

**Austin QRP Club**  
**Vector Impedance Analyzer**  
**User Manual**  
**Manual Version 2**



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**&**  
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# AQRV Vector Impedance Analyzer User Manual

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### Section 1: Introduction

#### Introduction:

Welcome and thank you purchasing the **AQRP Vector Impedance Analyzer (VIA)**. We sincerely hope that it has been an enjoyable and enlightening learning experience building this kit. It's understood this is not a kit for the novice or intermediate kit builder. However, with research on Surface Mount Technology (SMT), a good set of tools, and with some practice, this device will turn out to be an important tool for any electronic enthusiast. It's a very high quality piece of equipment with great flexibility in how it's completed to the builder's expectations. When this kit is finished, it will contain more functional capabilities than products costing twice as much with less functionality. Plus, the Kit contains the capability of uploading new Firmware to stay up with new features and capabilities. Please understand this is a state-of-the-art technology tool using the latest in SMT devices, with parts that may not be the easiest to assemble by hand. However, the **VIA** board layout has taken this into account. The part placement and solder joints have been spaced apart and extended slightly to help in the hand soldering of components. It's highly recommend that research is done on SMT soldering techniques before attempting the **VIA** assembly. Also having the right tools will make a big difference in the assembly; like magnification devices, good lighting, board holding devices, quality Soldering Iron with the capability to use very small tips, etc.

Also please understand this is a labor of love by two retired Electrical Engineers/ hams with years of technical experience, trying to keep up with today's technology, and just love doing this stuff, and who have happened to hit on a spectacular tool for Amateur Radio use and education. The tool is expected to evolve in functionality as new ideas arise with a minimum of hardware changes (i.e. mostly through firmware upgrades). However, there may be a point where hardware modifications may not be practical and/or cost effective; at which point a new version board may be required. This way people who have built this tool may benefit from new features by using simple to install firmware updates. However, we may reach the point where updates by firmware may not be practical and hardware changes ( new board) may be necessary. This is a great way to keep up with the future and we can be proud to say we built it ourselves!

Check out all the other documentation on the web. Just enter **K5BCQ** in the search engine, then click on "[K5BCQ & K5JHF Kits - QSL.net](#)", and scroll down to Kit #25 and follow all the other documentation to help in assembling this quality **Vector Impedance Analyzer**.

Thank you again, and we hope you find many many uses for what we believe to be one of the finest tools with even greater possibilities in the future.

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### History:

This project was a collaborative development adventure of Milt Cram (W8NUE) and Kees Talen (K5BCQ). They decided to develop a project utilizing some very good products like the STM32F407-Discovery board which contains plenty of microcontroller capability and features, with available “free” Development Tools, and at a price being right for this type of project.

Milt drew on his SDR2GO firmware experience and code he used for the NUE-PSK Digital Modem, and also the more recent STM32-SDR code. He decided to base the design on audio baseband I/Q signals and process those for the required data. This is done by using TWO synchronously tuned RF signals  $F_0$  and  $F_0+2$  KHz.... one to provide a signal to drive the measurements of the device under test and the other as a “local oscillator” to convert the measured signals to a low frequency using dual I/Q mixers. I-Q processing has the advantage of being able to readily process negative complex numbers (capacitive and inductive reactance) correctly—a problem with many of the mid-range commercial antenna analyzers in the market today.

After looking at several possibilities, including the little NOKIA touchscreen, it was decided to go for something far more usable and user friendly. Here we have it; The **AQRP Vector Impedance Analyzer kit #25**.

It's a standalone, battery powered, **Vector Impedance Analyzer** for portable operation. It can be used to check antennas, filter designs, etc., which we'll go into in the manual as they're available. As mentioned previously this design will evolve over time as changes and improvements are made to function and visual presentation. The STM board firmware is easily updated by using STM-LINK software (free) and a USB cable. So future firmware updates will be easy to do.

### DESIGN FEATURES: (Firmware Ver. 2)

- **Measures V (voltage) & I (current)**
- **Calculates Z (Impedance....in complex numbers), Y (Admittance....in complex numbers), k (Reflection Coefficient)....in complex numbers, RL (Return Loss...in dB), VSWR (Voltage Standing Wave Ratio)**
- **Plots Z, Y, k, RL, VSWR, and Smith Chart (Reflection Coefficient Plot). Z and Y are complex number plots. At the completion of a plot, you can choose to rescan using the same plot type, or to change the plot type. The latter choice, allows you to select a different plot of the data that was gathered during the initial plot.**
- **Vertical line cursor on all x,y plots, showing the frequency and the corresponding plot values at the location of the cursor.**
- **Smith Chart cursor--cursor follows encoder change along the plot, displays frequency, reflection coefficient, and VSWR.**

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- **The default HF mode Frequency Range of the data/plots is from 1 to 150 MHz .....an alternative LF mode Frequency Range is from 8KHz to 1.17MHz (1.17MHz is  $F_{max}/128$  which is a Si5351 constraint). Yes, all the way down to 8KHz. A set of preset bands is also available from which to choose. Selecting the band will also set the corresponding start, stop, and step values.**
- **Auto Scan and Manual Scan modes**
- **Adjustable Start & Stop Frequencies in Hz, Frequency Step in Hz, and Dwell Time (in msec to allow sufficient data processing time).**
- **All parameters are saved on command for the next use**
- **Stores up to 1,500 data points with associated parameters for later PC Processing using a 512K EEPROM.**
- **Powered by six AA batteries and a 5V Switcher or Linear Power Supply. The DC-DC switcher will accept an input of up to 36V DC. You may also use another power source (e.g. LiPo) if you want. There are many LiPo "Power Banks" available for less than \$10. Most of these contain a buck-boost regulator that allows a 3.7V Lithium Polymer 1800-2000 mAh battery to be charged from a 5 V charger (as is used in most cell phones) and produce a 5V regulated output that can power the Discovery board directly.**

When using LiPo battery packs it is often desirable to measure the actual battery pack voltage. The VIA kit is supplied with 2 axial lead resistors (10k and 68k ohm) to form a voltage divider for the STM32F407 ADC. The 68k ohm is connected between the battery and pin PC1 of the Discovery board and the 10k resistor is connected between pin PC1 and the nearest ground.
- **Uses a TFT\_320QVT display which is 320x240 pixels, color, and has a resistive touchscreen for parameter selection. These are readily available on eBay.**
- **New Firmware can be easily installed using a USB cable connected to a computer. A free utility from STM is used to download the firmware from the PC and install it in the VIA.**
- **Data stored in the VIA may be sent to a computer for further processing. A standard USB cable may be used for this purpose. As noted above, this data may also be re-plotted within the VIA. This facilitates plot selection within the shack, after recording data taken remotely at the antenna.**
- **Calibration data (Open/Short/Load) is captured and recorded for all frequency steps between Start and Stop Frequency. This allows data to be recorded at the end of a transmission line, effectively eliminating the coax from the computed and displayed data. These data values are sent to the PC when requested.**
- **Also included is the capability to change the value of the target characteristic impedance ( $Z_0$ ) and the value of the calibration load resistance ( $R_{cal}$ ). Standard values for  $Z_0$  are provided.**

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Rcal can be any integer value from 25 ohms to 150 ohms, with 50 ohms as the most common value. The default for both Z0 and RCal is 50 ohms.

- A newly added feature is the ability to characterize coax transmission lines (using a short piece of coax < than about 0.1 wavelength) . Attenuation Factor, Characteristic Impedance, and Velocity Factor can be measured.
- A recent feature that has been added is the ability to locate faults on a transmission line by using measurements over a wide frequency range and using an Inverse Fast Fourier Transform to provide data in the time domain—This is known as a Frequency Domain Reflectometer. Details in Appendix V.
- The VIA is capable of being used as a L/C meter and for making Coil “Q” measurement
- Entry of setup parameters has been simplified. Instead of clicking Up and Down buttons, the Cursor encoder is now used to select digits that are to be changed. The Frequency encoder is used to select the value. Pressing the push-button on the Frequency encoder saves the values in EEPROM or RAM.

**NOTE:** With the new calibration system, data is captured at all measurement points in the range from start frequency to stop frequency in increments of the step. When performing measurements with an unknown load, calibration information is extracted from memory, based on the sample number (I. e. the current frequency). If you change the frequency limits and/or step size, without recalibrating, you will likely see “garbage” on the display because the calibration data may not correspond to the frequency of each sample. Therefore—**IF CHANGING FREQUENCY PARAMETERS---RE-CALIBRATE BEFORE TAKING NEW DATA.**

Also, Firmware Version 2, and later, requires the 512kbit EEPROM (24AA512) in the VIA. Because of the increased storage of calibration data, the number to data samples is limited to no more than 1500 samples. 8 bytes are required for each of open circuit, short circuit, calibration load, and target load, at each frequency. Therefore, 32 bytes are recorded for each frequency. Since the new EEPROM can hold 64k bytes, and other data must be stored as well, it is best to keep the data/calibration storage to less than 48000 bytes (1500 samples). When changing an EEPROM, it is not necessary to “Clear the Memory Sentinels” , but recalibration of the VIA is needed. If your VIA already has the 512Kbit EEPROM and are upgrading from an earlier version to Version 2 or later, it is necessary to “Clear the Memory Sentinels” so that the system will not be looking for stored data in the wrong locations.,

### Theory of Operation:

The **VIA** consists of an RF generator, a V-I (voltage-current) circuit, and a vector voltmeter. The RF generator produces two RF signals that differ in frequency by 3 kHz, regardless of the frequency of the

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first generator. A Si5351 chip from Silicon Labs is used for this dual generator. The V-I circuit produces two output voltages, one is proportional to the voltage applied to the load impedance, and the other is proportional to the current flowing through the load impedance. The resistors in series with the load, limit the current in the load if it's a short circuit. The ratio of the amplitudes of the two voltages, and the phase difference between them provide enough information to accurately determine the load impedance.

From the calculated load impedance [**Impedance**], the complex reflection coefficient [**ReflCoeff**] and other parameters of interest may be determined. However, the “raw” measurements must be corrected for inaccuracies in the values used in the computations and stray circuit capacitance, inductance, etc. This is accomplished in the calibration procedure.

Since the V-I circuit produces two voltages that may have some phase difference between them, DSP IQ signal processing is used to make the computations. Each voltage signal is mixed with a local oscillator (the RF signal that is offset by 3 KHz from the RF excitation of the V-I circuit). The two 3kHz audio signals thus generated, are then digitized with a 16 bit A/D converter and sent to the STM32 microcontroller. Now in digital form, each signal is filtered with a 3 KHz band pass digital filter. These signals are further split into In-phase and Quadrature (IQ) components by multiplying each with complex local oscillator (complex mixer) to produce the I and Q components of each of the two channels. This is where conventional DSP techniques are used to further filter the four signals that now exist and to calculate the ratio of the amplitudes of the two IQ pairs and the phase difference between them.

The ratio and phase signals are then processed to provide uncalibrated impedance values. Using impedances obtained with calibration standards (Open, Short, and 50 ohm) we can process the raw impedance measurements to obtain corrected, calibrated data. The processing of the two channels of 3 KHz analog signals is what is referred to as a “Vector Impedance Analyzer”. Appendix II contains a description of the equations used in calibrating the VIA.

All in all, this is a rather conventional approach to impedance measurement, but it has been chosen to capitalize on our design experience with microcontrollers and Software Defined Radio (SDR) to implement measurement, computation, plotting, and display into a compact portable unit for field use— all at a very reasonable cost.

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## Section 2: Getting Started

### Let's Get Started:

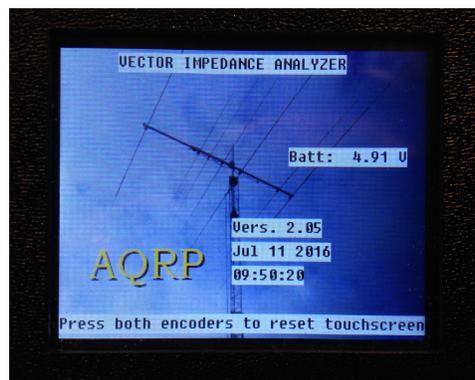
**BEFORE POWER ON** ---there are a few things that should be done prior to applying power to the VIA.

- 1) Make sure that the power supply is set to provide 5 to 5.1 VDC.
- 2) Before connecting the power supply to the VIA, use the ohmmeter to check the resistance from the 5V line on the VIA to a convenient ground connection on the VIA board. This resistance check should be at least 100 ohms.
- 3) Make sure the two pin connector that supplies power to the VIA is oriented correctly. Mark one side of the board and connector, to insure proper orientation when connected. **NOTE:** There are no reverse polarity protection diodes on the Discovery board. Later VIA boards will have a 3 pin power connector with the middle pin being 5V and the outer ones grounded. This should reduce accidental power reversal.,

These checks are to minimize the risk of "releasing the magic smoke" when the VIA is first powered on.



