

Upgraded Software for the W8TEE/K2ZIA Antenna Analyzer - Version 03.0

John Price - WA2FZW

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Introduction

The W8TEE/K2ZIA antenna analyzer was originally developed as a club project for the Milford Amateur Radio Club. The original author of the software, Jack Purdum, published the design and code online on the Yahoo [SoftwareControlledHamRadio_group](#) (which has now been moved to the [SoftwareControlledHamRadio_group](#) on Groups.io). Jack also published an article about the project in the [November 2017 issue of QST](#).

My main objective in modifying the software was to make it work on the 6 meter band (which requires replacing the AD9850 DDS with the higher frequency AD9851). In the process of going through the original code to figure out how to accomplish this, I did find a number of potential and actual bugs in the code (Definition: Working Software - Software with only undiscovered bugs) and came up with some enhancements to make it easier to use. Then I got a little carried away!

One might question why the initial release is Version 03.0. This software went through a couple months of testing and enhancement before it was deemed fit for public consumption.

Here, I will describe the operation of the analyzer using this software.

Acknowledgements

First of all, thanks to Jack (W8TEE) and Farrukh (K2ZIA) for the outstanding initial work on the project. Thanks to Edwin (PE1PWF) for the initial software work to add 6 meters and the modifications necessary to use the AD9851 DDS and for doing some really thorough analysis of the performance and investigation of ways to improve the hardware. Thanks to Jim (G3ZQC) and Dick (K2RH) for testing the new software as development progressed (it's still not finished). Thanks to Glenn (VK3PE) for his contribution of the AD8307 detector circuit. This greatly improves the accuracy of the SWR readings, and also for a lot of testing and debugging.

Hardware Modifications

There are three optional hardware modifications that can be made to the unit to take full advantage of the capabilities of this software.

Replace the AD9850 DDS with the AD9851

The [AD9851 DDS module](#) is pin compatible with the AD9850 Type II module used in the original design. It is alleged to be capable of operating at higher frequencies than the AD9850. If you desire to use the analyzer on 6 meters, you should consider making the change.

The only real hardware change other than swapping out the board that needs to be made is to put a jumper between the anode of diode D5 and the cathode of diode D6 on the board. This increases the voltage to the DDS from around 3.5V to around 5V.

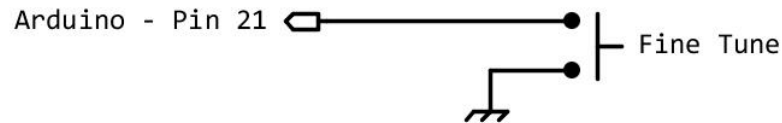
Instead of installing a permanent jumper on my own board, I ran the wires to a connector mounted on the edge of the board so a jumper plug can be installed or removed to undo the change.

The “Fine Tune” Option

In the original software, the band limits could only be set in 100KHz steps and the fixed frequency for the single frequency SWR reading could only be adjusted in 5KHz steps.

With the addition of a push button, the adjustment increments can be stepped through 100KHz, 10KHz or 2KHz. For the 6 meter and “Custom” bands which have much wider ranges than the HF bands, the frequency can also be tuned in 1MHz steps.

To modify the hardware, another switch is required; a push button type connected between between pin 21 of the Arduino and ground as shown here:



Wiring Diagram for Fine Tuning Button

If the modification is not installed, the software will function as it did in earlier versions, except that you will see a carat character ('^') displayed under the digit that will be changed when you rotate the encoder knob. If the modification is installed, you can move the carat with the button.

The button is enabled or disabled based on the definition of "FT_INSTALLED" in the "My_Analyzer.h" file. If the button is installed, un-comment the line reading:

```
#define FT_INSTALLED
```

If the button is not installed, the line should be commented out.

Better SWR Readings

Because of a number of factors in the original design of the hardware, although the analyzer will do a good job of showing you the frequency where the minimum SWR occurs, the accuracy of the actual numbers is not so good. We tried a few software solutions to improve the data with little success.

