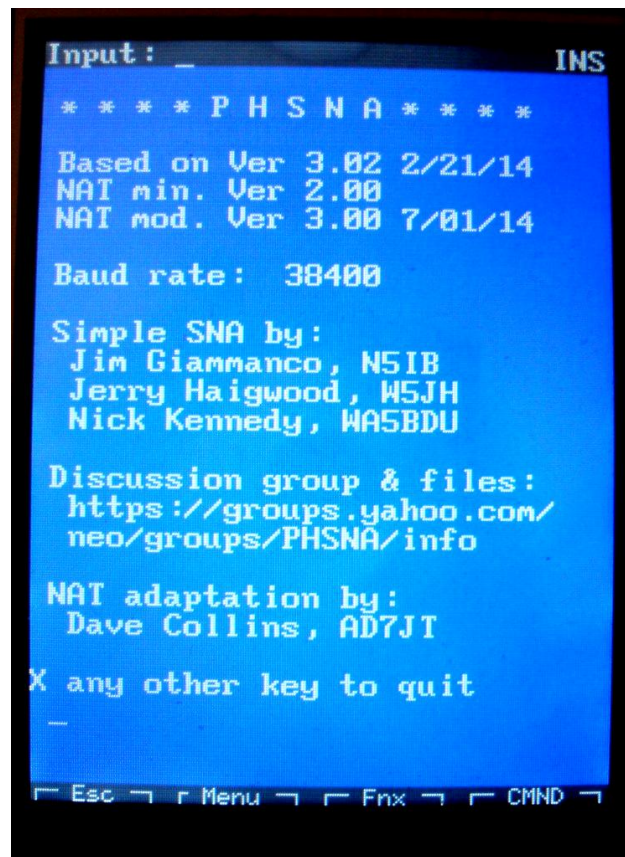


# POOR HAM'S SCALAR NETWORK

## ANALYZER (PHSNA)

### **User Guide**

*Modified Firmware Version 3.00*



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## **1 GENERAL INFORMATION**

The Poor Ham's Scalar Network Analyzer (PHSNA) firmware was initially developed to interface and be controlled by a PC either running a terminal emulator or executing Excel with a special VB macro that enables communications between the PHSNA firmware and the spreadsheet. The Network Analyzer Terminal was developed to replace the PC in either or both of its PHSNA roles.

An initial goal in the Network Analyzer Terminal (NAT) development was to minimize the changes to the standard PHSNA firmware to preserve the look and feel of the user interface and to minimize support efforts in anticipation of future releases. It was also felt that this approach would enable you, the user, to make use of existing PHSNA documentation. As a result, while developing the initial NAT firmware release (V1) the PHSNA firmware was changed little. Most of the changes were related to reformatting PHSNA menus and prompts to look better on the 30-character wide NAT display. It was expected that most users would prefer to use the NAT in PLX mode which is form-driven, not menu driven. However, the dumb terminal appearance and endless scrolling was not well received and menu mode was deemed to be not very user friendly.

During the development of NAT firmware V2, which activated the NAT's touch screen, it became evident that the minimal modification of the PHSNA firmware was not really effective. As a result, it was decided to completely overhaul the PHSNA menu system and release a modified version of the PHSNA firmware intended to only be used with NAT firmware V2 and later. The prime goal was changed to make the PHSNA menu system as user friendly as possible; however, the underlying functionality and capabilities remain unchanged from the unmodified, standard PHSNA firmware.

Appendix A of this document lists the more significant changes made to the modified PHSNA firmware since modification version 1.0 was released.

This version of the PHSNA firmware is labeled "PHSNA\_03\_02\_NAT\_02\_00\_V\_3\_00". The naming convention breaks down as follows:

PHSNA_3_02	The standard PHSNA firmware version this modification is based on (v3r02).
NAT_02_00	The minimum NAT firmware this modification is intended to run with (V2.00)
V_3_00	This revision of the modified firmware (V3.00)

After release, the modified PHSNA firmware can be downloaded from the following web site:

<http://midnightdesignsolutions.com/nat/>

Please direct any and all questions, comments, suggestions, critiques, etc to the authors:

