Ø kHz to 6Ø MHz with sub Hz frequency & 11.25 deg. phase resolution. Frequencies outside the above range can be programmed, but with degraded waveform quality. Phase is programmed from Ø to 31 representing the 11.25 deg. increments from Ø to 348.75 deg. There are many possible operating modes in this program and its main menu shows the possible options. One way to learn how to use this program is to tee a dual channel scope into the DDS to detector paths, try different program options and combinations of options, and observe what happens. The program can optionally write measured data to the following files:

a) ALLDEV.DAT, used to store Allan deviation data of measured ADC readings for a range of averaging values that permit a population of at least 1ØØ means to be used to calculate the Allan deviation.

b) MEANSDEV.DAT, used to store the means (averages) and standard deviation of the means for a range of averaging values that permit a population of at least 1ØØ means to be used to calculate the standard deviation.

c) PHLIN.DAT, used to store the results of a phase linearity test where the vector ADC readings are collected at each of the 32 possible LO phases.

d) DDSSCR.DAT, used to store the data displayed on screen.

11. Program sounds

These programs can emit two sounds - a low or a higher pitched beep.

The low pitched beep indicates a user entry that is in error.

The higher pitched beep is used shortly after program entry to alert the user that VNA has been detected. After that, it is generally used only to signal completion of some possibly long duration event that would normally then require the user's attention to change the hardware configuration.

12. VNA & Program Frequency Resolution

As a result of the 148.34 MHz clock frequency and the 32 bit DDS tuning word, the DDS frequency resolution is approximately Ø.Ø35 Hz. This is the smallest change in frequency that could be observed on an extremely stable frequency counter. Actually measuring this change would also depend on VNA clock stability and other factors, which would typically mask these small changes.

However, the programs are provided with Ø.Ø1 Hz resolution to permit the decimal frequency to be used to step through all possible DDS tuning words. In certain programs, such as VFO, SWPGEN, and DDS, where both the decimal frequency and the corresponding DDS tuning word is displayed, it will be seen that 3 or 4 steps at Ø.Ø1 Hz per step will be required between tuning word changes.

Except for situations where one might be interested in observing DDS spurs, recording frequency to Ø.1 Hz resolution will be at the limit of what is useful. Even Ø.1 Hz resolution, given long term stability and calibration of the VNA clØck frequency will generally only be useful for determining delta-f where the two frequency measurements occur within seconds of one another.

13. Graphics

The three stored data programs, REFL, TRANS, and GRPDEL, will each display a plot of the measured data vs. frequency after the data collection and reduction is complete. These programs will require the 640x480 capable VGA display mode and the EGAVGA.BGI file in the current working directory for each of them. Generally, DOS and Windows will support 640x480 mode if the hardware does. In Windows, the program will go to full-screen to display the plot.

14. Using the programs

All programs have specific use instructions, but here's some general comments:

a) 'Ctrl+C' without the Enter key can pressed at most times in the programs to abort the activity in progress and return to the program entry.

b) The contents of the VNA.CFG file in use are displayed shortly after program entry. You should review the parameters for the hardware in use, before continuing. In DOS, you will have to exit the program to make the changes to the VNA.CFG file. In Windows, you can make the changes to the VNA.CFG in a separate window and then continue with the VNA program.

c) Prior to calibration standard and DUT data collection, the measured vector components are continuously updated on screen to allow the user to verify that all of the connections are correct and that the readings are stable. Familiarization with these raw data readings is recommended as it can help spot set-up problems as well as minimizing measurement errors and wasted time.

d) Most programs will check the parallel port designated in the VNA.CFG file for the ADC in the VNA which is the only part of the hardware that can reply. If the VNA ADC is not detected via certain expected responses, the program will allow the user to correct some set-up problems such as the VNA powered down or a parallel port switchbox still connected to the printer instead of the VNA. If the parallel port number is not correct in the VNA.CFG file and if the program is operating under Windows, the VNA.CFG file can be updated in an editor window with the correct port number and re-read by pressing 'Ctrl+C' in the VNA program.

e) Many programs allow selection of three frequency entry modes: fundamental, harmonic mixing, and synchronous common LO up/down mixing. The later two modes extend the frequency range of the VNA, in narrowband fashion, beyond 60 MHz. They also require additional hardware to be described later in Part 3 of the VNA documentation. For now, use the fundamental mode.

f) While there are certain timing requirements for the VNA ADC, Windows time-sharing has not caused VNA programs to mal-function while they are interacting with the VNA hardware in usage so far. However, it is possible that slower PCs or ones with greater time loads imposed by other programs may cause VNA program mal-functions or aborts to occur. If aborts do occur, they may be preventable by keeping the VNA program in the foreground, and also to ensure that the VNA programs are not suspended when in the background.

g) The SWPGEN program, when used with a triggered scope sweep, may have some occasional trace aberrations due to Windows time-sharing. The DAC, to be described in a future hardware update, can be used to drive the scope's beam horizontally in place of the scope's internal timebase. Use of the DAC has been found to eliminate the occasional aberrations in Windows. Until the DAC becomes generally available, the SWPGEN program can be run under DOS to eliminate any objectionable effects of time-sharing.