There are 2 modifications that can be made to improve the accuracy of the readings. The first, and easiest to implement is described in [this document from Edwin \(PE1PWE\)](#), and just involves some minor changes to the original circuit and a tweak in the software.

The 2nd approach which probably offers better results was developed by Glenn (VK3PE). He designed an add-on circuit board to replace the entire detector circuit. [The details can be found on the SoftwareControlledHamRadio group web page](#). His modification does require some software changes, which have been included in this software.

Major Software Changes

Internally, the changes in this version of the code are too numerous to list, but as a user of the analyzer, the reader is probably much more interested in how it operates.

Rather than list all the changes here, I will just describe how each feature now works.

Installation on Your Computer

The program (why do they call them sketches?) consists of 2 files; the “.ino” file (whatever its current name is) and a header file, “My_Analyzer.h”. Both files need to be installed in a directory with the same name as the “.ino” file.

Due to the software changes, this new version will not work with files saved on the SD card created with the original (W8TEE) software, therefore, you should delete any old files before trying to read them with the new code.

Also, the structure of the data stored in the EEPROM has changed from the W8TEE versions and must be erased prior to installing this software. I have provided a separate “Erase_Eprom” program that *MUST* be used to accomplish the task before loading this software.

There is also a “Read_Eprom” program that will display the contents of the EEPROM on the Arduino IDE’s serial monitor. These functions are also built into the program however, the built-in “Erase EEPROM” function does not reset the file sequence number in the EEPROM.

Pre-Installation Edits

For All Users

Before you compile and install the software on your analyzer, there are some edits to be made in the “My_Analyzer.h” file. BTW, I use the program “Notepad++” for editing “.C” and “.h” files, although you can just as easily use the Arduino IDE.

There are 3 “#define” statements that determine which hardware options you have installed. You must select between the AD9850 DDS and the AD9851 DDS, and make sure the one for the DDS you are using is un-commented, and that the other one is commented out.

The 3rd “#define” should be un-commented if you have Glenn’s AD8307 modification installed. Make sure it is commented out if the modification is not installed.

If you want to enable 6 meter operation, you may need to modify the line that reads:

```
#define ADD_6_METERS
```

If you want to use the analyzer on 6 meters un-comment this line. If you don’t want 6 meter operation, this line needs to be commented out. Note that 6 meter operation will only be enabled if the AD9851 is also enabled (although, you can fudge this).

You can also change the 6 meter band limits. I have them set for use from 50MHz to 54MHz now. If you want to change the limits change the numbers on the lines that read:

```
#define    LOW_6M_EDGE    50000U
#define    HIGH_6M_EDGE   54000U
```

Make sure to leave the “U” at the end of the numbers, or all kinds of strange behaviors will be observed!

The final edits have to do with the newly added capability to add a “Custom” band, which you can set for any frequency range you desire. To enable or disable this feature, comment or un-comment the line that reads:

```
#define ADD_CUSTOM
```

As was the case for the 6 meter band, you can modify the band limits by changing the values on the lines:

```
#define    LOW_C_EDGE    1000U
#define    HIGH_C_EDGE   30000U
```

Again, make sure to leave the “U” at the end of the number. The limits are currently set to scan from 1MHz to 30MHz. Do not attempt to set the lower band edge to less than 1MHz.

Be aware that when you use this capability, you will be transmitting a low power signal across all frequencies in the set range, including frequencies that are not amateur radio frequencies.

Once you have made the changes to the “.h” file and run the “Eprom_Erase” program, you can compile and load the program just as you would any other Arduino program.

Edits for Non-USA Users

The frequency limits for each band are set in the software based on the [USA's frequency allocation chart](#). Other countries may have different allocations, and thus you should modify the frequency table for your country.