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## 2 INTRODUCTION

First we need to get the disclosure out of the way.

```
*****
***   THIS FIRMWARE IS PROVIDED IN AN "AS IS" CONDITION. NO WARRANTIES,   ***
***   WHETHER EXPRESS, IMPLIED OR STATUTORY, INCLUDING, BUT NOT LIMITED   ***
***   TO, IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A        ***
***   PARTICULAR PURPOSE APPLY TO THIS SOFTWARE. THE AUTHOR(S) SHALL     ***
***   NOT, IN ANY CIRCUMSTANCES, BE LIABLE FOR SPECIAL, INCIDENTAL OR     ***
***   CONSEQUENTIAL DAMAGES, FOR ANY REASON WHATSOEVER.                   ***
*****
```

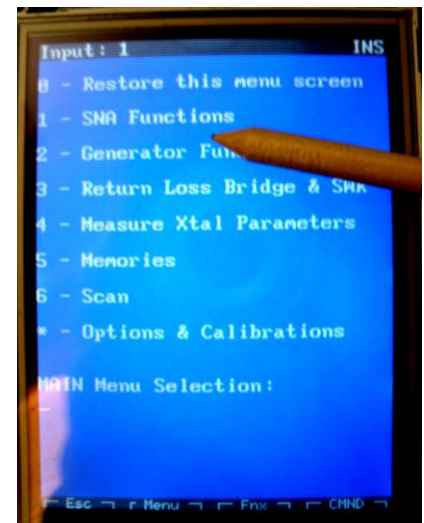
The PHSNA firmware including the modified version is open source and can be used and distributed freely. It can be customized to meet specific needs; however, we will only maintain the released version.

This document describes the modified PHSNA firmware menu system as seen from the NAT display. It does not provide detailed description of the NAT and its firmware beyond what is necessary to better describe operation with the PHSNA menu system. It also describes the installation of the PHSNA firmware and any required setup operations necessary for PHSNA operation under NAT control. It does not cover PLX mode operation; that topic is covered in detail in the NAT User Guide.

All of the menu operations and actions can be performed from the NAT's keyboard. With a few exceptions, all of these operations and actions can also be performed without a keyboard attached to the NAT using only the touch screen. This document primarily concentrates on touch screen operation.

It is important to note that there is no "special" communications protocol between the PHSNA firmware and the NAT. The PHSNA firmware always "thinks" it is either talking to a dumb terminal or to a VB macro running as part of an Excel spreadsheet. The NAT is unaware of what the PHSNA firmware is doing; it is only giving simple responses to menus and prompts and displaying and processing received data according to its operating mode and a few simple hot-key commands issued by the operator.

Before getting into specifics, it is worth while looking at how the NAT firmware can make selections from menus and respond to prompts without knowing anything about the meanings of the menu items and the prompts. In the picture on the right, we see the stylus touching the NAT screen with the PHSNA firmware's main menu displayed.



### 2.1 SINGLE-CHARACTER RESPONSES

The first thing to note is that all menu selections require only a single character to be transmitted to the PHSNA firmware. In this case, only a single character response is sent; there is no following carriage return.

When inputting from a keyboard, the character is entered on the input line and is not transmitted until the operator presses the Enter key. Holding down the Alt key while pressing the Enter key will send the response character but will suppress the trailing carriage return. Multi-character responses will always require a trailing carriage return.

#### PLEASE NOTE

Characters displayed on the input line have NOT been sent to the PHSNA firmware.  
They will not be sent until the stylus is raised or Enter is keyed.

### 2.2 SELECTION FEEDBACK

Note the figure '1' on the input line. This is showing you what will be sent to the PHSNA firmware when the stylus is raised from the screen. The text that is displayed on the NAT screen is buffered in a line buffer. In terminal mode, after a touch, the firmware will determine which line the stylus last touched

and will return the first character in the buffer for that line to the PHSNA firmware. If the first character position is blank (space), the firmware will return the first character in the line immediately above. This is why the menu is double spaced; it doubles the size of the touch target. The recommended way to do a menu selection is to aim for the base line of the line item you want to select. If the Input line doesn't show the response you want to send, drag the stylus up or down accordingly. This procedure enables touch screen operation even when the touch screen is somewhat out of calibration.