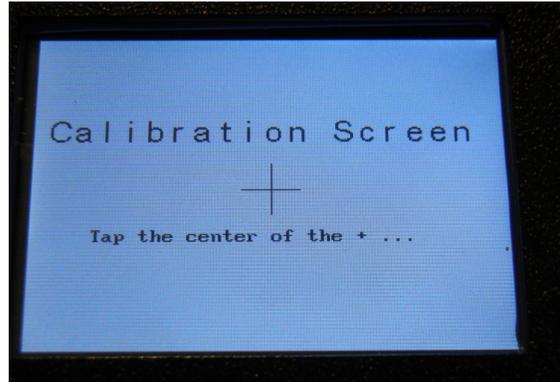
After the items above have been verified and the unit has been assembled, turn on the power. The "Splash Screen" should come up within two to three seconds after the power has been applied. It will display the date and time of the latest version firmware. In addition, if the extra resistors have been added to facilitate battery voltage measurement, the battery voltage will also be displayed on the Splash Screen. See below.



### Screen Calibration:

When the unit is turned on for the first time, the unit will immediately go from the "Splash" screen to the "Calibration" screen, shown below. Follow the instructions on the screen, and when instructed, tap the screen three times in quick succession, to save the touch screen calibration.

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Now turn the power off and back on. As mentioned before, the “**Splash**” screen should show up after about two to three seconds, and after the “**Splash**” screen is displayed for a few seconds, the **VIA Main** screen should be displayed. All is good! YEA! 😊

Okay, here’s where the fun starts and where the rubber meets the road! 😊 But it depends on how carefully the person who spent all this time building the **VIA** was in attention to details for the unit to startup in a fully working state.

CAUTION,-- we wish to point out that the most likely cause for a unit to fail to perform as expected during the power-on sequence is one, or more, **SOLDER PROBLEM(S)!!!!** Based on the experience of the designers and of the many kit builders who have assembled the **VIA**, we find that more than ninety five (95) per cent of problems are soldering related.

If the unit takes longer than two to three seconds to display the “**Splash**” screen, there is something wrong in the assembly of the **VIA** board. It usually means that the microcontroller is not communicating with the EEPROM memory, Si5351 oscillator, or the codec due to either a bad component or solder joint issue. Please remove the **VIA** and check the solder joints. You may just find one that looked like it was well soldered but did not make a good connection.

If the unit has no display at all, see “**No display when power is applied**” in the **Trouble Shooting** section of this manual.

After visually checking **ALL** the parts and touching up **ALL** the solder joints, re-assemble the unit and apply power. The sequence as mentioned earlier should occur. If not, then there is still something else to discover. See the “**Splash Screen turn on timing issue**” in the **Trouble Shooting section** of this manual for further assistance.

If the Screen Calibration was not made because of initial issues and the unit is now working, it’s easy to go back and do the **Calibration Screen**. Just push down both **Control** knobs at the same time until they click and turn on the power. Hold the **Controls** down until the **Calibration Screen** is visible. Then release

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the **Controls**. At this time go through the screen calibration, and when instructed, tap the screen three times in quick succession to save the touch screen calibration. If all parts are communicating, the screen will revert to the **VIA Main** screen.

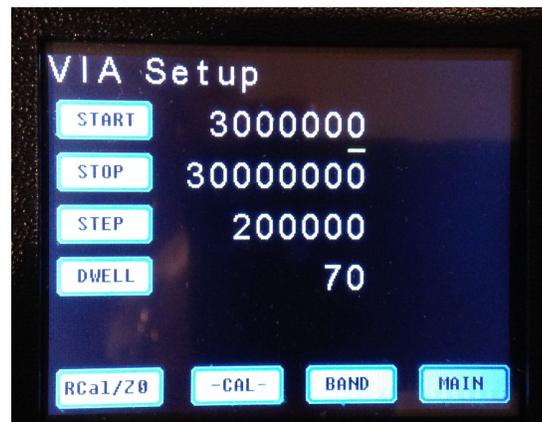
This is what the Main screen looks like:



## Operational Parameters--Frequency Setup:

Okay, now that the screens are doing what they should, let's continue with the setup. Tap SETUP to proceed.

Prior to performing the "Cal" function, we first need to enter some values into the different fields on the **VIA Setup** screen.



On the left side of the **VIA Setup** screen there are four labels for the various input parameters that must be set before performing any tests. These are used to set the **VIA** start frequency,, stop frequency, frequency step, and dwell time parameters for measurements. This, to some, may seem intuitive, but we'll explain their usage anyway.

**[Start\_Freq]** button is used to set the **Starting Frequency** for subsequent testing.

**[Stop\_Freq]** button is used to set the **Stop Frequency** for subsequent testing.

**[Freq\_step]** button is used to set the **Frequency Steps** at which data will be collected.

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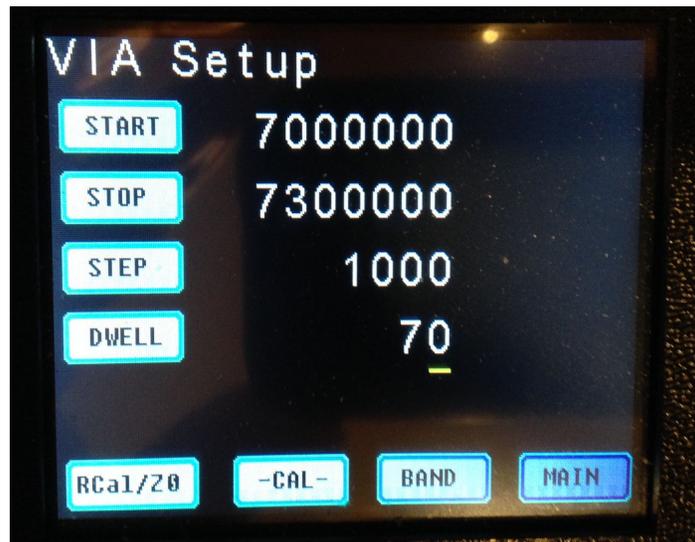
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[Dwell\_Time] button is used to set the speed at which the frequency is to be stepped and the chart is to be drawn.

**Please note**--Entry of the Start\_Freq , Stop\_Freq, and Freq\_Step must be done before Calibrating the unit as these frequencies are used in the calibration process.

Default values are shown in the above screen image. Each value may be changed by first selecting the digit that you wish to change using the Cursor encoder. Once the underline cursor is below that digit, rotating the frequency encoder will change the value of that digit. As you move the position of the cursor right, when you reach the end of a parameter entry field, the cursor will jump to the first digit of the next parameter on the line below. When the last digit of the last parameter is reached, the cursor will return to the first digit of the first parameter. When moving the cursor from left to right, after reaching the first digit of a parameter, the cursor will jump to the last digit of the previous parameter. After reaching the first digit of the first parameter, the cursor will jump to the last digit of the last parameter. Once all digits have been set as desired, momentarily press the Frequency encoder push-button to save the changes. Tapping RETURN, without using the push-button will abort the changes.

For the 40 meter test example, set the parameters as shown in the image below using the Cursor and Frequency encoders. Save the changes using the Frequency encoder push-button as described in the paragraph above.



**Band Presets:**

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If you wish to select a predefined band instead of manually entering the Start\_Freq, Stop\_Freq, Freq\_Step and Dwell\_Time parameters, you can select PRESETS from the Setup Menu. You will then see a screen similar to this:

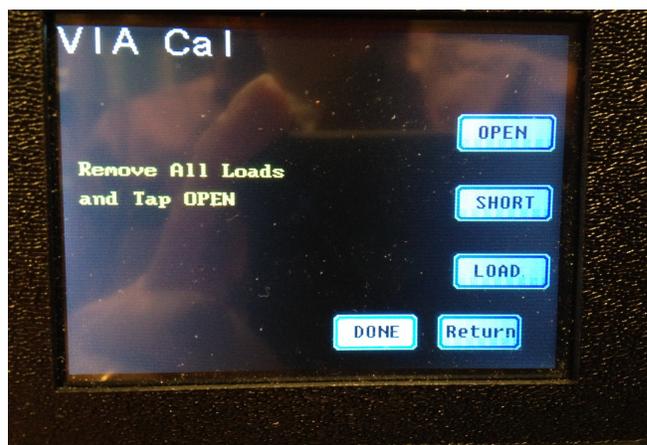


Rotating the Frequency Control will allow you to scroll through the predefined bands. Tapping RETURN will take you back to the Setup Screen without selecting a preset band. Tapping SELECT will make the currently displayed band the choice for the current operating sessions, but does not store them as power-on default. However, you can select STORE from the Setup Menu to store the currently selected band as the power-on default.

## “Cal” setup:

For this step, a good quality, non-inductive 50 Ohm resistor and a zero Ohm resistor are required. The 50 ohm calibration load can be made by soldering one side of the 50 Ohm resistor to the center pin of a BNC connector and the other to the ground or shield side of the connector. This will work for the “**50 ohm**” load. A shorted BNC connector will suffice for the “**0 Ohm load**”.

Now, tap the “Cal” button on the **VIA Setup** screen and the screen should change to show the “**VIA Cal**” screen. See below.



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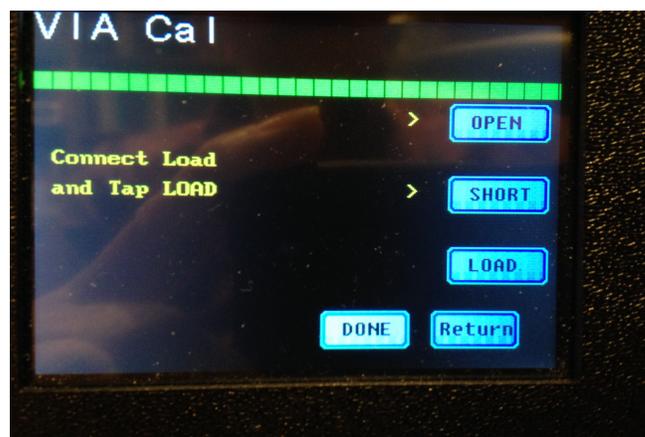
Please note the instruction in yellow on the screen.

1 – The display at the left of the screen will ask you to **“Remove All Loads and Tap OPEN”** (i.e. a open circuit load). Remove all terminations from the female BNC connector on the VIA. Tap the **“OPEN”** button. A progress indication should appear near the top of the screen. When scanning is completed, an arrow head appear just to the left of the OPEN button. You will now be instructed to **“Connect Short”**.



2 – You will next make a "short circuit" measurement. Tap the "SHORT" button. As before, the progress indicator will alert you that data is being captured and the arrow head will appear next to the SHORT button.

3 – Finally, you will be asked to Connect the “Load” to the female BNC connector. Now tap the **“LOAD”** button. **“Scan complete”** will shown on the display when all three steps have been completed.



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4--Tap “DONE” to save a marker in memory that indicates that the calibration was completed. Then tap “Return” to return to the SETUP screen.

Unlike previous versions of the firmware, there is no display of calibration data. There is simply too much of it to be displayed.

However, there are major advantages to the new calibration approach. Accuracy is improved! Also, you can now calibrate the VIA with a length of coax connected between your target load and the VIA. Performing OPEN, SHORT, and LOAD calibration, with the coax present, will allow display of data as though the coax were absent. That is, the displayed data should be essentially identical to what would be obtained if the load (e.g. antenna) were connected directly to the VIA. In other words, if calibration is done using the coax that will ultimately connect to an antenna, when you connect the antenna to the coax and make impedance measurements at the input to the coax, the data displayed by the VIA will be indicative of the impedance at the terminals of the antenna.

If you now make a scan of the 50 ohm load, you should observe that the displayed value will be very close to 50 ohms over the entire HF band (1 to 30 MHz).



Look carefully at the Smith Chart plot above and you will see a RED dot at the center. This represents 50+j0 ohms, or a reflection coefficient of zero in a 50 ohm system. This is actually a plot of the reflection coefficient for all frequencies in the selected range (1MHz to 30MHz, in 100kHz steps).

