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AIMuhf/AIM4170 Manual

Table of Contents

<u>Update History</u> Latest program is at: **www.w5big.com/prog_update.htm**

Aug 18, 2014 Version AIM_880:

Overlay scan files with any limits. Plotting style can be specified.
(Scan files from earlier versions of the AIM program can be recalled and overlaid .)
Improved crystal measurements for high Q crystals.
New Cal file data format. *This allows for new features but new cal files are required for version 880.*

June 2, 2014 Version AIM_876:

Amplitude programming in the Constant Freq mode can be used with AIMuhf and AIM4170D.

Added function to calculate length of phasing line.

Fixed BitMap function so it always shows the whole AIM graph.

Adjust graph size with mouse.
Graph size and also be entered manually in pixels or percent
(width, height value <= 100 means this value is a percentage of full screen).

Stub tuning runs much faster now.

Programmable Trigger Output (see Appendix 14).

Improved performance for low values of series resistance.

Optional cursor for a tablet pc makes it easier to move the vertical data cursor. (refer to the Setup menu)

Fixed graph overlay problem. (second graph was not being displayed at all)

Sept 27 2012
The stub tuning function has been generalized for any fraction of a wavelength

Aug 28 2012
Major changes to the **Point Data** function to aid in production testing.

May 21 2012
Changed the word *Theta* to *Phase*. The calculations and the data are the same as before.
Some of the pictures in the manual may show *Theta* but the meaning is identical:
Phase=arctangent(Xs/Rs).

SWR scale can be offset by one vertical division to improve readability in certain cases.
Smith chart trace can be displayed in varying colors across the frequency scan range.

Feb 2012
Added DSP filters for all models of the AIM.

Dec 19, 2011: version 852
DLL functions have been implemented for controlling the AIM with a user written program.

Data logging can be turned on and off while in the **Point Data Tune** mode.

Oct 10, 2011: version 846

New *Difference of Scans* function.
TDR range has been increased to 2000 feet.

Aug 2, 2011: version 845A
Scanning rate can change dynamically for faster scanning of a large frequency range.

July 21, 2011: version 845
Plot inductance or capacitance vs. frequency.
Optional labels for traces.
TDR files can be viewed in demo mode.
Sync output documentation added in Appendix 14.

April 30, 2011: version 840

Added **TDR** function.
Both swr rulers are displayed on the Smith charts.

March 8, 2011: version 835

Display cursor data and the differences for two points.
The recycle depth can be set using the Setup Menu.
The crystal analysis function now goes down to 25KHz.
Information on the usb interface as been added to Appendix 4.
A data Smoothing function has been added to replace Trend.
An offset can be applied to the plotted parameters.
Two rulers can be displayed for plotted parameters.
Overlay the last two graphs by pressing CNTL+Up Arrow.
The present state of all functions can be saved in a user specified file.

Quick Start

Loading the Software:

The AIMuhf, the AIM4170 and PowerAIM have the same basic features. The primary difference is the maximum frequency. The maximum frequency capability of the instrument is determined automatically when the program starts. In this manual, references to the AIM also apply to the AIMuhf and PowerAIM.

The AIM software does not require a formal installation procedure. It does not interfere with any other programs or the registry on your computer. Several versions of the program can be resident at the same time.

1) Create a folder or a subfolder on any convenient hard drive. Any name can be used for the folder, for example: "*C:\AntennaAnalyzer*".

2) Download the latest program:
AIM Program Update. (http://www.w5big.com/prog_update.htm)
This program works with the **AIMuhf**, the **AIM4170** and the **PowerAIM 120**.

The only difference between the AIM4170C and the AIM4170D is the AIM4170D has a USB connector for direct connection to a USB port on the PC.

3) Unzip all the files in the folder you just created for the analyzer software and documentation.

4) The file labeled "AIM_xxx.exe" is the executable file. It is ready to run without going through an installation process. If you don't see the exe extension, your file display has the "*don't show extensions*" flag set. This is the default setting for new Windows installations and the flag should be turned off. The AIM program can still be used, but it's a lot easier to navigate through all your folders if this flag is turned off so you can see the extension of all the files.

When later versions of the program are released, the number "_xxx" will be different. All versions of the analyzer program can reside in the same folder at the same time, although separate folders can be used to keep the files organized.

The older programs with the lower numbers will not interfere with the newest version, so they do not have to be deleted. If there is any question about the performance of a new version, you can switch back immediately to an earlier version for a comparison if they are in separate folders.

If you want to make a shortcut icon for your desktop, right click on the AIM_xxx.exe file and select "create shortcut" from the dropdown menu. Drag the shortcut to your desktop or task bar. Right click on the icon to bring up the renaming option and enter the file name.

If the files are loaded from a CD, they may be flagged as "**read-only**". In order for the calibration and initialization data files to be updated properly, the "read-only" flag must be cleared. Highlight all the files in the folder by pressing **control-A** and then right-click to see the properties of the files. If the "read-only" property box has a checkmark, uncheck it and then click "Apply". This will remove the read-only flag on all the highlighted files. None of the files in the folder need to be read-only.

For operating tips or to post your own ideas check this forum:
http://www.w5big.com/forum.htm

<u>HARDWARE CONNECTIONS:</u>

Plug in the DC power supply (8 to 12V at 500 ma recommended) and insert the connector into the jack on the rear panel of the analyzer. Note: if a power supply is included with your AIM, it is for **120VAC only**. [The ***Global Power*** **S*upply*** (120-240V) is available as an <u>option</u> when ordering the AIM.]

Press the power switch. The Green LED will blink a few times to indicate the version of software and then remain on continuously. The Red LED is on only when a measurement is in progress.

To turn off the power, press the power switch again. The green LED will go off when you release the power switch. If the analyzer does not receive a command from the PC for 10 minutes, it will power down automatically if it is in the default AutoPwrOff mode. The AutoPwrOff mode can be turned on/off with a menu selection under the **Setup** tab at the top of the screen.

When using the AIM with a new antenna system, check the **AC and DC voltage** between the **antenna ground** and the **ground used for the AIM and the PC**. This voltage should be less than 1V. A balanced antenna should have a DC connection to ground through a balun or RF choke on one side (or both sides). Of course there should **<u>always</u>** be a large value resistor (or balun) connecting both leads of any antenna to a ground path in order to drain off static electricity. This protects the AIM and any <u>capacitors</u> that are used in the antenna tuner.

NOTE: Before connecting a transmission line to the input of the AIM, be sure to momentarily short its pins together to drain off any static charge that may be present. Also, be sure there is **no DC voltage** on the antenna. If there is DC, use a blocking capacitor between the AIM and the antenna input.

Antennas and transmission lines can have enough static charge to damage sensitive electronic equipment. This can happen even when there is no rainstorm in the area. A strong wind can generate static charge. So can just flexing a coaxial cable by rolling it up or unrolling it, even if there is no antenna connected to it.

An antenna or a component to be measured should not be connected or disconnected from the analyzer <u>while a test is in progress. A test is in progress when the RED LED is on</u>.

<u>Be sure the maximum input voltage at the DC power connector does not exceed 15 volts. The minimum input voltage required is 7.0 volts.</u>

NOTE: Low cost power supplies that plug in the wall are usually not regulated and their maximum output when no load is connected may be several volts higher than their rated output. **Use a scope to check the peak output voltage with no load to make sure it does not exceed 15 volts**.

Power supplies that operate on a wide input voltage range such as 120V to 220V use a switching regulator. Evaluate the AIM measurement results to see if noise from the power supply may be a problem. For comparison, you can take some measurements while using a 9V or 12V battery and then with the AC power supply.

The AIM can be operated on battery power for remote operation with a laptop or tablet computer. The current required is about 250ma (400 ma for the AIMuhf) while a measurement is in progress and about 50ma when idle.

Batteries are not included with the AIM but you can make a battery pack using any type of batteries you like. There is room *inside the case* for a 9V battery and disconnect diodes are included so the battery and the AC power supply will not interfere with each other. There is also a space for an optional resistor to use for trickle charging a battery, if desired. Trickle charging generally should be limited to 5% of the maH rating of the battery. Check the data sheet for your battery for details. The main power on/off switch controls the battery power too, so the leakage current is less than one microamp when the AIM is turned off. Refer to Appendix 6 and the Application-Help file for more details

When using the AIM to test a mobile antenna on a motor vehicle, it is better to use a separate battery and **not** the 12V battery in the vehicle. A 9V battery will power the unit for several hours or a small 12V gel cell (sealed lead acid) battery can be used for extended operating periods. This avoids the problem of sneak paths through the ground between the DC power input and the antenna ground connection. It will also help reduce measurement noise if it's necessary to run the engine while taking data (such as to operate the air conditioner). **If it's essential to get power for the AIM from the vehicle, be sure to put 500 ma fuses in BOTH the +12V lead and the power ground lead.** A small voltage drop across the fuses will not affect the AIM since the battery voltage is much more than the required minimum operating voltage. The laptop computer being used should remain **floating** with its own battery for the best measurement accuracy.

PC INTERFACE CABLE:

Connect one end of the **RS232 cable** to the analyzer and the other end to COM1 on your PC. If you want to use a different COMM port, start the AIM program and click on the **Setup** menu at the top of the screen. Then click on **Enter Comm Port** and enter the port number that you want to use. This number will be saved in the setup file called *AIM_xxx.ini*.

If you are connecting to the RS232 port with a USB adapter, (or directly to the USB port with an AIMuhf) you will need the appropriate driver. The preferred USB adapters use a chip made by FTDI. The drivers for these adapters can be found here:
http://www.ftdichip.com/Drivers/VCP.htm

If the computer is connected to the internet when the AIM if first connected to the comm port, the Windows 7 or 8 program may be able to find the driver automatically on the internet. This may take two or three minutes.

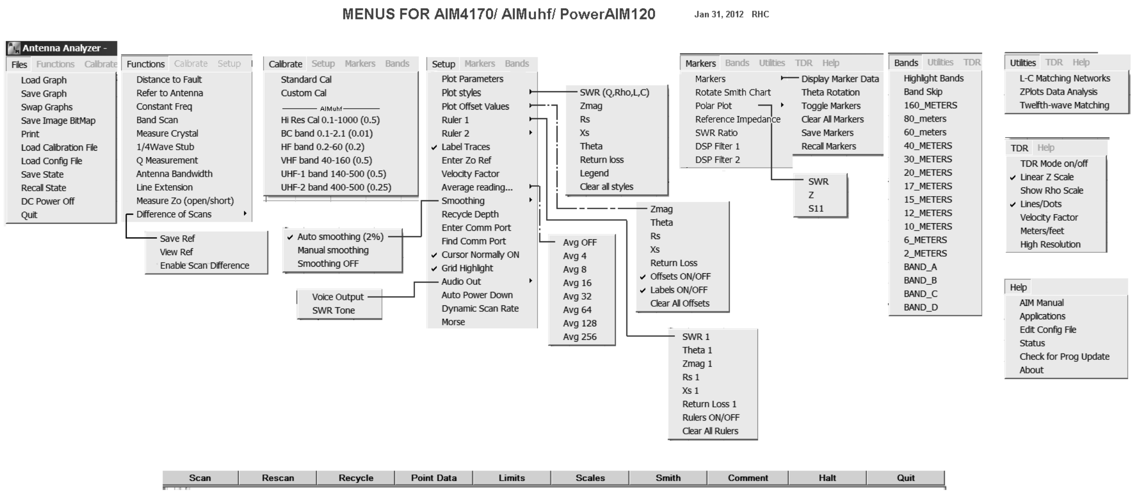
For more information on the USB interface, see Appendix 14 of this manual and this document: http://www.w5big.com/PC_USB_INTERFACE.pdf

To set the comm port, click on ***Setup -> Enter Comm Port*.**

The AIM program has been used with Windows versions 2000, XP, Vista, Win 7, Win 8 and Win 8.1. It also works with **tablet computers** that run Windows. When using the touch screen, a mouse and keyboard are not required. The program has also been used with MAC's.

For more information on running the AIM with a tablet computer, refer to this document:
http://w5big.com/aim_tablet.pdf

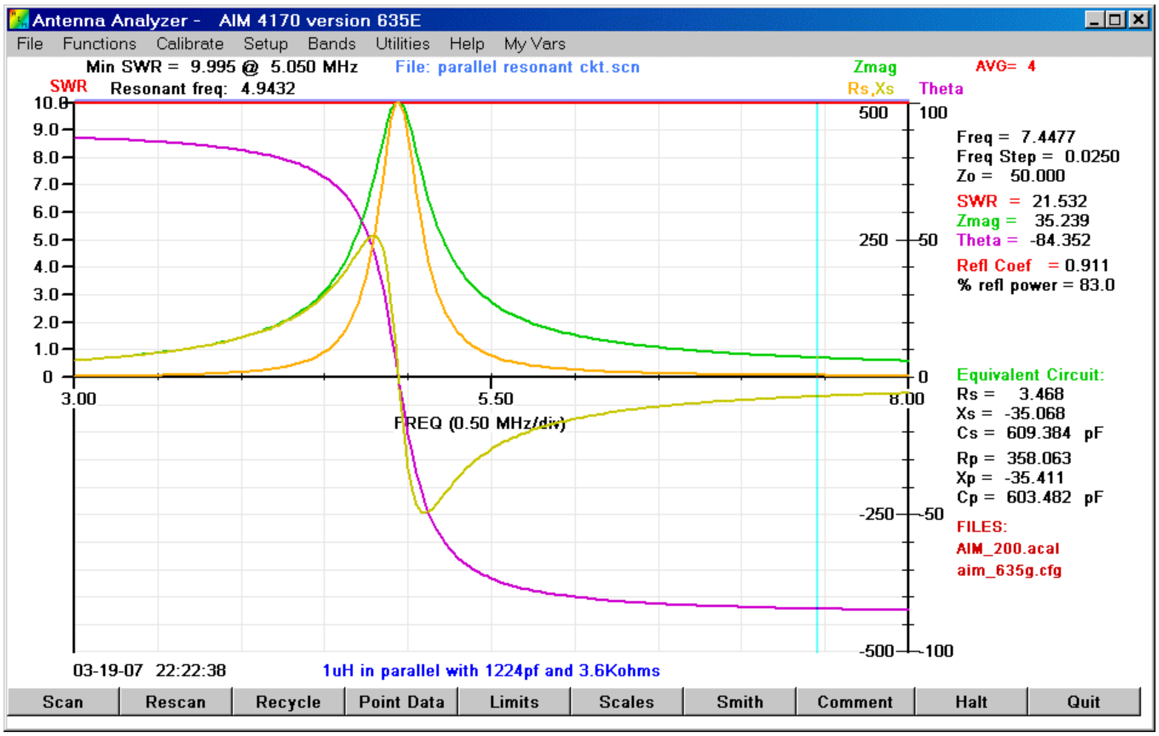
Be sure the configuration file is loaded:
Click ***Files -> Load Config File*** and select the file called: **_AIM_config.cfg** that is in the same folder with the AIM **exe** file.



[Larger version of this image](www.w5big.com/AIM_menu.png): **www.w5big.com/AIM_menu.png**

Initial Operation:

Launch the AIM_xxx.exe program. You will see a graph similar to this:



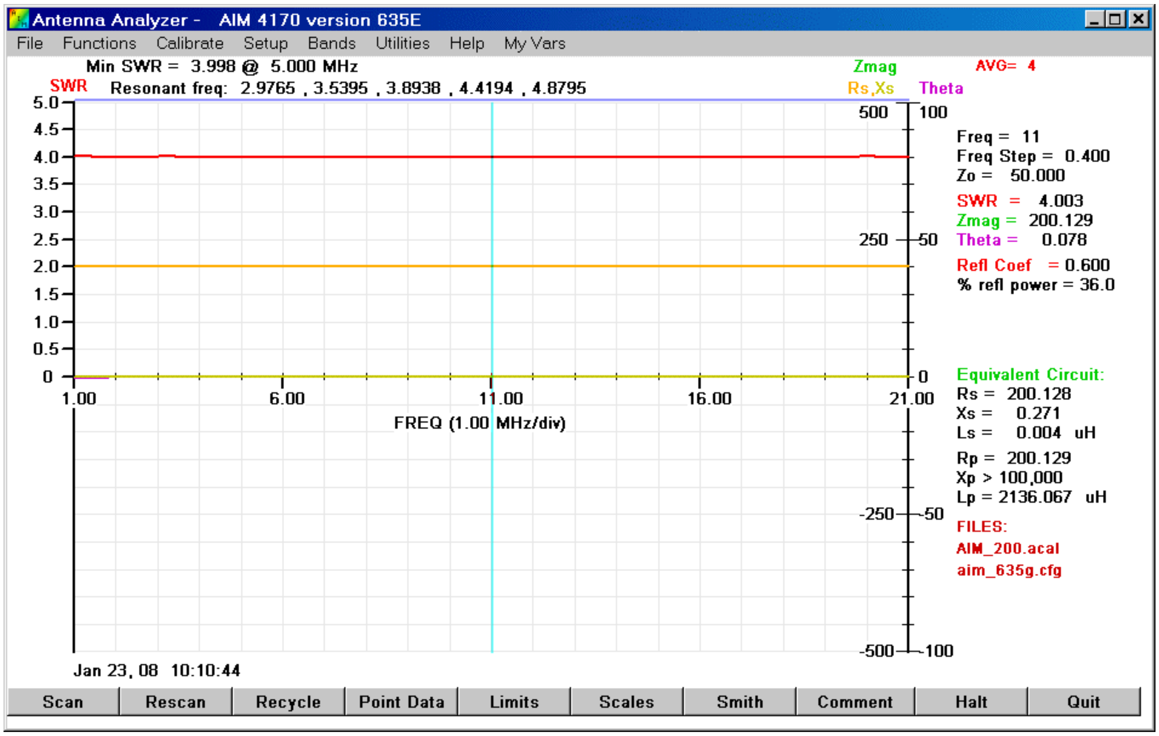
This is the last scan that was taken before the program was closed. Each time the program starts, it restores the previous scan.

When the AIM is present, it must be turned on **before** the PC program is launched. If the PC program starts when the AIM is not connected and powered up, the program will automatically enter the **DEMO mode**. In demo mode you can view previously saved scan files. This feature is handy for doing off-line analysis without having to hook up the hardware.

After calibrating, leave the **calibration resistor** attached to the RF connector and click the **SCAN** button in the lower left corner of the screen.

The Red LED will come on while the scan is in progress. A blue bar will move across the top of the graph as the scan progresses.

You will see a set of traces (similar to the picture below). The actual values are not important, but this shows the AIM is functioning.



Scan using a 200 ohm resistor for a test load.

The **size of the graph** can be specified in the **Config File**. The 'max graph width' and 'max graph height' parameters can be changed to make the graph compatible with smaller PC monitors. Graph sizes down to 640x480 (and perhaps smaller) can be used. The ratio of the width to the height is not critical. When using a larger monitor, the graph size can be increased, if desired.

The graph size can also be adjusted by dragging the corner of the window with the mouse or by using the Setup menu to enter specific dimensions in pixels or as a percent of full screen. Click Setup -> Graph Size. Several default sizes are already defined or you can enter a custom size. To go back to the previous graph size, click Setup -> Graph Size -> Previous size.

To save **screen shots for a document or a web page**, the size of the graph can be adjusted to optimize the screen to fit the finished document. This eliminates the need to rescale the image using a paint program (like Photo Shop), which sometimes distorts the lines in a graph. A special config file for this purpose can be saved and then easily recalled when it is needed. The size of the present graph being used can be found by looking at the **Status** window. Click **Help -> Status**.

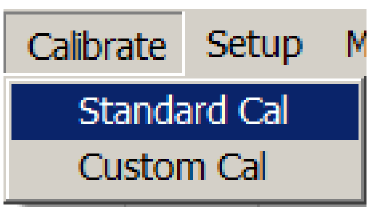
Calibration

Note: Beginning with program version AIM_880, the format of the cal data file is different. If you have special cal files that were made with an earlier version, put them in a separate folder with their own program so they can be easily recalled.

The AIM has **no internal adjustments**. There are no trim pots or variable caps inside. All the calibration is done with the following software procedure.

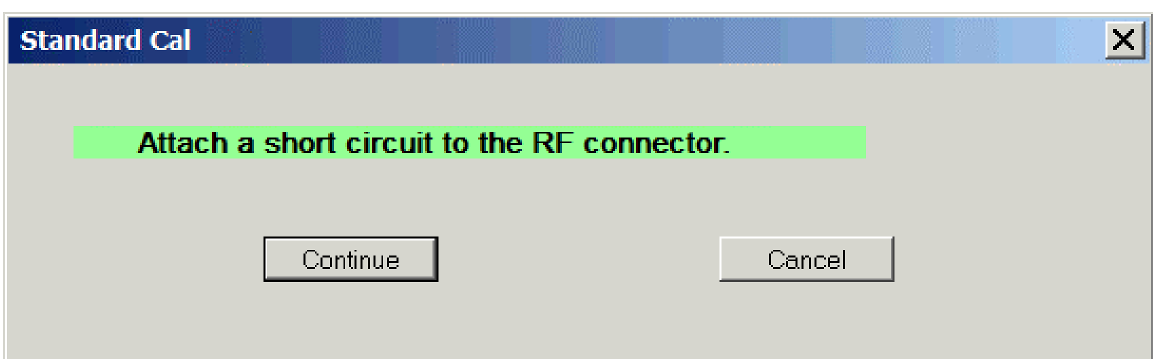
The new Standard Cal procedure calibrates at more frequency points over the whole range from 5KHz to the maximum frequency of the instrument. This more thorough calibration eliminates the need for custom cal in some applications, such as broadcast band measurements. *(The previous Standard Cal procedure only calibrated from 1 MHz to the maximum frequency.)*

Click on the **Calibrate** menu and select **Standard Cal**.



*(The **Custom Cal** option is used for special applications and will be discussed later.)*

A message box will appear near the center of the screen, as shown below:



Attach the connector with an internal short circuit (this is included with the AIM, it's labeled "**short**" and the label is **green**).

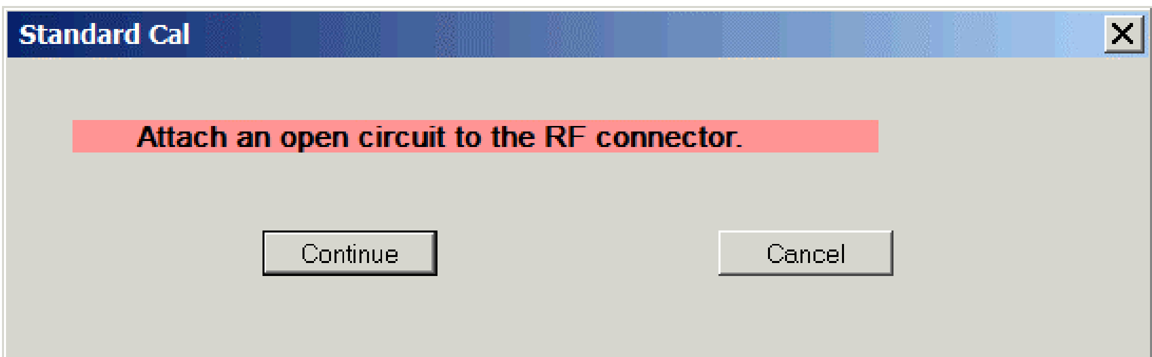
After the short circuit is in place, click **Continue**.

If the wrong load is attached, an alert is shown and you have the option to retry with the proper load or to stop the cal procedure. If you want to use a non-standard cal load, you can click "continue". This is only an alert, not an error message.

The program will run for a few seconds to take several readings of the **short circuit**. A number in the upper left corner shows a count down value.

Sometimes when calibrating with a coax stub or an external filter connected to the AIM RF port, the impedance may appear to be significantly different from a short circuit and a message will appear asking if this is a valid condition. If the connections are correct and you really do want to continue with the special external hardware hooked up, click **Continue**. Otherwise, click **Cancel** or **Retry**.

After the short circuit has been calibrated, a new prompt appears:



Replace the short circuit with an **open connector** (red label) and then click **Continue**.

The program will run for a few seconds to take several readings of the **open circuit**.

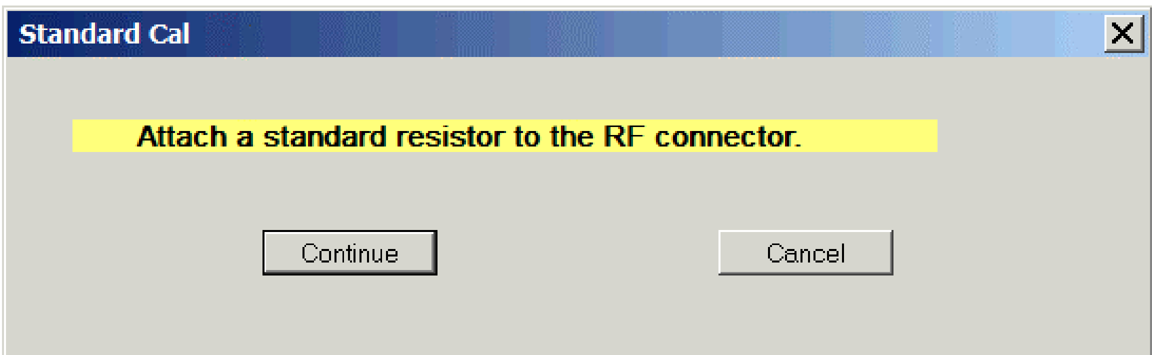
For the best accuracy, especially at high frequencies, use an **open connector** of the same type that is used for the **short circuit**. This allows the program to compensate for the stray capacitance of the connector itself. For example, 3 pF of stray capacitance due to a BNC connector represents a reactance of about 1K ohm at 50MHz which will appear to be in parallel with the load. This will seriously affect readings at higher frequencies if it is not properly compensated. Therefore, the three calibration devices (open, short, resistor) should be carefully constructed so they have similar stray capacitance and inductance which will be cancelled out by the calibration procedure.

NOTE: If you are using an adapter, leave it on the output connector of the AIM when calibrating the ***open circuit****. In this way, the capacitance of the adapter itself will be included in the calibration process.*

For example, If you want to use a BNC-to-binding post adapter, calibrate the short circuit with a **jumper wire** across the binding posts. Then remove the wire and calibrate the open circuit condition with the adapter still attached. This procedure cancels the stray capacitance of the adapter and you can get accurate readings of discrete components attached to the binding posts. The cal resistor can be a resistor with leads for this case.