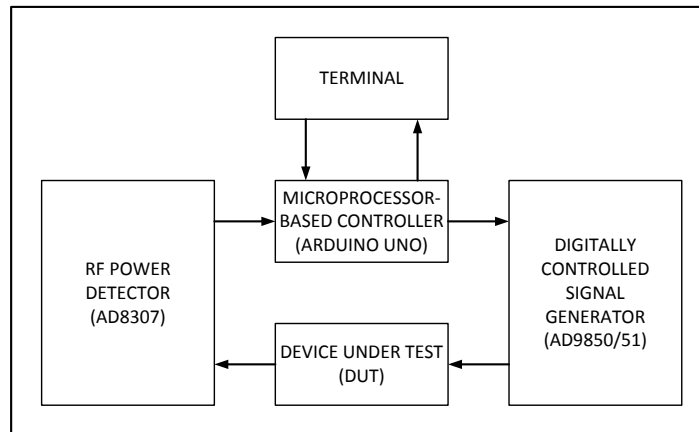
The current selection is shown on the input line while the stylus is touching. If the stylus is dragged up and down, the displayed character will change in accordance with the stylus position. If the stylus is raised from a line that does not put a character on the input line, nothing will happen; spaces are ignored.

## **2.3 SPECIAL EXTENDED CHARACTER SET**

Single character responses are not limited to letters and numbers. Note that the response to select the last line on the main menu is an asterisk (\*). Responses are also not limited to printable/displayable characters; any 8-bit character can be used except space (0x20) and null (0x00). This capability is used in some cases to generate special control characters to perform special functions such as clearing the NAT screen and to generate special hot-key sequences such as Ctrl-S and Home. When the character does not have a defined font, the NAT will display a negative (foreground and background colors reversed) question mark ("❓"). In these cases, the text on the menu or prompt line will generally say what the character is. A following example will illustrate this.

### 3 INITIAL SET-UP

The following block diagram illustrates the basic architecture of the PHSNA system:



Here we will assume the block marked "TERMINAL" is a NAT and the up and down arrows beneath the block represent receive and transmit lines in the serial interface. The block diagram shows an Arduino UNO microprocessor used to control the signal generator and receive power level information from the RF Power Detector. There is at least one other PHSNA version that uses an Arduino NANO for the microprocessor. The two versions are equivalent and the modified firmware will run in either version without change. It will, however, be necessary to inform the Arduino programmer/IDE which Arduino board is being used.

#### 3.1 PHSNA FIRMWARE LOADING

The PHSNA firmware is distributed as a collection of source code files packaged in a single zip file. The zip file also contains some informational files. The source files have file extensions of ".c" and ".ino"; the information files have file extensions of ".txt". The file set should be unzipped into a single folder with the same name as the firmware release (e.g., "PHSNA\_03\_02\_NAT\_2\_00\_V\_3\_00"). After unzipping, make sure all source files are in the one directory.

It is recommended that the Arduino IDE be used to load the PHSNA firmware. This IDE is very simple and straight forward to use and can be downloaded free from the Arduino web site:

<http://arduino.cc/en/Main/Software>

Versions of the IDE are available for Windows, Mac OS X, and Linux. This document assumes the Windows version, the others are similar. Follow the instructions on the Arduino web site to download and install the IDE. Connect the USB cable to an available port on the PC and connect to the USB port on the Arduino board in the PHSNA controller.

Once the IDE is loaded and started, the PHSNA firmware source files can be opened in the IDE. One of the files is the firmware starting point and it must have the same file name as the directory it resides in and must have a file name extension of ".ino". To open the firmware file set in the IDE select open in the File drop-down on the menu bar and navigate to the starting file with the same name as the folder. Click open and all of the source files in the directory will open in the IDE.

Next, use the "board" option in the Tools drop down to select the Arduino board you are using (normally UNO or NANO). The IDE should now locate the USB port the Arduino board is connected to. Use the Serial Port selection on the Tools drop down to confirm that the IDE has selected the correct port. If you are not sure what port the controller is on, use the Windows Device manager to list the active USB ports. The list will identify which port the controller is on.

The file set can be checked by just compiling it in the IDE. This is done using the button with the check mark on it on the IDE tool bar. Clicking the button with the right-pointing arrow will compile and load

the object code to the Arduino board. Compiling and loading progress will be displayed in the message area at the bottom of the IDE window. The message “Done uploading” indicates that the firmware has been compiled and loaded into the microprocessor.