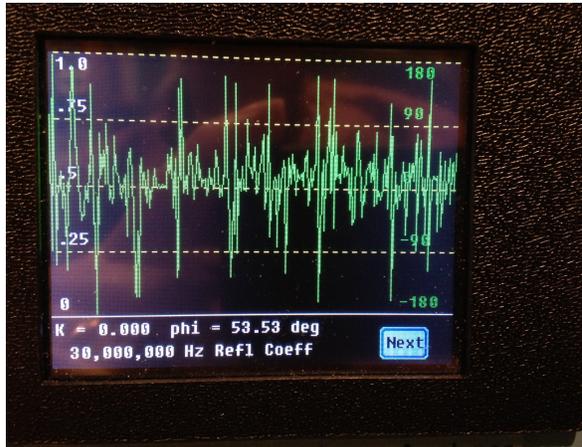
**Another cautionary note**—If you make a Reflection Coefficient plot (immediately after performing calibration) using the 50 ohm calibration load, you may be concerned with the apparent “garbage” on the plot. Don't panic. If you look carefully at the plot, you will see that the magnitude of the reflection coefficient is plotting at zero, as it should. Since the magnitude is zero, the phase is of no consequence—

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therefore, it plots as random data. The other plots are not affected like this because they do not involve taking the difference of two essentially equal values that result in an indeterminate phase.

The next image illustrates what was just described.



You may not see this “problem” if your measurement is much later than the calibration. This is because the calibration load resistor may change value by a few hundredths of an ohm due to temperature. This small change may be enough to make the computed reflection coefficient magnitude nonzero, thereby making the phase changes much smaller.

### Using the VIA to make measurements:

In Version 2.0 firmware and later, a new button has been added to the Setup Screen—ALPHA. Use this button to bring up the alphanumeric (tabular) display that appeared in previous versions when selecting AUTO or MANUAL. The alphanumeric display allows display of various parameters and computed quantities while manually adjusting frequency with the Frequency control. For example, it has an L/C display that shows the effective capacitance or inductance of the load, at the current frequency. This makes the VIA an effective LC meter. The LC display is both autoranging and L/C sensitive (that is, it automatically switches the display character from L to C—and vice versa—when the sign of the reactance changes). It is also very useful for diagnosing problems with the VIA using the V1, V2 and IF-Sig values displayed on this screen. The ALPHA mode is described in more detail below. Also, see the troubleshooting sections of this manual for more information.

### VSWR Measurement using the Auto Plot mode:

To create the chart of the 40 meter antenna example, tap the “Auto” button in the **VIA Setup** screen and it will change to a screen with three choices—SETUP, MANUAL, or PLOT. Select PLOT.

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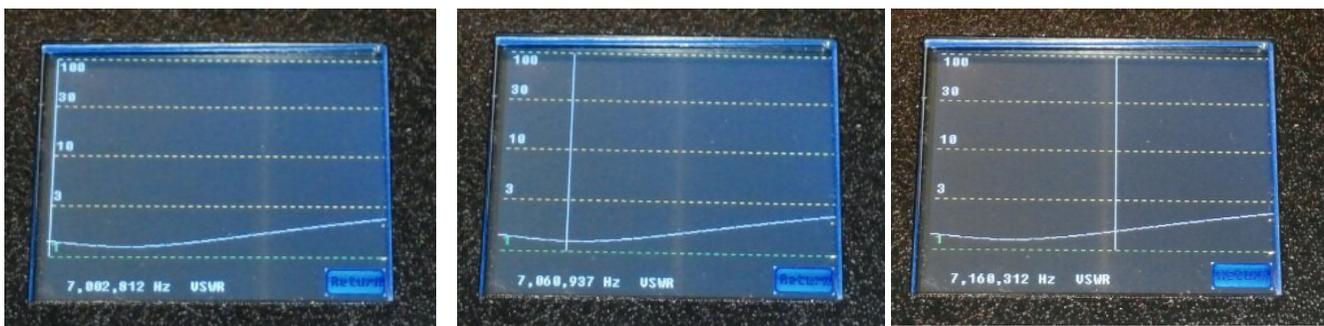
This will move to the **Plot Selection Screen** to select which Plot type is to be made on the data obtained from the load connected to the **VIA**.

Once a plot is complete, tapping the **NEXT** button will present you with a choice of either changing the Plot Type, or Rescanning the load with the currently selected plot type. You may also choose to Return to Setup by tapping the **RETURN** button.

The **VSWR** test for the 40 meter antenna is the next step. So tap the **“VSWR”** button and watch the show as the chart is drawn on the screen as we speak.



If the data from the antenna is within the pre-programmed limits of the **VIA**, it should look something like the views below. The antenna in the example below is set to the **CW** end of the Band and at the low end of the phone band as indicated by the line using the **“Cursor Control”**. The location of the individual function knobs may vary based on the person laying out the position of the controls. The **“Cursor Control”** is used to move the vertical line on the screen to identify the frequency at the lowest indication on the curve, or lowest **VSWR** in this example. Note—the cursor does not automatically appear when plotting is completed. Rotate the cursor control and the cursor will appear at the center of the screen. As you continue to rotate the cursor control, the cursor will move left or right and the values at the point where the cursor intersects the data trace will be displayed. In addition, the frequency corresponding to the cursor location will be shown at the bottom of the screen.



**Please note: The VSWR value is shown for the point where the Cursor line intersects the plot line.**

## **VSWR Measurement using the Manual Plot Mode:**

In the **VIA Setup** screen there is also a **“Manual”** button. When this button is selected, it requires the use of the **“Frequency Control”** knob to plot the chart manually instead of automatically.

The processes are the same as the **“AUTO”** mode, but this time tap the **“Manual”** button from the **VIA Setup** screen, than tap the **“Plot”** button, and tap the **“VSWR”** button. After the screen changes to the **“Chart”** screen, rotate the **“Frequency Control”** knob in a clock wise direction to plot the curve.

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Continue turning the knob until the frequency displayed stops changing. This should equal the [Stop\_Freq] setting (7,300,000 Hz). This completes the **Manual** creation of the plot for the device under test.

To avoid cluttering the display during plots, the cursor is initially blanked, and, as in the **AUTO** mode, rotating the "**Cursor Control**" will make the cursor appear and move the vertical cursor line across the screen displaying the frequency and corresponding data values.

By the way, if **both Control** knobs do not increase their function to the right on the screen when turned in the clock wise direction; please see "**Control Reverse wiring Function**" in the **Trouble Shooting** sections of this manual.

**In the Manual mode, the cursor will not be available until the frequency has been increased manually to the stop frequency (plot all the way to the right side of the display).**

To return to the **VIA Setup** screen, tap the "**Return**" button from the **RePlot/ReScan** screen. This completes the VSWR test of a 40 meter dipole.



The same process is used to test any other antenna by setting the Start and Stop Frequencies and connecting the antenna to the **VIA** and running the test. Multiple band antennas may also be tested by just entering the lowest frequency for the start frequency and the highest frequency of the highest band for the stop frequency.

**Plot Type Selection with the VIA:** (for more details see Section 3)

**[SmithChart]** = **Smith Chart** - used in solving problems with transmission lines and matching circuits

**[Impedance]** = **Impedance** - is the complex-valued generalization of resistance

**[Admittance]** = **Admittance** - a measure of the opposition to time-varying electric current in an electric circuit

**[ReturnLoss]** = **Return Loss** - is the loss of power in the signal returned by a discontinuity in a transmission line

**[RefCoeff]** = **Reflection coefficient** - is a parameter that describes how much of an electromagnetic wave is reflected by an impedance discontinuity in the transmission medium

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[VSWR] = **Voltage Standing Wave Ratio** - is a measure of how efficiently radio-frequency power is transmitted

## Selecting A Plot Type:

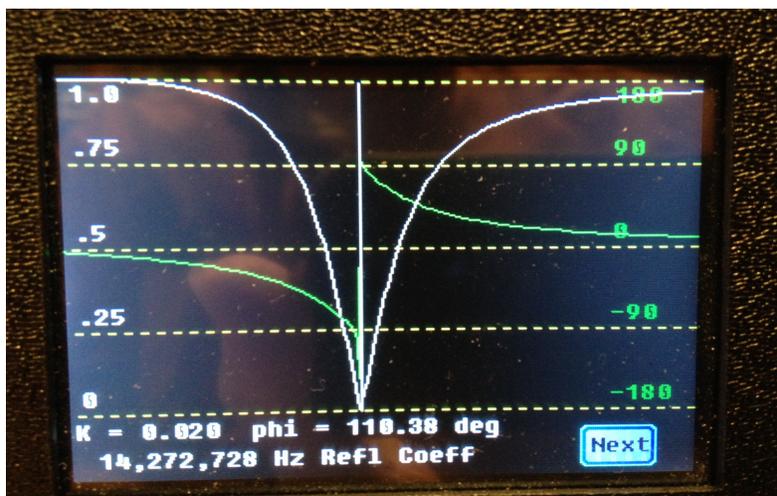
With the Start and Stop Frequency parameters set, different plots may be made with the **VIA** by just selecting the type of plot. ([SmithChart], [Impedance], [Admittance], [ReturnLoss], [ReflCoeff], and [VSWR]).

## [SmithChart]:

Creating a Smith Chart of an antenna may be accomplished by simply tapping the [SmithChart] button and watch the magic. That's if it's still in the Auto Plot mode. ☺

**Each type of chart may be created by these same steps, just select the type of profile as the last step.**

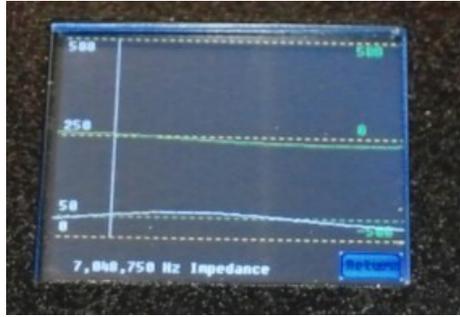
The following Reflection Coefficient Screen was made with a simple series RLC circuit as a load. The frequency range is from 1 to 30 MHz. The resonant frequency of the circuit is about 14.3MHz. The series resistor is about 49 ohms.



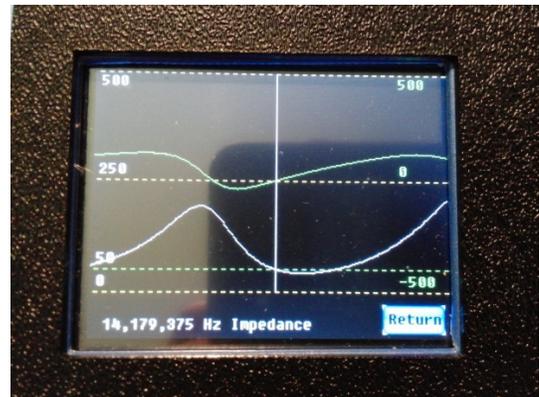
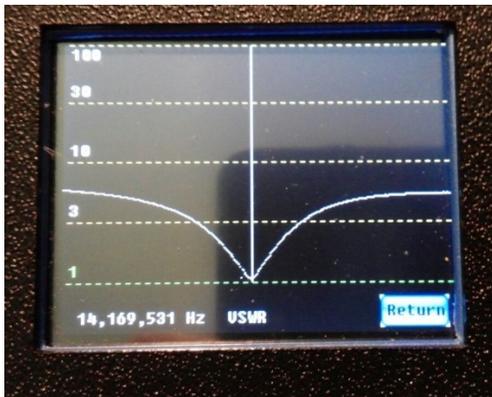
## [Impedance]:

To create an Impedance profile select [Impedance] as the last step.

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Please note when making an Impedance plot there are two lines and scales, the White line corresponds to the scale on the left side of the screen which is for the **Resistive Part** of the Load Impedance, and the Green line corresponds to the scale on the right side and is for the **Reactive part** of the load impedance. Use the “**Cursor Control**” to find where the white line intersects the 50 Ohm line on the left scale, and the Green line intersects the Zero line on the right scale. This will result in the optimum frequency of the device being tested which should also approximately correspond to the lowest VSWR frequency measurement. However, this may not always be true, e.g. if the **VIA** is being used to check a very narrow band antenna such as a high Q magnetic loop.



## [Admittance]:

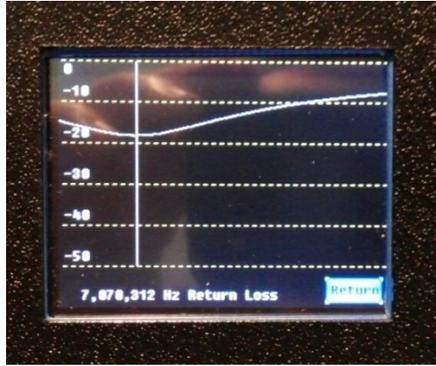
To create an Admittance profile select **[Admittance]** as the last step.

Again we have two scales to compare, however in this case no matter at what frequency the “**Cursor Control**” is at really doesn’t matter, because both the White and Green line are pretty flat. See the definition for Admittance for more details on this graph. Admittance plots are most useful when the impedances being investigated are quite low –as in the case of small loop antennas (admittance is the reciprocal of impedance and will therefore be high)

## [ReturnLoss]

To create a Return Loss profile select **[ReturnLoss]** as the last step.