The band limit definitions are near the top of the “.ino” file:

```
uint32_t bandEdges[][2] = { { 1800,  2000 },    // 160 Meters
                             { 3500,  4000 },    //  80 Meters
                             { 5330,  5404 },    //  60 Meters
                             { 7000,  7300 },    //  40 Meters
```

I didn't show the whole table here. The frequency definitions are in MHz divided by 1000. To change the upper or lower limit for any particular band, simply change the number. Be careful though to leave the commas and braces where they are, or you're going to have problems compiling the code.

Using the Arduino IDE Serial Monitor

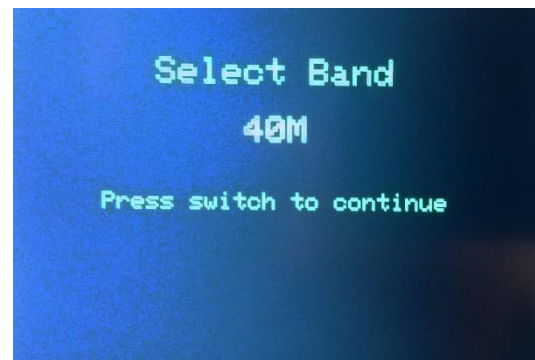
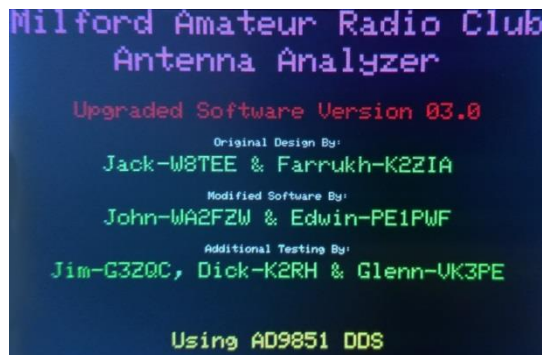
A couple of the functions in the analyzer make use of the Arduino IDE's serial monitor as an output device ("Plot>Serial" and "EEPROM>Serial"). If you plan on using these features, you must set the baud rate for the serial monitor to 9600. That can be done with a button at the lower right hand corner of the serial monitor window.

Startup

When you turn the analyzer on, you will be greeted by a screen showing all the credits for 3 seconds followed by a screen asking you to select the band you wish to use.

Note, at the bottom of the startup screen, it tells you which DDS you are using and whether or not you are using the VK3PE detector circuit.

Also note, if you failed to enable one of the DDS types in the "My_Analyzer.h" file, an error message will start flashing on the display and program execution will stop.



The first time you turn the analyzer on with this software the "Select Band" screen will display "40M" in the selection box. After the analyzer has been used once, the band displayed will be the last one that you used.

You can rotate the encoder knob right or left to select a different band. Pushing the encoder switch will save the selection.

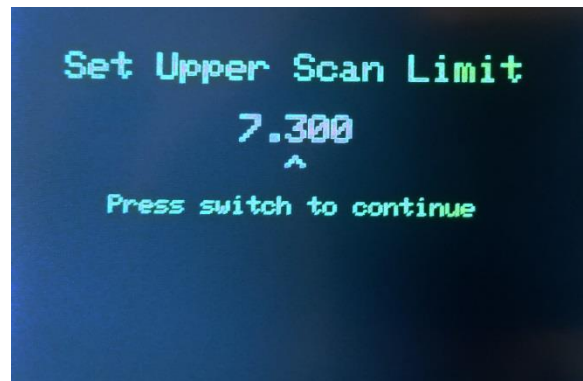
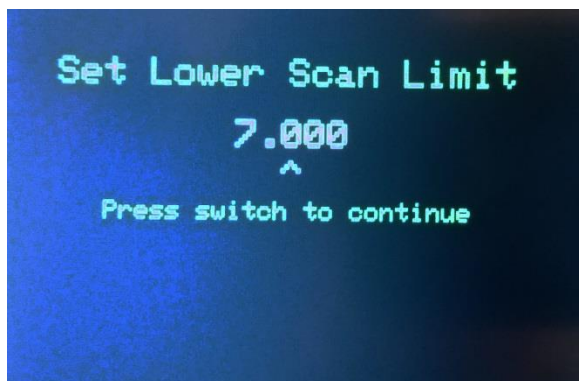
The next screen will ask you to “Set Lower Scan Limit”. The selection box will display the lower (US) frequency limit for the band selected in the previous step (or the limit you previously set for the selected band). Again, rotating the encoder knob to the right or left will raise or lower the frequency in 100KHz steps if the “Fine Tune” hardware modification has not been made. If the “Fine Tune” option is installed, the frequency can be changed in 100KHz, 10KHz or 2KHz steps by using the “Fine Tune” push button to move the cursor. For 6 meters and the “Custom” band, the frequency may also be changed in 1MHz steps.