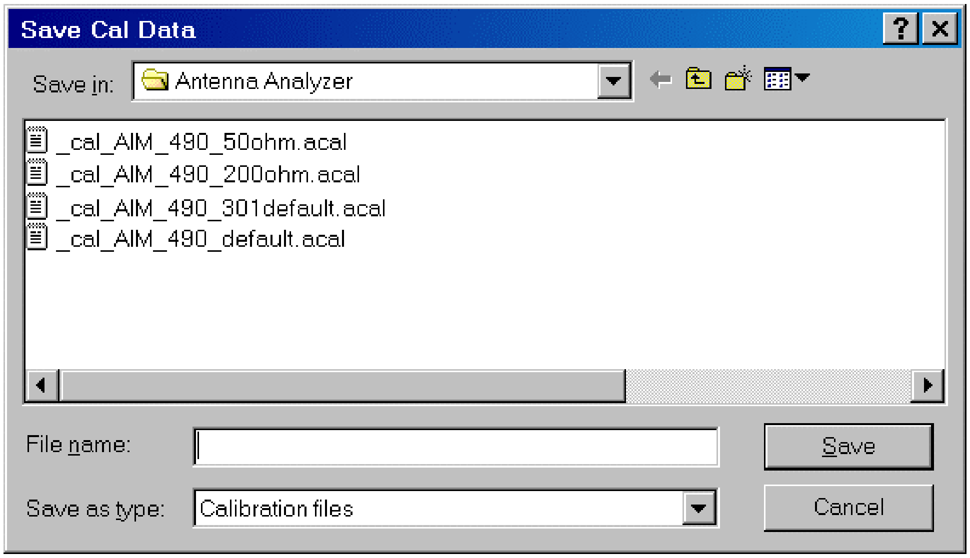
The calibration procedure can also cancel the effect of a short piece of coax that is used as a jumper to connect the AIM to the load. In this case, the open, short and standard resistor are connected to the far end of the jumper. Good results have been obtained with as much as two feet (60 cm) of jumper coax. *Longer coaxes can be calibrated with the Custom Cal procedure (discussed later).*

If the jumper is close to 1/4 of a wavelength long, the calibration data may not be accurate and a warning message is displayed. You can continue to cal but be sure to check the scan data for reasonable values under this condition. If you're sure the data is satisfactory, you can disable this warning message with a flag in the configuration file.



After taking several readings of the open connector, the program will prompt for the standard resistor with a typical value between 50 ohms and 500 ohms. This resistor should be mounted on a connector like those used during the open and short calibration steps. The exact value is not critical and it is not necessarily related to the reference impedance Zo. For example, if you are measuring 75 ohm coax, you can still calibrate with a 50 ohm cal standard. Enter the value that you measured with a digital ohmmeter and click Continue. If you are using the cal resistor (yellow label) that is included with your AIM, the number printed on it should be entered. If you have a different cal standard, enter that value.

After reading the standard resistor, the Red LED goes off and the prompt for a **comment** appears. This optional comment will be saved with the cal file and can be read later in the **Status window**. It can also be viewed in the cal file itself with any text editor (such as Notepad). After entering the comment a request for the calibration data file name appears. A separate folder can be used for cal files, if desired.



Enter the name of the calibration file and click "Save". There is no restriction on the name of the cal data file. Its extension is automatically set to .acal ("**a**nalyzer **cal**"). It is helpful (but not required) to include the program version name in the name of the cal file so you can tell at a glance which cal file can be used with a particular version of the AIM program. If you have more than one AIM in your lab or work area, it is helpful to include the serial number with the cal file name too

Any of these cal files can be recalled later using the menu option **File → Load Cal File**.

Then the **cal complete** message box is displayed as shown below:

Click **OK** to continue.

Each time the AIM program starts, the last calibration file that was used will be read to restore the cal data.

Each AIM has an ID number associated with it. This ID number is attached to each calibration file so that cal files will not be used with the wrong AIM. This is important when several AIM's may be in use in the same work area. This ID number is placed in the cal file automatically and no additional user input is required. The AIM's ID number can be seen by clicking "Help" -> "About". If you don't see the ID number, your AIM PC program is not the latest version but it will still work satisfactorily.

This completes the calibration procedure.

NOTE: Before connecting a transmission line to the input of the AIM, be sure to momentarily short its pins together to drain off any static charge that may be present. Also, be sure there is no DC voltage on the antenna. If there is DC, use a blocking capacitor between the AIM and the antenna input.

Antennas and transmission lines can have enough static charge to damage sensitive electronic equipment. This can happen even when there is no rainstorm in the area. A strong wind can generate static charge. So can just flexing a coaxial cable by rolling it up or unrolling it, even if there is no antenna connected to it.

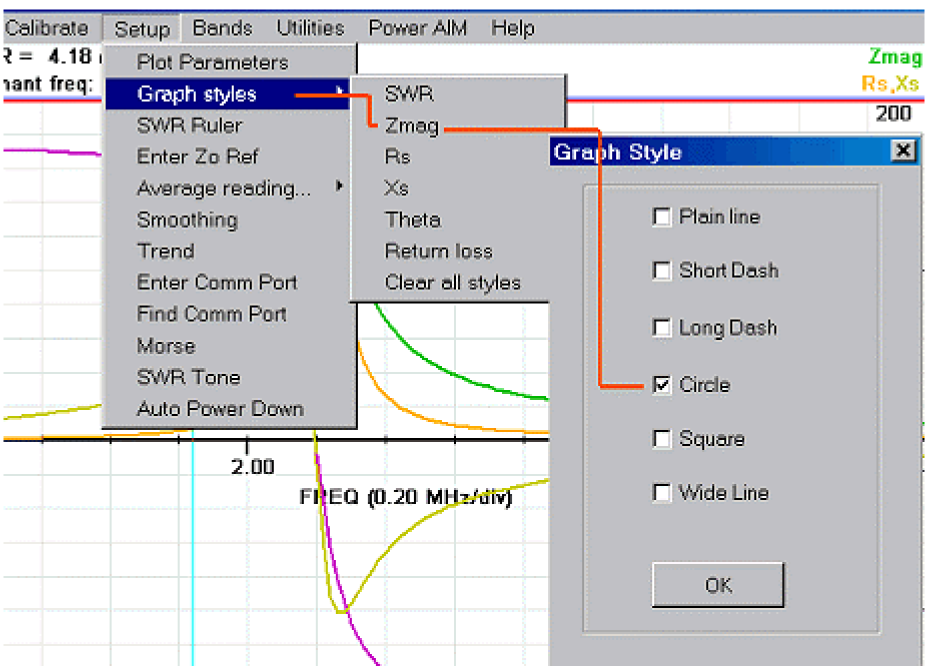
An antenna or a component to be measured should not be connected or disconnected from the analyzer while a test is in progress. A test is in progress when the RED LED is on.

Colors and Styles

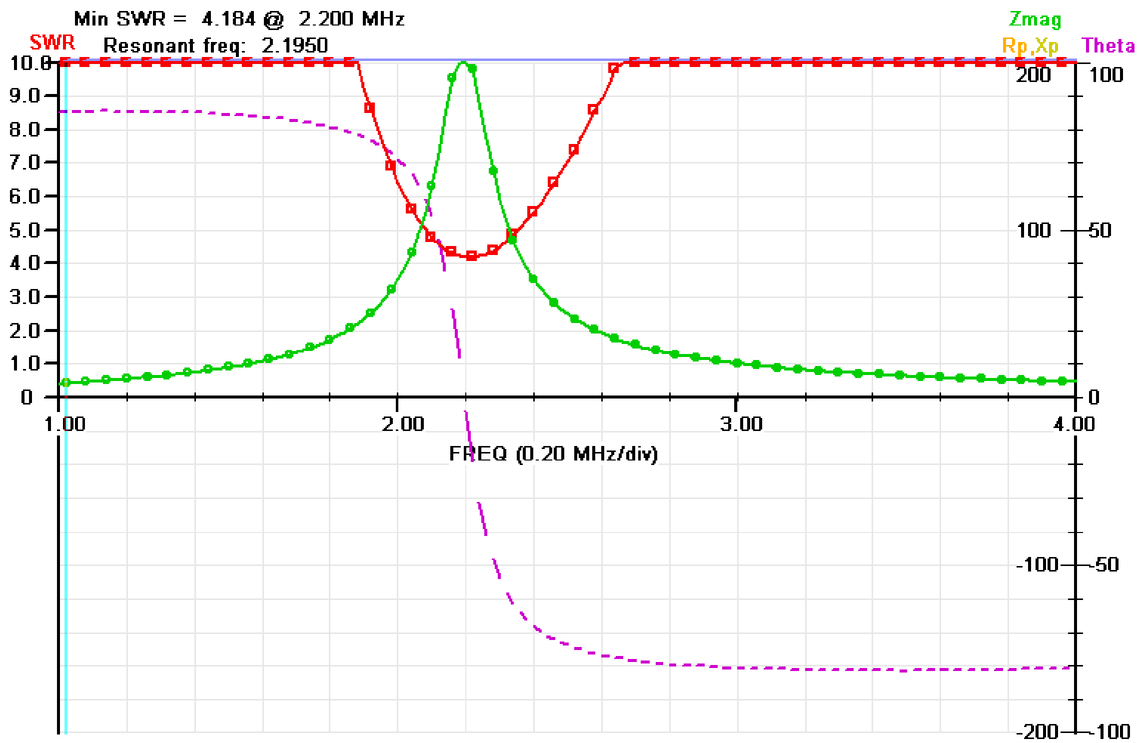
The color of each trace corresponds to the color of the label at the top of the Y-axis. **SWR** is RED and this scale is on the left side of the graph. On the right side the magnitude of the **impedance** is the inside scale and the trace is GREEN. The **reactance** is in YELLOW, also on the inside scale. Reactance and impedance use the same scale. Reactance can be positive (inductive) or negative (capacitive). The **phase angle** of the load impedance is plotted in MAGENTA and this scale is on the outside of the right hand vertical axis. These colors can be changed in the configuration (*.cfg) file if desired.

The **width of the traces** can be specified in the config file. The default width is “2”. For some situations, such as presentation slides, a wider line may be desired. A separate config file can be set up so you can switch between display options quickly with the **Files->Load config file** menu.

Each trace can be plotted in a different **style** to make it easier to visualize. This is particularly helpful when graphs are printed in **black and white**. The menu is shown below:



This example shows some of the styles:



When a new style is selected, the graph is redrawn to show its effect. The styles are saved in the *.ini file. The style only applies to the image on the screen, the raw data is not affected. The traces for a "rescan" are plotted with plain lines.

A legend showing the graph styles presently in effect can be displayed by clicking "**Legend**" on the **Graph Styles** sub-menu. This will appear in the lower right corner of the graph. The legend window can be repositioned so it doesn't interfere with the plot. This is handy when using a screen shot ("Prt-Scr") for documentation.

Command Buttons

The most common commands use the buttons along the bottom edge of the screen.
Hot key equivalents are shown in parentheses:

SCAN (S)– Starts the frequency scan between the specified limits: Start_freq to the End_freq. (see Limits button below.) Each time the scan button is clicked, the graph is cleared and the new scan data replaces the previous data in memory.

RESCAN (R) – A new scan is started but the graph is **not** cleared. This makes it easy to see the before and after effects of changes to an antenna (or any discrete component being measured). The new data replaces the previous data in memory but both graphs can be viewed simultaneously. RESCAN can also be used to overlay new data on top of a scan that was loaded from a data file. See "File -> Load" below. Rescan also works with the Band Scan function to repeat a band scan if the Scan button has not been clicked.

RECYCLE – Scanning is repeated over and over until the RECYCLE or the HALT button is clicked. This makes it possible to continuously view the results while adjusting an antenna or tuning a stub. The resonant frequency is displayed above the graph and it's updated after each scan during recycle. The scan limits can be adjusted to narrow the scan range for a faster update rate.

The number of scans between screen erasures is set using the **Setup Menu** item called **Recycle Depth.** If the depth is *zero*, the screen is never erased while recycling. If the depth is set to 5 (the default value), the screen will be erased after every five scans.

POINT DATA (D) - Measure the impedance of a circuit at a specified frequency. The measurement can be a single-shot reading or repeated about 2 or 3 times per second while the point data window is open. Click the "**Tune**" button to start the repetitive mode. As its name implies, the Tune mode has been found to be very useful when adjusting an antenna tuner. This avoids stressing the power amplifier when the antenna is mismatched and it eliminates interference to other people since the AIM output power is less than 20 microwatts.

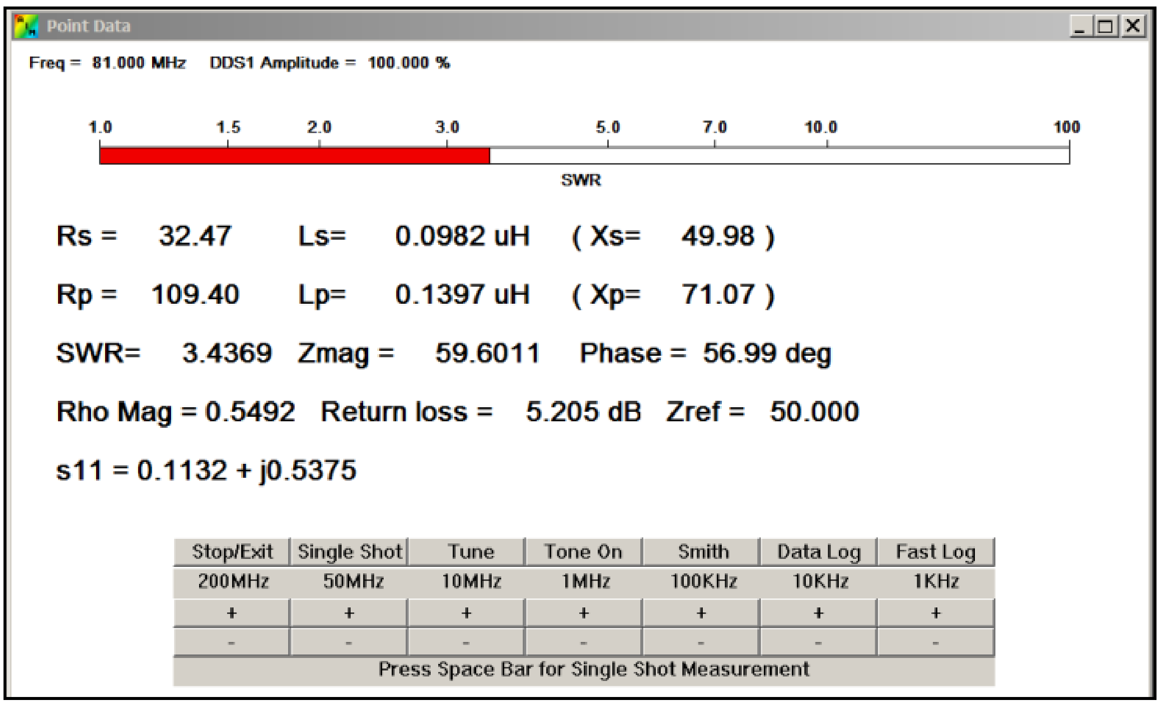
You can switch between **Tune** mode and **Single Shot** mode any time by clicking the buttons in the Point Data window.

While in Tune Mode a tone related to the SWR can be played through the PC speaker to assist in making adjustments without watching the monitor. Click the button labeled "Tone On" to start the tone. The parameters of the tone can be changed using the setup routine called "**Tone**" under the **Setup** tab on the main menu at the top of the screen.

SWR, Zmag and Phase can be sounded out in Morse code. See the Setup menu to enable this function. The swr tone or Morse code can be played over an extension phone or cell phone while making adjustments to an antenna. SWR can also be sounded out using speech wav files for the set of numbers. *These files can be customized for other languages.*

If the **Data Log button** is highlighted, the Point Data is written to a **data log file**. The log option <u>can be turned on and off</u> any number of times during one session. Only the data read while the data log button is highlighted will be saved. In the Single Shot mode, one reading is taken each time the Single Shot button is clicked or each time the Space Bar is pressed. This makes it easy to data log a number of components at a particular frequency. The frequency can be changed by clicking the frequency increment or decrement buttons.

This file can be saved with a user specified name when the tuning session ends by clicking the **Stop/Exit button**. The data file has the default extension *.AIMlog but it can have the extension *.csv if you like. The log file can be imported into a program like Excel for customized processing.



Point Data Window for AIMuhf

Measured impedance at the AIM RF port = Z = Rs + j*Xs
*Rp and j*Xp correspond to the equivalent parallel circuit values.*

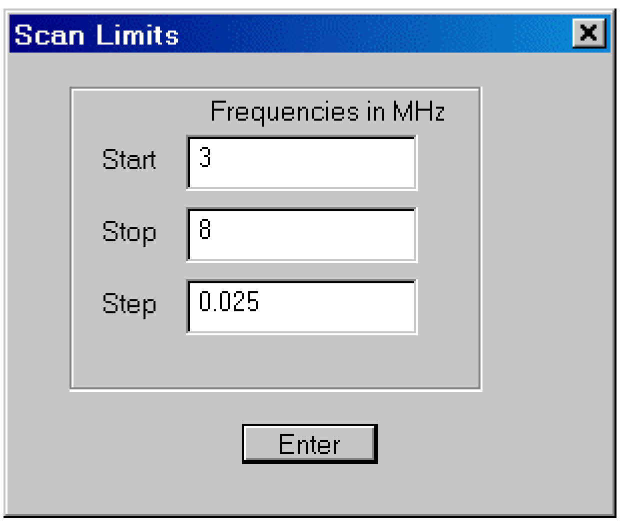
Zref is the reference impedance (typically 50 ohms) used to calculate SWR and the reflection coefficient, **s11**. Zref can be <u>any</u> desired value (including a complex value). For example, when testing a dipole antenna, the Zref can be set to 75 ohms if desired. It is entered using the **Setup menu -> Enter Zo Ref**

The Fast Log mode gives a faster measurement rate while data logging, which may be useful when manually adjusting a circuit.

```
Created: 08-26-2012  14:24:28
 903485640 // start time in msec
"Short transmission line" ——— Comment
Z0, 50 ——— Z reference
Index,  Time,               Freq(MHz),  SWR,   RhoMag, ReturnLoss, Rs,     Xs,     Zmag,   Phase(deg)
    0   08-26-2012 14:24:32 65.000000   3.291  0.5339  5.452       17.707  19.205  26.122  47.327
    1   08-26-2012 14:24:34 65.000000   3.286  0.5333  5.460       17.736  19.210  26.145  47.287
    2   08-26-2012 14:24:35 65.000000   3.299  0.5347  5.437       17.642  19.128  26.021  47.317
    3   08-26-2012 14:24:36 65.000000   3.291  0.5339  5.450       17.692  19.163  26.082  47.289
    4   08-26-2012 14:24:38 65.000000   3.299  0.5348  5.436       17.647  19.159  26.048  47.356
**** End of Log File *****
```

Data Log File Example

LIMITS (L)– When this button is clicked, a dialog box, as shown below, pops up for entering the **start** and **stop** frequencies and the size of the frequency increment (**step**) between measurement points. The **start** and **stop** frequencies range from 5 KHz to 180MHz for the AIM and 5 KHz to 1GHz for the AIMuhf.



For example, to scan the 40-meter band, you might enter 6.9MHz for the Start frequency, 7.4MHz for the Stop frequency and 0.01MHz for the frequency Step (the spacing between measured points). This would result in a scan of 50 points across the band. The maximum number of scan points is 30,000 and the minimum number is 5.

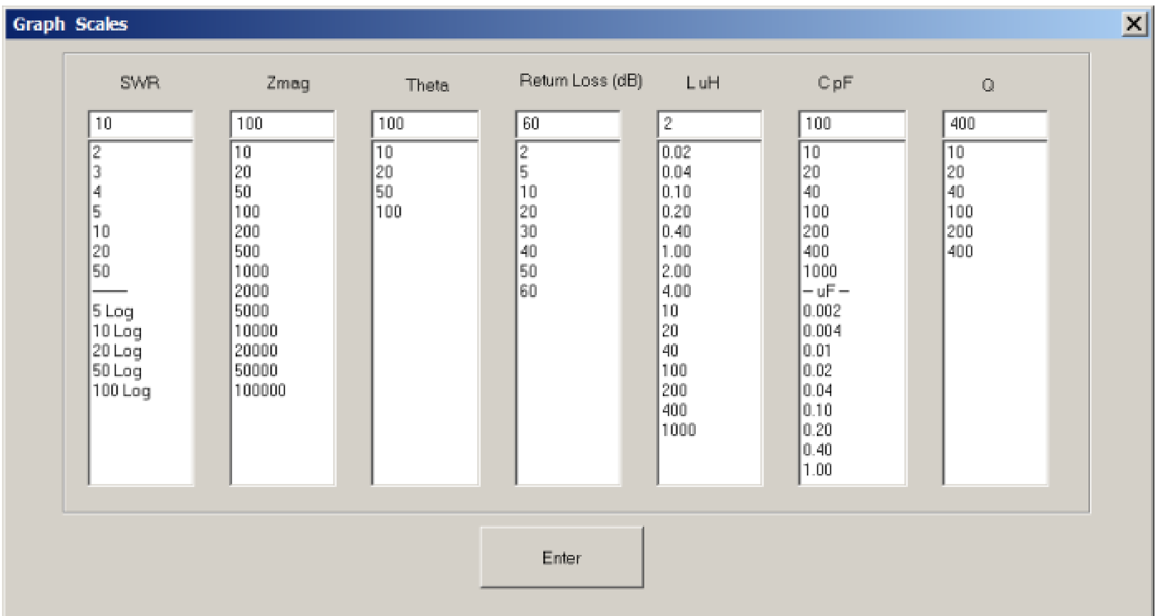
Frequency values can be in **KHz** instead of MHz if the number is followed by a **K** or **k**.

There is an option to begin the plot along the X-axis at **zero** rather than at the Start Freq. This makes the plot easier to read in some cases. The scan will still begin at the specified Start Freq which cannot be less than the minimum frequency of the instrument. For example, if you want to scan from 1MHz to 20MHz, the graph will be numbered starting a 1 and go up to 26. This makes the numbers on the X-axis: 1,6,11,16,21,26. However, if you start at 1MHz, stop at 20MHz and select the “start plot at zero” option, then the X-axis will be labeled: 0, 5,10,15,20 and the actual scan will be from 1MHz to 20MHz.

If you enter a number greater than 20 in the Step box, the scan will use that many **data points**. (A step size equal to or greater than 20 is interpreted as a **number of points** rather than a frequency step in MHz.) If the number in the Step box is followed by a percent sign "%", the step size will be that percentage of the total scan width.

Note that when using the cursor to read out numeric data (discussed in detail later), the displayed values are **interpolated** between the measured values. Therefore, in some cases it may be desirable to use a larger frequency step for a **faster scan rate**. You can still read the parametric values at intermediate frequencies with the cursor. The scan rate is about 20 to 70 points per second, depending on the speed of the PC and the value of averaging that is used.

SCALES - When this button is clicked, a dialog box pops up for entering the full-scale values for the traces.



If the actual measured value is off the scale (flat line at the top of the graph), the value readout by the cursor is still valid since it uses the raw data stored in memory. For example, you can set the Zmag scale to 500 ohms in order to see fine details but if the impedance actually goes up to 1600 ohms at some frequencies, the cursor can still read the true value and display it in the data window on the right side of the screen.

There is an option to plot the SWR with *swr=1* on the center line (y=0) or shifted up by 1 division. Clicking the **Offset** entry in the Setup menu will alternate between shift or no shift. The offset does not affect the display when Log SWR is selected, in that case swr=1 is always on the y=0 axis.

If you would like a full scale value that is not in the drop-down list for a parameter, you can manually enter **any value** in the box at the top of the list. For example, if you want to evaluate a 50 ohm resistor, you can enter a full scale value of 60 in order to get better resolution on the graph. *(this does not affect the accuracy of the raw data saved in memory).*

Plot <u>Offset</u> and <u>scale factors</u> can be combined to get better resolution when the parameters don't change much over the frequency scan range. Refer to the Setup menu.

If you select a new scale factor, the last data scan will be replotted using that scale.

COMMENT – A dialog box pops up for you to enter a comment that will be displayed at the bottom of the graph. This is very useful for documenting the test conditions. This comment will appear in a screen capture or a screen print and it will be saved in the raw data file on disk if this scan is saved. Comments can also be added to a calibration file before it's saved.

HALT - While the scan is in progress, you can stop it by clicking this button. This is different from the QUIT button (shown below).

QUIT – This stops the program, saves the setup conditions (limits, scales, etc) and exits back to the Windows OS. When the program is launched again, the setup conditions and calibration data will be restored automatically.

File Commands

Load Graph-- Load a raw data file from a previous scan. After this file is loaded, its data is just like the original scan. The vertical cursor can be used to read out the numeric values.

When a data file is being displayed, the name of the file appears at the top of the graph.

After a graph is loaded, a new scan can be done and superimposed on top of the old data by clicking **Rescan**. This is useful for comparing before and after conditions when adjustments are made or when there may be a long term change in a component or an antenna. For example, you can see if your antenna is the same today as it was last week before the windstorm.

When a new graph is loaded from disk with the same limits as the present graph, it can be overlaid over the existing graph or it can replace the graph. Several graphs can be overlaid on each other.

Save Graph -- Save the raw data for the **last** scan that was done. If you clicked the RESCAN button, the data that will be saved is for the rescan. Even though the earlier scan is being displayed on the graph, its raw data was replaced in memory by the new data corresponding to last rescan command. The raw data is saved in a file with the extension .scn. Another file is created with the same name and the extension .csv. The .csv file has the same data in a format that can be read into a spreadsheet. The format of this file is shown in Appendix 5.

You can enter an optional comment when the graph is saved.

Overlay Graph - Load multiple graphs with <u>any</u> frequency limits. The data will be plotted on the present graph even if the start/stop frequency limits and scale factors are different. The **style** (circles, squares, etc) of the overlay graph can be specified to make it easier to distinguish the different graphs. Up to eight graphs can be overlaid at the same time. Scan files that were saved with earlier versions of the AIM program can still be reloaded and overlaid.

Swap Graphs -- Swap back and forth between the present scan and the previous scan. This function can be disabled by setting the “autoscansave” flag in the config file to zero (*default is enabled*).

Swap can also be done by pressing either the **up** or the **down arrow key**. (Press the **CONTROL** key and then the arrow key to **Overlay** the graphs.)

Save Image Bitmap -- Save the current graph image to a file in the .bmp format. If you just want to put the image on the clipboard to paste it into a document or another program, press **Alt-PrintScreen** instead using of this menu function. Then paste it into another application using **Control-V**. The bitmap image can be pasted into a paint program or a document, like Microsoft Word.

Print -- Print the graph on the system printer. Before printing in black and white, you can change the **graph display styles** to highlight each trace. This option is under the **Setup** menu.

Load Calibration -- Load a calibration data file for a particular test setup or adapter. These files have the .acal extension.

Load Config -- Any of several configuration files can be loaded. A selection window will show all the files in this folder with the .cfg extension. For example, this can be used to change the screen size or the colors for different applications. After loading a new config file, close the program and restart it for the changes to take effect.

Save State -- The present state of the programmable functions can be saved in a file named by the user. This is the same data that is normally saved in the *.ini file when exiting from the program. It allows the user to quickly recall a new set of limits and scale factors for specific applications. The state file can also be send to someone else so they can duplicate the test conditions.

These files have the extension ***.stat**

Load State -- Load a new state file. Restore the scan limits and scale factors.

DC Power Off -- Remotely turn off the DC power to the AIM. *(It cannot be turned on remotely)*

Quit -- Stop the program and exit.
This is the same as the QUIT button at the bottom of the screen.

Function Commands

Distance to Fault --Measure the distance to a cable open or short. This can also be used to measure the ¼ wave length frequency of tuning stubs. The impedance of the cable is also measured.

For accurate results, it is important that the cable be uniform, that is, it should not be made up of more than one type of cable.

Refer to Antenna -- The impedance readings are transformed to be equivalent to readings directly at the antenna terminals. This procedure does not require disconnecting the transmission line from the antenna if you know the parameters of the coax.