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In this plot there is only one scale, and rotating the “**Cursor Control**” to the lowest location on the graph will identify the frequency of the lowest reading on the plot or, **least reflected power**. Again this should be close to the lowest VSWR measurement frequency. See the definition for **Return Loss** for more details on this graph.

## [ReflCoeff]

To create a Reflection Coefficient profile select [**ReflCoeff**] as the last step.



50 Ohm Terminated 25 Ft RG-8X

Open ended 25 Ft RG-8X

Shorted end of a 25 Ft of RG-8X



This test may be used to check the condition of a length of coax with the end of the coax terminated with 50 Ohms, Open Ended coax, and with a short at the end of the coax. For more details on the explanation of the **Reflection Coefficient**, please see the **Technical Definition** section. Also the photos used in this example were made with a relatively narrow frequency range. Generally, coax testing is

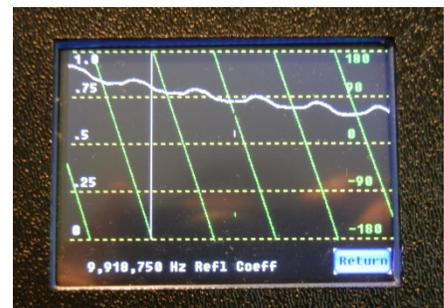
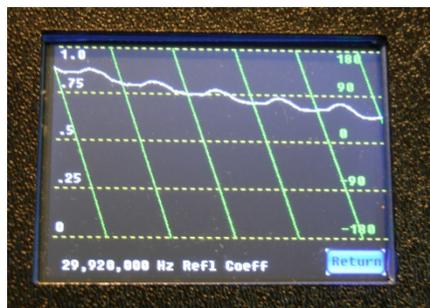
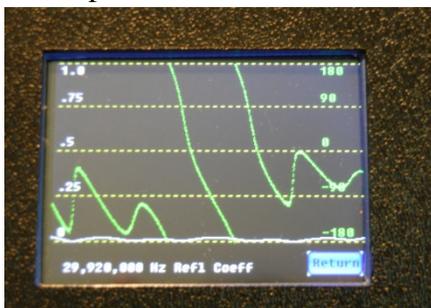
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done over a wide range of frequencies where the length may be one or more quarter wavelengths and the plots will show much greater variation, as in the plots below.

## Another example:

Below are graphs of a piece of RG-8A coax, 66 feet long and made for a 40 meter  $\frac{1}{2}$  wave length feed line to feed a 40 meter coaxial antenna. The coax was rolled up into a about a 15 inch diameter loop when the measurement was taken.

Note: the waveforms for an **Open Output** and **Shorted Output** should be the similar when measured directly at the VIA coax connector. However, the phase curves will be shifted on the frequency scale. These plots were made with Version 1.x firmware in the VIA.



**$-\frac{1}{2}$  Wave on 40m W/50 Ohm load     $\frac{1}{2}$  Wave on 40m Open Ended     $\frac{1}{2}$  Wave on 40m W/Shorted End**

Once a plot is completed, tapping the NEXT button will bring up the following screen:



From this screen, you have the option of changing the plot type or to re-scan the load using the currently selected plot type. If you select "Change Plot", you will not be re-measuring the load, but will be taken to the Plot Choice Screen. There you can select a different Plot Type, and use data that was recorded in your initial plot selection. (This will result in much faster plotting than would be the case if making an initial plot) If you are "tweaking" the load and want to see the effect of your tweaks, you can select Re-Scan Plot without having to make a new Plot Selection. Tapping RETURN will take you immediately to the Setup Screen.

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### RePlay:

Selecting this button on the Setup Screen allows you to Plot data that was previously recorded in EEPROM Memory within the VIA. For example, you may make a plot/scan at a remote location that you want to display later. Using the RePlay feature allows you to do this. The Replay button will take you to the Plot Choice Screen where you can select the type of plot you desire. Once you make your selection, data will be retrieved from memory and displayed using the plot type you selected. As before, when the plot is completed, you will have the option to change the plot type.

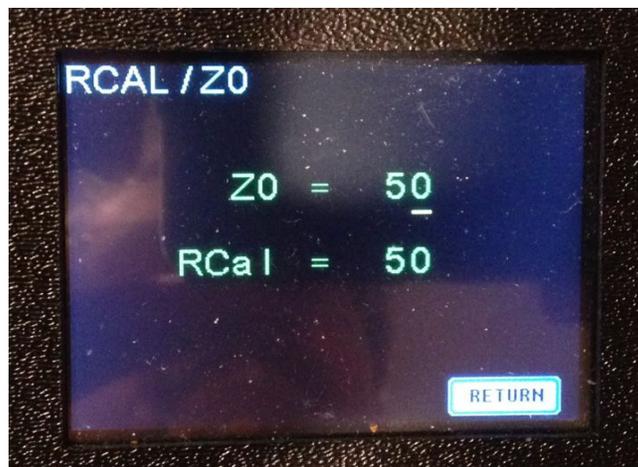
### Rcal/Z0:

There may be times when the user wants to use the VIA to check a system that uses something other than 50 ohm coax. For this reason, we added the ability to select Characteristic Impedance values from 35 to 125 ohms.

In addition, the VIA may be calibrated with a Calibration Resistor (Rcal) of other than 50 ohms. The VIA may use any integer value of 25 to 150 ohms.

To change either or both of these values, tap the Rcal/Z0 button on the setup screen.

On the new screen, move the cursor to the digit you wish to change and rotate the Frequency encoder to change the value. When you move the cursor to the end of a parameter field, it will move to the first position in the next parameter field. Pressing the Frequency encoder push-button will save



### Other Encoder Functions:

Anytime the unit is turned on without **Encoder** action, the default **HF** frequency will be set.

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HF Frequency = 1 MHz to 150 MHz

LF Frequency = 8 KHz to 1.17 MHz (1.17 MHz is  $F_{max}/128$  which is a Si5351 constraint)

When the **Cursor Control** knob is pushed down to engage the switch while applying power, the unit will set the frequency range from 8 KHz to 1.17 MHz. When applying this function, the **Control** must be held down until the **VIA Setup** screen is visible.

When the **Frequency Tuning Control** knob is pushed down to engage the switch while applying power, the unit will reset the Start and Stop Frequencies to their initial default values of 1MHz and 30MHz respectively. Remember to hold the **Control** down until the **VIA Setup** screen is visible. This is also referred to as "Clearing EEPROM Sentinels".

### Alternate VSWR measurement using ALPHA Screen:

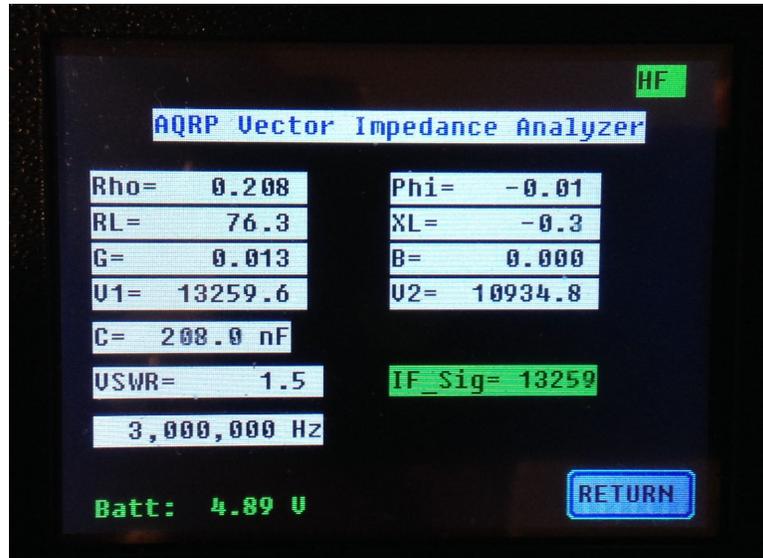
The **VIA** can display the **VSWR** associated with a frequency without showing the plot. Instead of running the **Auto** or **Manual** scan to display the plot of the antenna, choose **ALPHA** from the setup screen. Rotating the Frequency Control will show the various computed parameters, including VSWR that are associated with the current frequency, without the need of a plot.

Let's try an example. Attach an antenna to the **VIA**. Set the **Start** and **Stop** frequencies, and select the **Alpha Mode** from the **VIA Setup Screen**. Immediately the screen will change to the **Tabular Screen**. At this point, rotate the **Frequency Tuning Knob** in the clockwise direction and watch the **VSWR** display as the frequency is changed. As the frequency changes, the **VIA** calculates the **VSWR** of the antenna at the frequency steps shown. This is a quick and easy **alternate method** to check the **VSWR** at a specific frequency without running a plot. Yes, that's correct! It will do the same thing if the **Start Frequency** is set to a specific frequency. As soon as the **Alpha Mode** is selected from the **VIA Setup Screen**, the **VIA** will switch to the **Tabular Screen** to calculate and display the **VSWR** at that specific **Start Frequency** with no need to rotate the **Frequency Tuning Knob**.

### L/C Measurement:

When in **Alpha Mode**, the tabular display will also show the effective Inductance or Capacitance that appears across the input terminals of the VIA while manually adjusting frequency with the Frequency control. This makes the VIA an effective LC meter. The display is auto-ranging and switches the display between L and C when the polarity of the quadrature component of the impedance changes sign. The following display is typical--note the reading of 208.0 nF for Capacitance just below the V1 display.

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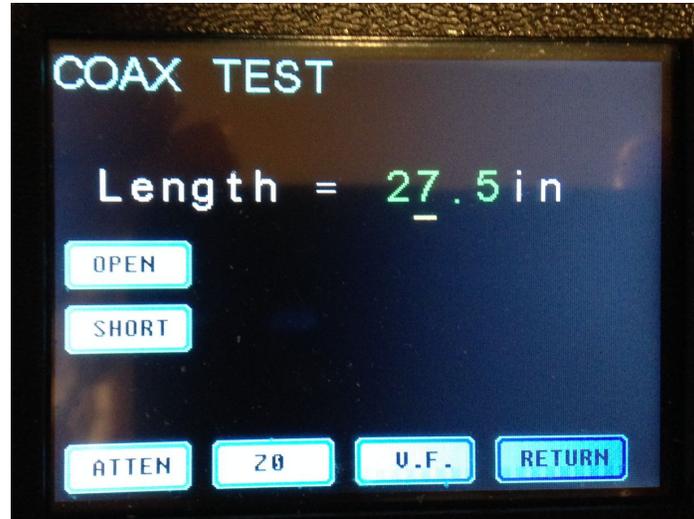
## Coil "Q" Measurement:

Measure the coil at resonance by adding a small series capacitor to obtain RL, then short the capacitor and read the **Inductance "L"** in microhenries. **Coil "Q"** is defined as  $2(\pi)F_oL/R$  where  $2(\pi)$  is "6.28",  $F_o$  is the resonant frequency in MHz, L is the inductance in microhenries, and R (RL) is the inductor effective resistance at resonance. Small silver mica or air variable Capacitor "Q" is generally very high .....3500 or so and has negligible effect.

## Coax Cable Characterization:

The VIA may be used to determine properties of coax cable. As described in APPENDIX IV, measurements made using an open circuit, and a short circuit allow one to determine the attenuation factor (dB/meter or dB/100 feet), Characteristic Impedance, and Velocity Factor (percent of the speed of light). To utilize this capability, first set the start, stop and step frequencies—e.g. Start = 1MHz, Stop = 50MHz, Step = 200kHz. You may use different values if desired. Then select COAX from the main menu. Adjust the length parameter to match the length of coax that you are testing. As noted in the Appendix, the cable should be less than 0.1 wavelength at the highest frequency you have selected.

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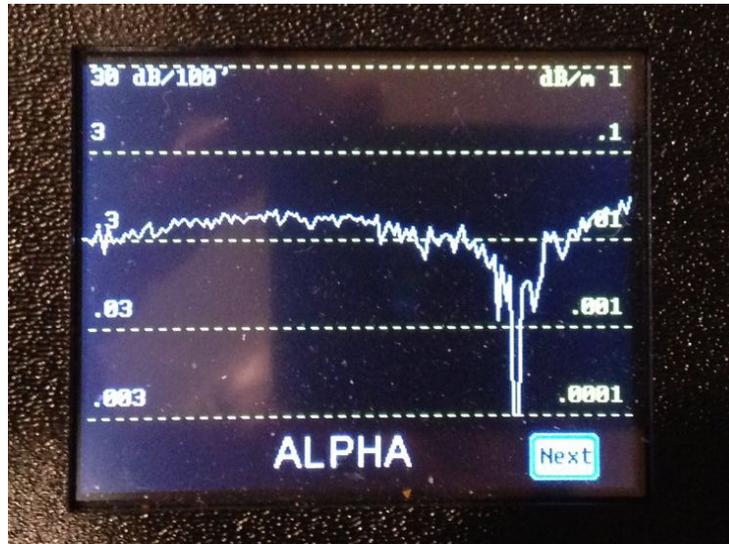
Next perform the OPEN circuit scan. When this is complete, perform the SHORT circuit scan.