The software will allow you to set it equal to or less than the selected lower band limit, but it will not allow you to set it equal to or higher than the currently set “Upper Scan Limit”

Pushing the encoder switch will save the frequency.

The third screen asks you to “Set Upper Scan Frequency”. This works just like setting the low frequency except it won’t allow you to set it to less than or equal to the low frequency setting.

It’s also a good idea to not make the scan range less than 100KHz.



Main Menu

Once the band information has been set and saved, the main menu will be displayed. Currently there are three items in the main menu, “Analysis”, “View/Save” and “Maintenance”.

Rotating the encoder knob one way or the other will move the selection highlight, and pushing the encoder button will select it.

In the following sections, we will discuss the selections under each heading.

Analysis Menu Items

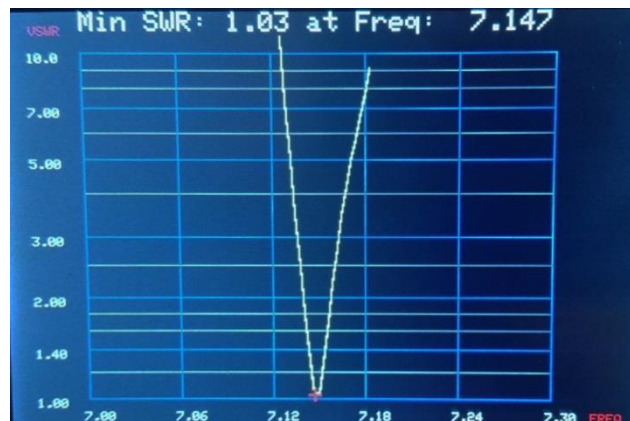
Currently, there are five choices under the “Analysis” menu item (not counting the choice to go back to the “Main Menu”). The following sections will describe what each does.

Single Scan

This option will scan the antenna from the lower frequency limit previously set to the upper frequency previously set and produce a graph of the SWR versus frequency.

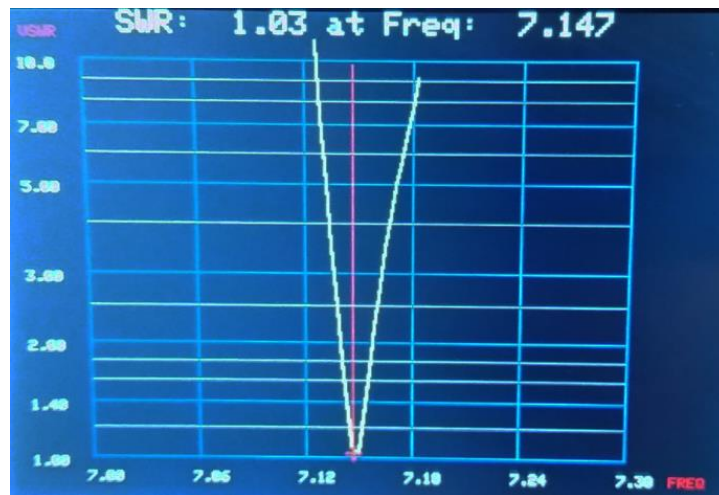
The SWR values are plotted on the vertical axis, and the frequencies on the horizontal axis. A red ‘+’ marks the minimum SWR on the graph, and the minimum SWR value and the frequency at which it occurred are shown in the heading.