This should not be used if the transmission line is made up of several **different kinds of line**, such as, coax cable plus ladder line.

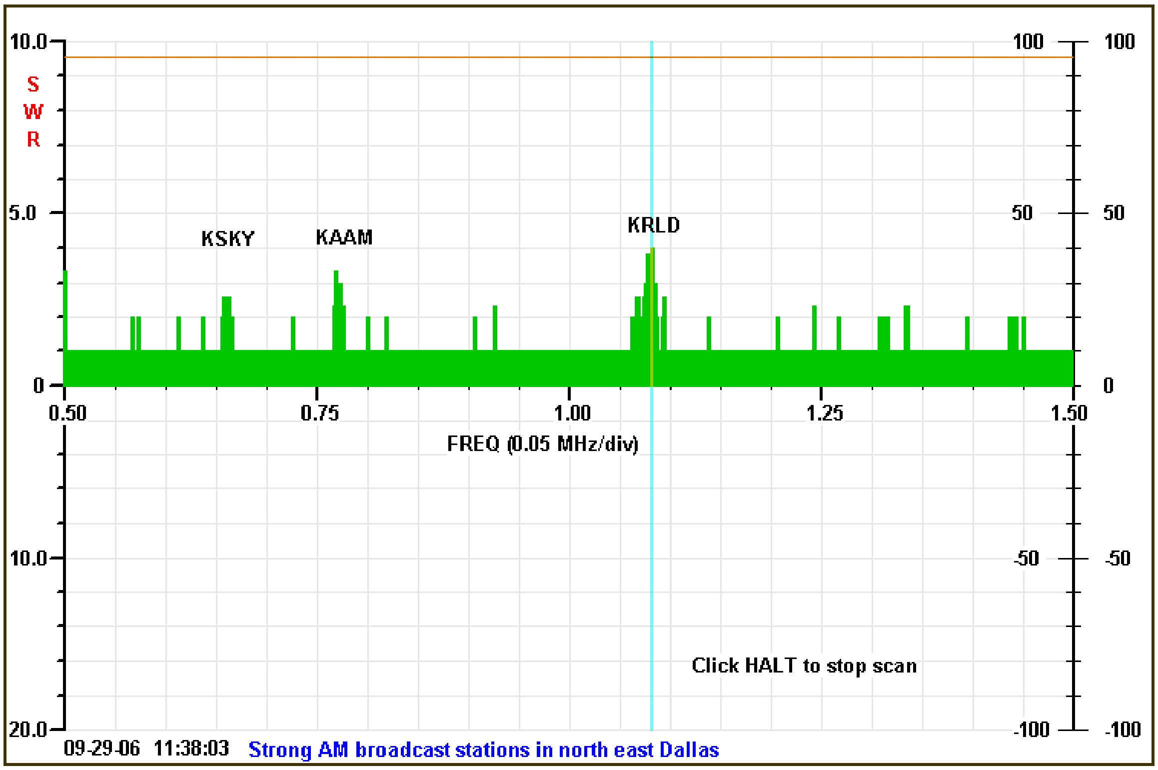
For complex transmission lines, the **Custom Cal** procedure should be used. It's discussed later in this manual.

Constant Freq -- Output a constant frequency that can be used as a test signal. Initial frequency accuracy is +/-2ppm for the AIMuhf and +/-30ppm for the AIM4170. At 1MHz, the output amplitude into 50 ohms is about 25 to 30mV-rms (-18 dBm) and somewhat less at higher frequencies. The exact frequency can be calibrated using WWV or a frequency counter. The default cal frequency is 10 MHz, but any value can be entered. The initial setting has to be within 2 KHz of the standard used for calibration.

The Frequency Compensation Factor that is used to correct all subsequent programmed values can be seen in the Status Window (Help->Status). The value is always very close to unity. The compensation factor is used to adjust the programmed frequency during a Scan or in the Point Data mode.

Band Scan -- Scan a band (particularly the AM broadcast band) to look for strong signals that may interfere with antenna measurements. The scan start/stop limits are set using the same LIMITS button that is used for an impedance scan. The maximum **scan range** is 10MHz. The maximum **frequency step** is 2KHz, but a smaller step can be specified when the limits are set. The *recommended* maximum amplitude limit for an external signal is indicated by a red line, which corresponds to approximately 150mv peak. (This level is not precisely calibrated.) Signals above this limit may result in less accurate impedance readings. It is not a rigidly fixed limit and in some cases, impedance readings may still be sufficiently accurate when external signals are above the red line.

Click the **Rescan** button to repeat the band scan.



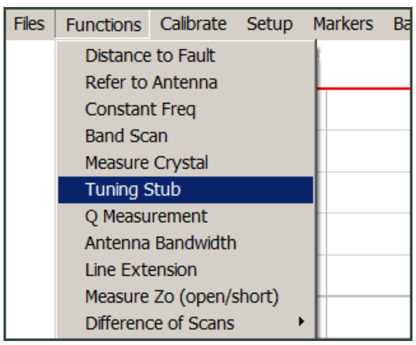
Example of a scan in the AM broadcast band

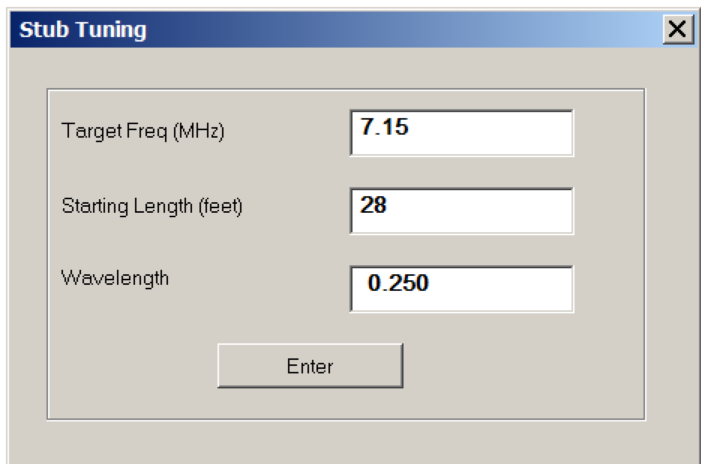
Measure Crystal -- Measure the parameters of a quartz crystal automatically. Details are in a later section. The crystal data can be saved in a file that can be imported to a spreadsheet program, such as Excel.

The **AIMuhf** has a temperature compensated oscillator (**TCXO**) which makes it much more accurate than the AIM4170 when measuring crystals. At room temperature, the drift over several hours is typically less than 1 Hz for the AIMuhf. The oscillator can be calibrated in the Constant Freq mode by using a frequency counter or zero beating with WWV. This calibration will then be applied to all measurements. The AIM4170C and

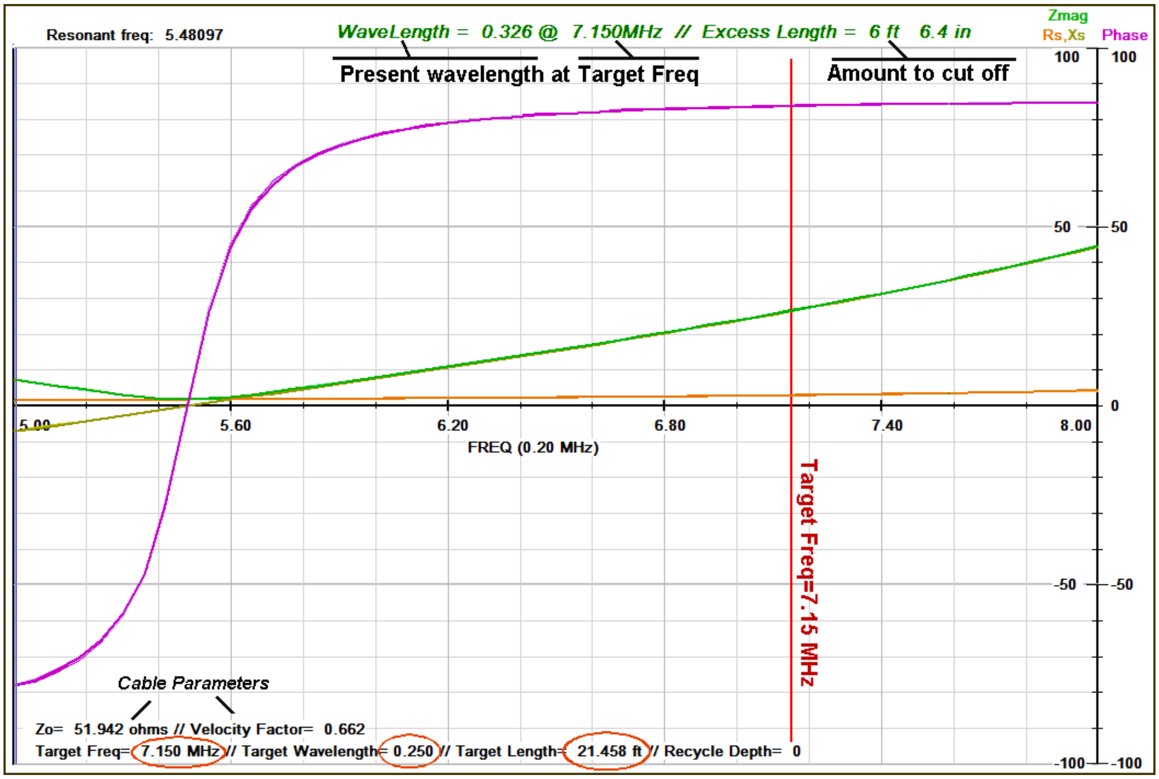
AIM4170D can be retrofitted with a TCXO without too much trouble. This is described in a separate application note called the AIM4170_Options_Guide.pdf.

Stub Tuning -- Adjust a coax line to be a specified fraction of a wavelength at a given frequency. The target frequency and the initial length (in feet or meters) of the coax are entered in the dialog box. The unit of measure used for the cable length is given in the config file. This parameter can be overridden by entering a value for the cable length followed by the letter **"f" or "F"** for feet and **"m" or "M"** for meters. This value for physical length should be accurate because it is used to calculate the velocity factor. The wavelength can be entered as a decimal fraction or as degrees. If the number is larger than 10, it is assumed to be degrees and it's divided by 360. For example, entering "120" means the target wavelength is 0.333 (i.e. 120 degrees = one-third of a full wave) at the target frequency.





The program runs in recycle mode and displays the amount of cable that needs to be cut off ("**Excess Length**") to obtain the target wavelength at the target frequency. A vertical red line on the graph highlights the target frequency. The magenta colored phase plot crosses the horizontal axis at the quarter wave frequency. As the cable is trimmed, the present wavelength at the target frequency is displayed at the top of the graph along with the amount of cable that needs to be trimmed off.



Data at the bottom of the graph shows the cable impedance and the velocity factor along with the target values for **frequency**, **wavelength** and **cable length**. The Recycle Depth indicates how often the graph will be erased while in the Recycle mode. *Zero* means don't erase at all. *Five* means erase and start over every five scans. The Recycle Depth value is entered with the Setup menu, click: **Setup -> Recycle Depth**

Q Measurement – This is used to measure the Q of **resonant circuits**. First, do a scan with the limits set to include the resonant frequency and most of the response on either side of the resonant frequency. The step size is not critical but Q may change slightly with different step sizes. Experiment to see what is appropriate for your application. The resonant frequency does not have to be in the center of the graph.

Antenna Bandwidth-- The bandwidth of an antenna at an SWR value set by the SWR ruler is determined. First, enter the **SWR ruler 1** value with the **Setup** Menu. Then position the cursor near the valley of the SWR curve and click "Antenna Bandwidth". The bandwidth and high/low frequencies will be displayed in a message box. Vertical green lines will highlight the bandwidth region. For a multiband antenna, the bandwidth at each resonant frequency can be read by moving the cursor to the desired SWR valley. *The cursor does not have to be exactly at the minimum SWR point.*

After positioning the cursor near the desired point, press the **left mouse button** to freeze the AIM cursor while moving to the bandwidth selection button on the **Function** menu.

Line Extension-- see the Line Extension section of this manual.

Measure Zo - Measure the impedance of an open or shorted coaxial line.

Difference of scans - see details later in this manual.

Trigger output - see details in Appendix 14

Calibration Commands

Standard Cal -- Calibrate the AIM using open circuit, short circuit and resistive load conditions. The calibration data is saved in a disk file that's read each time the program is started. The frequencies used for calibration are predefined in the program so the user does not have to enter these parameters.

Any number of calibration files can be saved for different applications.

An optional comment can saved with each cal file. The comment for the cal file presently in use can be seen in the Help->Status window.

Custom Cal -- The start, stop and delta frequency values can be user specified. The regular **short, open & resistor** loads are used. Long transmissions lines of any type can be calibrated at the far end so impedance data is then referred to the antenna terminals. It can also be used to calibrate out the effects of filters in the line. This function takes into account the length of the cable, its impedance and the loss.

After a transmission line or filter is calibrated, the start, stop and step frequencies can be changed as long as they are within the original custom cal start and end limits. The step size can be different too.

For the AIMuhf model, the menu shows several <u>optional</u> calibration ranges for quick reference. The values shown in the dialog box can be changed to anything you like.

Setup Commands

Plot Parameters -- Select the parameters that are plotted during a scan. The optional parameters are: SWR or reflection coefficient or Q, L or C, Return Loss, Impedance Magnitude, Series Load Circuit or Parallel Load Circuit, Phase (phase angle). The last scan data will be replotted with the new parameters.

Graph Styles -- A different style for plotting each trace can be specified to make the traces more distinctive. This is especially helpful when the graph will be printed in black and white. For examples of the styles, refer to the section of the manual above called "**Colors and Styles**".

A style **legend** can be displayed in the lower right corner of the window. This window can be repositioned if desired.

Plot Offset Values -- The **traces can be offset** by a specified amount to make it easier to see small variations around an average value.

For more information see the **Rulers and Offsets Section**

Ruler 1 and 2 -- Horizontal rulers can be defined to help visualize where a parameter lies with respect to user specified limits. Two rulers can be defined for: SWR, Phase, Zmag, Rseries, Xseries, and Return Loss. These are referred to as Ruler 1 and Ruler 2. Ruler 1 is used when measuring antenna bandwidth. Either ruler can have the larger value.

For more information see the **Rulers and Offsets Section**

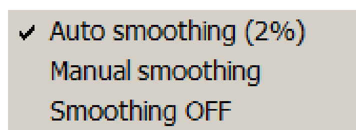
Label Traces-- A letter can be displayed at the beginning of each trace to help distinguish it. This is very useful for documentation if the graphs are printed in black and white.

Enter Zo -- Enter the nominal impedance of the transmission line. This is used to calculate the SWR. This is usually a real number, but a complex number can be entered with the imaginary part denoted by "**i**" or "**j**".

Average Readings-- Measurement noise can be reduced by averaging several readings at each point. When this option is selected, “AVG =N” appears in red in the upper right corner of the graph. N is the number of readings being averaged and is between 4 and 256. N equal zero or 1 is equivalent to No Averaging.

Smoothing -- Noise can be reduced by averaging (smoothing) a number of data values over a narrow frequency range. The smoothing process does not shift the frequency of a peak or phase zero crossing.

The magnitude of the **peak** or **valley** of a rapidly changing parameter may be affected. **Check the results with and without smoothing if there is any doubt.**



Auto smoothing uses an averaging size corresponding to 2% of the number of scan points. This value is recalculated automatically when the scan parameters are changed.

Manual smoothing allows the averaging size to be specified by the user. This is always an odd number between 3 and 15. A value of 0 turns smoothing off.

Smoothing can be **enabled** or **disabled** without changing the value of the manual smoothing parameter.

Recycle Depth -- In the Recycle mode, this is the number of scans made before the screen is cleared and it starts over. If the value is zero, the screen will not be cleared and the scans accumulate indefinitely.

Enter Comm Port -- The value of the comm port is entered. This can be determined by using the Windows Device Manager. There is more information in the section about setting up the USB interface. Some earlier versions of the AIM program had a Find Comm Port function, but that was always reliable, so it is not included here. There are details about finding the comm port using the Windows Device Manager in the app note called: AIM_Tablet.pdf

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Cursor Normally ON -- If this item has a check mark beside it, the cursor will move with the mouse and it stops when the left mouse button is pressed. If this item is not checked, the cursor <u>only moves</u> when the left button is pressed.

Grid Highlight -- Some grid lines can be highlighted to make the display easier to read. The appearance of this effect depends on the monitor and it may not be desirable in all cases**.**

Audio Out -- Options to output the parametric data through the audio channel in the Point Data mode. This can make it easier to perform adjustments without having to watch the monitor.

Auto Power Down -- When using battery power, the AIM can be turned off automatically after about ten minutes of inactivity to conserve power.

<u>Scan Mode</u> --

Standard mode - This is the commonly used mode**.**

Fast mode - Fast mode is about 3x faster than the standard mode. It can be used when the phase doesn't change too abruptly during the scan. The faster scan rate is handy when making adjustments to circuits or antennas in real time. For a final check, change back to the standard scan mode to make sure no aberrations were introduced by the fast scan process.

Dynamic Scan Rate -- The scan rate can be changed progressively during a scan to speed up the process. This is useful when scanning from a low frequency to a much higher frequency. It is similar to a logarithmic scan (the horizontal scale is still linear).

The frequency steps get larger from left to right, so the trace may not be as smooth but it is good for getting a quick overview while making adjustments.

BAND Functions

Highlight -- Highlight the frequency bands, such as the ham bands or AM or FM radio bands. These frequencies are specified in the configuration file (*.cfg). The start/stop limits do not have to be the actual amateur band limits. The highlight color can also be specified in the config file.

The name of the band can also be user specified to be more descriptive. Refer to comments in the config file. The AM radio config file has examples showing the names of several station.

Band Skip -- Scan only in the specified bands that are included in the present start/stop scan range and skip between bands. This makes it possible to scan several bands for a multiband antenna much more rapidly.

Click on the desired band to set the start/stop scan limits and the frequency step between measurement points. These limits can be changed in the configuration file.

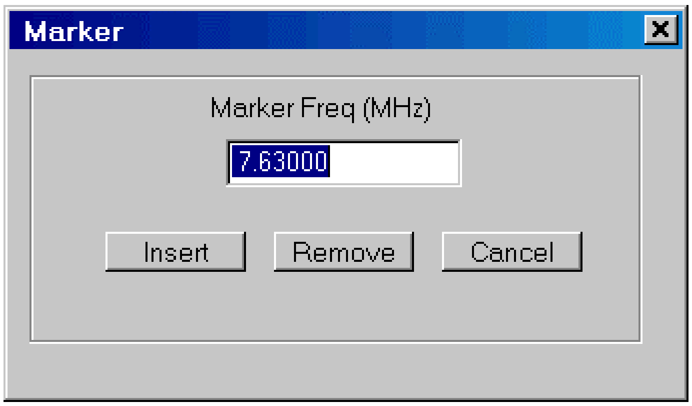
Note these bands do not have to be amateur radio bands, they can be anything.

The **title** of the band can be changed in the **config file**. For example, bands can be assigned for specific radio stations and their call letters can be used for the title.

Band A..D are additional user specified band limits. Same as above.

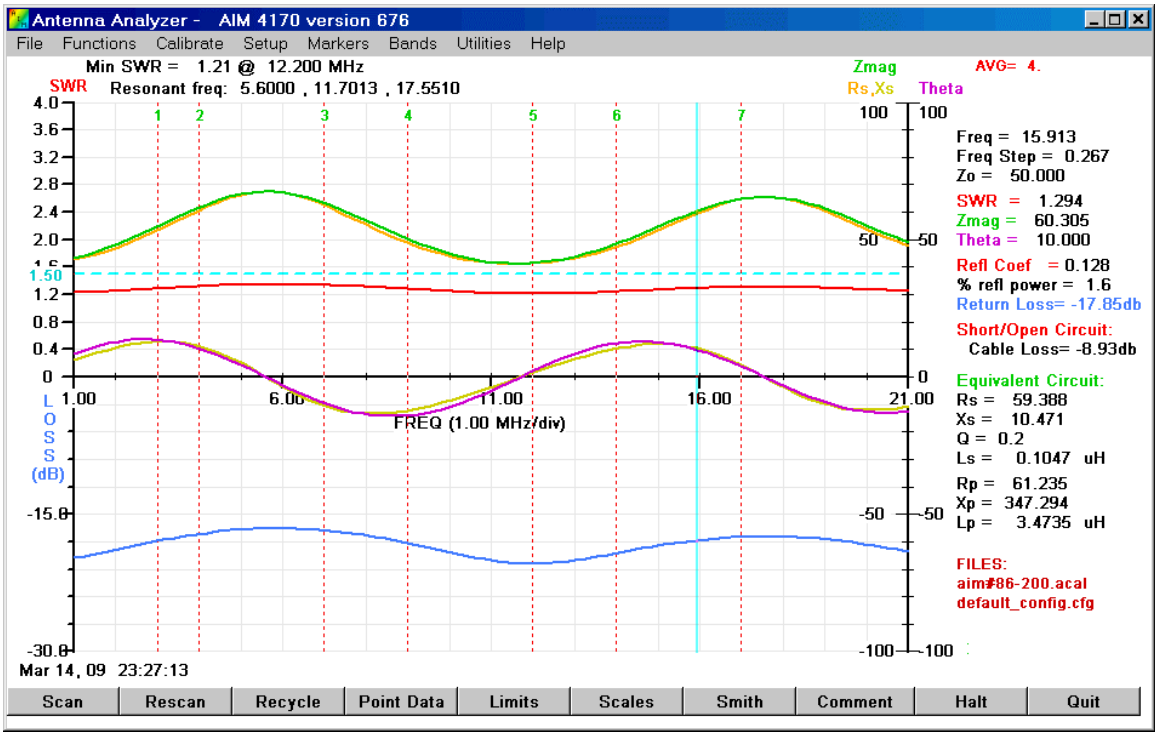
Marker Commands

Markers can be defined to aid in collecting data at specific frequencies. Position the mouse near the desired point and **right click**. The marker frequency at the mouse appears in a dialog box. This value can be changed with a keyboard input. The marker index number is assigned automatically. The markers are always sorted by increasing frequency. A number followed by **k** or **K** is considered to be in kilohertz, otherwise, it is in megahertz.

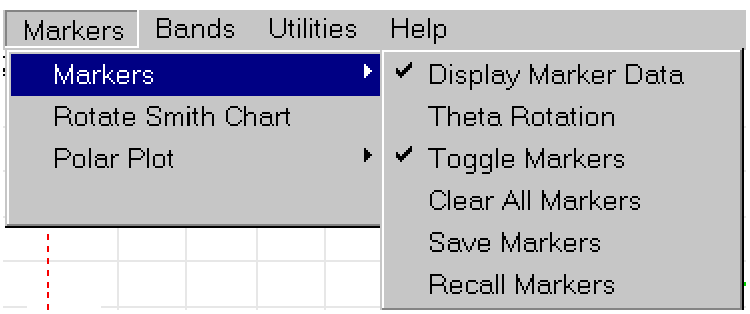


Click the **Insert** button to add a new marker or the **Remove** button to remove a marker. When removing a marker, the one closest to the mouse position will be removed. The mouse does not have to be positioned exactly on the marker.

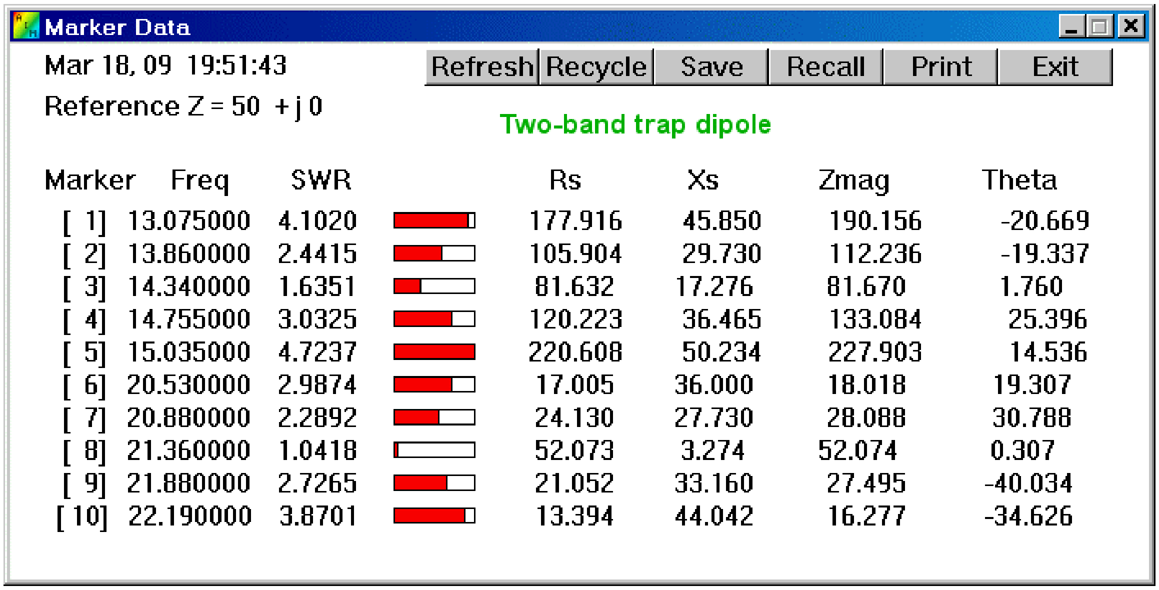
As markers are entered, they are displayed as red dotted lines, as shown below.
The marker display can be turned on or off with the ***marker toggle*** function (see below). After a marker is inserted or removed, the set of markers will be resorted in the order of ascending frequency. Up to 20 markers can be entered at one time. Sets of markers can be saved in files and recalled later.



Markers are controlled using the menu items under the **Marker** tab:
Several options for the markers are shown in the submenu below:



Display Marker Data – open a window to display all the presently defined markers and the data at these frequencies. The data is read once when the window is opened. Click **Refresh** to take another set of readings. Click **Recycle** to read the raw data at the marker frequencies repetitively. In the Recycle mode, the horizontal gauge in red shows the SWR graphically on a log scale from 1 to 5. This corresponds to the actual numeric value of SWR displayed in the third column. This feature is very useful when adjusting multiband antennas since the SWR in each band is displayed in real time while adjustments are made. Several markers can be defined for each band to get an idea of the bandwidth. The following image shows marker data for a two-band trap dipole with five markers per band. Note how the red gauge dips to a minimum at the resonant point of both bands (14.34 and 21.36 MHz) :



Marker Data

Mar 18, 09 19:51:43

Refresh Recycle Save Recall Print Exit

Reference Z = 50 + j 0

Two-band trap dipole

Marker	Freq	SWR	Rs	Xs	Zmag	Theta
[1]	13.075000	4.1020	177.916	45.850	190.156	-20.669
[2]	13.860000	2.4415	105.904	29.730	112.236	-19.337
[3]	14.340000	1.6351	81.632	17.276	81.670	1.760
[4]	14.755000	3.0325	120.223	36.465	133.084	25.396
[5]	15.035000	4.7237	220.608	50.234	227.903	14.536
[6]	20.530000	2.9874	17.005	36.000	18.018	19.307
[7]	20.880000	2.2892	24.130	27.730	28.088	30.788
[8]	21.360000	1.0418	52.073	3.274	52.074	0.307
[9]	21.880000	2.7265	21.052	33.160	27.495	-40.034
[10]	22.190000	3.8701	13.394	44.042	16.277	-34.626

The numbers in parentheses in the first column are the marker index numbers. The markers frequencies do not have to be equally spaced.