### **WARNING**

**The USB port and the NAT share the serial port to the microprocessor. For this reason, the NAT must be disconnected from the microprocessor serial port during the firmware upload. If you forget, you will get an “avrdude: not in sync” error message.**

## **3.2 SETTING THE SERIAL INTERFACE BAUD RATE**

The PHSNA controller and the NAT serial interface baud rates must be the same before they can communicate. The NAT's baud rate can be set in command mode as a menu option. The PHSNA firmware baud rate is hard coded but can be changed in the source code. To change the PHSNA firmware baud rate, scroll down the start-up source file to the section labeled “SETUP() Function” (about line 233 in the current version). You should see the following lines of code:

```
// Set baud_rate to the desired bit rate for the serial port. The reliable
// rates for use with the NAT are: 1200, 2400, 4800, 9600, 14400, 19200,
// 28800, and 38400.
```

```
long baud_rate = 38400;
```

The double slash (“//”) at the start of a line means that line is a comment line and will be ignored by the compiler. The comments list the baud rate settings at which the serial interface can be reliably operated with. Edit the line of code following the comments by entering the desired baud rate after the equal sign and before the ending semi-colon.

The code above shows the baud rate is 38400 bps which is the default for the current release. Slower rates will work but the current firmware version will not reliably run faster than 38400 bps.

Changing the baud rate will require the source code to be recompiled and reloaded into the controller. It will also be necessary to cycle power on the NAT after a baud rate change.

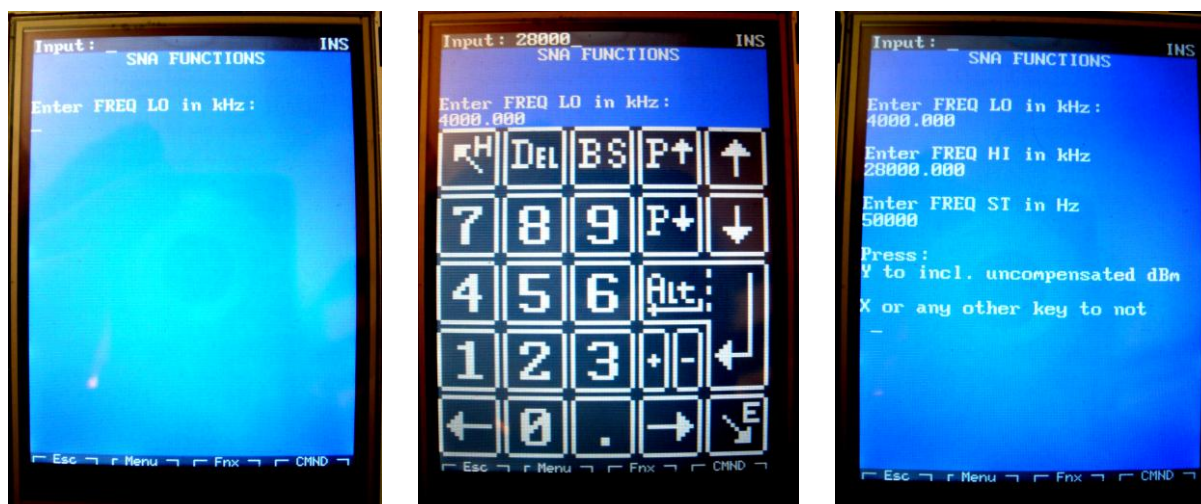
## **3.3 SYSTEM START-UP**

Once the firmware has been loaded, the serial interface connected, and everything powered up, you are ready to use your PHSNA system. The NAT will normally come up in Terminal mode ready to display text received from the PHSNA firmware. Pressing the reset button on the Arduino board will start the action. The PHSNA firmware will send a number of information lines to the NAT showing the current state of a number of operating parameters including the serial port's current baud rate setting.. These lines will be displayed for a few seconds and then the PHSNA main menu will be displayed. A Picture of the PHSNA main menu was shown above in the Introduction section. Menu selections are made as described in the same section.



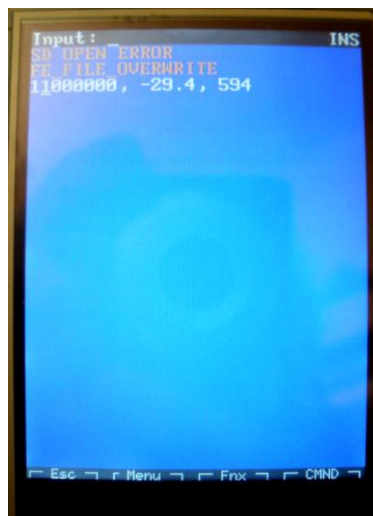
## 4 OUR FIRST SWEEP

It will be helpful to go step-by-step through an example using the PHSNA menu system to perform a scan and plot the results. This example assumes the Device Under Test (DUT) is a 7 MHz low pass filter (LPF). We will use main menu option #1, SNA Functions, to perform our scan. After selecting SNA Functions the PHSNA firmware will prompt you for the parameters needed to perform the scan. In this case, the firmware needs the starting frequency (FREQ LO), the ending frequency (FREQ HI), and the frequency step size (FREQ ST). You will also be asked if you want the data to include the uncompensated power readings to be included in the data set.