This is a scan of my 40 meter magnetic loop done with the band limits set for 7.0MHz to 7.3MHz.



Notice, that we changed the vertical axis from a linear scale to a logarithmic scale, which is how SWR readings should really be plotted. This change also allows a maximum SWR reading of 10:1 to be plotted as opposed to the 3:1 limit in the original software.

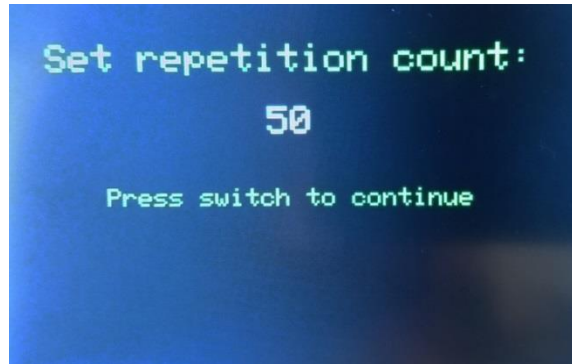
Once the scan is completed, rotating the encoder knob will produce a red vertical line on the plot that can be moved right or left. At the same time, the information in the header will change to show the frequency that the red line is on and the SWR at that frequency. The same thing can be done after using the “Repeat Scans” or “View Plot” options.



Pushing the encoder switch will return you to the main menu. If you don't want to use the “Examine” feature, simply pushing the encoder switch upon completion of the scan will take you back to the main menu.

Repeat Scans

Added in Version 02.8 is the ability to “Repeat Scans” any number of times you like (up to a maximum of 100 times). When used, the function will ask you to set the number of repetitions to run.



The first time after startup, the default will be set to 50. The number can be adjusted from 10 to 100 in steps of 10 by rotating the encoder. On subsequent requests, the initial setting will be the same as the last time you used the function (since turning the analyzer on).

Once the number of cycles has been set, the analyzer will proceed to start scanning. The scans are not continuous; there is a 1 second pause between scans to allow you to read the header.

Pressing the encoder button during a scan will cause the function to terminate upon completion of the current scan. After the last scan, the encoder button must be pressed again to return to the main menu just like when you do a “Single Scan”, or moving the encoder knob will activate the “Examine” feature just as can be done after a “Single Scan”.

The “Save Scan” option can be used after the last scan completes. The scan saved will be the last one run.

The pause time and other related parameters that control the allowed number of cycles are in the “My_Analyzer.h” file and can be modified if you desire.

Frequency

This selection allows you to measure the SWR at specific frequencies. The display will show the frequency being tested and the SWR for that frequency, and we even added an “analog” SWR meter to the display!

The starting frequency is set to the mid-point of saved frequency range.

Rotating the encoder knob one way or the other will change the frequency up or down in 5KHz steps if the “Fine Tune” hardware modification is not installed. The frequency can be moved past either of the pre-established frequency range settings, but not past the band edges. Note, however that you can use the “Custom” band to set up any range of frequencies you want to look at from 1MHz to 65.5MHz.



If the “Fine Tune” option is installed in the hardware, the “Fine Tune” button can be used to cycle through which digit in the number will be changed when the encoder is moved. The digit that will change is denoted by a carat character (‘^’) under the digit.

If the carat is under the 1KHz digit, moving the encoder will change the frequency in 2KHz steps if the “Fine Tuning” option is installed and 5KHz if the “Fine Tuning” option is not installed (this can be adjusted by changing the definition of “FIXED_FREQ_INCR” in the “.ino” file).

Change Band

This option allows the operator to change to a different band and set the frequency range exactly like was done at startup.

Set Limits

This option allows the operator to change the lower and upper frequency limits without changing the band. It works just like the frequency selection process done during startup.

If the “Fine Tune” option is installed in the hardware, the “Fine Tune” button can be used to cycle through which digit in the number will be changed when the encoder is moved. The digit that will change is denoted by a carat character (‘^’) under the digit.