If the graph presently displayed is from a scan that has been saved, the marker data will be taken from that data in memory and no new data is read from the hardware. In this case, if some of the markers are outside the scan limits, a reminder will pop up indicating that data for some of the markers cannot be read. Also, the **refresh and recycle buttons** will be grayed out.

Phase Rotation – The marker data can be transformed to correspond to data that would be measured at the end of a transmission line with a specified electrical length or a network with a specified phase shift.

Toggle Markers - turn the marker display on/off without changing the markers in memory.

Clear all Markers – removes all markers from memory.

Save Markers – saves this set of markers to a user specified file. Any number of marker files can be saved. These files have the extension ***.mrk.**

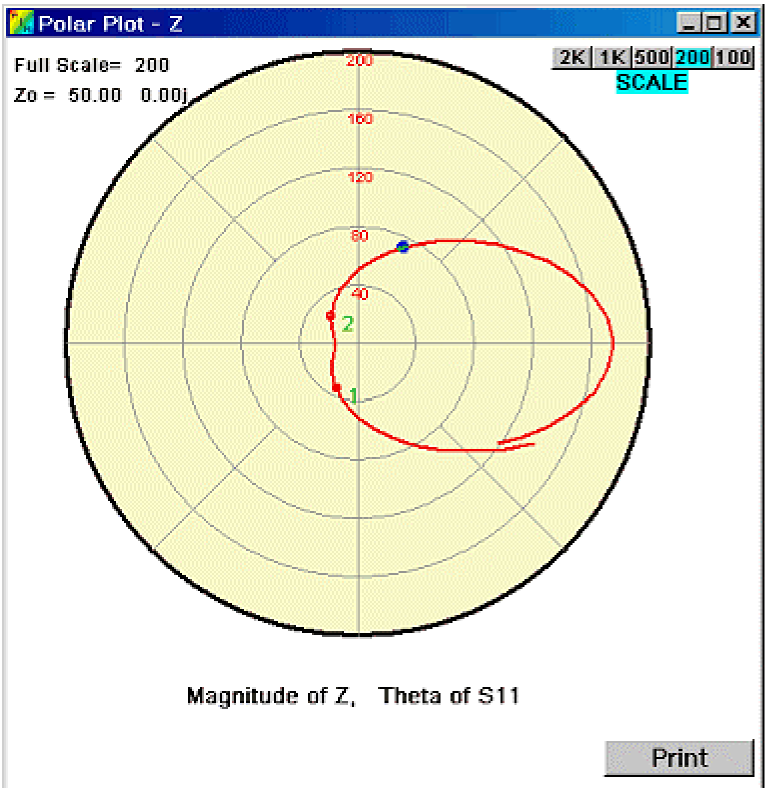
When the marker data is saved using the **SAVE** button on the marker data window, a second file is also saved in a comma-separated-variables format (csv). This file as the same user specified name and the extension ***.mrx**. It can be input to a spreadsheet, such as, **Excel**.

When the AIM program is closed, the present set of markers is saved in the *.ini file.

Recall Markers - recall a set of markers from a file.

Rotate Smith Chart – A second Smith chart can be displayed. There is an option to rotate its data by a angle corresponding to electrical distance along a transmission line or phase shift in a network. The actual geometric rotation of the plot on the chart will be twice the value of the angle that is entered.

Polar Plot – In addition to the Smith chart, several parameters can be plotted in **polar format.** The parameters are: SWR, Z and s11.



UTILITIES

L-C Matching Networks by WY2U

This program which is available on the web takes the impedance data (R and X) that is measured at the input end of the transmission line and calculates the L-C network required to transform it to the correct impedance (for example, 50 ohms) to match the transmitter. This can be used when designing a tuner to find the components to match an antenna over the desired frequency range.

When you click on this link, your computer must be connected to the internet. You may have to authorize the connection if you have a firewall program.

ZPlots by AC6LA

This program uses the data saved in the .csv file (by "File Save") to plot graphs for presentations. It features plot parameter selection and zoom capability. It can plot parameters that were not included in the original AIM plot and the plot range can be a subrange of the original data.

When you click on this link, your computer must be connected to the internet. You may have to authorize the connection if you have a firewall program. You can download the **Zplots** program to your computer and then run it off-line.

Twelfth Wave Matching - an interesting way to join two coaxes that have different impedances without using a matching section with a special (non-standard) impedance value. This technique only requires two short pieces of the same cables that are being joined together.

HELP Commands

AIM Manual -- This manual can be displayed as a pdf file.

Applications -- Information about particular applications with the AIM. This is in html format and can be **edited by the user** if desired. The file name is "applications_xx.htm".

Edit Config File -- The config file is opened in a text editor for making changes to parameters. After saving the file, be sure to close the AIM program and **restart** it to load the new config file.

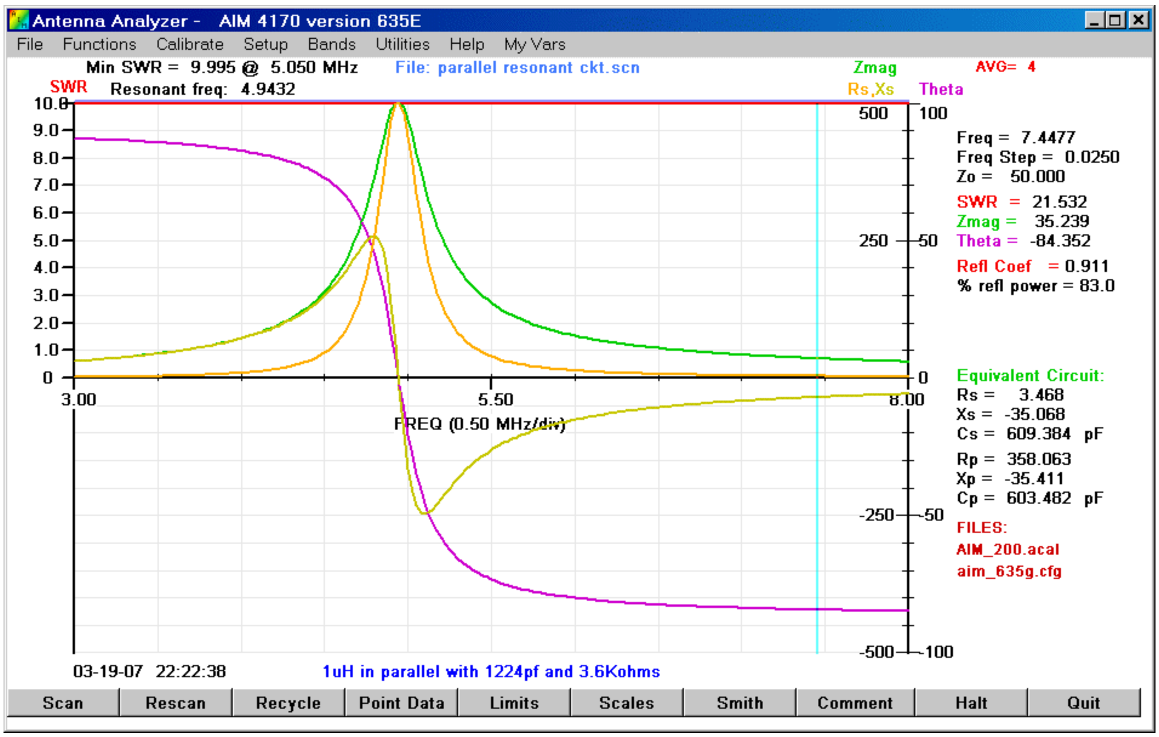
Status -- The status window shows the value of some variables and the current path names for files. When Custom Cal is being used, the start, stop, & step parameters are displayed.

Check Program Update -- Click this link when connected to the internet to go directly to the program update page at w5big.com.

About -- The present version of the programs in the PC and the controller are displayed. The url of the W5BIG website is also displayed.

Data Display

After a scan (or after loading a file from disk), the mouse can move a vertical cursor along the frequency axis and the numeric data for several parameters will be displayed continuously in a data window on the right side of the screen. An example is shown below:



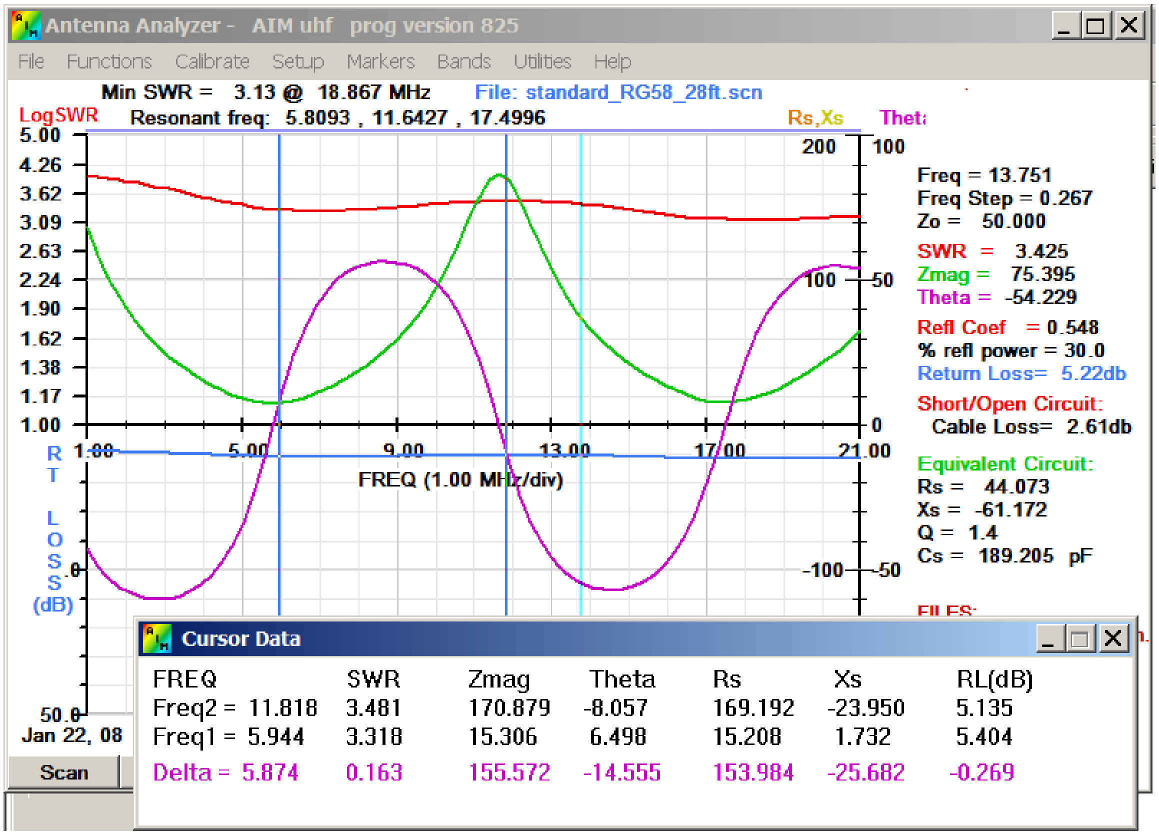
The light cyan vertical line is the cursor. It moves with the mouse whenever the mouse pointer is inside the graph area. In this example, the frequency is 7.4477 MHz. The frequency changes in 1-pixel increments due to the mouse resolution, so some specific frequencies may not be displayable. The data is interpolated between the actual data points that were recorded during the scan. The cursor can also be moved in small increments using the Left/Right Arrow Keys on the keyboard.

Normally the cursor moves whenever the mouse pointer is inside the graph area. The cursor movement can be stopped by pressing the **left mouse button**. This makes it easier to select items on the menu without disturbing the data being displayed on the right side of the graph. The action of enabling/disabling the cursor with the left mouse button can be reversed with an option on the Setup Menu.

Data in the window shows the characteristic impedance, Zo, has been specified to be 50 ohms for this example. The SWR at 7.4477 MHz is 21.532, Zmag=35.239 ohms, and Phase= -84.352 degrees.

Parameter values for both a series and a parallel equivalent circuit are shown as Rs, Ls (series circuit) and Rp, Lp (parallel circuit). Note that when the phase angle, Phase, is negative, the equivalent components, Ls and Lp, change to Cs and Cp automatically.

Cursor Data



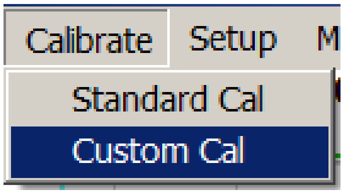
The data at two frequencies can be displayed along with their differences by pressing numeric key **1** for the first point, moving the cursor to the second frequency and then pressing **2** for the second point. This action can be repeated by moving to other points and pressing **1** or **2**. Data in the small window will be updated each time. The two selected frequencies are indicated by blue vertical lines on the graph. Close the data window by clicking the **x** in the upper right corner.

*Information on selecting **markers** for up to twenty frequencies is on a following page.*

At the top of the graph in the main window, up to five resonant frequencies of the antenna are displayed. These are the frequencies where the phase angle passes through zero.

The names of the calibration and configuration files being used are shown in the lower right corner of the data window. The color used to display these file names can be selected in the configuration file.

Custom Calibration



This specialized calibration procedure is useful for situations involving filters or long cables. For most routine work with physically small sockets, adapters, or short cables, the **Standard Calibration** procedure can be used.

This calibration technique allows the measurement reference point to be moved from the RF connector on the front panel to the end of a transmission line and/or a filter. This cancels the effect of complex transmission lines and filters so the data at the antenna can be determined more accurately. The custom cal routine can be used to calibrate long transmission lines or a relatively short line that may be used for an interconnection in a lab setup. This calibration process may take longer when a small delta-freq is used, but the actual scan rate is essentially the same using either standard or custom cal data.

The user specifies the **start, stop** and **delta frequency** values for the calibration. Typically the delta frequency will be 1MHz or less to take advantage of the improved accuracy when a complex circuit is connected between the RF connector and the measurement point. *Note: the standard calibration procedure takes cal data at 1MHz increments.*

The custom calibration procedure for the AIMuhf can be faster than the standard cal by specifying only the frequency range of interest rather than calibrating over the entire operating range of the instrument.

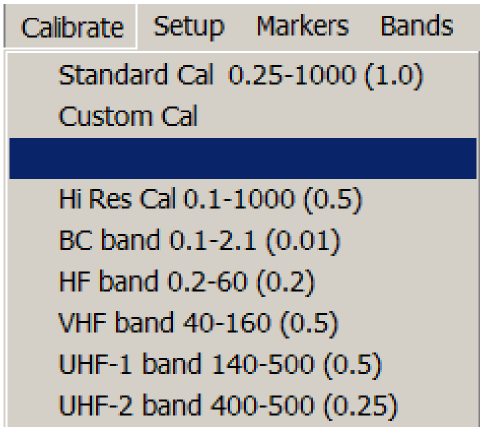
The AIMuhf has some predefined cal limits that will be automatically entered into the custom cal dialog. These values can be modified for specific applications.

The **short, open** and **resistor** loads are used. The resistor value is not critical as long as it is accurately known. When adapters are used, be sure to be consistent so that all three loads have the same capacitance and inductance. For the open cal load, be sure to use an actual open connector. If the open cal load is not attached to the test connector, the stray capacity will not be properly calibrated. This can represent an error of several picofarads.

Click **Calibrate -> Custom Cal** and the parameter entry dialog box will open.

By default, data entries are in MHz but if a number is followed by a **K** or **k** then the number will be interpreted as KHz.

For the AIMuhf there are several predefined calibration bands shown on the menu. These ranges are used for the Custom Cal and the values can be changed to anything desired. The menu value are just a shortcut for filling in the dialog box before doing a custom cal. The three values on each line are the Start - Stop and (Delta Freq) values, all in MHz.



After the start, stop and delta limits are entered, there will be prompts to attach the short, open and resistor loads. After the calibration is complete, there is a prompt for an optional comment to be included with the cal data file. Then the name of the data file is entered. The name can be anything, but you may want to make the custom cal files distinctive from the standard cal files so it's easy to tell them apart. After calibration, a scan is done automatically (without plotting the data) to see if the custom cal data is likely to be accurate enough for this particular setup. When the external circuit has rapid changes in phase (such as a filter), the custom delta freq has to be small enough to include data during the phase transitions. In extreme cases it may be necessary to use a delta as small as 1 KHz. Up to 30,000 cal points can be used.

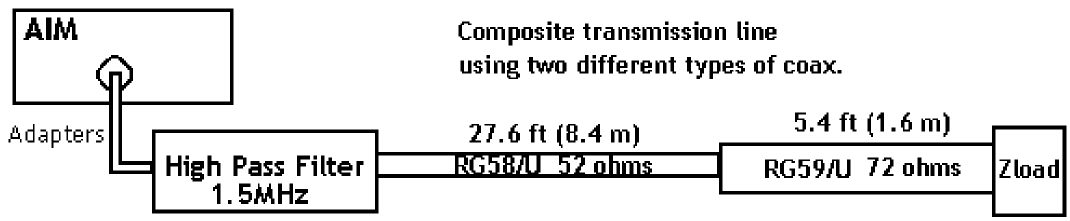
If a warning message is displayed, the cal data may still be ok in the frequency range of interest. The overall results should be evaluated with known loads, such as resistors with good RF characteristics.

The scan **start/stop and delta limits can be changed** without having to do the custom cal again. Any start and stop values can be used as long as they are within the original custom cal start/stop limits.

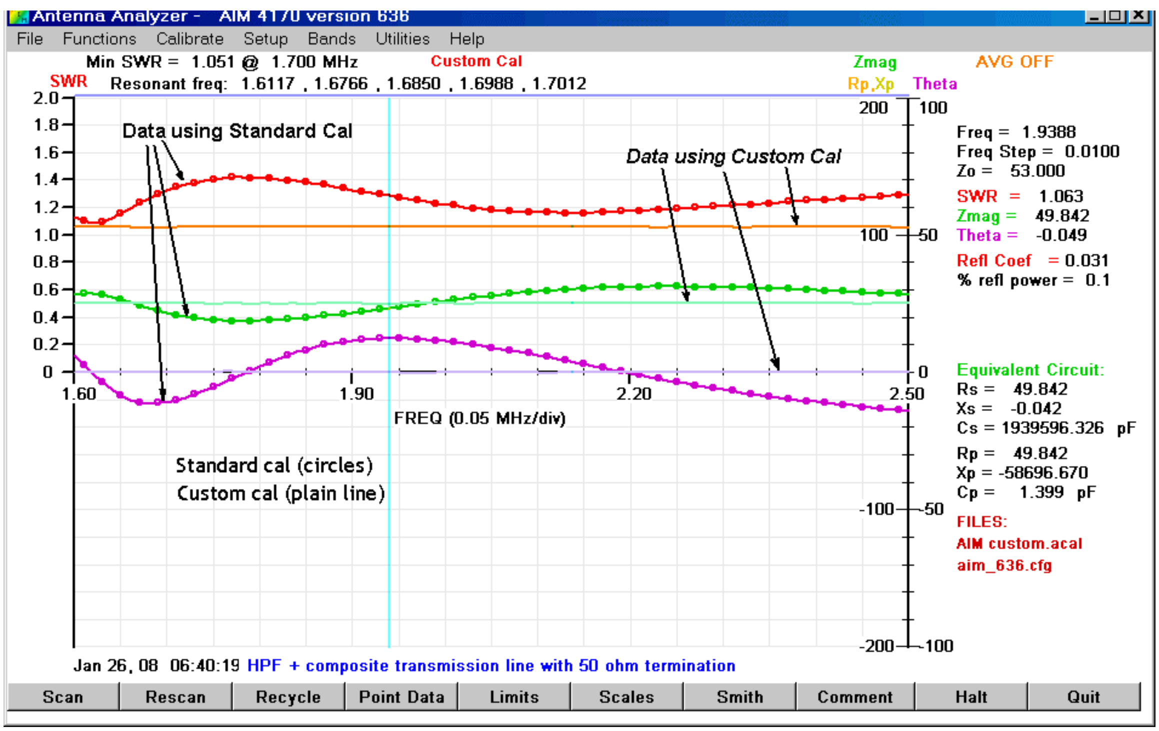
The comment that is included in the current cal file can be viewed by clicking **Help -> Status.** The status window also shows the start, stop and delta parameters used for this custom cal file. *If a custom cal file is not being used, these data do not appear in the status window.*

Custom Cal Examples:

The effectiveness of the custom cal procedure can be seen in the following examples. For this series of tests, a transmission line made up of two different kinds of coax was used:



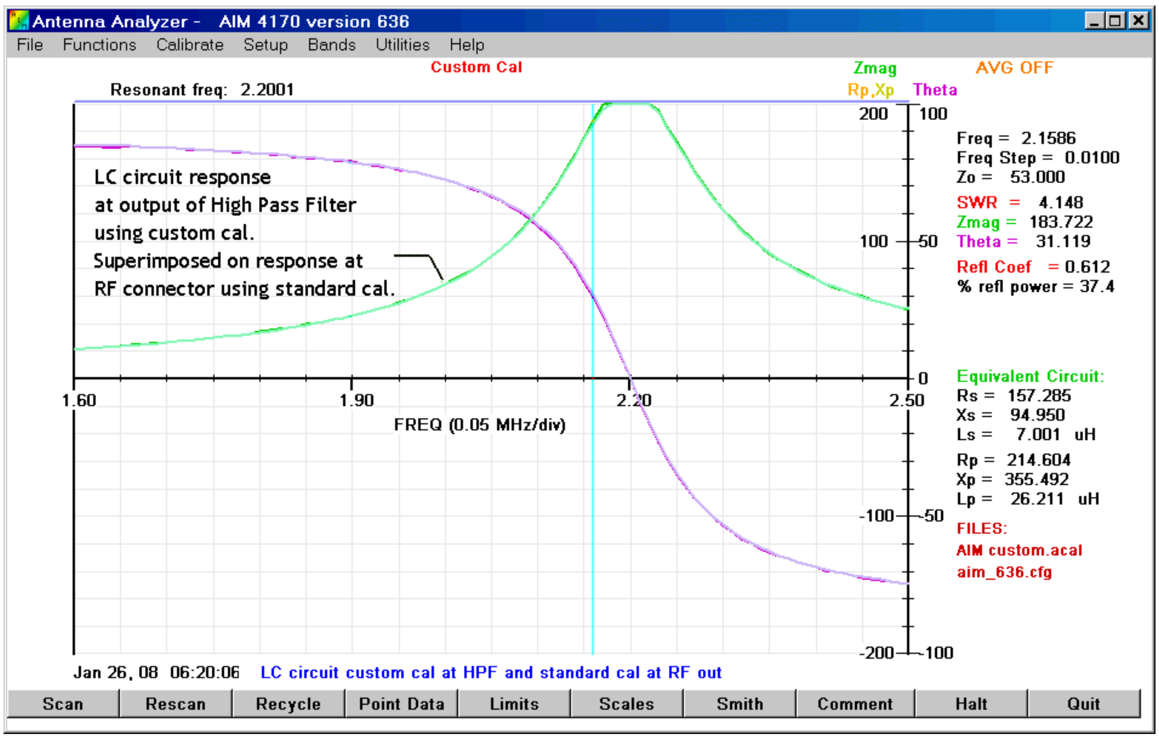
The high pass filter cuts off below 1.8MHz. It's a **Broadcast Band High Pass Filter** from **Array Solutions**. (see their website for more information). This is very useful for rejecting local broadcast stations while tuning a 160 meter antenna. Inserting this filter will normally preserve the SWR readings around 160 meters but the impedance and phase angle may be changed. By calibrating at the far end of the transmission line, the AIM can then transform the antenna data and significantly reduce the distortion caused by the filter as well as the effect of two different types of transmission line.



The figure above shows a scan using the **standard** calibration method when the composite transmission line above is terminated with 50 ohms. This scan is **highlighted**

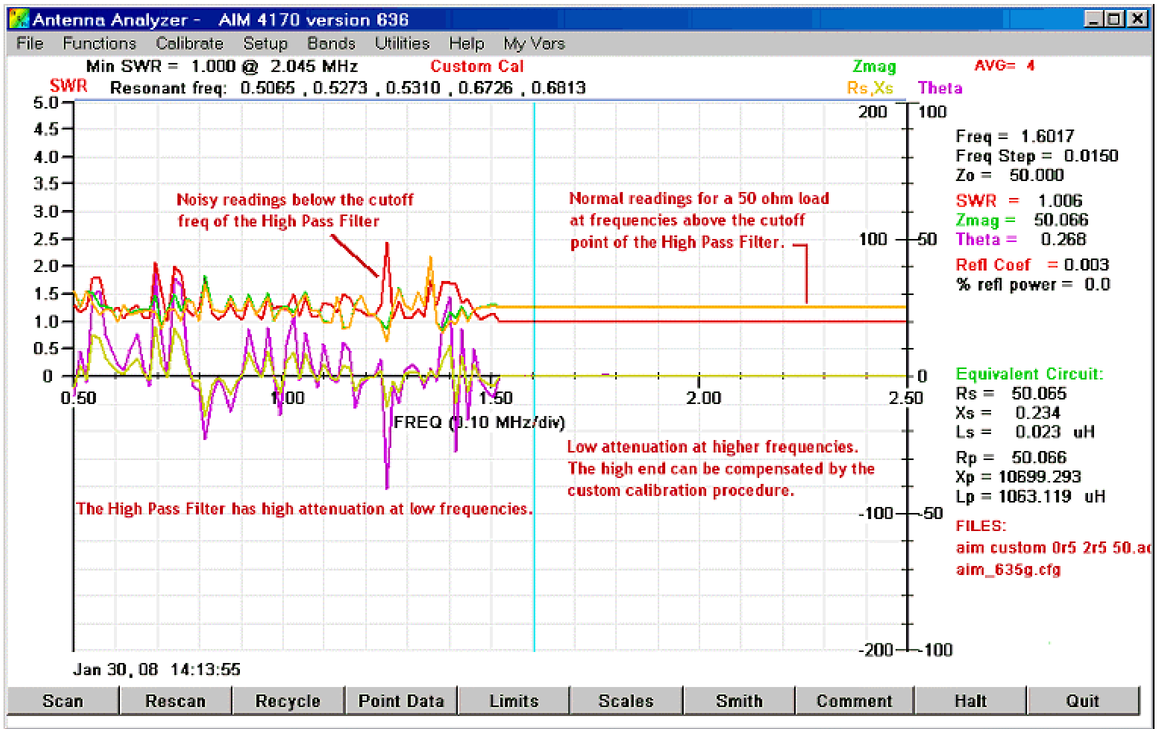
with dots along each of the three traces: SWR, Zmag, and Phase. The SWR shows some variation. The phase angle is off about 15 degrees at 1.95MHz.

Then a scan was done using **custom** calibration data obtained at the end of the transmission line. The new data is plotted with plain lines. Now the data is flat, indicating a nearly ideal 50 ohm termination. The phase angle is essentially zero; *it lies on the x-axis so it's not easy to see.*



The figure above shows the results when using an LC parallel turned circuit for a load. One scan was taken with the LC circuit connected **directly** to the AIM's RF connector using **standard cal** data.