When performing the OPEN circuit and SHORT circuit scans, a progress bar will appear near the top of the screen as shown here:

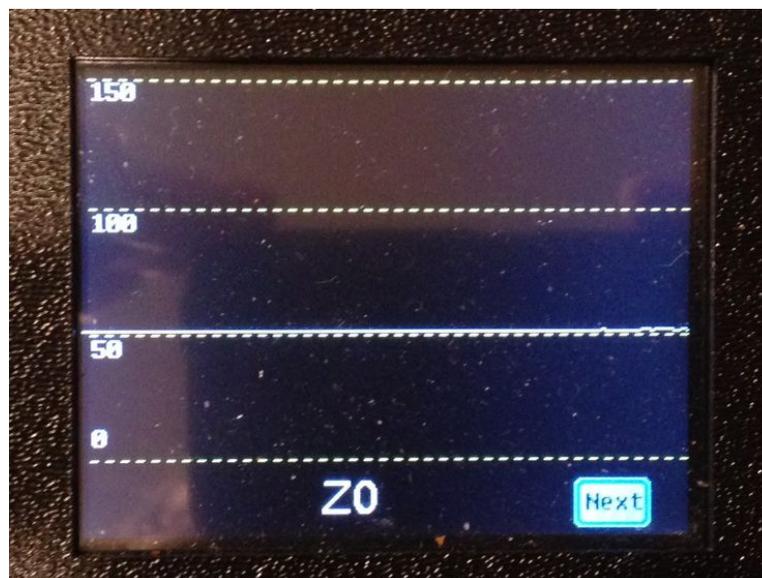


At completion of the OPEN measurement, you will be instructed to place the Short on the coax under test and tap SHORT. After both scans are completed, you may then select the parameter (attenuation, characteristic impedance, or velocity factor) you wish to see plotted. When your selection is made, the data will be plotted on the screen. Here are some examples.

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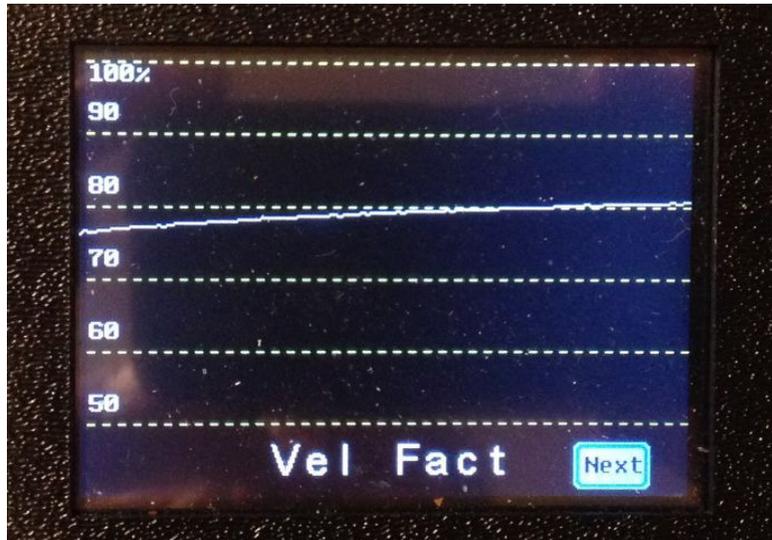


Plot of attenuation factor versus frequency.



Plot of Characteristic Impedance versus frequency.

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Plot of Velocity Factor versus frequency.

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## Transmission Line Fault Location (Frequency Domain Reflectometer):

Some of our users may be familiar with Time Domain Reflectometry, in which a very short pulse is applied to a transmission line and reflections are monitored as a function of time. Such a method allows the user to locate problems such as poor connections or impedance mismatches as a function of distance from the pulse generator.

We do not have such a pulse generator in the VIA. However, we have the capability of making measurements over a wide range of frequencies. If we connect our VIA to a transmission line that is attached to a load, such as an antenna, and measure the impedance over a frequency range of, say, 1MHz to 150MHz we can locate impedance discontinuities with a resolution of about 2 feet and a maximum distance (length of feedline) of about 500 feet. See Appendix V for more details.

This feature is available from the Main Menu by choosing the FDR button. To obtain distance in feed, one has to enter a value for the velocity factor of the feedline. This may be obtained either from measured data (using a sample of the feedline), or from the manufacturer's data sheets. It is typically in the range of 60 to 80 per cent. After entering the Velocity Factor, tap the SCAN button and a plot will appear showing "spikes" along the horizontal trace at locations where the VIA has determined that there are impedance discontinuities.

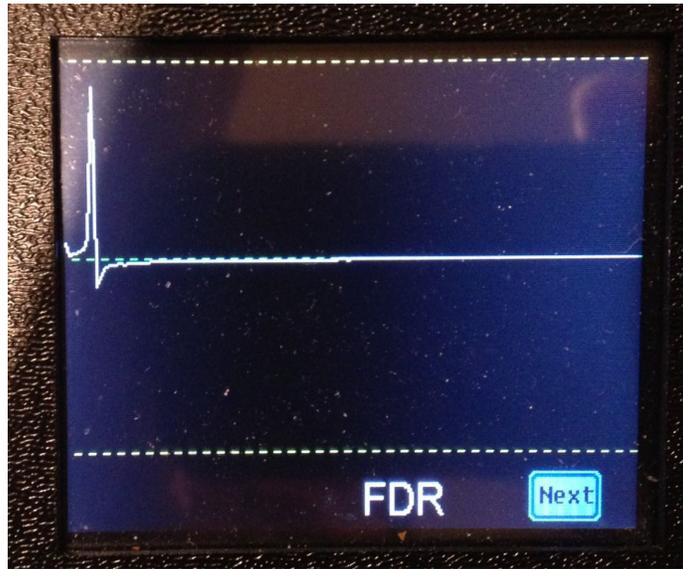


REMINDER—be sure that you have set the Start and Stop frequencies as noted above. A Start Frequency of 1MHz, Stop Frequency of 150MHz and a Step Frequency of 582kHz are recommended.

Although the FDR is not as accurate as a TDR, it should be quite useful for locating faults.

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Here is an example of the FDR scan on a 25 foot open ended coax:



Since an open circuit results in a reflection coefficient of +1, this is what one would expect.

Here is the same coax with a short circuit:



Since a short circuit results in a reflection coefficient of -1, this result is to be expected.

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### Section 3: Technical Definitions:

#### [SmithChart]

The **Smith chart**, invented by [Phillip H. Smith](#) (1905–1987),<sup>[1][2]</sup> is a graphical aid or [nomogram](#) designed for [electrical and electronics engineers](#) specializing in [radio frequency](#) (RF) engineering to assist in solving problems with [transmission lines](#) and [matching](#) circuits.<sup>[3]</sup> Use of the Smith chart utility has grown steadily over the years and it is still widely used today, not only as a problem solving aid, but as a graphical demonstrator of how many RF parameters behave at one or more frequencies, an alternative to using [tabular](#) information. The Smith chart can be used to simultaneously display multiple parameters including [impedances](#), [admittances](#), [reflection coefficients](#), [scattering parameters](#), [noise figure](#) circles, constant gain contours and regions for [unconditional stability](#), including mechanical [vibrations](#) analysis.<sup>[4]</sup> <sup>[5]</sup> The Smith chart is most frequently used at or within the [unity radius](#) region. However, the remainder is still mathematically relevant, being used, for example, in [oscillator](#) design and [stability](#) analysis.

#### [Impedance]

**Impedance** is the complex-valued generalization of [resistance](#). It may refer to:

- [Acoustic impedance](#), a constant related to the propagation of sound waves in an acoustic medium
- [Electrical impedance](#), the ratio of the voltage phasor to the electric current phasor, a measure of the opposition to time-varying electric current in an electric circuit
  - [Characteristic impedance](#) of a transmission line
  - [Impedance \(accelerator physics\)](#), a characterization of the self interaction of a charged particle beam
  - [Nominal impedance](#), approximate designed impedance
- [Mechanical impedance](#), a measure of opposition to motion of a structure subjected to a force
- [Wave impedance](#), a constant related to electromagnetic wave propagation in a medium
  - [Impedance of free space](#), a universal constant and the simplest case of a wave impedance
  -

[Resistance](#) is a measure of the opposition of a circuit to the flow of a steady current, while impedance takes into account not only the resistance but also dynamic effects (known as [reactance](#)).

Impedance is represented by the equation:

$$Z = R + jX$$

#### [Admittance]

In [electrical engineering](#), **admittance** is a measure of the ease with which a time-varying electric current flows in an electric circuit. It is defined as the [inverse](#) of [impedance](#). The [SI](#) unit of admittance is the [Siemen](#) (symbol S). [Oliver Heaviside](#) coined the term *admittance* in December 1887.<sup>[1]</sup>

Admittance is defined as

$$Y \equiv \frac{1}{Z}$$

where

$Y$  is the admittance, measured in [siemens](#)

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$Z$  is the impedance, measured in [ohms](#)

Admittance is not only a measure of the ease with which a steady current can flow, but also the dynamic effects of the material's susceptance to polarization:

$$Y = G + jB$$

where

- $Y$  is the admittance, measured in Siemens.
- $G$  is the [conductance](#), measured in Siemens.
- $B$  is the [susceptance](#), measured in Siemens.
- $j^2 = -1$
- 

### [ReturnLoss]

In [telecommunications](#), **return loss** is the loss of [power](#) in the [signal](#) returned/reflected by a discontinuity in a [transmission line](#) or [optical fiber](#). This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. It is usually expressed as a ratio in [decibels](#) (dB);

$$RL(\text{dB}) = 10 \log_{10} \frac{P_i}{P_r}$$

where  $RL(\text{dB})$  is the return loss in dB,  $P_i$  is the incident power and  $P_r$  is the reflected power.

Return loss is related to both [standing wave ratio](#) (SWR) and [reflection coefficient](#) ( $\Gamma$ ). Increasing return loss corresponds to lower SWR. Return loss may be used as a measure of how well devices or lines are matched, assuming that the transmission line is low loss. The match is good if the return loss is high. A high return loss is desirable and results in a lower [insertion loss](#). Don't be fooled, however, as a very lossy line can also result in high return loss.

Return loss is often used in modern practice in preference to SWR because it has better resolution for small values of reflected wave

### [ReflCoeff] - Reflection Coefficient

In [physics](#) and [electrical engineering](#) the **reflection coefficient** is a parameter that describes how much of an [electromagnetic wave](#) is reflected by an impedance discontinuity in the transmission medium. It is equal to the ratio of the [amplitude](#) of the reflected wave to the incident wave, with each expressed as [phasors](#). For example, it is used in [optics](#) to calculate the amount of light that is reflected from a surface with a different index of refraction, such as a glass surface, or in an electrical [transmission line](#) to calculate how much of the [electromagnetic wave](#) is reflected by an impedance. The reflection coefficient is closely related to the [transmission coefficient](#). The [reflectance](#) of a system is also sometimes called a "reflection coefficient".

A wave experiences partial transmittance and partial reflectance when the medium through which it travels suddenly changes. The reflection coefficient determines the ratio of the reflected wave amplitude to the incident wave amplitude.

A signal travelling along an electrical [transmission line](#) will be partly, or wholly, [reflected](#) back in the opposite direction when the travelling signal encounters a [discontinuity](#) in the [characteristic impedance](#) of the line, or if the

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far end of the line is not [terminated](#) in its characteristic impedance. This can happen, for instance, if two lengths of dissimilar transmission lines are joined together.

Reflections cause several undesirable effects, including modifying [frequency responses](#), causing [overload](#) power in [transmitters](#) and [overvoltage's](#) on [power lines](#). However, the reflection phenomenon can also be made use of in such devices as [stubs](#) and [impedance transformers](#). The special cases of open circuit and short circuit lines are of particular relevance to stubs.

Reflections cause [standing waves](#) to be set up on the line. Conversely, standing waves are an indication that reflections are present. There is a relationship between the measures of [reflection coefficient](#) and [standing wave ratio](#).