The initial parameter input screen only asks you to input FREQ LO as is seen in the first screen shot above. After FREQ LO has been entered, you will be asked to enter FREQ HI, and so on. Data can be entered with the keyboard or with the NAT's num pad as shown in the center screen shot. (The num pad is activated by tapping once on the input line and is deactivated when one of the Enter keys is tapped.) Once the frequency parameters have been entered, you are asked if you want the uncompensated (un-calibrated) data included in the data set. Once you make this selection, the sweep will begin. Note that, in this case, FREQ LO and FREQ HI are entered in kHz and FREQ ST is entered in Hz. The kHz values are shown to three decimal places so they are essentially displayed in Hz. They can be entered with decimal places too so virtually any frequency can be entered within the limits of the DDS signal generator. The PHSNA firmware currently limits FREQ LO to 1 MHz or above and requires FREQ HI to be greater than FREQ LO and less than an upper limit determined by the DDS chip used in the signal generator. If you enter a value outside of these limits, the PHSNA firmware will repeatedly ask for the same parameter until you enter one within the limits.





After all the sweep parameters are entered, a summary of the selections is shown and you are given the option to abort the operation and quit or to run the scan. If a log file has been specified (see NAT User Guide) the data may be spooled to the log file on the SD Card. If the user selects CTRL-R and the specified log file does not already exist, one will be created and all received data rows will be spooled to the new file. In this case, if the specified log file already exists, an error will be posted and data will not be spooled. If the user selects ALT-R and the specified log file already exists, that file will be deleted, a new file created with the same name, and all received data will be spooled to the new file.

During the scan, a screen such as the middle one above will be displayed. The data is received in a comma separated value (csv) format. Each data row ends with a carriage return. Data rows are all displayed on one line, continuously overwriting the data from the previous row. This avoids having to scroll the display. In this example, the first field is the frequency, the second is the compensated power output reading in dBm, and the third field is the raw reading from the ADC receiving the power meter output. If we had selected to include the uncompensated power output readings, that value would be in field three and the raw ADC readings would be in a fourth field.

The two reddish lines at the top of the display are reporting a file management situation. In this case, the operator selected CTRL-R and the specified spool file already existed. The first line indicates an error was detected when trying to open the log file on the SD card. The second line indicates the error was reported because a file with the specified file name already exists. If a file with the log file name did not exist, the NAT would have created and opened a file having that name for writing and would have spooled the data to it as it was received from the PHSNA. In this case, the data row display would be on the top line of the display. Setting up the log file and the various other file management errors that could occur at this point are described in the NAT User Guide. In either case, if a new file is successfully opened, no error or warning messages are displayed.

After the data set has been received and buffered, it is processed and plotted along with some analysis of the data set. An example is shown in the third picture above. The plot format and details are described in the NAT User Guide. Once the data is plotted it will be displayed until the user enters Escape either from the keyboard or by touching the permanent Esc button in the lower left corner of the display. Entering Esc once will clear the plot display and return to the first display of the three shown above. Here the user may choose to quit (Esc) or rerun the sweep and plot (CTRL-R or ALT-R). Selecting Esc will exit to the main menu.

### PLEASE NOTE

**In some cases it may be necessary to enter Esc more than once to get the desired result.**

This example gives us a feel for how the menu system works. The following sections briefly describe each menu option including what parameters need to be provided and what the result will be.

## 5 MAIN MENU OPERATIONS

The above example gives us a feel for how the menu system works. The following sections briefly describe each main menu option including what parameters need to be provided and what the results will be. Note that the following discussion only describes the significant points in each function, menu, and prompt. Obvious items like selections to quit the function are generally not covered.

### 5.1 SNA FUNCTIONS

The SNA function performs a single scan across a defined frequency range and returns a list of data points showing the frequency and the output power level measured at that frequency.