Then the LC circuit was moved to the end of the composite transmission line (shown previously) and another scan was done with the **custom cal** data. When the two scans are overlaid, they are very close to each other. This before and after comparison was done by loading a new cal data file without changing the scan limits. Then click **Rescan** and the new scan overlay the original data. The same type of comparison can also be done by loading a stored graph file and clicking rescan.



This scan shows the effect of a High Pass Filter that has high attention in the AM radio broadcast band. It is very effective in reducing interference picked up on a 160 meter antenna. The filter's cutoff frequency is about 1.6 MHz. To cancel the effect of the filter in the 160 meter band (1.8 to 2.0 MHz), the **custom calibration** procedure can be used.

Below 1.6MHz, the cal data is noisy due to the attenuation through the filter. This is because the instrument sees essentially the same thing when any of the calibration loads are attached, so the compensation data is not consistent with the specific load. Above 1.6MHz the signal through the high pass filter is normal, with low attenuation, and the calibration is accurate. The 50 ohm load read accurately in the frequency range of interest, 1.8 to 2 MHz.

When using new filters or baluns that may have limited bandwidths, be sure to evaluate the results using loads with known characteristics before testing the antenna itself.

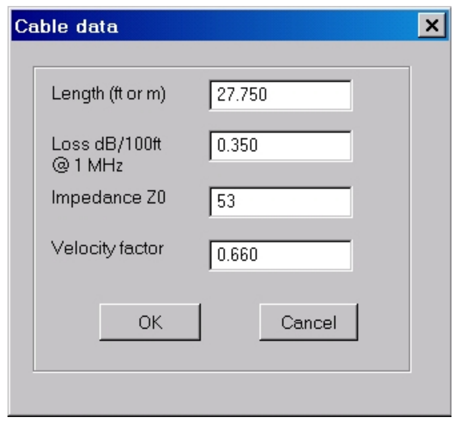
Data Referred to Antenna

Sometimes it is desirable to know the impedance right at the antenna terminals. The most accurate method uses the **Custom Calibration** procedure discussed previously. In some cases it may be impractical to disconnect the coax from the antenna feed point so another procedure is available that only requires data from the manufacturer's spec sheet.

This method of transforming the data to the antenna can be used when the properties of the transmission line (Zo, length, loss and velocity factor) are accurately known. This does not require disconnecting the transmission line from the antenna. It should only be used for transmission lines that employ a single type of coax.

To select this feature, click **Functions -> Refer to Antenna.**

Then enter the transmission line data in the dialog box.



The length and velocity factor are combined to find the effective **electrical length**. Rather than trying to measure the physical length of the transmission line and estimate its velocity factor (which may vary from one roll of coax to another), you can measure the **electrical length** directly using the AIM. Put a **short circuit** across the antenna terminals (or disconnect the coax from the antenna) and scan to find the first point where the phase angle is zero. This is listed at the top of the graph as the first **resonant freq**, F1. This frequency corresponds to one-quarter of a wavelength, so the **electrical length** of the line is:

$$\text{Electrical\_length} = 0.25*(299.8/F1) \text{ meters}$$

$$= 0.25*(984/F1) \text{ feet}$$

This corresponds to the physical length of the coax divided by its velocity factor. The electrical length is longer than the physical length since the velocity factor is less than one. Radio waves only care about the electrical length. When entering the cable parameters, if you know the electrical length (by measuring F1 above), the top line can be a close "estimate" of the physical length and the velocity factor is the electrical length that was accurately measured, divided by this "estimate". For example, when I installed the antenna did I use 120 feet or 125 feet of coax? Rather than trying to measure the length of the coax again, estimate its length as 125 feet. Assuming the electrical length was measured to be 185 feet, the velocity factor would be 125/185 = 0.6757.

Alternatively, if you know the velocity factor, calculate the physical length by multiplying the velocity factor times the electrical length.

The cable loss is usually given in terms of "dB per 100 feet" on data sheets. Enter the value of loss for 1MHz, if it's listed. If you're interested in higher frequency bands and want a bit more accuracy, pick a frequency close to your region of interest and divide the loss at this frequency by the **square root** of the frequency in MHz.

For example, if the loss at 10MHz is 1.5dB/100feet, enter 1.5/SquareRoot(10) = 0.47 dB/100 feet for the loss. This attenuation value is close to the value at 1MHz. You can enter loss as either a positive or a negative number, it doesn't matter.

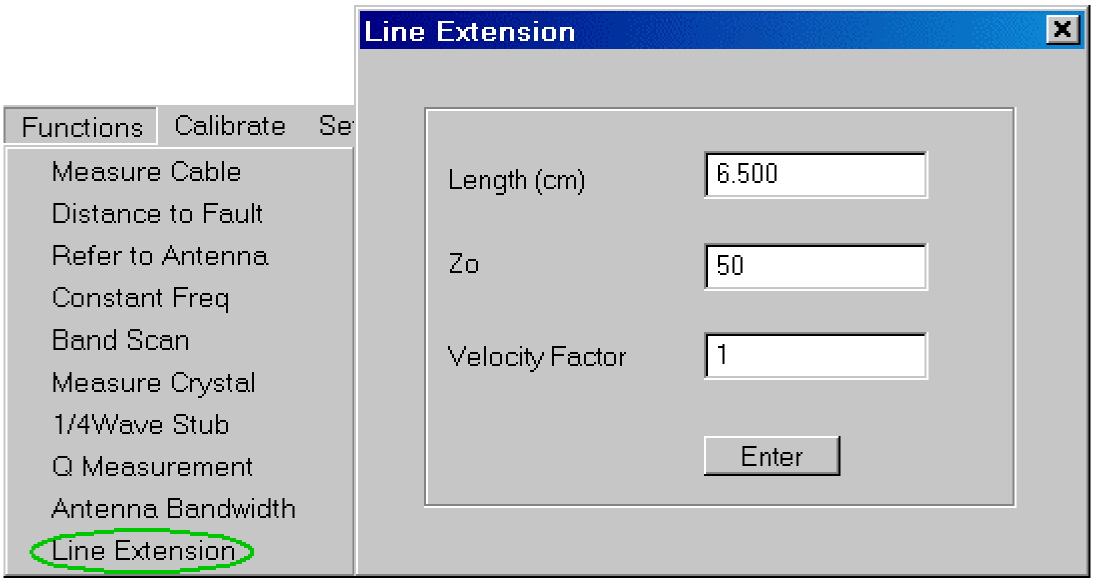
When calculating loss, the **physical length** of the cable is used. Although the physical length of the coax may not be known with great accuracy, the loss has a secondary effect and it's not as critical as the electrical length. Using 120 feet or 125 feet for the loss calculation will not affect the final answer very much, but the **ratio** of physical length to the velocity factor is important (as mentioned above).

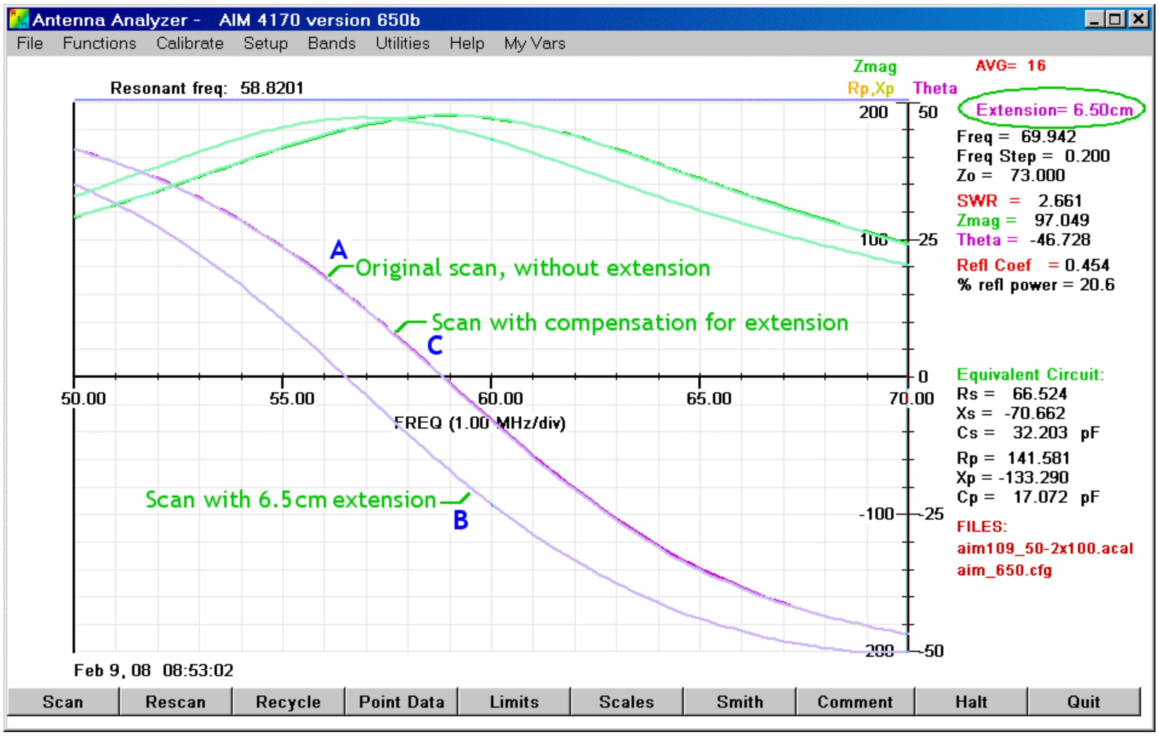
The nominal impedance, **Zo**, of the coax is <u>very important</u>. This can be found from the manufacturer's data sheet. It does vary from one manufacturing run to another and it varies somewhat along the roll of coax. This value may be fine tuned by using a known terminating resistance of a few hundred ohms to experimentally optimize the transformed value. After the cable is characterized by testing the actual cable or an equivalent piece of cable (ideally from the same roll), the transformed impedance values will be accurate to within a few percent.

Line Extension

When an adapter is used to connect a line to the AIM, there will be some shift in the displayed parameters due to the phase shift in the adapter. This can be compensated by doing the regular calibration with the adapter in place. Alternatively, it can be compensated after calibration by treating the adapter as an extension of the transmission line and reversing the phase shift. The extension is assumed to be a short piece of **ideal coax** (no loss) with a specified length, characteristic impedance (Zo) and velocity factor. There is no limit to the length, but typically the extension will be short. The default unit of length is **centimeters**. The length can be entered in inches, feet, or meters by following the number with an “i”, “f” or “m” (upper or lower case can be used).

The length can be **positive or negative**. Enter **zero** to turn the extension function **off**.





This graph shows the effect of inserting an adapter in series with a piece of RG59/U coax that is terminated with a 200 ohm resistor.

A- The first trace for the phase crosses the frequency axis at 58.8 MHz.

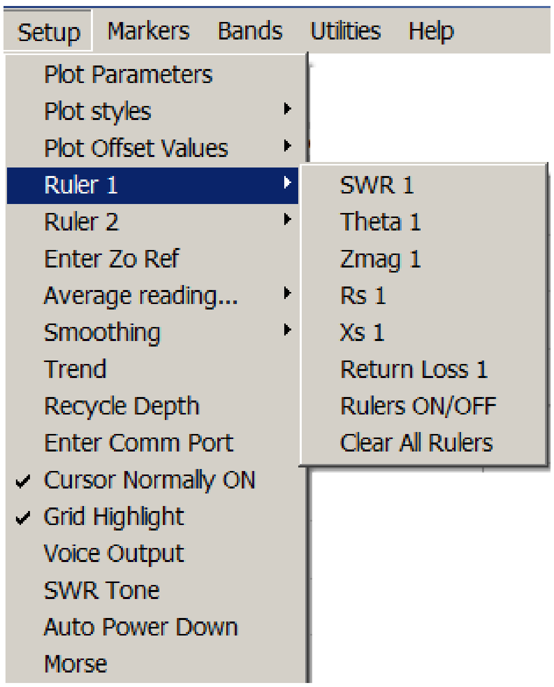
B- When the adapter, which is 6.5 cm long is inserted, the phase plot crosses at 56.5 MHz since the line appears to be longer now and the frequency corresponding to a half wavelength is lower.

C- Enabling the line extension function with length=6.5 cm, Zo=50, and Velocity Factor=1 compensates for the extension and the last trace coincides with the first trace that was made without the extension.

Note the value for **Zo corresponds to the adapter that is being compensated**, <u>not</u> to the transmission line. Depending on the construction of the adapter, it may take some experimentation to find the equivalent length. Only the **electrical length,** not the physical length, is important for this function, so the velocity factor can be left at 1.0 if desired.

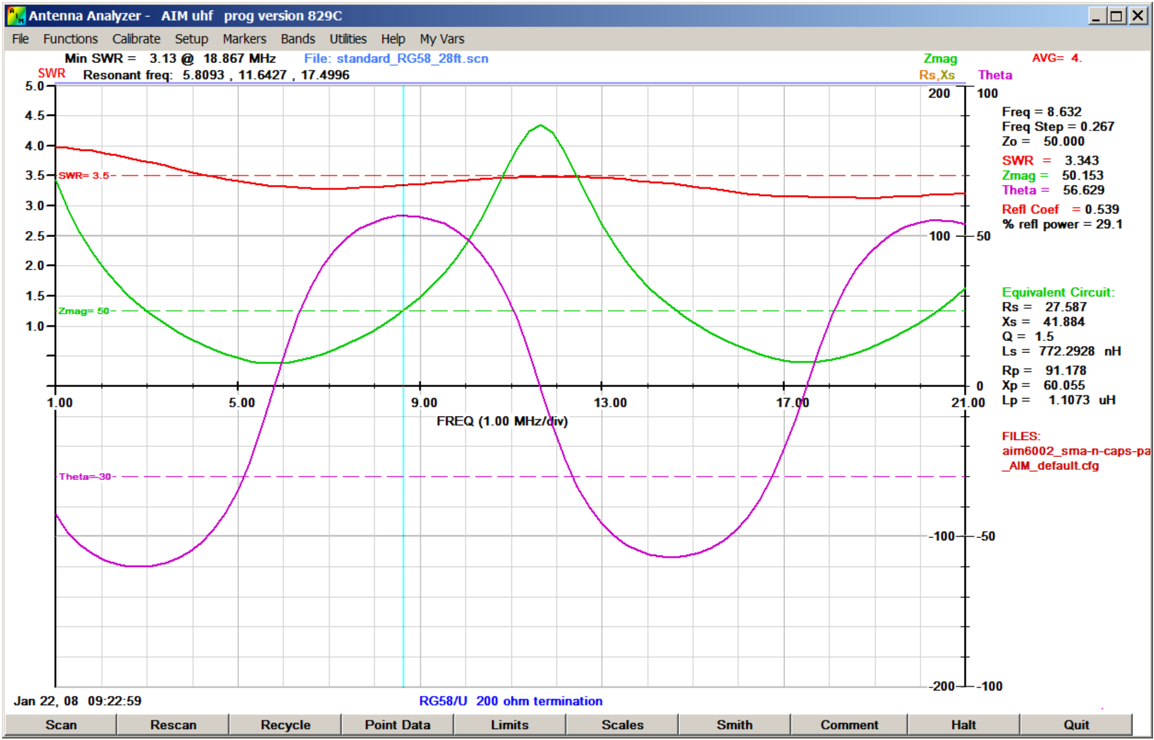
Rulers and Offsets

Horizontal rulers can be defined to help visualize where a parameter lies with respect to user specified limits. Two rulers can be defined for: SWR, Phase, Zmag, Rseries, Xseries, and Return Loss. These are referred to as Ruler 1 and Ruler 2. Either one can have the larger value.



The rulers are displayed as dashed lines with the same color as the trace they are related to. The numeric value is displayed at the left end of the ruler.

The ruler display can be turned on or off without affecting the value of the rulers by clicking **Rulers ON/OFF**. All the rulers can be set to zero by clicking **Clear All Rulers**. This applies to both Ruler set 1 and Ruler set 2.



Rulers for SWR (red), Zmag (green) and Phase (magenta)

The **traces can be offset** by a specified amount to make it easier to see small variations around an average value.

After the trace is offset, the **Scale** can be expanded to highlight the interesting part of the trace. Click the **Scale** button at the bottom of the screen to call up the Scale factor selection dialog.

For example, the quality of a dummy load can be evaluated by offsetting the Zmag and Rs data by 50 ohms and then expanding the vertical Zmag scale to 10 ohms full scale for better sensitivity

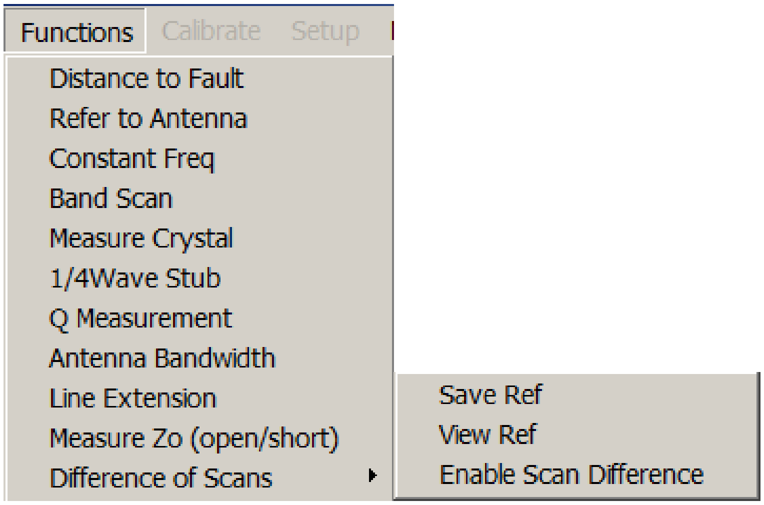
The offsets can be turned off without having to change the offset values by clicking **Offsets ON/OFF.** Clicking this tab again re-enables the offsets.

All the offsets can be set to zero by clicking **Clear All Offsets.**

The value of the offset is displayed at the left side of each parameter. If these labels interfere with the some traces, the labels can be turned off while leaving the offsets in effect. **Click Labels ON/OFF.**

Scan Differences

When evaluating changes to a system, it is sometimes interesting to plot the difference between scans. This feature makes it possible to save a scan as a reference and then subtract it from each subsequent scan.



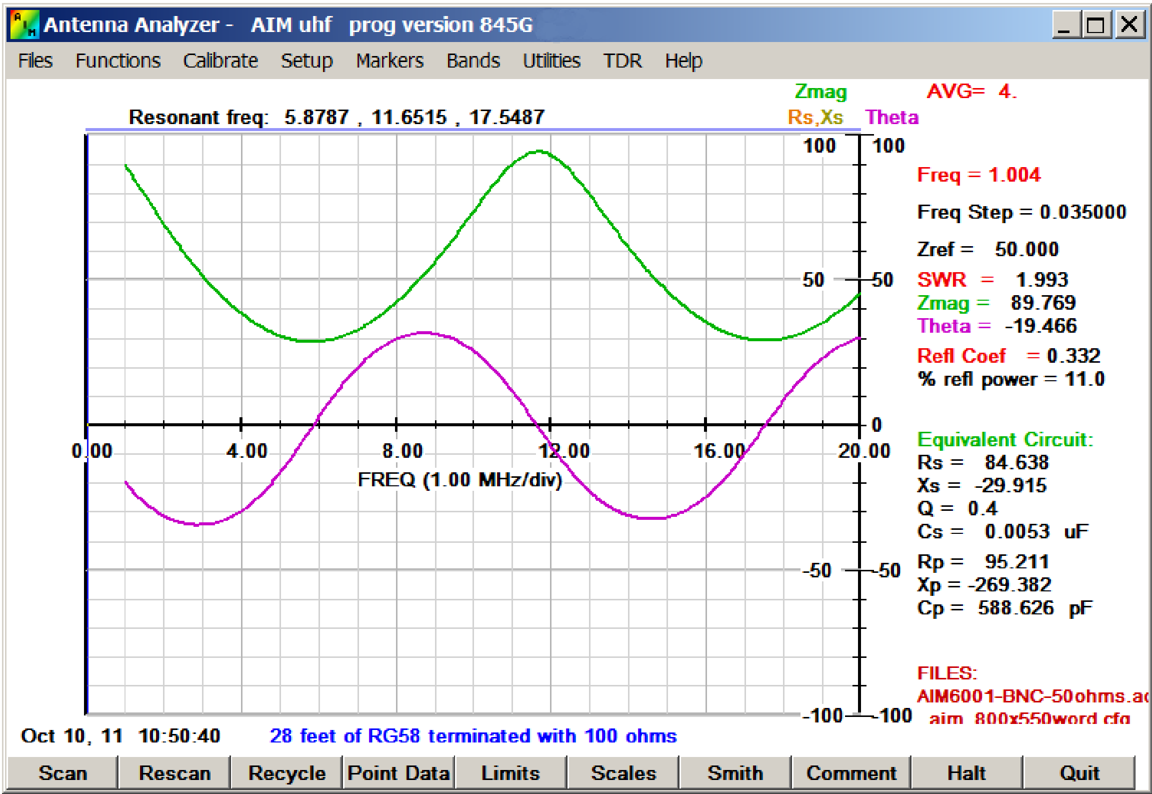
The scan that is presently being displayed can be saved as the reference by clicking **Difference of Scans => Save Ref**

This reference will be saved indefinitely in memory as long as the program is active. *It is cleared when the program is closed or when the scan limits are changed*. The differencing operation can be turned on and off by clicking **Enable Scan Difference.** This does not affect the reference itself. The reference scan can be recalled for viewing at any time by clicking **View Ref.** The reference is not affected by this operation. The reference scan is not saved with the init file when the program is closed.

When the differencing operation is enabled, a reminder is displayed in the lower left corner of the graph. **The difference applies to Zmag, Phase, Rs and Xs**. Any of these traces can be turned off, if desired.

New scale factors and offsets can also be used to expand the difference traces.

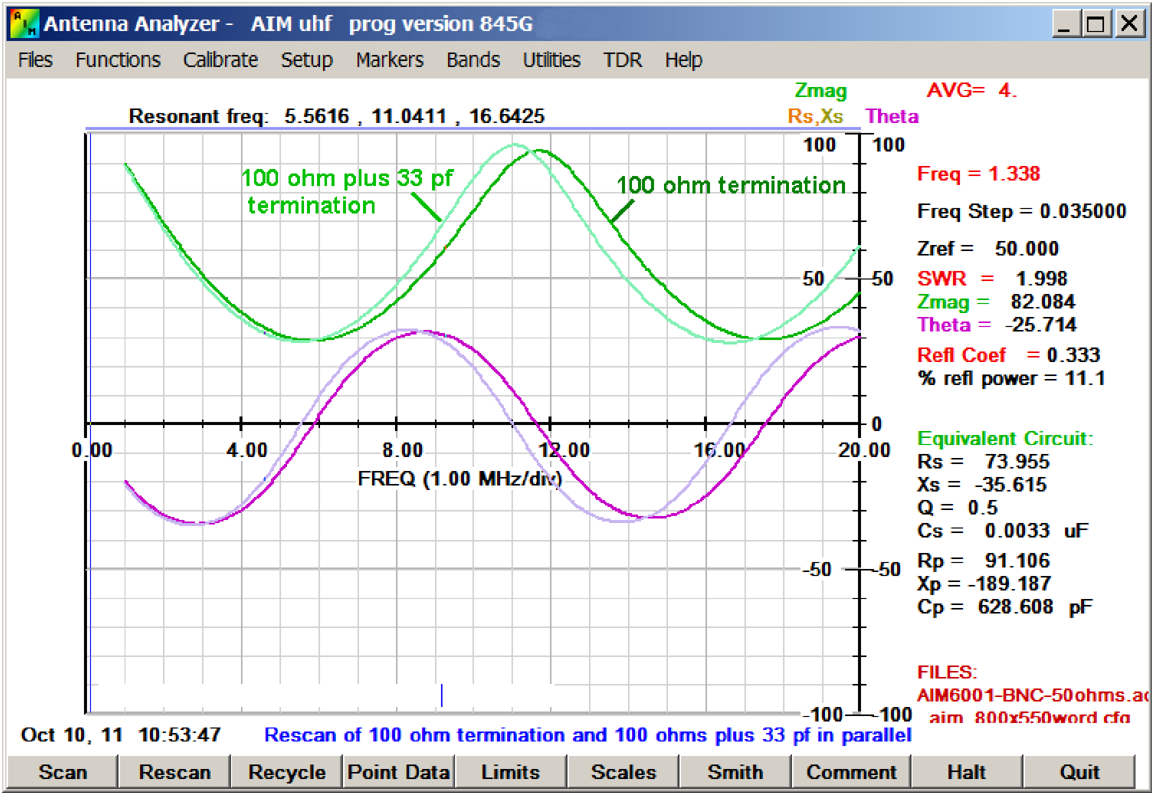
This example shows how the effect of a small impedance change at the end of a cable can be highlighted.



This shows a piece of RG58 coax 28 feet (8.5m) long, terminated with a 100 ohm resistor.

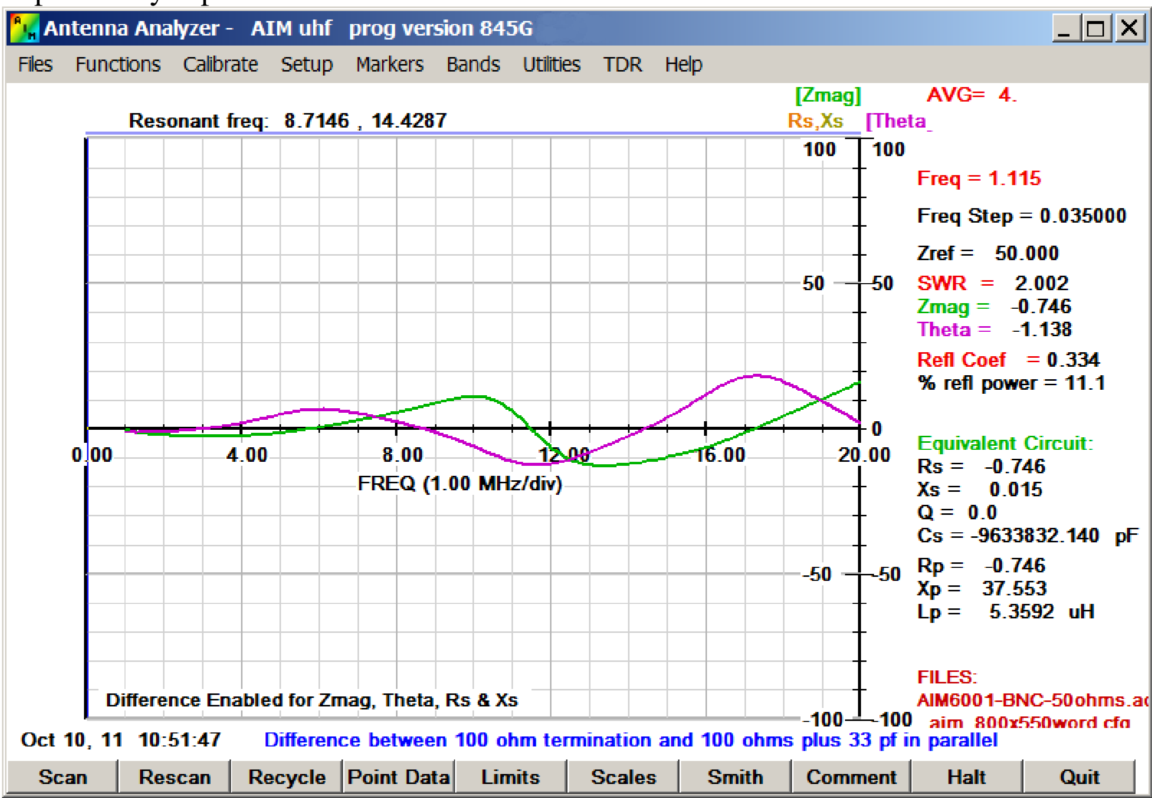
This is saved as the **Reference** scan for this example.