The View/Save Menu

The selections under the “View/Save” menu allow one to save scan data on the SD card or to view the saved data in a number of ways.

Save Scan

This option will save the scan range, and the SWR/frequency pairs for the most recent scan in a file on the SD card.

The files are all named “SCANnn.CSV”, where the sequence number “nn” is assigned by the software. Note that the maximum file sequence number is 99. If more than 100 files are created, the sequence number will be reset to zero, and files will be overwritten on the SD card.

The files are “comma separated variable” (CSV) files suitable for reading into Microsoft Excel or other spread-sheet programs.

If no scan has been run since the analyzer was turned on, the operator will see an error message indicating that there is no active scan, and thus, no new file will be created. However, it should be noted that if you used the “View Plot” or “View Table” options, there will be an active scan in memory which you can save. Of course, you will now have 2 different files with the same data!

View Plot

This selection will display a list of the saved scan files on the SD card (up to 20) and allow the operator to use the encoder to select one.

The saved data will be displayed in graphical format exactly as it was displayed when the scan was first performed (picture above).

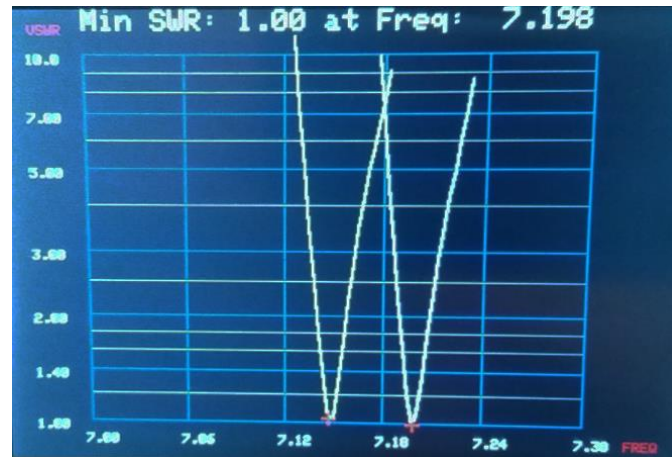
After the scan is displayed, the encoder button must be pressed to return to the main menu or moving the encoder knob will activate the “Examine” feature just as can be done after a “Single Scan”.

Overlay

This option can be used to overlay the graphical results of a previous scan over the current one. The SWR curve for the current scan is displayed in yellow, and the overlay scan curve is in white.

In order to use this capability, there must be a valid scan already in the analyzer’s memory. That can be done by doing a “New Scan” or by using the “View Plot” or “View Table” functions first.

Here’s an example:



The minimum SWR shown in the heading is that associated with the overlay.

If there is no active scan already in memory, an error message will be displayed. Similarly, if the current scan and the overlay scan have different frequency ranges, an error message will be displayed. In either case, the “Overlay” will not be done.

View Table

This selection allows the saved data to be displayed in a table format showing the SWR/frequency pairs for each of the 101 scan points. The output is a multi-page affair. Rotating the encoder will display the next or previous page.

The minimum SWR for the saved scan and the frequency at which it occurred are shown in the header.

Min SWR: 1.00 at Freq: 7.147 Page: 2					
45.94	7.081	20.28	7.108	2.65	7.135
44.22	7.084	17.13	7.111	2.03	7.138
42.00	7.087	14.28	7.114	1.56	7.141
39.72	7.090	11.73	7.117	1.20	7.144
36.80	7.093	9.48	7.120	1.00	7.147
33.66	7.096	7.54	7.123	1.06	7.150
30.41	7.099	5.92	7.126	1.34	7.153
26.97	7.102	4.58	7.129	1.74	7.156
23.59	7.105	3.50	7.132	2.25	7.159

Plot>Serial

This allows the contents of a saved scan file to be sent to the Arduino IDE’s serial monitor provided the analyzer is connected to a PC and the IDE is running.

The output is in CSV format. The first line of the output contains the low and high frequency limits for the scan and the remaining lines are the SWR/frequency pair numbers. The output is an exact replica of the data in the file.