In metallic conductor systems, reflections of a signal traveling down a conductor can occur at a discontinuity or [impedance](#) mismatch. The ratio of the amplitude of the reflected wave  $V_r$  to the amplitude of the incident wave  $V_i$  is known as the [reflection coefficient](#)  $\Gamma$ .

$$\Gamma = \frac{V_r}{V_i}$$

When the source and load impedances are known values, the reflection coefficient is given by

$$\Gamma = \frac{Z_L - Z_S}{Z_L + Z_S}$$

where  $Z_S$  is the impedance toward the [source](#) and  $Z_L$  is the impedance toward the [load](#).

In discussing transmission lines the **source** value is replaced with  $Z_0$ , the characteristic impedance of the transmission line. Consequently,

$$\Gamma = (Z_L - Z_0) / (Z_L + Z_0)$$

Note that  $\Gamma$  approaches -1 when  $Z_L$  goes to zero. In addition, Gamma approaches +1 when  $Z_L$  becomes very large.

Return loss is the negative of the magnitude of the reflection coefficient in dBs'. Since power is proportional to the square of the voltage, return loss is given by,

$$RL(\text{dB}) = -20 \log_{10} |\Gamma|$$

where the [vertical](#) bars indicate [magnitude](#). Thus, a large positive return loss indicates the reflected power is small relative to the incident power, which indicates good impedance match from source to load.

When the actual transmitted (incident) power and the reflected power are known (i.e., through measurements and/or calculations), then the return loss in dB can be calculated as the difference between the incident power  $P_i$  (in [dBm](#)) and the reflected power  $P_r$  (in dBm),

$$RL(\text{dB}) = P_i(\text{dBm}) - P_r(\text{dBm})$$

### [VSWR]

VSWR (*Voltage Standing Wave Ratio*), is a measure of how efficiently radio-frequency power is transmitted from a power source, through a transmission line, into a load (for example, from a power amplifier through a transmission line, to an antenna).

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In an ideal system, 100% of the energy is transmitted. This requires an exact match between the source impedance, the characteristic impedance of the transmission line and all its connectors, and the load's impedance. The signal's AC voltage will be the same from end to end since it runs through without interference.

In real systems, mismatched impedances cause some of the power to be reflected back toward the source (like an echo). Reflections cause destructive interference, leading to peaks and valleys in the voltage at various times and distances along the line.

VSWR measures these voltage variances. It is the ratio of the highest voltage anywhere along the transmission line to the lowest. Since the voltage doesn't vary in an ideal system, its VSWR is 1.0 (or, as commonly expressed, 1:1). When reflections occur, the voltages vary and VSWR is higher -- 1.2 (or 1.2:1), for instance

it may be shown that

$$VSWR = (1 + |\Gamma|)/(1 - |\Gamma|)$$

Observe that VSWR approaches infinity whenever the magnitude of  $\Gamma$  approaches 1, and approaches 1 when the magnitude of  $\Gamma$  goes to zero.

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## Section 4: Troubleshooting:

### Troubleshooting

Ok, you've completed assembly and are now ready for checkout.

If you have soldered all components correctly (and the parts are in the correct location), and you have the correct supply voltage, the VIA should power up and operate correctly from the “get go”. If, however, you are like most of us, you may encounter some difficulties.

To start, load the latest version of the firmware.

The following is an attempt to provide a step by step procedure to get you up and running in the shortest amount of time.

Before proceeding, check all solder connections to each IC, resistor, capacitor, and board connector. Retouch as needed. Check also for solder splashes that might short adjacent connection. It is also recommended that you use the schematic to check for proper continuity of all signal and power traces.

### Display blank and no back light.

#### Check 3.3V Power:

A short on the 3.3 Volt line in the **VIA** will cause the screen to not display.

#### 3.3 Volt check:

The 3.3 Volt is supplied from the **Discovery** board and needs to be checked for a **steady level voltage**. This can be accomplished by attaching the ground lead from a DVM to the chassis and checking the voltage on pin 5 & 6 on P2 on the **Discovery** board, or by using a scope to see the 3.3V line for fluctuations. Look for the Voltage markings on the **Discovery** board.

A reduction in the voltage below its nominal could mean there is a short somewhere on the **VIA** board. This will require a thorough check of the **VIA** board and its 3.3V line connections.

Turn off the power, remove the power connection from the **VIA** board and remove the **Discovery** and **VIA** boards from the stack, and don't forget to unsolder the leads to the BNC connector.

**While checking components, it's advisable to use high magnification and good lighting to inspect between leads for shorts!**

#### Areas to check:

##### U6:

Pins 7 to pin 8

##### U5:

Pins 7 to pin 8

##### U1:

Pins 6 to pin 7

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Across C1

across C4

across C6

Pins 26 to pin 28

across C9 and C10

Do a detailed visual inspection of all the areas mentioned above, and re-solder any suspicious area. Use an ohmmeter on the lowest resistance setting to check the points mentioned above.

If the reading indicates a short, re-solder the leads or component to remove the excess solder and inspect the part very closely.

### Check connections to the LCD

You may have a solder connection problem on the 40 pin connector for the LCD display. Check all connections, and touch up each solder connection as needed. The LCD Checklist Spreadsheet (Appendix I) identifies the LCD connections between the Discovery Board connectors and the LCD connector on the VIA board that need to be verified. This will hopefully get the display working.

If both the 3.3V is OK and the LCD connections verify, you should have, at least, backlight illumination on the LCD.

### Long Delay before Splash Screen Appears

If the Splash Screen is taking ~ 20 seconds or so, there is something else wrong. This problem is usually due to a failure of communications between the STM microcontroller (on the Discovery board) and the Si5351 chip(U6) or the EEPROM (U5). The Inter-Integrated Circuit bus (I2C) is used for this communications. Loss of communications may be due to lack of power and ground to one of the devices, or an open or short on the SCL, SDA lines.

To check power, make sure that U6-8, U5-1,2,3,4,7 and U1-7, 17, 28 are all grounded. Also check that U6-1,7, U5-8 and U1-6,26 are connected to 3.3V (junction of L1 and L2).

Check continuity of the I2C signals: U6-5 to U5-5 to U1-10. Also check U6-4 to U5-6 to U1-9. Make sure none of these pins are shorted to ground. Re-solder, repair as necessary.

Assuming that you have fixed the communications problem, restart the unit and select SETUP.

**If the display shows the splash screen within about 2 or 3 seconds**, you are well on your way. If not, you could have a defective display or Discovery board (both of which were working when the kit was sent).

### Preliminary signal checks

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Set the Start Frequency to 3MHz, Stop Frequency to 30MHz, Frequency Step to 10kHz, and Dwell time to 40mSec. Save these values by tapping STORE. Now select ALPHA Mode. Check the display for the readings for V1, V2 and IF-Sig.

### Typical values for V1, V2 and IF\_Sig:

The following table shows values that are typical when the *start frequency is set for 3 MHz* and with various loads: This is good information to better understand the readings in the "Plot" screen prior to creating a chart.

Load	V1	V2	IF_Sig
<b>OPEN</b>	3900	60	16000
<b>50 Ohm</b>	3200	3200	9200
<b>0 Ohm</b>	2800	4700	7000

Component variations may change these values, but their relative magnitudes should be consistent for the various load conditions. Note particularly that **V1** will be much larger than **V2** with an open load. V1 and V2 will be nearly equal with a 50 ohm load. With a 0 Ohm load (SHORT), **V2** will be larger than **V1**. In addition, IF-Sig will be largest with an open circuit load and will drop as the load resistance approaches 0 ohms.

If the (relative) values listed above are not observed, first make the following resistance check:

**Measure the resistance from the center pin of the BNC connector to the ground of the connector.** You should measure about 107 ohms. If you measure something outside of the range of 102 to 112 ohms, you likely have a problem in a solder connection of one or more of the resistors R1 to R6.

Here are some examples of resistance values that you may observe under various fault conditions:

R14 and/or R16 open--infinite

R1 and/or R2 open--115 ohms

R3 open--146 ohms

R12 and/or R13 open--123 ohms

Please note that these values are based on the assumption that all resistors are nominal and that your meter is accurately calibrated. You may find your measured values differ from these by a few ohms. The values given above are intended to provide guidance only. If the values are considerably different from the listed values, verify that the resistors are marked with the correct values per the schematic.

If the measured resistance from the center pin of the BNC connector to ground is ~107 ohms, proceed with the following checks.

**If V1 and IF-Sig are very low** (and V2 is close to normal) you likely have a problem in the signal path from U3 pin 4, through C16, to U1 pin 16. .

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If **V2 is very low** (and V1 and IF-Sig are close to normal), you likely have a problem in the signal path from U2 pin 4, through C15, to U1 pin 15.

If either of these is your problem, you are lucky. There can't be too much wrong. Most likely a solder problem.

If **both V1 and V2 (and IF-Sig) are low**, the problem will be more difficult to sort out. However, a step by step approach should help resolve the problem in the shortest time. It may be necessary to trace the signals from the RF source, through attenuator networks, to the bridge, to the mixers, and on to the codec input.

For this, you will need an oscilloscope that is capable of viewing a signal with a frequency of at least 3 MHz, or whatever start frequency you have entered. Ideally, a 30 MHz bandwidth (or greater) oscilloscope would be used.

Start at the signal source, U6. This chip has two outputs that can be monitored by connecting your scope across R1 and R4. The signals should be very close in frequency (2 kHz apart) and have an amplitude of about 1.6 volts peak to peak. If the bandwidth of your scope is sufficient, the waveform should approximate a square wave. If one of the two signals is missing, check the solder connections to U6 again, and also the connections to C2 and C3. Once you have signals across both R1 and R4, check the signals across R3 and R6. You should still have signals that look like those across R1 and R4, but somewhat smaller in amplitude. The voltage across R3 should be near 200 mV peak to peak. The voltage across R6 should be near 150mV peak to peak. If either signal is missing, check the series resistors R2 and R5 for solder issues.

If you have no signals across R1 and R4, it is possible that the crystal X1 is not properly soldered, or there is another solder problem at the pins of U6.

Once you have RF signals across R3 and R6, proceed to trace the signal to the junction of C19 and C20 and also to the junction of R11,12,14 and 15. If you find levels approximately the same as across R2 and R5, you are good to proceed.

If the solder connections on C19 and C20 are good, you should also have a "local oscillator" signal into the mixers, U2 pin 6 and U3 pin 6.

If the solder connections to C21 to C24 are good, there should be bridge RF signals getting to the two mixers.

When both the RF and LO signals are present at each Mixer, there should be 2 kHz outputs at U2 pin 4 and U3 pin 4. These two signals are coupled via C15 and C16 into the codec. Place a 50 ohm load on the

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BNC connector and check for a low level 2 kHz signal at the junction of C13 and C15, and at the junction of C14 and C16. If you can see the 2 kHz signal (several millivolts peak to peak) at each codec input, you should see sizeable V1 and V2 signals on the ALPHA display.

Assuming that you now have signals going into the codec, if you still have very low signals displayed for V1 and V2, there is probably a connection problem with the Codec U1. Because this is a leadless chip and the connections are slightly recessed, this is not uncommon. Reheat all of the solder connections, being careful not to create any solder bridges and recheck the V1 and V2 readings on the display.

### **Start, Stop, Step, Dwell not being saved:**

When trying to enter new parameters, tapping **START**, results in strange values on the display. This can be because this is the first time the EEPROM (U5) has been used and has no previously stored data.

This could also be due to problems communicating with the EEPROM (U5). Check the solder connections to all of the pins on U5 and C4.

If the **Discovery** board has not been updated with V2.0 or later firmware, maybe updating the **Discovery** board with the latest firmware will help because it takes care of pre-loading information into the EEPROM (U5) when power is applied to the system. See **Firmware Updates** on page 26.

### **“nan” in the “ALPHA” display:**

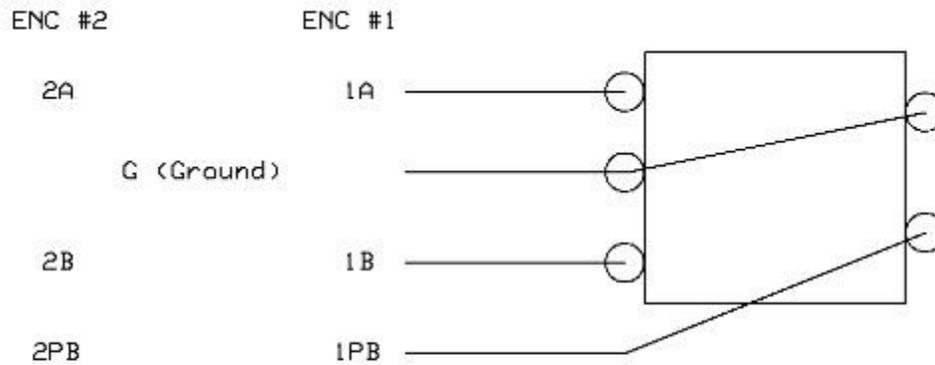
This situation is not too bad. It frequently means that before the “**Cal**” procedure is done, a set of frequencies needs to be entered into the unit. So start the unit and when it goes to the **VIA Setup** screen go and add a start and stop frequency. See **Frequency Setup** on page 8 for setting the parameters.