Now we'll add a 33 pf capacitor in parallel with the resistor:



A **Rescan** shows the effects with both terminations superimposed.

Displaying the **difference** between these scans makes it easier to see the effect of the 33pf of stray capacitance:



The differences can be highlighted even more by plotting Zmag and Phase on larger scales. The difference can be displayed in the **Recycle** mode while tuning a circuit or antenna.

Smith Charts

Click on the button labeled “Smith” at the bottom of the graph to open a window with a Smith chart showing a plot of the reflection coefficient versus frequency. As the cursor is moved with the mouse over the **original** scan, a marker dot is displayed at the corresponding point on the Smith chart and the relevant data is displayed on the right side of the graph.

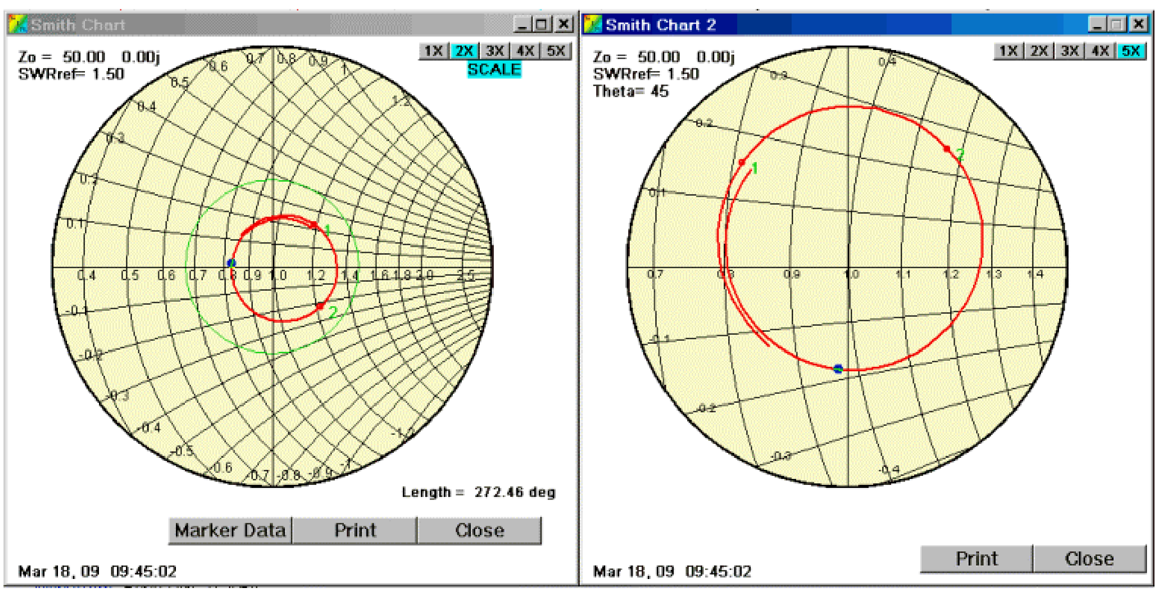
Note, the point that is highlighted on the Smith chart corresponds to the frequency on the horizontal frequency axis of the graph. This graph may be under the Smith chart and the horizontal axis, hence, it may not be completely visible. The Smith chart window can be moved to optimize the display.

A green circle of constant SWR will be displayed when the **SWR Ruler #1 (**see the **Setup** menu**)** is set to a value greater than 1.0. A second SWR ruler #2 can also be used. It will be plotted in blue. The SWR reference values for the rulers are shown in the left side of the Smith chart window.

A red dot marks the start of the Smith chart trace.

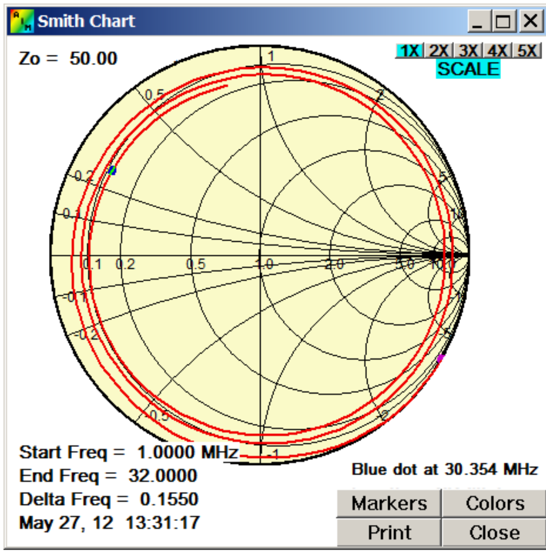
The center of the Smith chart corresponds to 50 ohms in the example below. The Zref value is specified using the Setup Menu. Zref can be any value and it can be a complex number.

Buttons in the upper right corner of the Smith chart window provide for zooming by factors from 1x to 5x. When the second Smith chart is displayed, it can have a different zoom value. (see Marker Menu)

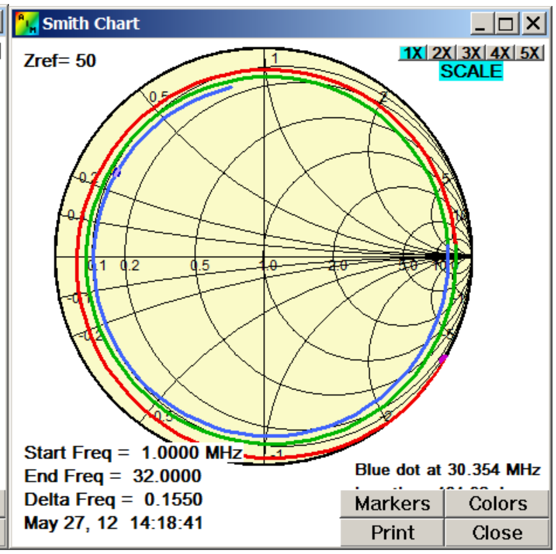


Smith charts of the same scan with zoom values of 2x and 5x. The right hand Smith chart has an offset of 45 electrical degrees. (geometrical plot rotation is 90 degrees)

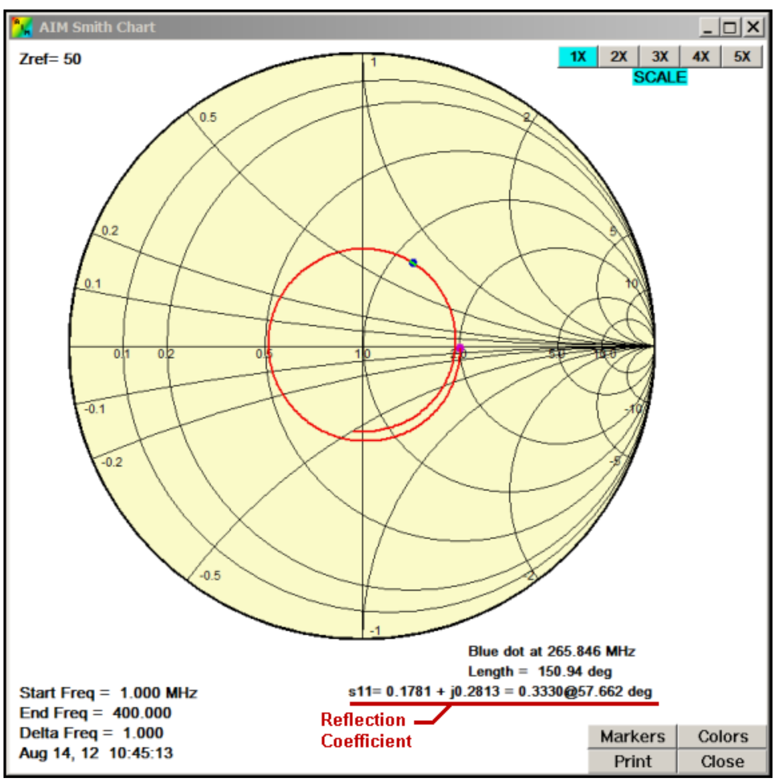
When the Smith chart has a complex trace, it may be helpful to highlight the data for each cycle around the center by plotting with different colors. This feature can be turned on and off by clicking the **Colors** button in the lower right hand corner of the Smith Chart.



Standard Smith Chart



Color Highlighting

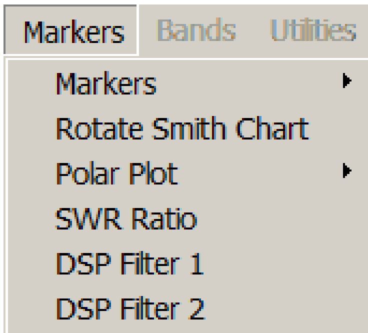


Reflection Coefficient in rectangular and polar coordiantes

The **electrical length** of the line at a particular frequency is displayed in the lower right corner of the Smith chart.

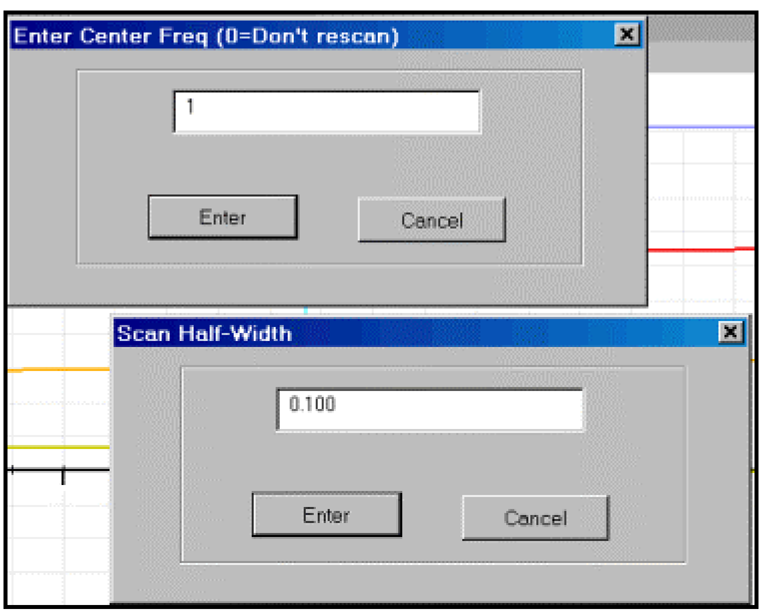
DSP Filters

The DSP filters are used primarily with the PowerAIM when testing antennas that are subject to strong interfering signals from radio stations on or near the same channel.



DSP filters 1 & 2 - A station on the same channel may cause a small but noticeable disturbance of the scan where you want to make a measurement. This interference can often be eliminated by using the DSP filters.

These filters have two parameters: **center frequency** & **scan width**. The **center frequency** does not have to correspond exactly to the point where the noise is centered. Also, there can be more than one burst of noise in the scan range. Typically the scan range will be small, no more than 100KHz for signals in the AM broadcast band and up to 1MHz in the FM band. The scan range is specified by its **half-width**. The scan will be between f1 and f2 corresponding to the center frequency minus the half-width and the center frequency plus the half-width. The numbers can be entered in kilohertz by following them with a “K” or “k”.

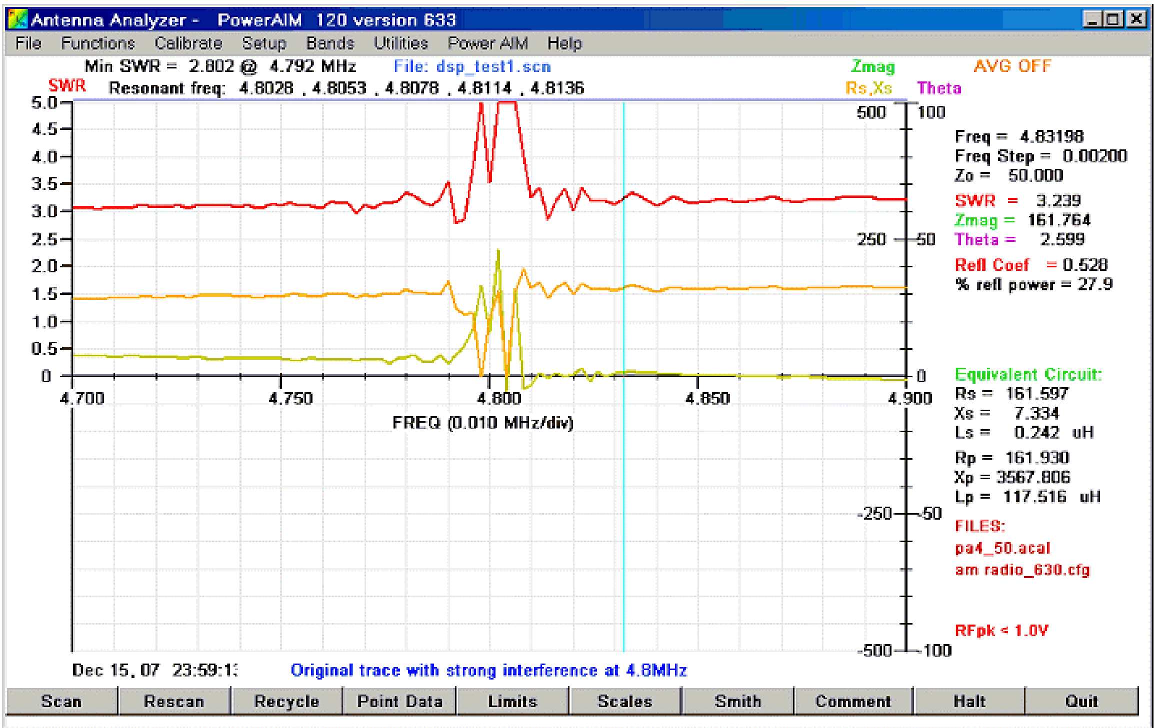


If 0.0 is entered for the center frequency, the DSP filter will process the data already in memory from a previous scan. This is useful for processing data saved in scan files. Otherwise, a new scan will be done with the specified scan limits and this new data will be processed.

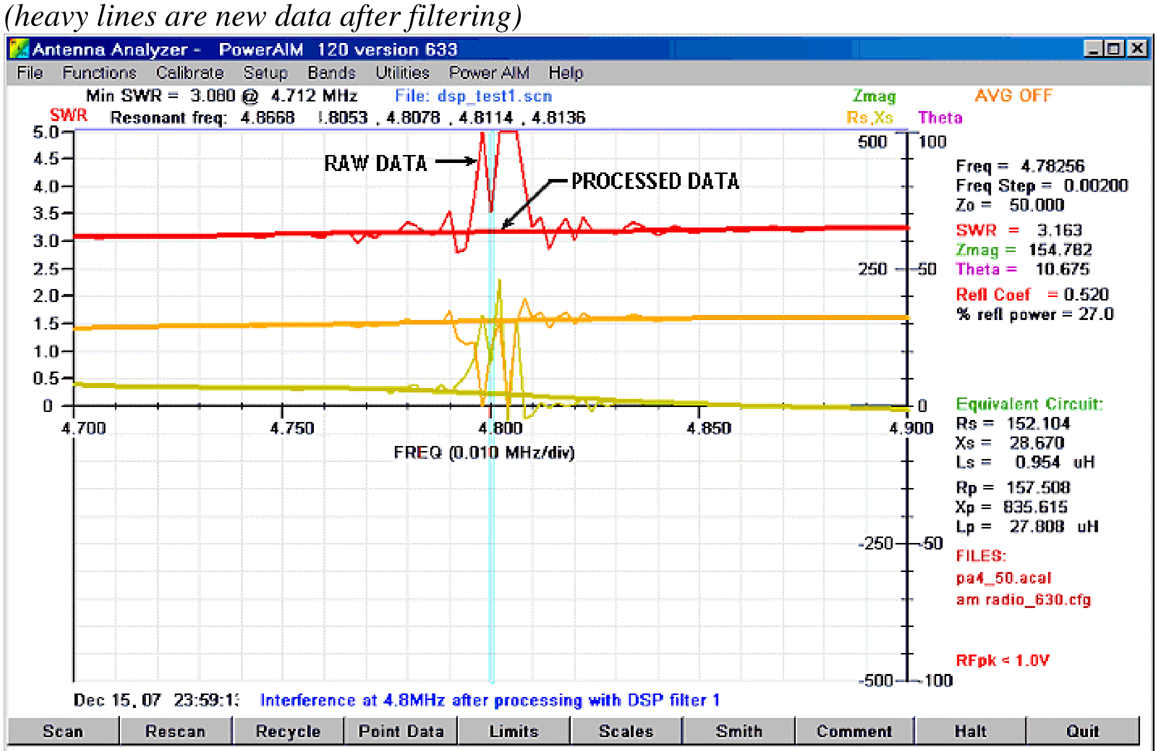
The two filters use different techniques and one may work better that the other, depending on the situation. The calculated data will be superimposed using a heavy line over the original data so you can see its effect. The new trace can be displayed by itself by clicking on a function that causes the display to be refreshed, for example, click the **scales button** and then **enter**.

An example is shown below using **DSP filter 1**:

ORIGINAL SCAN: BEFORE PROCESSING WITH DSP FILTER 1:



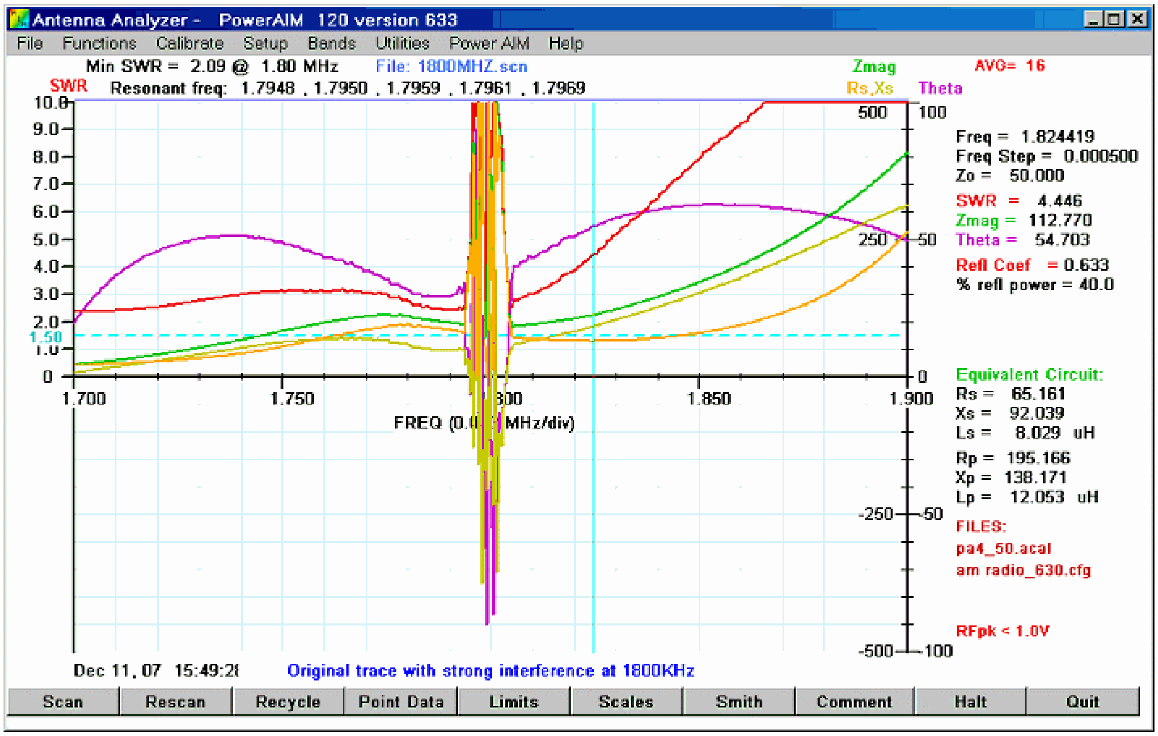
AFTER PROCESSING WITH DSP FILTER 1:
(heavy lines are new data after filtering)



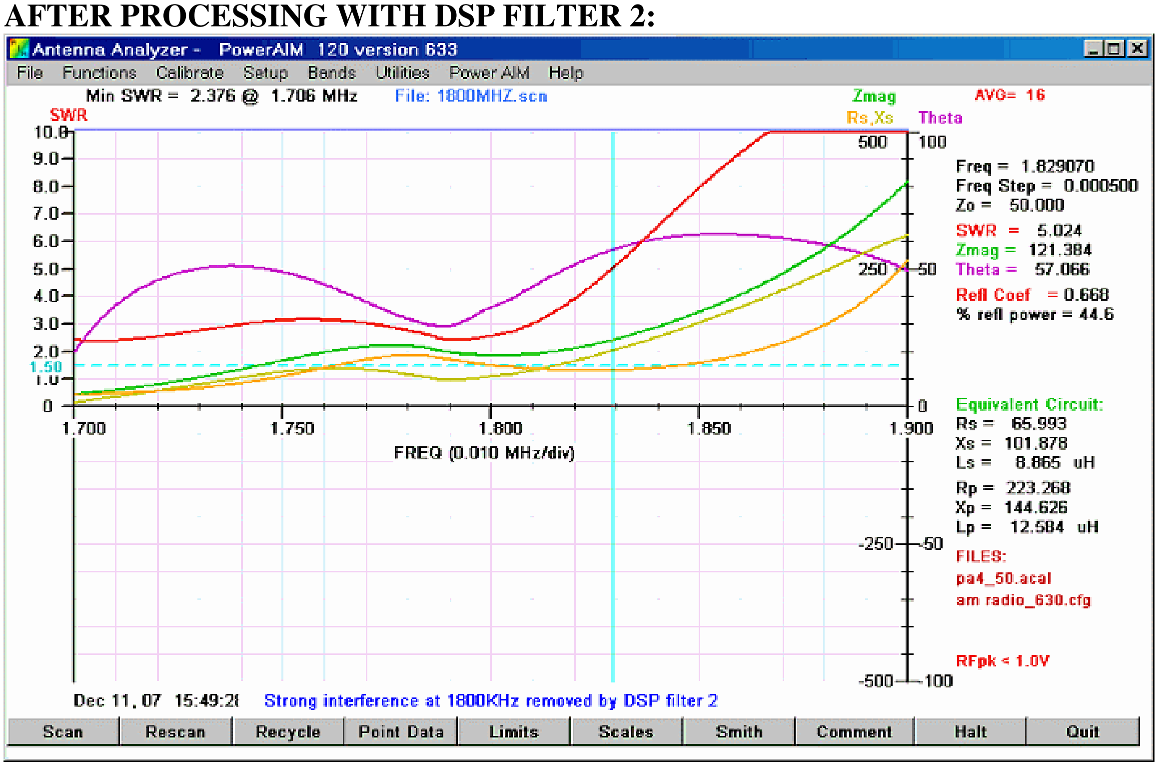
In the example above, the heavy, highlighted lines are shown so it's easier to see the effect of the filter. Red corresponds to SWR, orange to Rseries and yellow to Xseries.

Below are two screen shots showing the effect of using **DSP filter 2**. The interfering signal in this scan was injected using a transmitter feeding one antenna while the PowerAIM was scanning another nearby antenna.

ORIGINAL SCAN:



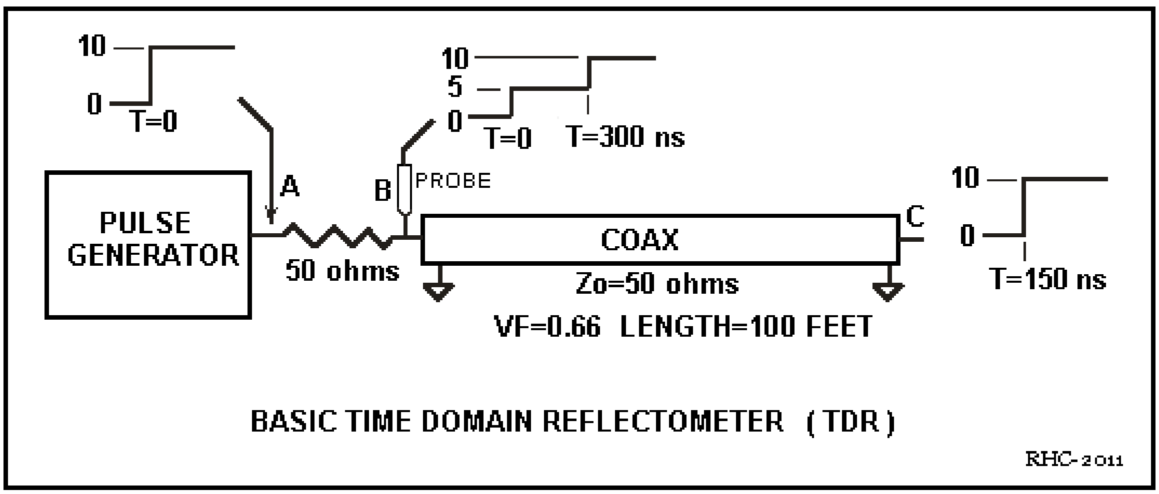
AFTER PROCESSING WITH DSP FILTER 2:



TDR (Time Domain Reflectometry)

The TDR feature enables measurement of transmission line impedances and lengths even when they are not open or shorted at the far end. This is also very useful when two or more different types of transmission line are connected in series. For example, 50 ohms and 75 ohms. The distance to the antenna can be measured without having to disconnect the line from the antenna.

For many years TDR's have been built with analog pulse generators and oscilloscopes. This requires a wideband scope (or a sampling scope) but basically the system is straightforward. This was the only practical way to implement TDR before low cost powerful computers became available.



This diagram shows the basic components of a TDR. The test pulse has a rise time that is short compared to the times to be measured. Typically the pulse has a sharp leading edge and it is much wider than any time to be measured. The trailing edge of the pulse is not used. This is called a **step function**. The amplitude of the pulse is not critical since the measurements involve ratios. In this figure the amplitude is 10 volts. (It could be a low amplitude pulse too.)

The output of the pulse generator is a voltage source. The leading edge of the pulse steps up to 10V at time T=0 and the voltage seen at point A is always the same regardless of the load that is connected.

There is a resistor in series with the output of the pulse generator, typically this is 50 ohms. For this example, a piece of coax is connected to the output which has a characteristic impedance, Zo, of 50 ohms. This test coax is 100 feet long and it has a velocity factor of 0.66.