15. Data files & on-screen data display

The reflection, transmission, and group delay stored data programs save the measured results in ASCII text files called REFL.DAT, TRANS.DAT, and GRPDEL.DAT respectively by default. Optionally, the user can select either that no test data will be written to a file or the part of the filename preceeding '.DAT'. Each of these files will be created in the applicable current working directory if it does not exist, or over-written with its previous contents destroyed, or appended with the new data added at the end of the previous data.

These files can be viewed by most text editors. The text editor can be used to selectively copy & paste certain data from these files into other files or other programs, such as MathCAD, spreadsheets, word processors and e-mail. Alternatively, since the files have comma delimited data and column header fields, they can be generally imported directly into a spreadsheet.

As these files may get quite large, it's useful to periodically review their contents, save the important data, and discard the rest. This editing can be done safely with a text editor while no VNA programs are running. Subsequent writing to the file by the VNA programs will simply append the new data to the end of the file.

File growth can also be limited by selecting DAT filenames based on some user recognizable criterion, such as a short DUT description, that conforms to the DOS 1-8 character file naming conventions.

The programs also provide a 'no file name' option for cases where the user may want to only view the test data on screen either numerically or graphically and does not want the data stored on the hard drive.

In addition, REFL.RAW, TRANS.RAW, and GRPDEL.RAW can be optionally used to store the raw measured DUT and calibration standards for user review, debug, and additional data analysis as needed. This option is enabled with 'Raw=1' in the applicable VNA.CFG file.

Note that the *.RAW and *.CAL files cannot be named within the programs by the user at this time. However, they can be re-named as needed externally.

Here's a brief summary of the key column headers in each of the DAT files. Much of this data also appears on-screen as well.

REFL.DAT

```
   Date
   Time
   Freq.MHz
   Reflection Coefficient:
      Real         - real part of the complex reflection coefficient
      Imag         - imaginary part
      |rho|        - magnitude
      deg          - polar angle in degrees
      RL.dB        - return loss in dB
   SWR             - (voltage/current) standing wave ratio
   Rs.ohms         - real part of the impedance in series form
   Xs.ohms         - reactive part of the impedance in series form
   |Zu|.ohms       - magnitude of impedance
   <Zu.deg         - angle of the impedance in degrees
   Q               - quality factor = |Xs|/Rs
   Cs.pF           - Xs expressed as a capacitor in series with Rs
   Ls.uH           - Xs expressed as an inductor in series with Rs
   Rp.ohms         - real part of the impedance in parallel form
   Xp.ohms         - reactive part of the impedance in parallel form
   Gp.mS           - Rp expressed as conductance
   Bp.mS           - Xp expressed as susceptance
   Cp.pF           - Xp expressed as a capacitor in parallel with Rp
   Lp.uH           - Xp expressed as an inductor in parallel with Rp
   Rdgs            - number of ADC readings averaged
   cfp             - value of Continuous Frequency Programming
   ZØ.ohms         - reference value for the reflection coefficient
   Cop.pF          - Open cal. standard value from VNA.CFG
```

```
   Rsh.ohms        - Short cal. standard value from VNA.CFG
   Lsh.nH          -   "    "      "      "      "     "
   Rld.ohms        - Load cal. standard value from VNA.CFG
   Lld.nH          -   "    "      "      "     "     "
   Cld.pF          -   "    "      "      "     "     "
   DUT Description - Optional user supplied description of the DUT
```

TRANS.DAT

```
   Date
   Time
   Freq.MHz
   |G|             - magnitude of the transmission gain
   |G|.dB          - magnitude of the transmission gain in dB
   <G.deg          - angle of the transmission gain in degrees
   Rdgs            - number of ADC readings averaged
   cfp             - value of Continuous Frequency Programming
   ZØ.ohms         - not used in calcs, for reference only
   DUT Description - Optional user supplied description of the DUT
```

GRPDEL.DAT

```
   Date
   Time
   Freq.MHz        - Center frequency of each aperture in MHz
   Apert.MHz       - Frequency aperture used
   mean |G|        - magnitude of the aperture mean (average) gain
   |G|.dB          - mean gain in dB
   <G.deg          - angle of mean gain in degrees
   delta.deg       - change in measured angle at the aperture endpoints
   GrpDel.Sec      - group delay in seconds.
   Rdgs            - number of ADC readings averaged
   cfp             - value of Continuous Frequency Programming
   ZØ.ohms         - not used in calcs, for reference only
   DUT Description - Optional user supplied description of the DUT
```

16. Contact the author

The author of the software and designer of the VNA hardware is Paul Kiciak, N2PK. Please report any program bugs, comments, or questions by e-mail to pkiciak@adelphia.net.

17. Acknowledgements

I wish to acknowledge and thank the following individuals for their contributions to the software portion of this project. Harold Johnson, W4ZCB, suggested the idea of re-usable calibrations. I initially resisted implementing this, but it is now a feature I would not do without. Bill Carver, W7AAZ, suggested a simple yet elegant way to extend the frequency range of the VNA into the VHF and UHF range. This resulted in the "Synchronous Common LO up/down mixing" frequency entry mode that is available in many of the programs. Bill also suggested providing the user with the option of naming the test data files - another feature that should prove generally useful. Jim Tonne, WB6BLD, graciously provided a wonderful jumpstart in the design of the Smith Chart that appears in the REFL program.

Harold Johnson and Bill Carver have also provided a great deal of assistance & feedback generally by building their VNAs and being the primary beta software testers.

Harold also now refers to his VNA as "the lab in a box."