### **“inf” in the “ALPHA” display:**

“**inf**” indicates that the **VIA** has performed an operation that resulted in a number that is beyond the limit of the processor. The cause can be the same as for “**nan**” and may be resolved by performing the Calibration.

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## Encoder Reverse wiring Function:



If the Encoder works in reverse, just flip the A and B leads

## Section 5: Firmware updates

### STM32 Utility link:

Download the STSW-LINK004 STM32 ST-LINK utility. Click on the link, or enter this link into the search a computer search program: <http://www.st.com/web/en/catalog/tools/PF258168>

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After clicking on the link a web page will open for the **STSW-LINK004 SSTM32 ST-LINK utility**. Scroll down the page to where it show the **Download** button. Click on the **Download** button and



follow the installation instructions.

Once the file is installed it will put a short cut Icon on the Desk Top. Click on the Icon to open the file (**STM32 ST-link Utility**). This sets up the utility to update the latest firmware on the **VIA**.

Connect a USB cable to the VIA and then connect the other end of the cable to the computer. The unit will be powered and turn on from the connection in the computer.

### **VIA Firmware Updates:**

Next get the latest Firmware upgrade and copy it to a folder. Go to <http://www.qsl.net/k5bcg/Kits/Kits.html> site and scroll down the kit page until the section called:

### **PROGRAMMING/RE-PROGRAMMING**

#### **Download the desired AQRP VIA HEX file.**

Right click on the latest Firmware and click on “**Save Target as....**”, from the dropdown window. The computer will ask what to do with the file. Select a folder or create a new **VIA Firmware folder** and save the file into that folder. When the computer comes up with the window at the bottom of the screen, click on “**Open folder**”.

Go back to the **STM32 ST-Link Utility** and click on “**File**”. From the dropdown window click on “**Open File...**”. From the next window find where the firmware was saved, select that folder, click on the latest firmware file to highlight it, and click on the “**Open**” button at the bottom of the screen. This will open the file and set it ready to down load to the unit.

On the Utility program Tool Bar, click on “**Target**”. From the dropdown window, click on “**Program & Verify...**” This will open a window to down load the firmware to the **VIA**. Click on the “**OK**” or “**Start**” button, and watch the process window. It will take about 20 second to down load and verify. After the program is loaded see the information in the bottom of the window which defines what has been completed.

Close the Utility program and disconnect the VIA from the USB cable. Turn on the **VIA** and notice in the Splash Screen for the new firmware update.

That’s it, now go and enjoy this versatile tool with its new firmware functionality.

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## Appendix I

### CONTINUITY CHECKLIST -- DISPLAY

	From	To		
<input type="checkbox"/>	P2-1,2	P3-1	GND	Display Power and Control
<input type="checkbox"/>	P2-3,4	P3-3	5V	Display Power and Control
<input type="checkbox"/>	P2-5,6	P3-37	3.3V	Display Power and Control
<input type="checkbox"/>	P2-27/PD7	P3-29	TFT-CS	Display Power and Control
<input type="checkbox"/>	P2-29/PD5	P3-9	TFT-WR	Display Power and Control
<input type="checkbox"/>	P2-32/PD4	P3-11	TFT-RD	Display Power and Control
<input type="checkbox"/>	P1-43/PD11	P3-7	TFT-RS	Display Power and Control
<hr/>				
<input type="checkbox"/>	P1-46/PD14	P3-2	D0	Display Data
<input type="checkbox"/>	P1-47/PD15	P3-4	D1	Display Data
<input type="checkbox"/>	P2-36/PD0	P3-6	D2	Display Data
<input type="checkbox"/>	P2-33/PD1	P3-8	D3	Display Data
<input type="checkbox"/>	P1-25/PE7	P3-10	D4	Display Data
<input type="checkbox"/>	P1-26/PE8	P3-12	D5	Display Data
<input type="checkbox"/>	P1-27/PE9	P3-14	D6	Display Data
<input type="checkbox"/>	P1-28/PE10	P3-16	D7	Display Data
<input type="checkbox"/>	P1-29/PE11	P3-13	D8	Display Data
<input type="checkbox"/>	P1-30/PE12	P3-15	D9	Display Data
<input type="checkbox"/>	P1-31/PE13	P3-17	D10	Display Data
<input type="checkbox"/>	P1-32/PE14	P3-19	D11	Display Data
<input type="checkbox"/>	P1-33/PE15	P3-21	D12	Display Data
<input type="checkbox"/>	P1-40/PD8	P3-23	D13	Display Data
<input type="checkbox"/>	P1-41/PD9	P3-25	D14	Display Data
<input type="checkbox"/>	P1-42/PD10	P3-27	D15	Display Data
<hr/>				
<input type="checkbox"/>	P1-36/PB12	P3-20	TP-CS	Touch Panel Control
<input type="checkbox"/>	P1-37/PB13	P3-18	TP-CLK	Touch Panel Control
<input type="checkbox"/>	P1-38/PB14	P3-26	TP-MISO	Touch Panel Control
<input type="checkbox"/>	P1-39/PB15	P3-22	TP-MOSI	Touch Panel Control
<input type="checkbox"/>	P2-30/PD6	P3-28	TP-IRQ	Touch Panel Control

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## Appendix II

VIA Measurement Equation

$$Z_L = Z_{Cal} * \frac{(z_m - z_{sc}) * (z_{oc} - z_{cal})}{(z_{cal} - z_{sc}) * (z_{oc} - z_m)}$$

where

$Z_{Cal}$  is the desired "reading" when the calibration load is measured

$z_m$  is the raw measurement with an unknown load

$z_{sc}$  is the raw measurement with a short circuit at the input

$z_{oc}$  is the raw measurement with an open circuit at the input

$z_{cal}$  is the raw measurement with a calibration load at the input

Note the following-

if  $z_m = z_{sc}$ ,  $Z_L$  will be zero

if  $z_m = z_{oc}$ ,  $Z_L$  will approach infinity

if  $z_m = z_{cal}$ ,  $Z_L$  will be  $Z_{Cal}$

Note also--the above equation is independent of  $Z_0$ . If a length of transmission line is added between the system input and the various loads, the effect on  $z_m$ ,  $z_{sc}$ ,  $z_{oc}$ , and  $z_{cal}$  will suppress the effect of the added line. That is, the calibration process (measurement of  $z_{sc}$ ,  $z_{oc}$ , and  $z_{cal}$ ) negates the effect of the line and produces measured  $Z_L$  as though the line were absent.

Other equations that ARE DEPENDENT ON  $Z_0$ :

$k = (Z_L - Z_0)/(Z_L + Z_0)$  This is the equation for the complex reflection coefficient.

$VSWR = (1 + |k|)/(1 - |k|)$  This is the equation for the Voltage Standing Wave Ratio

$RL = -20\log_{10}(|K|)$  This is the equation for Return Loss

Note, in previous text, we used Gamma interchangeably with  $k$ .

In addition, the Smith Chart is a means for displaying the Complex Reflection Coefficient in a simple circular plot. All possible values of complex  $k$  can be plotted within a circle of unit radius—because the maximum magnitude for  $k$  is 1.

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### Appendix III

#### Sending Data to a PC

To facilitate processing of VIA data on a PC, the VIA firmware includes a “Virtual Com Port”. The micro-USB connector on the Discovery board can be connected with a standard cable to a USB port on a PC for transmitting data stored in the VIA EEPROM.

A driver known as a “Virtual Com Port Driver” may be downloaded from the STMicro website. This driver should be installed on the PC while the VIA is still disconnected from the PC. Once the driver is installed and the VIA is connected to the PC with the USB cable, the PC should recognize the VIA as an STM Virtual Com Port and assign a Com Port Number (e.g. Com3 or Com4).

Get the driver from here:

[http://www.st.com/content/st\\_com/en/products/development-tools/software-development-tools/stm32-software-development-tools/stm32-utilities/stsw-stm32102.html](http://www.st.com/content/st_com/en/products/development-tools/software-development-tools/stm32-software-development-tools/stm32-utilities/stsw-stm32102.html)

Scroll down to STSW-STM32102 and click on “Get Software”. Download and install.

In addition to the driver described above, you will need a “Communications Terminal Program” to communicate with the VIA and to capture data sent from the VIA. The free program TeraTerm is recommended for this purpose. TeraTerm may be downloaded from:

<https://en.osdn.jp/projects/ttssh2/releases/>

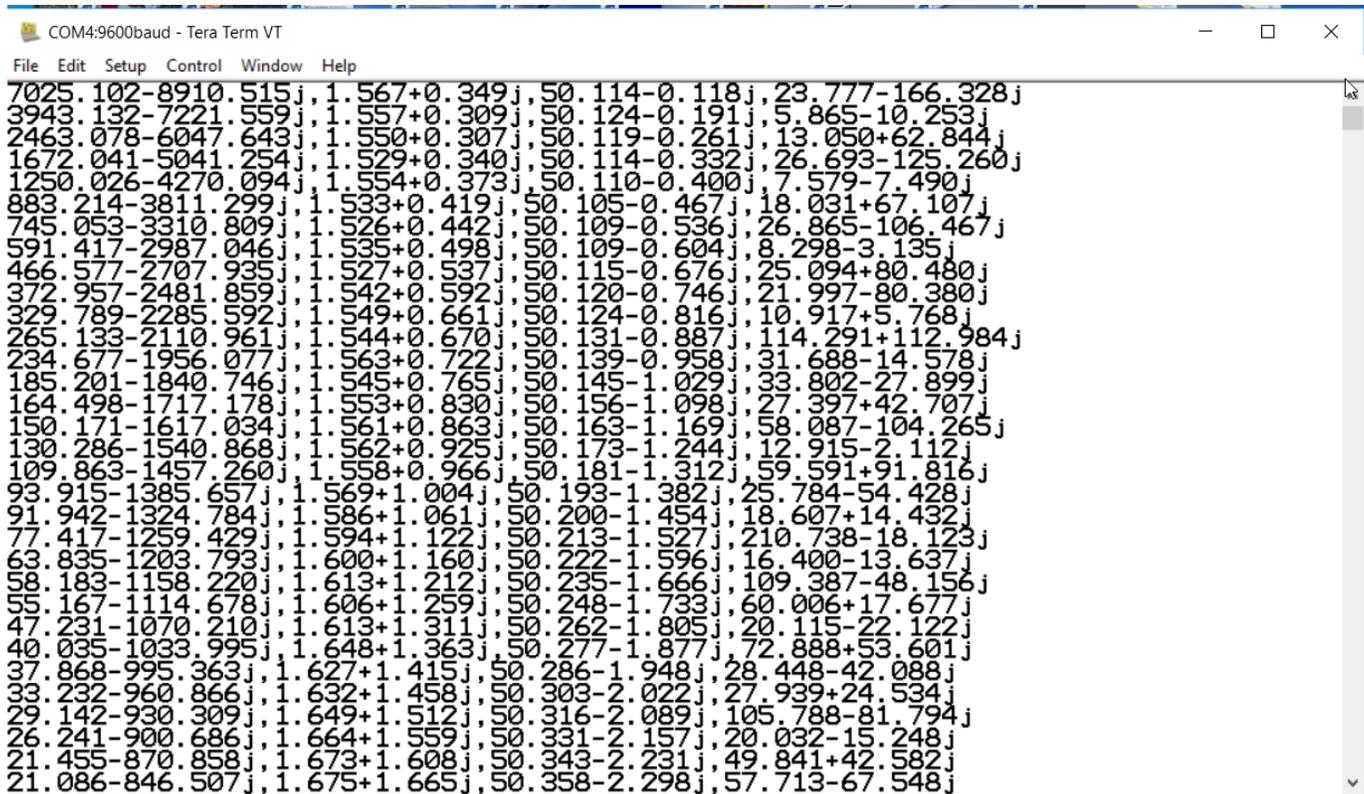
Scroll down the page to find teraterm-4.91.exe or teraterm-4.91.zip

Install Tera Term and configure it for the virtual com port identified after installing the STM virtual com port driver. You should be able to run the communications at 115.2 kbaud.