It should be noted that there is no way to detect whether or not the USB connector on the Arduino Mega is actually connected to something or not, so if there is no connection to a PC, the function will appear to complete successfully. In other words, there is no way to display an error message indicating that there is no connection established.

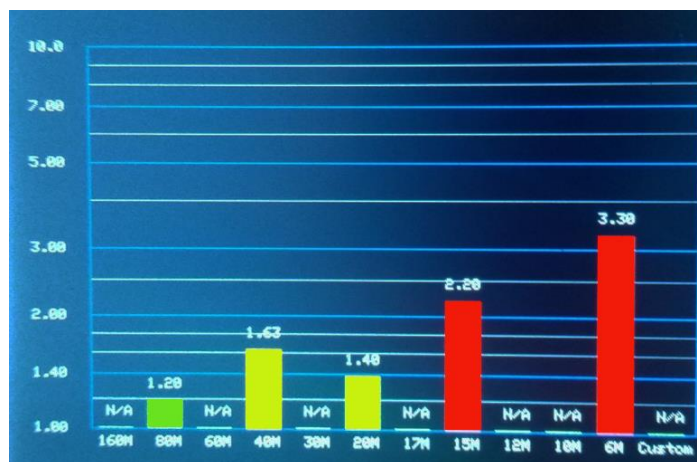
And, again, make sure the Arduino's serial monitor bit rate is set to 9600.

The data displayed in the serial monitor can be copied and pasted into a text file to be saved as a ".csv" file, which can then be opened with Microsoft Excel or other spreadsheet programs for further analysis.

View Mins

Every time a scan is performed, the program saves the minimum SWR for the scan in the EEPROM. The "View Mins" function allows you to display a bar graph showing the most recent minimum SWR readings for all bands that have been scanned. Note the ability to display a bar graph for a single band was eliminated in this software.

Here's what the bar graph display looks:



The bars are painted in different colors for different SWR readings; a green bar indicates that the SWR is less than 1.5:1. A yellow bar indicates that the SWR is between 1.5:1 and 2:1. A red bar indicates an SWR of over 2:1. Those colors correspond to the colors used on the "analog" SWR meter in the "Frequency" function.

The bars are labeled with the band below the bar and the actual SWR at the top of the bar.

The picture shows the display with the 6 meter and "Custom" bands enabled. If either or both of them are not enabled, there will be blank spots where their bars should be. It would have taken a lot of extra code to recalculate the bar widths based on the actual number needed.

Maintenance Menu

The following choices can be found under the "Maintenance" menu:

Delete File

This allows you to delete a single file from the SD card. It displays a list of the files (only 20 of them if you have more than that on the card; it's an internal limit in the software right now).

Moving the encoder knob will allow you to select the file to be deleted and pushing the button will bring up a screen asking to either actually delete the file or cancel the operation.

Delete All

This choice allows you to delete all the files on the card. It will again display a list of the first 20 files on the card for 3 seconds then take you to a screen to allow you to either perform the operation or cancel it.

If there are more than 20 files on the card, it will inform the operator that only the first 20 files are listed, and if the operator chooses to delete the files, it will only delete the 20 files listed.

It will briefly display the name of each file being deleted.

Reset Seq#

This allows you to reset the file name sequence number to zero as long as there are no scan files remaining on the SD card.

If there are still scan files on the card, you will be informed of that fact, and the operation will be cancelled.

Clear Mins

This allows you to zero out all the saved SWR minimum readings.

Erase EEPROM

As noted in the setup instructions, using this version of the software requires running a program to zero out the EEPROM memory prior to installing this version. As that also might be required in future releases, I figure it would be a good idea to provide the option under the “Maintenance” menu.

The program detects that the EEPROM is not initialized and takes care of setting things up correctly itself during startup.

Note that the function does NOT reset the next file sequence number.