The scope is connected to point B. Keep in mind that at T=0, the coax looks like a 50 ohm resistor to the wave that is starting to travel down it. During the initial transient stage this value of Zo will apply until the wave has time to travel all the way to a discontinuity in the system and be reflected back. If there is no discontinuity and the wave travels down the line forever or is absorbed by a load resistor at the end, then the impedance at point B will continue to be Zo forever. In a typical case, a ideal 50 ohm coax terminated with an ideal 50 ohm resistor looks like 50 ohms at DC and at all RF frequencies. *In actual practice, loss in the coax and skin effect complicate things somewhat but we won't worry about that for now.*

The 50 ohm resistor in series with the generator output and the Zo of the transmission line form a voltage divider of 50 ohms and 50 ohms, so one half of the voltage appears at point B at T=0.

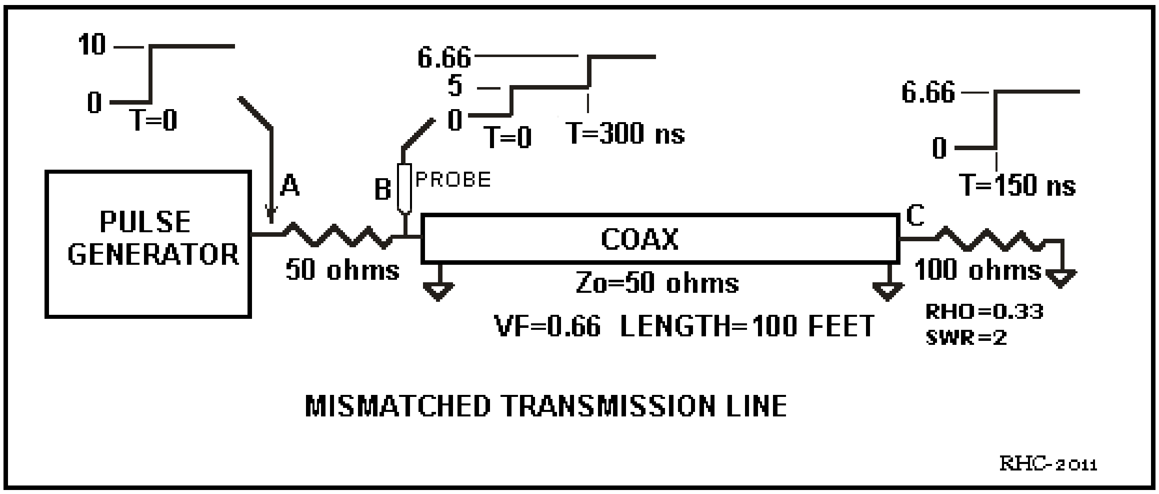
The wave would travel down the coax at the speed of light, which is about 1 foot per nanosecond, but the dielectric material in the coax slows it down. The **velocity factor** is the actual velocity of the wave through the dielectric divided by its velocity if the coax did not have a dielectric (that is, the speed of light in air) . Typically this is in the range of 0.66 to 0.9, depending on the material used for the dielectric. The dielectric makes the line appear to be longer than it really is, that's why a quarter wave coax stub is shorter than a quarter wave length of the signal in air.

The voltage step in this example takes 150 nsec to travel down the coax to the open end. A scope probe at point C will see a step that is 10 volts high but it's delayed by 150 nsec with respect to the step seen at point A (the 50 ohm series resistor has negligible delay).

Wait a minute, the voltage at point B was only 5 volts and now we have 10 volts at point C. How did that happen? In fact, a scope probe placed anywhere along the coax will see the 5 volt step traveling down the line for the first 150 nsec. When it gets to the open end of the coax, the wave is reflected in phase and the 5 volt step now becomes 5 + 5 volts to form the 10 volt step seen at point C. Now, as we watch the signal travel back down the line, its amplitude is 10 volts. When the reflected wave reaches point B, the probe at point B sees 10 volts. It takes 300 nsec for the wave to travel down the line and back. The scope can measure this time which is two times the electrical length of the coax. If the velocity factor is known, then the physical length of the line can be calculated by multiplying the electrical length by the velocity factor.

The 50 ohm resistor in the generator is the same as the Zo of the test line, so there is no reflection at the generator and the final value seen at point B is 10 volts. It takes a short time (usually nanoseconds or microseconds) for the voltage to reach its final value. This time delay usually isn't a factor for ordinary radio communication . *For high speed data communication, it can be a factor when the delay is comparable to or even greater than the time interval between data bits.*

In this example, the wave at the open end of the coax was reflected in such a way that it was positive and it added to the incoming wave. The ratio of the reflected signal to the incoming signal is called the reflection coefficient. **Anytime there is a change in the impedance, there will be a reflection.** In this special case the reflection is equal to the incoming signal so the reflection coefficient is **+1**. Another interesting case is when the end of the coax is shorted. In this case the reflected signal will be inverted and it subtracts from the incoming signal so the wave that travels back toward the generator has an amplitude of 5-5=0 V. The reflection coefficient is **-1**. In this case, the voltage at point B will drop to zero after 300 nsec, which is what you expect since an ohmmeter at point B will read zero ohms due to the short circuit. In summary, the reflection coefficient is always in the range of **+1 to -1**. It can't be greater than one because the reflected wave cannot be greater than the incident wave.



Here's a practical example where the coax is terminated in a 100 ohm resistor which does not match the characteristic impedance of 50 ohms. The line is said to be mismatched. To help visualize what is going to happen, let's look at the final state of the voltage after a long time has elapsed. The generator is outputting 10V, there is a voltage divider of 50 ohms and 100 ohms, so the final value at point B has to be 6.66 V after things have settled down. *The question is how long does it take for this steady-state result to be reached?*

In the previous examples with an open circuit and a short circuit, the reflection coefficients were +1 and -1 respectively.

The general formula for the reflection coefficient, RHO, is:

RHO = (Zload - Zo)/(Zload + Zo)

where Zload is the load at the far end of the line and Zo is the characteristic impedance of the line. We can check this for the two extreme cases, one when Zload is infinite (open circuit):

RHO= (infinity - Zo)/(infinity + Zo) = +1

When Zload=0:

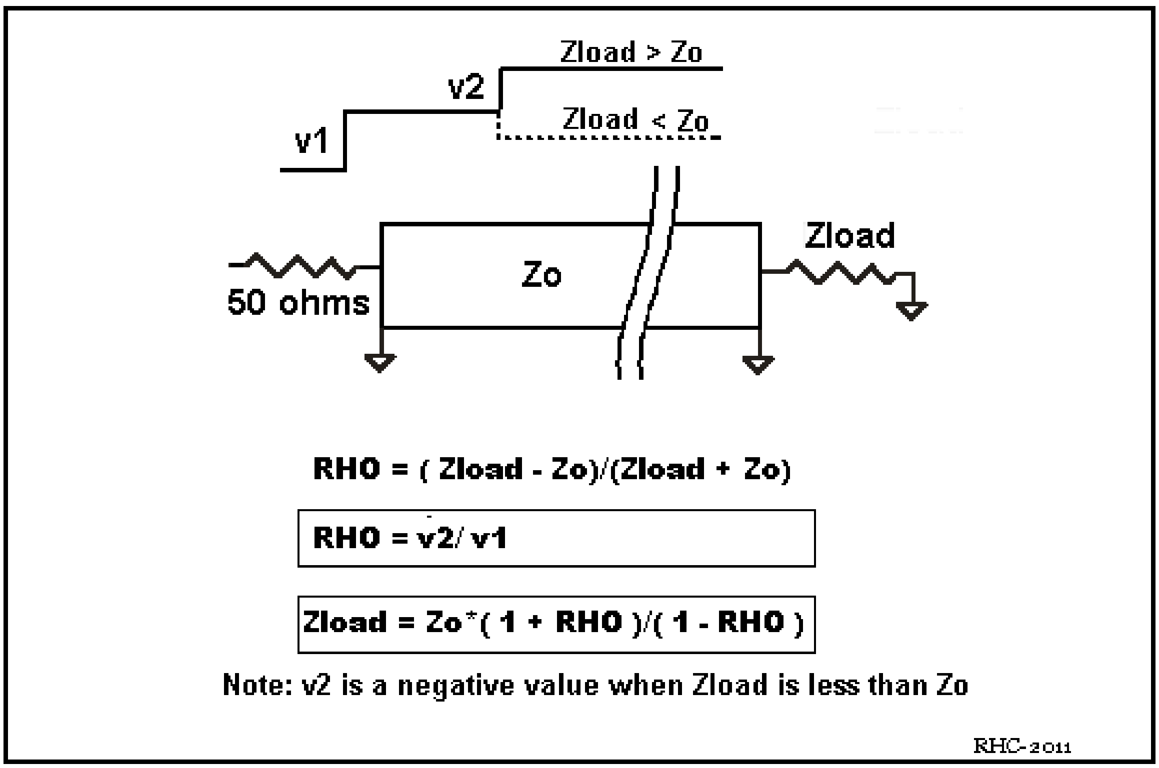
RHO=(0 - Zo)/(0 + Zo) = -1

For values of Zload between zero and infinity, RHO varies between -1 and +1.

Therefore, for the above diagram, RHO = (100 - 50)/(100+50) = +0.33

This means that if the incoming signal has an amplitude of 5V, the reflected wave will have an amplitude of 5*0.33 = 1.66V and it will add to the incoming wave so the final value at point C at T=150 nsec is 5+1.66 = 6.66V. This reflection of 1.66 V travels back down the line and after another 150 nsec it arrives back at point B and the voltage at point B jumps up to 6.66V. Thus the final voltage at B and C is 6.66V just as we expected from the preliminary analysis when we treated the circuit as a simple voltage divider.

By measuring the reflected wave at Point B, we can work backward and calculate what Zload must be to cause this reflection. The following diagram shows the measurement point B expanded.



The reflection coefficient is the value of the second step, **v2**, divided by the value of the first step, **v1**. Note that v2 is a negative number when Zload is less than Zo.

Zload = Zo* (1 + RHO)/(1 - RHO)

Let's check some special cases for measured values of RHO:

V1 and V2 can be measured with a scope.

If the line is open: v2 = v1
Then RHO = v1/v1 = +1
Then Zload = Zo * (1 + 1)/(1 - 1) = infinity

If the line is shorted: v2 = -v1
Then RHO = -v1/v1 = -1
Then Zload = Zo * (1 - 1)/(1 + 1) = 0

If the line is terminated with 100 ohms: v2 = 0.33*v1
Then RHO = 0.33v1/v1 = 0.33
Then Zload = Zo * (1 + 0.33)/(1 - 0.33) = 50 * 2 = 100 ohms

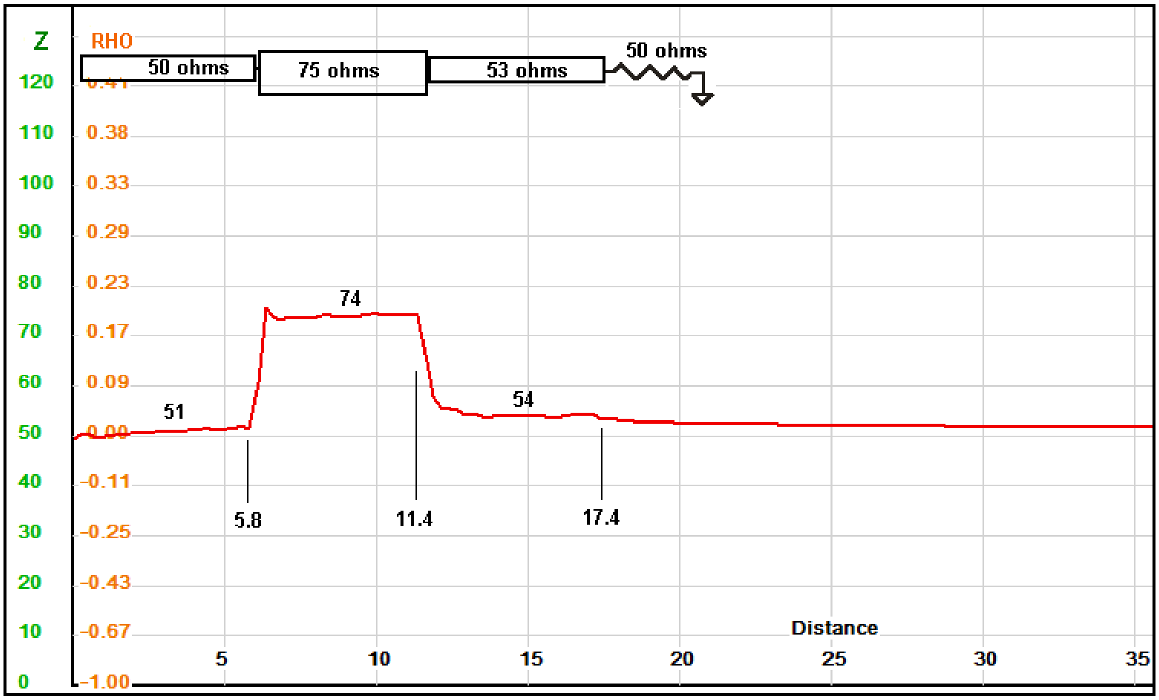
If the line is terminated with 50 ohms: v2=0 (no reflection)
Then RHO = 0/v1 = 0
Then Zload = Zo * (1 + 0)/ (1 - 0) = Zo = 50 ohms

If the line is terminated with 30 ohms: v2 = - 0.25*v1
Then RHO = -0.25v1/v1 = - 0.25
Then Zload = Zo * (1 - 0.25)/(1 + 0.25) = 50 * 0.60 = 30 ohms

This is a brief introduction to the basic principles of TDR. In recent years the increased power of low cost computers has made it possible to create a TDR in software using the data from a frequency scan of a circuit. The vector network analyzer first collects data for the reflection coefficient at a number of frequencies. Then mathematical operations convert the frequency data to the corresponding time data. In this way the analyzer, which is basically a frequency domain instrument, does double duty by providing both frequency and time domain data with no extra cost in hardware.

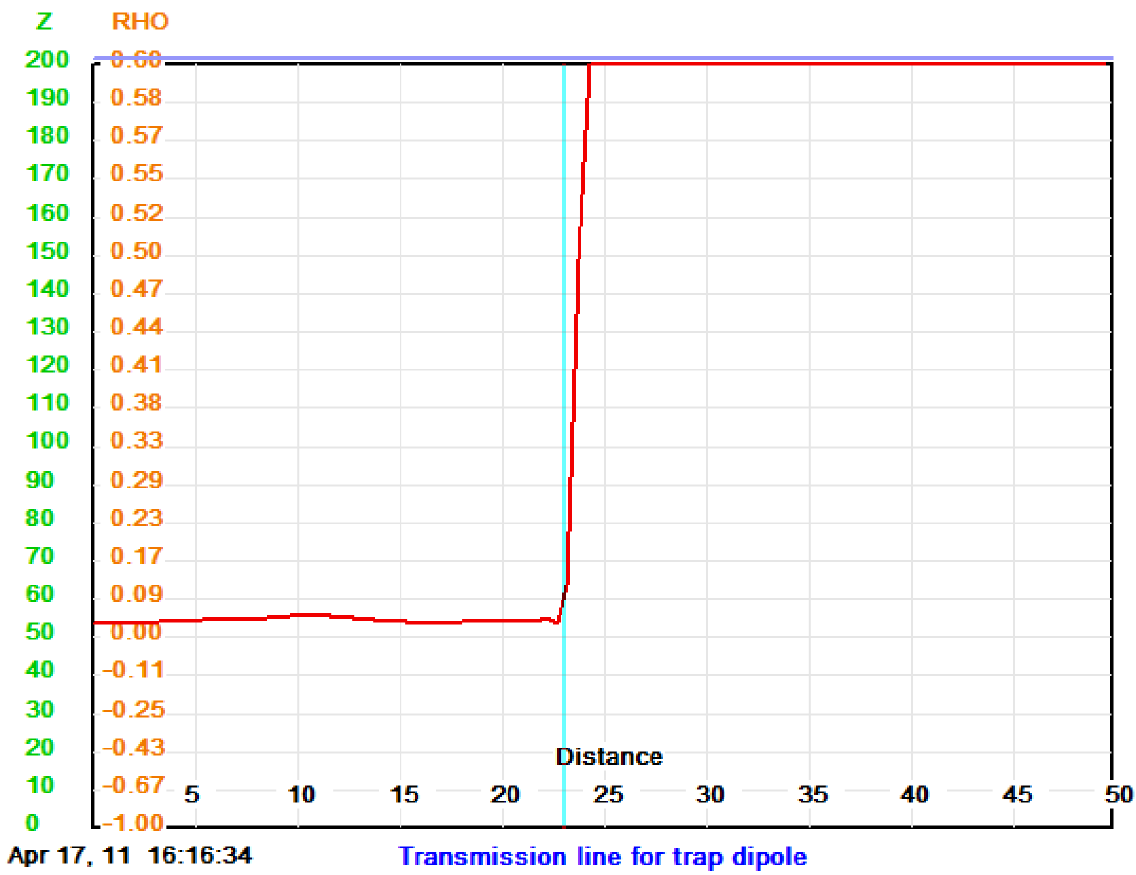
An interesting Application Note on TDR fundamentals can be found here:
Agilent Ap note 1304-2

An interesting thing that can be done with a TDR is determine the impedance and lengths of several different cables in series. This diagram shows data from an AIM for a transmission line made up of three lengths of coax with nominal impedances of 50, 75 and 53 ohms. The composite line is terminated with 50 ohms. The numbers along the horizontal axis are distance.



The first section of line has a measured impedance of 51 ohms and it's 5.8 feet long. The second section has a measured impedance of 74 ohms and it is (11.4 - 5.8)=5.6 feet long. The third section is (17.4 - 11.4) = 6.0 feet long.

Multiple reflections quickly complicate the interpretation of a TDR scan.
This web page has an excellent presentation on a technique for the Analysis of reflections
http://home.comcast.net/~howard.heck/3-1.ppt



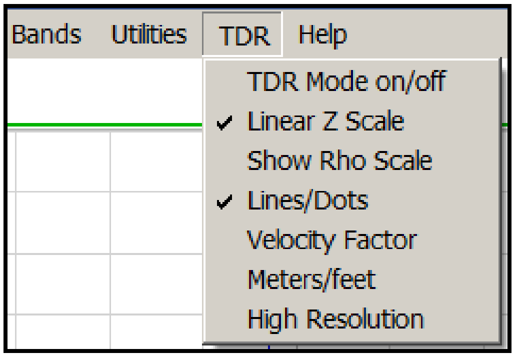
This picture shows the TDR picture of a simple trap dipole antenna feed with a 53 ohm coax that is 23 feet long (indicated by the vertical cyan cursor). Since the antenna is a relatively narrow band circuit, its impedance is very high over most of the frequency range scanned by the TDR. This causes a large jump in the reflection coefficient at the far end of the coax, so it's possible to determine the length of the transmission line without disconnecting it from the antenna.

In this case the antenna is an open circuit for DC, so the impedance is very high at the feed point. If the antenna has a DC path to ground at the feed point, the TDR trace will go to zero ohms at the end of the transmission line.

The final steady state impedance displayed by the TDR is the same impedance that would be measured at DC. Depending on the horizontal scale, this final value may not be reached because of multiple reflections in the system.

The resolution in distance is approximately 0.25% of full scale for the AIMuhf and 0.5% of full scale for the AIM4170 and the PowerAIM. For distances greater than 200, the three instruments have essentially the same resolution.

TDR Operation



TDR Mode on/off - alternates between the normal Frequency mode and the TDR mode.

Linear Z Scale - If this is checked, the vertical Z display is a linear scale. If it is not checked the vertical scale shows RHO on a linear scale and Z is a function of RHO.

Show RHO Scale - If this is checked, RHO will be displayed on the vertical axis along with Z.

Lines/Dots - Plot the trace with continuous lines or dots at each measurement point.

Velocity Factor - Enter the velocity factor used for calculating distance based on electrical length. The same value is used for the whole transmission line system when multiple cables are involved. The typical value is 0.66 to 1.0. The electrical length can be displayed on the graph by setting the Velocity Factor = 1.

Meters/feet - Display distance data in meters or in feet. (meters can be selected as the default in the config file)

High Resolution - Increases the resolution along the distance axis by approximately 2x.

In the TDR mode, these functions work similarly to the way they do in the frequency mode:

Scan - clear the screen and do a TDR scan. The AIM takes a series of impedance readings, converts these readings to the reflection coefficient at each frequency and then transforms the frequency data to time data using the inverse Fourier transform.

Rescan - do a TDR scan without erasing the screen. The color of the plot cycles through five different colors.

Scales - enter the distance and Zmag scales.

Halt - stop a scan

Quit - exit the program

The buttons at the bottom of the screen that are not used in the TDR mode are grayed out.

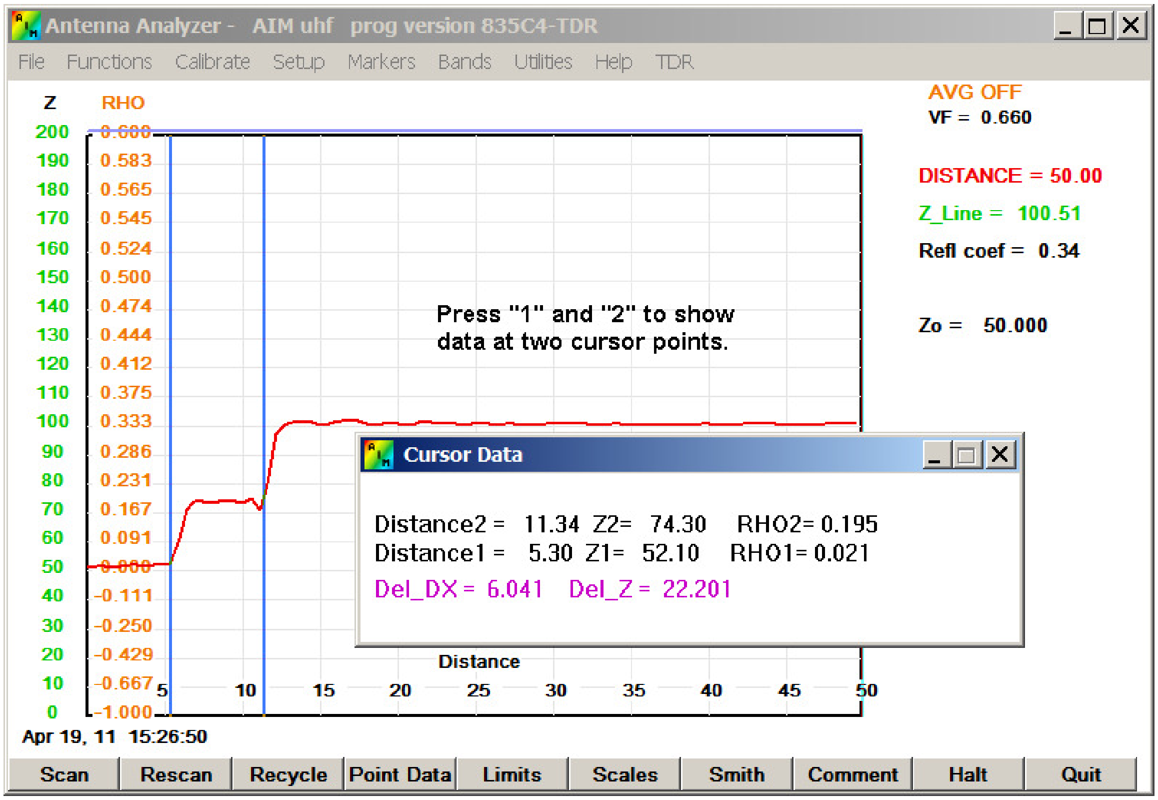
On the **Files Menu** (upper left corner of the screen), the same menu items are used for saving TDR graphs and recalling them from memory.

The AIM uses the same calibration file and config file in both the frequency mode and the TDR mode.

Setup -> Ruler 1 and Ruler 2 - Rulers for Zmag can be used.

Setup -> Average Reading - The averaging is normally set to zero (no averaging) but it can be turned on while in the TDR mode.

CURSOR DATA



This figure show how data at two points can be displayed along with their differences by moving the cursor to the first point and pressing a **1** on the keyboard, then move the cursor to the second point and press **2**. This action can be repeated by moving to other points and pressing 1 or 2. Data in the small window will be updated each time. The two selected distances are indicated by blue vertical lines on the graph. Close the data window by clicking the **X** in the upper right corner.

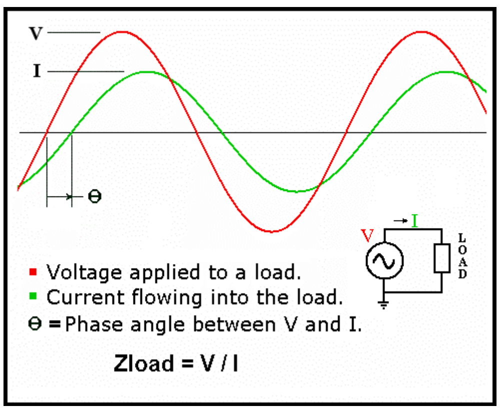
The data at the cursor position is displayed in the upper right corner of the main window just like it is for the frequency mode. In this diagram, the mouse cursor is all the way to the right side of the graph at Distance=50 and the line impedance is 100.51 ohms. The value of Zo (Zref) is used for calculating the reflection coefficient. This can entered by using the **Setup** menu.

AIM Principles of Operation

The AIM4170 is based on the same technology used in the AIM430 and AIM4160.
The AIM430 was featured in an article in the Nov 2006 issue of QST magazine.

1. An RF voltage is applied to the transmission line input.
   To reduce the chance for interference to nearby radio receivers, the maximum output power is less than 20 microwatts (-17 dBm).

2. Measure the applied voltage and the current flowing into the load. The current is measured across a precision resistor which has a much wider bandwidth than a transformer. (The AIM does not use any RF transformers). The current sensing resistor does not have to be adjusted and it has excellent long-term stability.

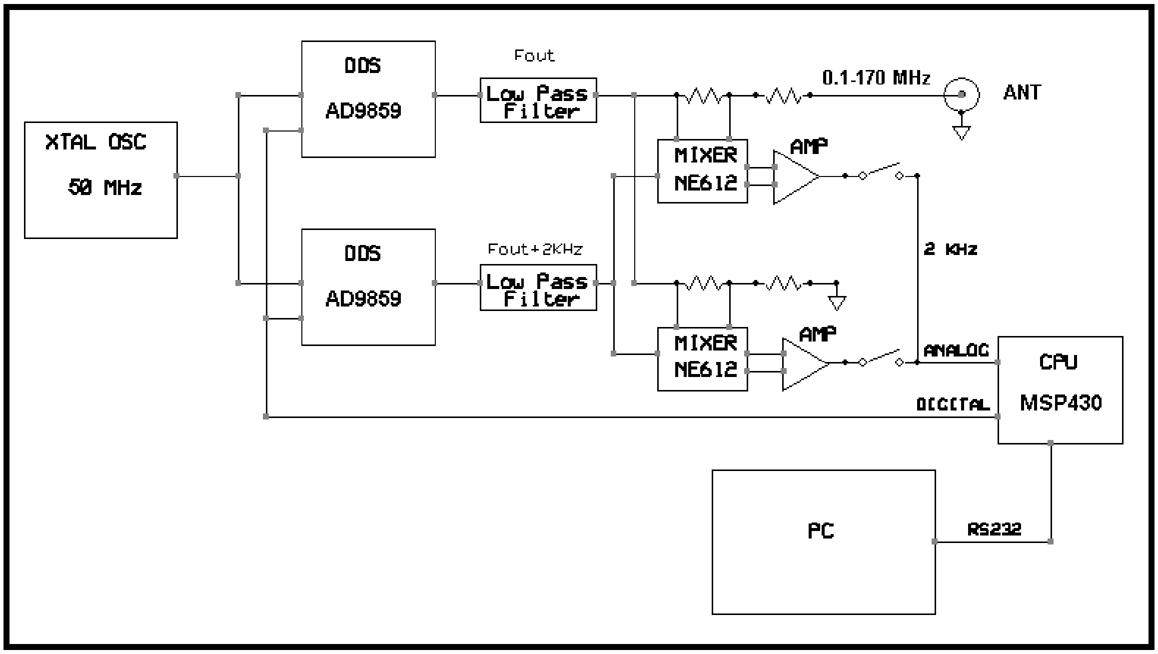


3. Calculate the magnitude and phase of the input impedance. The magnitudes and phases of the applied voltage and resultant current are measured with an analog to digital converter (12-bit ADC) and their ratio determines the magnitude of the impedance. The sign of the phase is also measured so that capacitive and inductive reactances can be distinguished.