To transfer data, connect the VIA to your PC. Turn on the VIA. Open TeraTerm. If TeraTerm is unable to communicate with the VIA, an error message will pop up. If communications is OK, you can hold down the CTRL on the PC keyboard, while tapping the Q key (i.e. ctrl-Q). ASCII Data should appear on the PC screen. The initial data will be Z0 and Rcal followed by the Number of Steps (number of data sets), Start Frequency, and Step Frequency. Following this will be Complex Impedance values of Open Circuit raw impedance, Short Circuit raw impedance, Rcal raw impedance, and finally Load raw impedance. Each Impedance value is in the form Real-Part +/- Imaginary Part\*j. From the raw impedances, one can use the equation in Appendix II to reproduce any of the plots that can be created with the VIA. (Don't forget—the impedances used in the equations in Appendix II are all complex values.

The screen shot on the next page is a typical output as displayed on the PC display. Copy/paste data from the TeraTerm buffer directly into Open Office Calc. For Microsoft Excel, you must first Copy/Paste the data into a Wordpad or Notepad “text document” This document can then be imported into Excel. The impedance values are comma delimited to facilitate pasting into the columns of a spreadsheet. Using Ctrl-Q to initiate transfer will send only the four raw impedance values at each frequency. To determine the frequency associated with each set of four values, you will need to know the start frequency and the frequency step. See the instructions below the next image.

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```
COM4:9600baud - Tera Term VT
File Edit Setup Control Window Help
7025.102-8910.515j,1.567+0.349j,50.114-0.118j,23.777-166.328j
3943.132-7221.559j,1.557+0.309j,50.124-0.191j,5.865-10.253j
2463.078-6047.643j,1.550+0.307j,50.119-0.261j,13.050+62.844j
1672.041-5041.254j,1.529+0.340j,50.114-0.332j,26.693-125.260j
1250.026-4270.094j,1.554+0.373j,50.110-0.400j,7.579-7.490j
883.214-3811.299j,1.533+0.419j,50.105-0.467j,18.031+67.107j
745.053-3310.809j,1.526+0.442j,50.109-0.536j,26.865-106.467j
591.417-2987.046j,1.535+0.498j,50.109-0.604j,8.298-3.135j
466.577-2707.935j,1.527+0.537j,50.115-0.676j,25.094+80.480j
372.957-2481.859j,1.542+0.592j,50.120-0.746j,21.997-80.380j
329.789-2285.592j,1.549+0.661j,50.124-0.816j,10.917+5.768j
265.133-2110.961j,1.544+0.670j,50.131-0.887j,114.291+112.984j
234.677-1956.077j,1.563+0.722j,50.139-0.958j,31.688-14.578j
185.201-1840.746j,1.545+0.765j,50.145-1.029j,33.802-27.899j
164.498-1717.178j,1.553+0.830j,50.156-1.098j,27.397+42.707j
150.171-1617.034j,1.561+0.863j,50.163-1.169j,58.087-104.265j
130.286-1540.868j,1.562+0.925j,50.173-1.244j,12.915-2.112j
109.863-1457.260j,1.558+0.966j,50.181-1.312j,59.591+91.816j
93.915-1385.657j,1.569+1.004j,50.193-1.382j,25.784-54.428j
91.942-1324.784j,1.586+1.061j,50.200-1.454j,18.607+14.432j
77.417-1259.429j,1.594+1.122j,50.213-1.527j,210.738-18.123j
63.835-1203.793j,1.600+1.160j,50.222-1.596j,16.400-13.637j
58.183-1158.220j,1.613+1.212j,50.235-1.666j,109.387-48.156j
55.167-1114.678j,1.606+1.259j,50.248-1.733j,60.006+17.677j
47.231-1070.210j,1.613+1.311j,50.262-1.805j,20.115-22.122j
40.035-1033.995j,1.648+1.363j,50.277-1.877j,72.888+53.601j
37.868-995.363j,1.627+1.415j,50.286-1.948j,28.448-42.088j
33.232-960.866j,1.632+1.458j,50.303-2.022j,27.939+24.534j
29.142-930.309j,1.649+1.512j,50.316-2.089j,105.788-81.794j
26.241-900.686j,1.664+1.559j,50.331-2.157j,20.032-15.248j
21.455-870.858j,1.673+1.608j,50.343-2.231j,49.841+42.582j
21.086-846.507j,1.675+1.665j,50.358-2.298j,57.713-67.548j
```

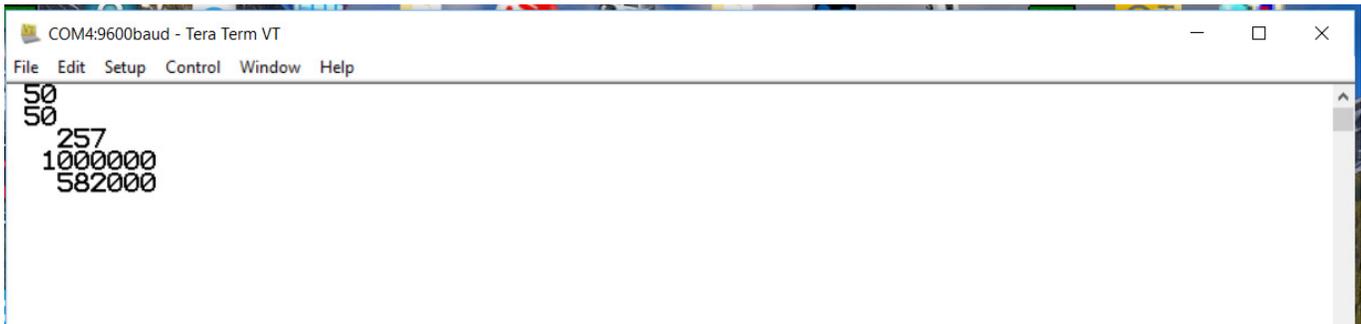
## Additional choices for Data Transmission to the PC

The above describes the transmission of the 4 raw impedance data values (Open Circuit, Short Circuit, Calibration, and Unknown). Instead of using Ctrl-Q to initiate transfer, the user can choose to send only calibrated values of impedance by entering Ctrl-C on the PC keyboard. In this case, the transmitted data will include the frequency, and the real and imaginary parts of the calibrated impedance. Finally, Ctrl-P may be used to transmit the operating parameters (which includes the value of both the Characteristic Impedance  $Z_0$  and the Calibration Resistor  $R_{cal}$  used in the calibration and subsequent calculations, the total number of data points that have been captured --the number of frequency steps, not the number of all types of data-- the start frequency and the frequency step).

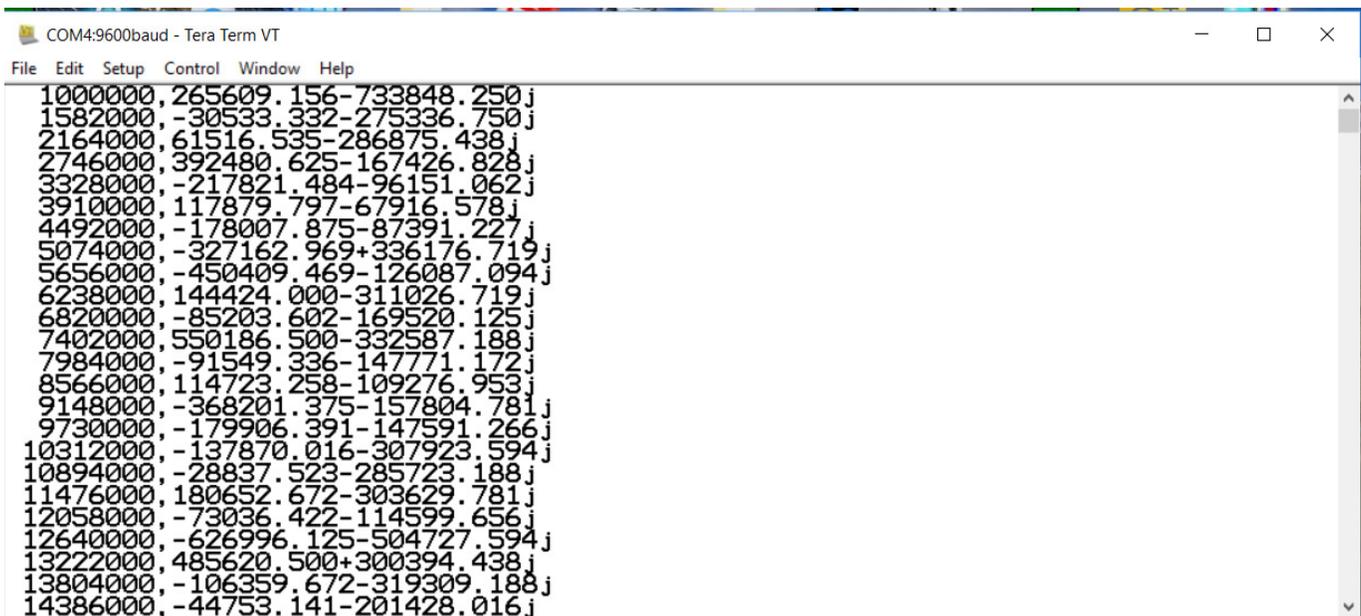
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The next image shows the result of sending Ctrl-P from the PC keyboard. Z0, Rcal, number of data points, start frequency and frequency step are returned from the VIA



The next image is produced by sending Ctrl-C from the PC keyboard to the VIA. For each data point, the VIA sends the frequency, real part of the calibrated impedance, and the imaginary part of the calibrated impedance.



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## Appendix IV Coax Cable Measurements

The impedance of a length of coax cable, with the far end shorted is given by--

$Z_{sc} = Z_0 \cdot \tanh(\gamma L)$  where  $Z_0$  is the characteristic impedance of the cable,  $\gamma$  is the complex propagation factor, and  $L$  is the length of the cable.

Similarly, the impedance of the same coax cable with the far end open circuited is given by--

$$Z_{oc} = Z_0 / \tanh(\gamma L)$$

If we take the product of the two impedances, we have

$$Z_{oc} \cdot Z_{sc} = Z_0^2 \tag{1}$$

Therefore,  $Z_0$  may be obtained by taking the square root of the  $Z_{oc} \cdot Z_{sc}$  product.

If we take the ratio of  $Z_{sc}$  and  $Z_{oc}$  we obtain--

$$Z_{sc} / Z_{oc} = (\tanh(\gamma L))^2 \tag{2}$$

and we can determine the complex propagation constant from the ratio of  $Z_{sc}$  and  $Z_{oc}$ .

Both equation 1 and 2 require the ability to compute the square root of a complex number. In addition, equation 2 requires a means to compute the inverse hyperbolic tangent of a complex number.

The solution of equation 2 yields both the attenuation per length  $L$  of the coax, and the phase per length  $L$ .

That is,  $\gamma L = (\alpha + j\beta) \cdot L$

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To solve equation 2 for  $\gamma L$  it is essential that the length  $L$  be less than about 0.1 wavelength at the maximum frequency used for the measurements of  $Z_{oc}$  and  $Z_{sc}$ . The reason for this restriction is that the inverse of the tanh function can yield multiple values for  $\beta$ . The ambiguity is eliminated by using electrically short cables for our measurements.

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## Appendix V Frequency Domain Reflectometer

The resolution of the VIA FDR is determined by the maximum frequency used. The VIA is currently limited to 150MHz.

This equation is used to determine the spatial resolution--

$$\text{resolution(m)} = 0.5 * C * \text{v.f.} / \text{max\_frequency}$$
 where C is the velocity of light in free space ( $3 \times 10^8$  meters per second) and v.f. is the velocity factor of the cable under test. In the case of the VIA, max\_frequency is  $1.5 \times 10^8$ . Consequently the resolution is (v.f.) meters.

For most coax cables, the velocity factor is approx 0.66, resulting in a resolution of about 2/3 of a meter, or approx. 2 ft.

The other equation of interest is for the range, or total length of coax, that can be measured.

$$\text{Range} = N * \text{resolution}$$
, where N is the number of points in the Inverse FFT that is used to convert our frequency domain measurements to time (and consequently distance)

We are currently using a 256 point complex Inverse FFT. This results in a range of about 500 ft.

To operate the FDR function, first setup the VIA for the following parameters:

Start\_frequency—1 MHz  
Stop\_Frequency—150MHz  
Freq\_Step—582kHz  
Dwell—60 or 70 mSec

Calibrate using these parameters.

I know that the Frequency Step seems a bit odd, but it is chosen so that the number of samples will be approximately 256 (a good number for the FFT).

# AQRP Vector Impedance Analyzer

## User Manual

Next, select FDR from the main menu. Then enter the velocity factor for the cable you are using. (Press the frequency encoder push button to save the value in RAM) Then tap the SCAN button to perform the FDR. When the VIA is through measuring data (as indicated by the progress bar) the data will be plotted. At the completion of the plot, the cursor will be enabled and can be moved using the cursor encoder. The “computed distance” corresponding to the location of the cursor will be displayed at the bottom of the display.