EEPROM>Serial

This function reads the data stored in the EEPROM and sends it to the Arduino IDE’s serial monitor in a fairly readable format. For those locations that have symbolic addresses defined in the software, the contents are explained.

Mount SD

Formerly if the analyzer was started with no SD card installed, simply putting one in would not allow it to have been used, as the only check for it was in the startup sequence. This function allows the card to be installed at any time of the operator’s choosing.

If no card is actually installed, a message indicating that fact will be displayed. If the card is mounted successfully, a message to that effect will be displayed.

There is still a slight problem with this function that I have not figured out how to solve yet. It is described below in the “Known Bugs & Glitches” section of this document.

Some General Notes about Menu Choices

In most cases, after an operation such as a scan or display of data in a saved file is performed, you will need to push the encoder button to take you back to the main menu. In some cases, such as deleting files, you are simply returned to the main menu automatically upon completion of the process.

One thing that was missing from the original code was a lot of the error handling that should have been included. I've added a lot of it, but there are still places where you may just be sent back to the main menu with no explanation. Most of these errors have to do with the SD card not being installed or not having any files on it.

On a related note, when you start the analyzer, if there is no SD card installed, you will be informed that any operations having to do with the SD card will be disabled. That's not exactly true right now. You can still try to perform file related operations, but you will usually get another error message explaining the problem. In the future, I plan to completely remove the menu options that require the file system if no card is installed.

It is also important to note that if the analyzer is started without the card installed, simply inserting one won't work. The analyzer must be restarted, or the "Mount Card" option in the "Maintenance" menu can be used.

Known Bugs and Glitches

There is one known issue that can be considered a real "bug". If you don't have an SD card installed when you turn the analyzer on, you can use the "Mount SD" command in the "Maintenance" menu to enable it, and that works. But, if you remove the card and reinsert it while the analyzer is running, it won't work. The "Mount SD" command will tell you that it was successfully mounted, however, it is not. I'm still trying to figure this one out.

Another slight inconvenience is that when using the single frequency measurement function, it sometimes won't respond to pushing the encoder button to exit the function. This is due to the fact that there is a 250mS delay between when it takes readings, during which the software won't see the encoder button operated. If you're too quick on the button, the software doesn't see it. Just holding the switch in a little longer takes care of it.

It's an optical illusion! When using this software, you will notice that the curve for a "New Scan" plots very slowly as compared to the original code. In the original software, the software painted the graph axes, then ran a loop to get the readings, then ran a loop to find the minimum SWR, and finally another loop to plot the results. In this software, all three processes were put in a single loop. In the old software, there was a 5 to 6 second delay between when the axes were plotted and when the curve was plotted while the data was being gathered.

Now, the data gathering time is done in small increments between plotting the data points. It actually takes the same amount of total time. It just looks slow!

The maximum file sequence number currently allowed is 99. If more than 100 files are saved on the SD card, the sequence number will be reset to zero. This will cause the program to overwrite earlier saved files.

Coming Attractions

There are still a bunch of internal changes that I want to make in the software to clean up some sloppy stuff that may or may not affect the outward behavior of the program.

Some of the outward changes that you will notice are:

Calibrate

A number of folks on the [SoftwareControlledHamRadio](#) group have made comments regarding the accuracy of the SWR readings, so we decided to try to add a calibration function!

So far, however, we have not been able to come with a working solution. The errors in the displayed SWR are due to a number of factors including the differences in signal levels as the frequency increases and mismatches in the values and characteristics of the components used in the SWR bridge circuit.

If you're concerned about getting more accurate readings, see the notes about various options in the "Hardware Modifications" section of this document.

Frequency Calibration

It is possible in the software to adjust the calibration of the DDS, and that capability could be controlled through use of the display and encoder. I'm not sure how important this feature would be as if the analyzer is within a few hundred Hertz of the displayed frequency, it's probably close enough for government work, as they say.

Suggestion Box

We welcome any suggestions for further improvements. Please feel free to post on the "[SoftwareControlledHamRadio](#)" group, or email me at WA2FZW@ARRL.net.