Initial inputs:

- FREQ LO in kHz
- FREQ HI in kHz
- FREQ ST in Hz

You also have the option to include uncompensated power readings in the data set. The scan and the data set transfer are started when you press either CTRL-R or ALT-R. After the data set transfer is complete, the NAT will plot the data. The plot will be displayed until you enter Esc and then you will be given the option to repeat the scan or exit to the main menu.

### 5.2 GENERATOR FUNCTIONS

The generator function lets the operator set the signal generator output frequency and adjust it up and down while the RF signal is being generated.

Initial inputs:

- Frequency in kHz
- FREQ ST in Hz

The step size and the current DDS frequency are show at the top of the display followed by the last measured output power level as the raw ADC output value and in dBm. A number of options are listed to adjust the DDS frequency up and down by FREQ ST and to change the size of FREQ ST. Options are also listed to reread and update the current output power level one time or continuous (about four times per second).

### 5.3 RETURN LOSS BRIDGE & SWR

Similar to the SNA Function except the VSWR is also calculated and displayed.

Initial inputs:

- FREQ LO in kHz
- FREQ HI in kHz
- FREQ ST in Hz

You are then asked to disconnect or short the unknown RLB port so the firmware can calibrate the RLB. A summary of the selections is then displayed with options to run the scan or quit. The scan and the data set transfer are started when you press either CTRL-V or ALT-V. If run the scan is selected, the scan is run, the data captured and plotted. Pressing Esc with the plot displayed returns to the option display and the scan can be repeated or you can quit and return to the main menu. If you select CTRL-V and the log file already exists, an error will be posted and the data will not be spooled. If the log file does not already exist, a new log file will be created and the data will be spooled to it. Selecting ALT-V will delete any existing log file and create a new one of the same name and spool the data to it.

Note that even though the PHSNA firmware is computing the VSWR and including it in the data stream, the NAT firmware is actually computing the VSWR data that is plotted. If the data is spooled to the log file, the VSWR data computed by the PHSNA firmware is spooled. The VSWR calculations done by the NAT firmware are only used for the plot.

## 5.4 MEASURE XTAL PARAMETERS

This function is provided to measure the operating parameters of quartz crystals. It is typically used to grade crystals for use in crystal filters. This function performs the following:

1. A name (default "XTAL") can be entered and assigned to and included in the data set.
2. The crystal test fixture can be calibrated by shorting the crystal socket pins and specifying a frequency at which to measure the 0.0 dBm power meter output level. The user has the option of taking a new measurement or using a value previously stored in EEPROM. A new measurement may be stored in EEPROM for future use.
3. Insert the first crystal to be measured and enter the following:
  - a. Test fixture termination resistance (typically 12.5 or 50 ohms).
  - b. FREQ LO in kHz
  - c. FREQ HI in kHz
4. FREQ ST is automatically set to 1Hz. A scan is made (this may take several seconds) and the results are displayed.
5. You are given the option to exit and return to the main menu or to do another scan. If another scan is made, you have the option to change the name field (step 1). Each scan uses the same parameters.

The NAT cannot process this data stream as it is so intermixed with menu prompts and input data as to not be readily recognizable. If you need to plot and/or spool the data, consider using the NAT in PLX mode as described in the NAT User Guide.

## 5.5 MEMORIES

The PHSNA manages a set of ten memory cells in EEPROM that you can set to ten different frequencies. Selecting one of these memory cells will set the signal generator to that frequency. The Memories function lists the current frequency settings and let you select one to set the signal generator frequency. It also offers options to program and clear individual memory cells.

## 5.6 SCAN

This function performs a continuous sweep of a specified frequency range using a specified frequency step. The frequency changes from FREQ LO to FREQ HI in steps of FREQ ST. When the frequency goes above FREQ HI, it is reset to FREQ LO. You can also specify a time delay between steps.

Initial inputs:

- FREQ LO in kHz
- FREQ HI in kHz
- FREQ ST in Hz
- Delay/step in ms

Once the data is entered, the sweep runs continuously and a menu is displayed offering the option of changing any of the entered parameters while the sweep is in process. You can also temporarily pause and restart the sweep. When the sweep is paused, the signal generator continues to output the RF signal and the current frequency is displayed.

## 6 OPTIONS & CALIBRATIONS MENU OPERATIONS

The last option on the main menu selects a submenu of setup and calibration functions that would normally only be used to set static operating parameters or to set operating modes.

### 6.1 AD8307 SLOPE / INTERCEPT

This function calculates the slope and intercept parameters used to calibrate the output from the RF power meter. You are asked to apply two or more RF signals of known power level to the input of the RF power meter. After each signal is applied, you enter the known power level in dBm. In response, the PHSNA records and displays the resulting power meter output level. After the last power level has been entered, enter a value of 100 to terminate the input session. The PHSNA then displays the calculated slope and intercept parameters and gives you the option of saving them to EEPROM. If the input data and measured power levels do not yield valid slope and intercept levels, the PHSNA will display "nan" (not a number) for their values. This can happen, for example, if two different power levels are input that yield the same power measurement.

### 6.2 CURVE FIT POLY CONSTANTS

The PHSNA measurement system must be calibrated to get accurate results. Once calibrated, a sixth-order polynomial equation is applied to each power level measurement to yield power readings in dBm. You must enter these values and save them to EEPROM to complete the PHSNA calibration process. The procedure for generating the six polynomial coefficients can be found in the document:

[Calculations compensate for SSNA output change vs frequency.pdf](#) by Jim Giammanco, N5IB

which can be downloaded from the Files section of the PHSNA Yahoo Group:

<https://groups.yahoo.com/neo/groups/PHSNA/files>

Once the coefficients are known, they can be entered, one at time, and saved to EEPROM. You also have the option of clearing all six coefficients in EEPROM.

### 6.3 DDS REFERENCE FREQUENCY

With this function, you determine an adjustment factor to be used when setting the signal generator DDS output frequency. The output frequency is set to 10.0 MHz and you are directed to feed the RF output to a frequency meter/counter. You are then presented with a number of options to increase or decrease the reference clock frequency until the frequency meter/counter registers as close as possible to 10.0 MHz. The result may be saved to EEPROM for future use.

The algorithm for calculating the set frequency command value is normally explained in the data sheet for the specific DDS device used.

### 6.4 TOGGLE PLX (EXCEL) MODE

This function sets or clears a flag in EEPROM that determines what mode the PHSNA will start in when first powered up. You select 'P' for PLX mode, 'N' for Normal (menu) mode, or X to exit without change.

When the PHSNA firmware starts in PLX mode, it repeatedly tries to access spreadsheet cell "L2". This is a test to determine if the Excel macro is running. After 30 unsuccessful tries, the PHSNA firmware displays the main menu. The repeated attempts to access L2 can be stopped by pressing or touching Esc. Use this function to change the EEPROM mode flag to normal to avoid starting in PLX mode every time.

### 6.5 SET START-UP FREQUENCY

Enter the frequency (in kHz) the signal generator will be started in each time the PHSNA is powered up.

## **6.6 TOGGLE AD9850/51 MODES**

The PHSNA firmware must know which DDS is being used in order to accurately specify the output frequency. This function displays the current setting and gives you the option of changing it or exiting without change. The result is saved in EEPROM.

## **6.7 ABOUT PHSNA**

Displays the information screen shown on the cover page of this document.

## **APPENDIX A. RELEASE NOTES**

### \* Version 02.00

- \* 1. Many menu changes to accomodate NAT screen and touch screen options and menus.
- \* 2. Added Version info to main menu intro.
- \* 3. Reworked SNA Functions to automate all after starting recording.

\*

### \* Version 02.01

- \* 1. Double-spaced the main menu
- \* 2. Reworked Generator Functions for touch screen and added manual dBm update
- \* 3. Reworked RLB Functions - will require NAT V2.00 to be fully functional
- \* 4. Added Ctrl-R and Ctrl-V characters to prompts for touch screen use.
- \* 5. Extensive rework of menu system for MM items 1, 2, and 3 and abandoned marking changes with my call sign.
- \* 6. Decided to require NAT V2 to run this version of the PHSNA firmware.
- \* 7. Completed menu system overhaul.

\*

### \* Version 03.00

- \* 1. Merged SNA and RLB functions to save program memory space.
- \* 2. Made a lot of say\_ functions to save program memory space.
- \* 3. Added Alt-R and Alt-V to SNA and RLB menus to allow file overwriting.
- \*c 4. Receiving ESCAPE character while in main menu loop escapes to loop() loop thus simulating a reset.
- \* 5. Changed baud rate to ram variable and added it to the say\_version list.
- \* 6. Added more places for Escape to terminate PLX mode immediately.
- \*d 7. BUG FIX - Alt-V was improperly encoded.
- \* 8. Added Escape to the switch for returning to the main menu from the option menu to avoid a hang when starting a PLX operation while in the option menu.
- \*