4. The signal processing circuits are linear, so the nonlinearity problem inherent with diode detectors is eliminated.

5. Calculate various parameters including: SWR, equivalent input resistance and reactance, cable length, cable loss. A large number of parameters can be calculated using the fundamental impedance measurement. The load is assumed to be an antenna but the data is displayed in such a way that discrete capacitors and inductors can be measured too. These values are plotted versus frequency and the exact numeric data can be read by moving a cursor to the point of interest.

Block diagram of the AIM4170:



The AIM uses two Direct Digital Synthesizer (DDS) chips. One generates the test signal and the other acts as a local oscillator to heterodyne the RF signals to the audio range. You can read about the basic principles of the DDS at this address: *http://www.analog.com/library/analogDialogue/archives/38-08/dds.pdf*

A 50 MHz crystal controlled oscillator drives both of the DDS chips. Inside the DDS, the clock is multiplied by a factor of 8, so the effective clock rate is 400 MHz. Program frequency resolution is a fraction of a Hertz. The output of each DDS goes to a 170 MHz low pass filter to remove the harmonics and aliases of the digitally generated signal. The output of the low pass filter is a sine wave in the range of 0.1 MHz to 170 MHz. Any amplitude variations or phase shift in the low pass filters do not affect the measurement accuracy since they affect the current and the voltage channels equally and thus cancel out when the ratio is taken.

The output of one DDS supplies the test voltage and current to the load impedance and the other DDS acts as the local oscillator to heterodyne the voltage and current signals down to 2 kHz. Audio amplifiers boost the 2 kHz signals and drive the input to the 12-bit analog to digital converter (ADC) that is inside the MSP430 microprocessor. This microprocessor is mounted inside the AIM case. The raw data is sent from the microprocessor to the external PC. The PC calculates the various data values and displays them graphically.

<u>Reflection Coefficient:</u>

To find the SWR (standing wave ratio) of an antenna, we first calculate the **reflection coefficient**. This is the ratio of the voltage that is reflected at the antenna to the voltage that arrives at the antenna from the transmitter. If all the power from the transmitter is radiated into space, there is no reflection, the reflection coefficient is zero and the SWR=1.0.

*The following discussion uses the concept of complex numbers. A tutorial on complex numbers is available in **Appendix 1**.*

Reflection_Coefficient = Rho = (Zload – Zo) **/** (Zload + Zo)

Zload = antenna impedance
Zo = transmission line impedance

Note that in general, Zload and Zo are <u>complex numbers</u> of the form:

Zload = Ra + jXa and
Zo = Ro + jXo.

Xo, which is the imaginary part of Zo, is often neglected since it is usually small compared to the real part, Ro.

Since **Zload** is a **complex number**, the reflection coefficient, **Rho**, is also a **complex number**.

The reflection of the incoming power from the transmitter is caused by a mismatch between the **transmission line impedance** (Zo) and the **impedance of the antenna** at the operating frequency. For example, if the transmission line has an impedance of 50 ohms and the antenna is a dipole with an impedance of around 75 ohms, there is a mismatch and some of the power is reflected even though the antenna itself may be very good. If the transmission line is changed to 75 ohms, the match is much better, there is less reflection and the SWR is closer to 1.0.

In the special case where the transmission line is open at the antenna (due to a broken wire), all of the power that arrives at this open circuit will be reflected back toward the transmitter and the reflection coefficient is 1.0 and the SWR= infinity. Another interesting case is when the transmission line is shorted at the antenna terminals. Again, all the power will be reflected (none is radiated) but the <u>signal is inverted</u>, so the reflection coefficient is now –1.0 (minus one). The magnitude is still unity (that is, +1) and the SWR=infinity.

Thus, we see that the *magnitude* of the reflection coefficient will be in the range of zero to 1.0 for any combination of transmission line and antenna.

The reflection coefficient also has an associated *phase angle*, Phase, between the incident voltage from the transmitter and the reflected voltage. The real and imaginary parts of Rho can be related to its magnitude and phase angle with the following equations:

Real_part_of_Rho = rho_a = Magnitude_of_rho * COS(Phase)

Imaginary_part_of_Rho = rho_b = Magnitude_of_rho * SIN(Phase)

Rho = $rho_a + j\ rho_b$

Standing Wave Ratio (SWR):

SWR is the ratio of the Maximum Voltage to the Minimum Voltage along a transmission line. On a perfectly matched line, the maximum is equal to the minimum since there is no variation in the voltage along the line and the SWR is 1.0. In the real world, SWR is somewhere between 1.0 and infinity. The special case of infinity means all the power from the transmitter is reflected back by the antenna. This would the case for a short circuit or an open circuit at the antenna when using a lossless transmission line.

If the transmission line has no loss, the SWR is the same at all points along the line. That is, the SWR at the transmitter is the same as it is at the antenna. As the transmission line loss increases, the effect is to make the SWR measured at the transmitter appear to go *down* since less power is received back from the antenna. This power gets lost along the transmission line, so it does not arrive at the SWR meter and the meter responds more to the outgoing power from the transmitter. The meter thinks the antenna is a better match than it really is because there seems to be less reflected power.

The SWR only depends on the *magnitude* of the reflection coefficient, Rho:

SWR = [1 + magnitude(Rho)] / [1 – magnitude(Rho)]

This shows that when the magnitude of Rho = 0 (that is, the transmission line and the antenna are a perfect match), the SWR is [1+0]/[1-0] = 1 (this is the ideal case).

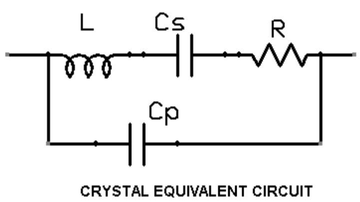
When the mismatch is very large and the magnitude of Rho is nearly 1, the term in the denominator approaches zero and the SWR approaches infinity.

Since only the magnitude of Rho appears in this equation, SWR is **not** a complex number (it's a real number).

For calculations involving complex numbers, a very useful program can be found here: SpeqMath.com

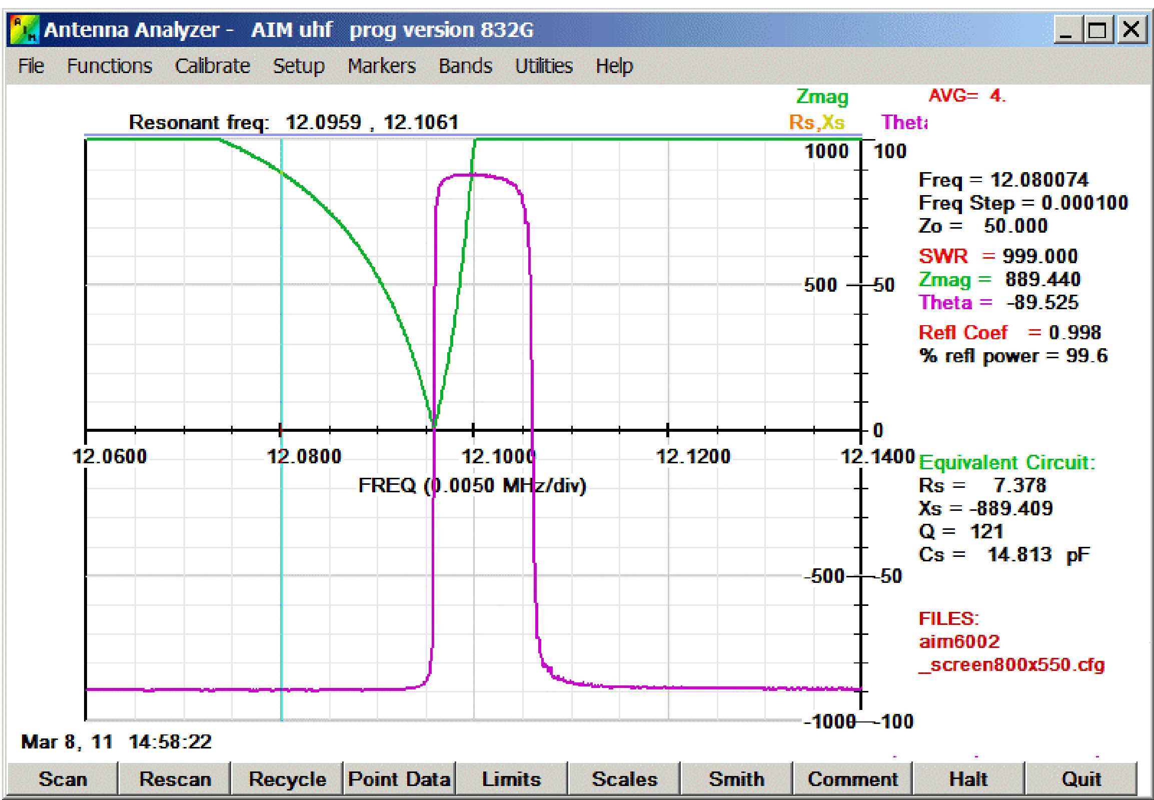
Measurement of Crystal Parameters

Quartz crystals can be modeled as shown below:



The series resonant frequency is the lower of the two frequencies. It's determined by **L** and **Cs**. The higher parallel resonant frequency is determined by **L** and **Cp+Cs**.

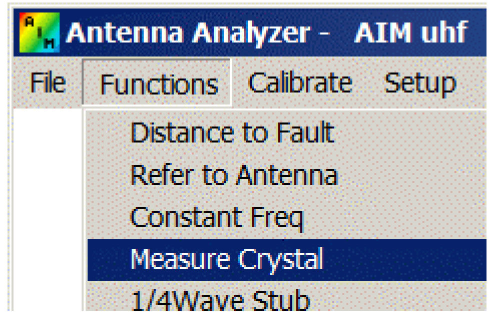
A broad scan can be done to locate the resonant frequencies. They will be displayed at the top of the screen. Typically, these two frequencies only differ by a few kilohertz.



Automatic Crystal Parameter Calculation

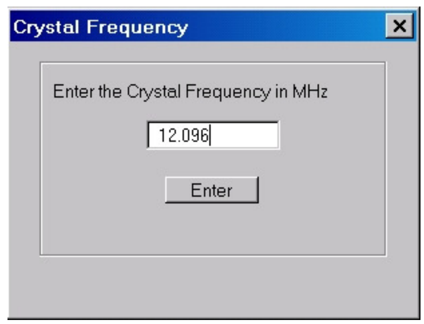
The calculations to find the crystal parameters are tedious so they have been combined into a procedure than can be called from the Functions menu. First click "Measure Crystal".

Be sure the AIM has been calibrated with the cal loads at the point where the crystal will be connected.



Then enter the series resonant frequency.

This should be within 100KHz of the series resonant frequency. When measuring an overtone crystal, enter the appropriate harmonic frequency.

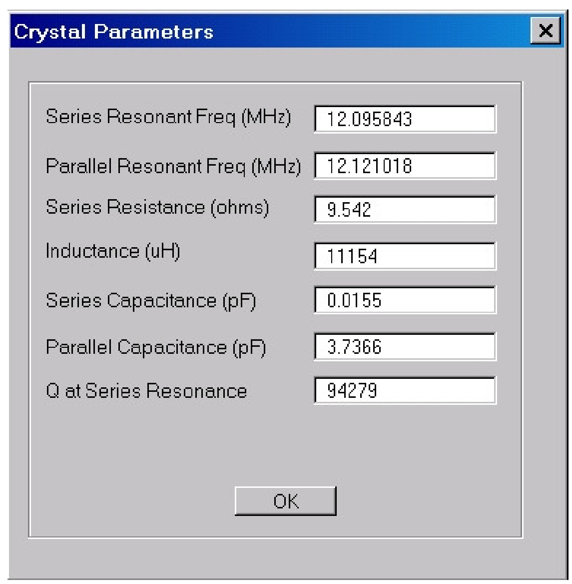


After a few seconds the crystal parameters will be displayed

The data can be saved in a file. If the file already exists, the data will be appended (added) to it. If the file does not exist, a new one will be created with the **.xdat** extension.

This file is compatible with programs that read comma separated variables (*.csv) files, like **Excel**. A legend is included at the beginning of the file to show the variable name in each column. An Excel utility can be used to sort the data to determine the best crystals to use for a particular crystal filter.

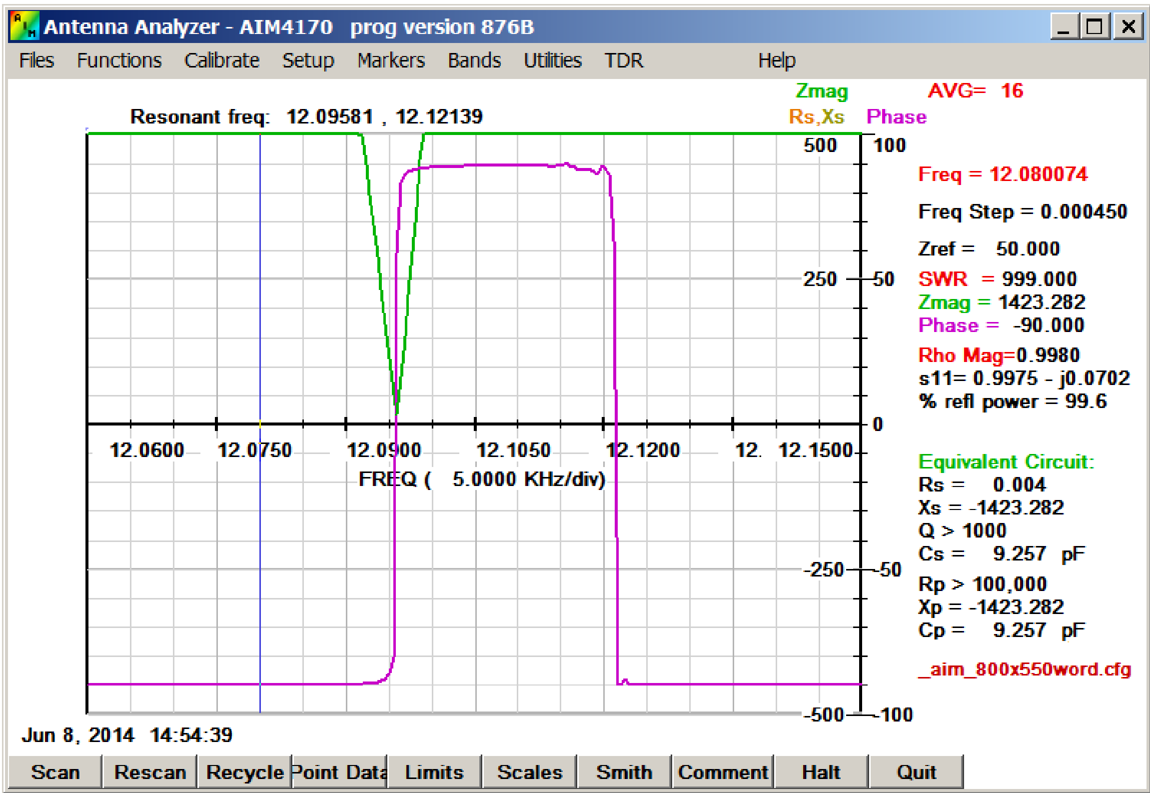
If the **Parallel Capacitance** is more than 20 pf it will highlighted in red because this may indicate there is excessive stray capacitance in parallel with the crystal due to long leads.



The following discussion goes into more detail about the crystal calculations.

After the resonant frequencies are located, you can change the scan limits to focus in more detail on the region of interest.

At the series resonant frequency, the reactances of L and Cs cancel out and the magnitude of the impedance becomes equal to R. Therefore, the series resistance of the crystal can be read directly at the minimum value of Zmag on the graph (where Phase = 0). The numeric value is Rs in the Data Window.



At frequencies well below the series resonant point, the impedance value is the total capacitance, Ctotal, which is essentially equal to Cparallel. Cparallel is read at a frequency equal to 78% of the series resonant frequency.

Cparallel = 3.5119 pF

The value of Cseries is given by:

Cseries = Cparallel * 2 * (Freq_parallel - Freq_series) / Freq_series

Where Freq_parallel is the **parallel** resonant frequency and Freq_series is the **series** resonant frequency.

Freq_series = **12.095902 MHz**

Freq_parallel = **12.121317 MHz**

Cseries = 3.5119pF * 2 *(12.121317 – 12.095902)/12.095902 = **0.0147577 pF**

The inductance of L is given by:

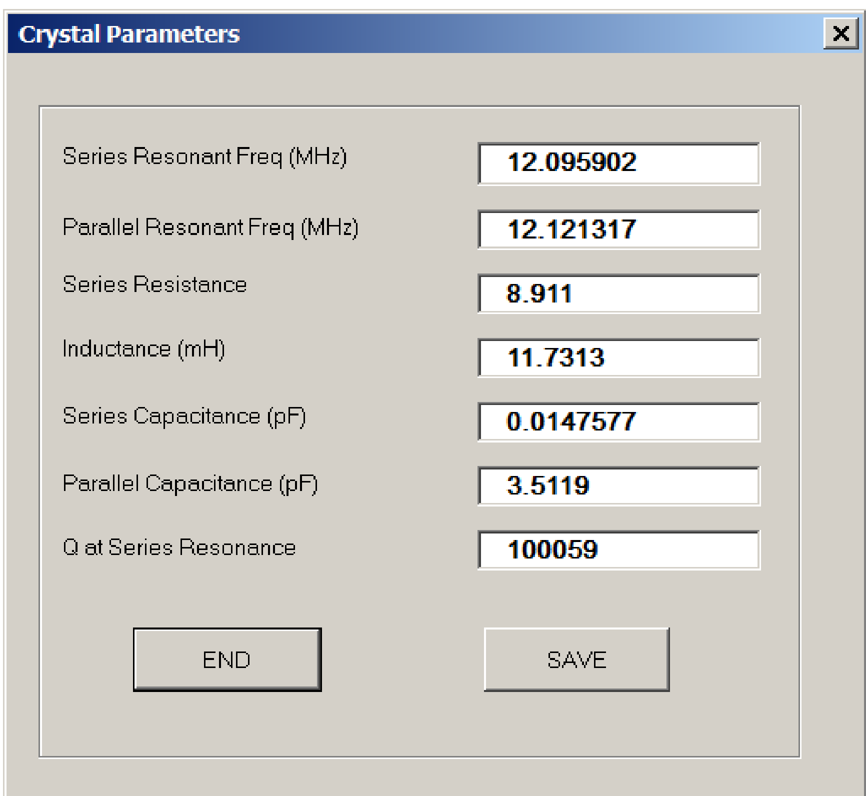
L = 1 / (4 * pi*pi * Freq_series * Freq_series * Cs)

L = 1/(4*pi*pi*12.095902MHz^2*0.01476pf) = **11.7313 mH**

Rseries = **8.911** (= Zmag where Phase = 0)

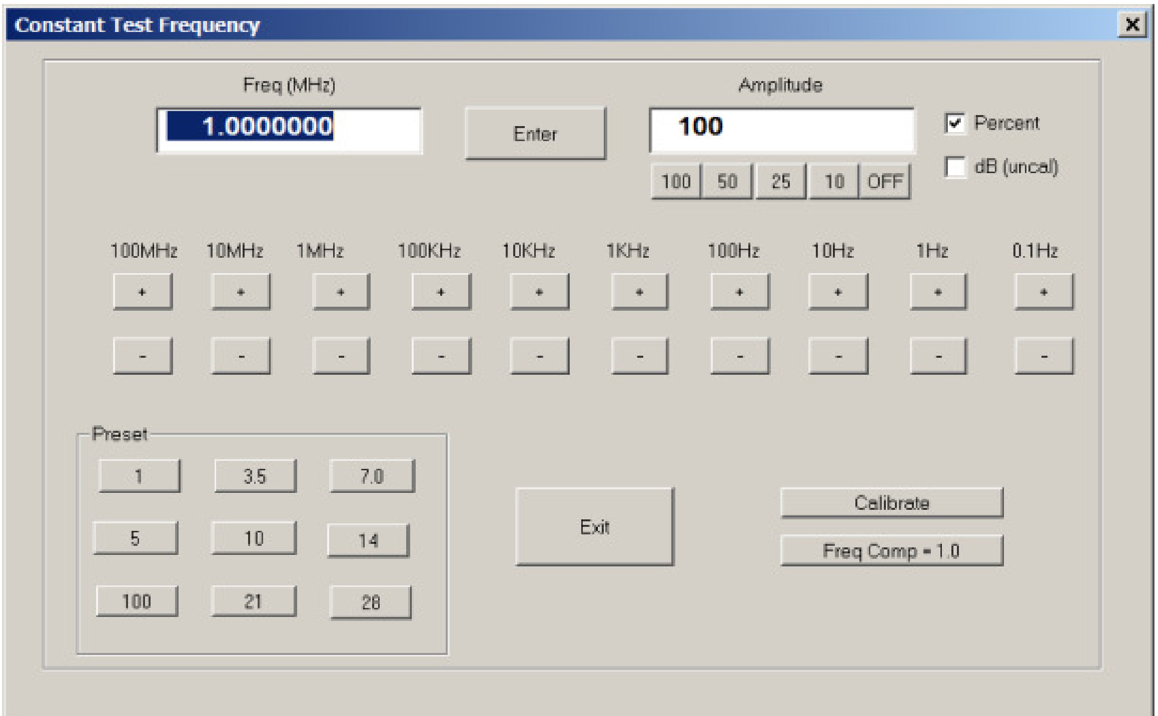
Reactance_of_ L = 2*pi*Freq_series*L = 891.588 K

Q = Reactance_of_L / Rseries = **100059**



Frequency Source

When the AIM or AIMuhf is used as a signal source, DO NOT connect it directly to the antenna connector of a transceiver. If the transmitter is accidentally turned on, the output will exceed the AIM's maximum safe input level.



The AIM can be used as a signal source for testing electronic circuits, such as radio receivers. The programmed frequency has an initial accuracy of **+/-30ppm** for the **AIM4170** and **PowerAIM**. The **AIMuhf** will be within **+/-2 ppm** of the specified frequency . It can be calibrated with respect to WWV or with a frequency counter at 10MHz. The AIMuhf has a temperature compensated oscillator (**TCXO**) and it will stay within 0.2ppm for several hours.

The **AIM4170D** and the **AIMuhf** have an option to set the output amplitude over a range of 100% to 10% when using Custom Cal or the Constant Frequency mode. The amplitude of the output is not regulated by an AGC circuit but it is flat within 1 db across the high frequency (HF) amateur bands.

The **AIMuhf** is limited to **200 MHz** in the constant frequency mode because the output signal becomes very complex due to the presence of several aliases at high frequencies.

The nominal signal delivered to a 50-ohm load by the AIM4170 and the AIMuhf is about 30mV rms.

Enter a frequency value in the text window and click "Enter". The frequency can then be incremented or decremented by clicking the +/- buttons.

The output frequency of the AIM can be calibrated with a frequency counter or a radio station with a known accurate frequency. The AIM has to be tuned to within 2KHz of the specified cal frequency for the calibration to be effective. The cal frequency can be <u>any</u> value up to 200 MHz.

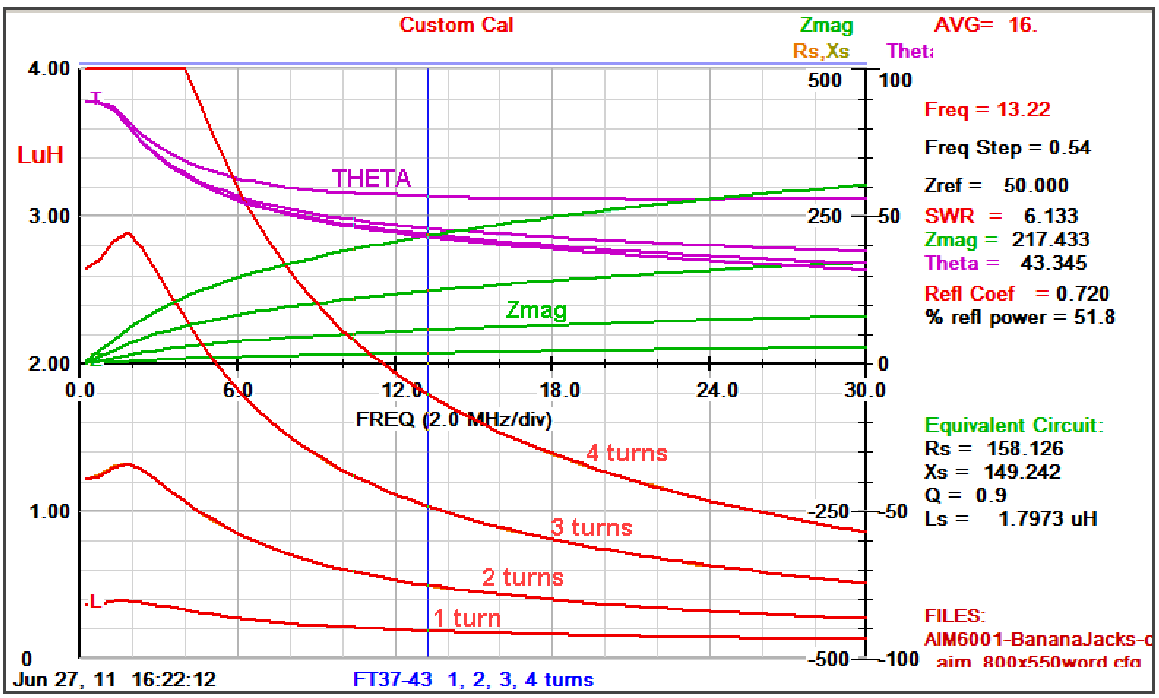
For example, to calibrate the frequency to WWV, tune in WWV at 10MHz and adjust the AIM output to zero beat with it. Then click the "cal" button shown in the dialog box below. *There is an option to enter the exact frequency, the default value is 10 MHz.* This will apply a correction factor to all frequencies that are programmed later. The correction is also saved in the .ini file and it's automatically recalled each time the program starts up. The value of this correction factor can be seen in the Status Window (click **Help -> Status**).

*The frequency calibration factor can be reset to 1.00 by clicking the button called **"Set Freq Comp = 1.00"**.*

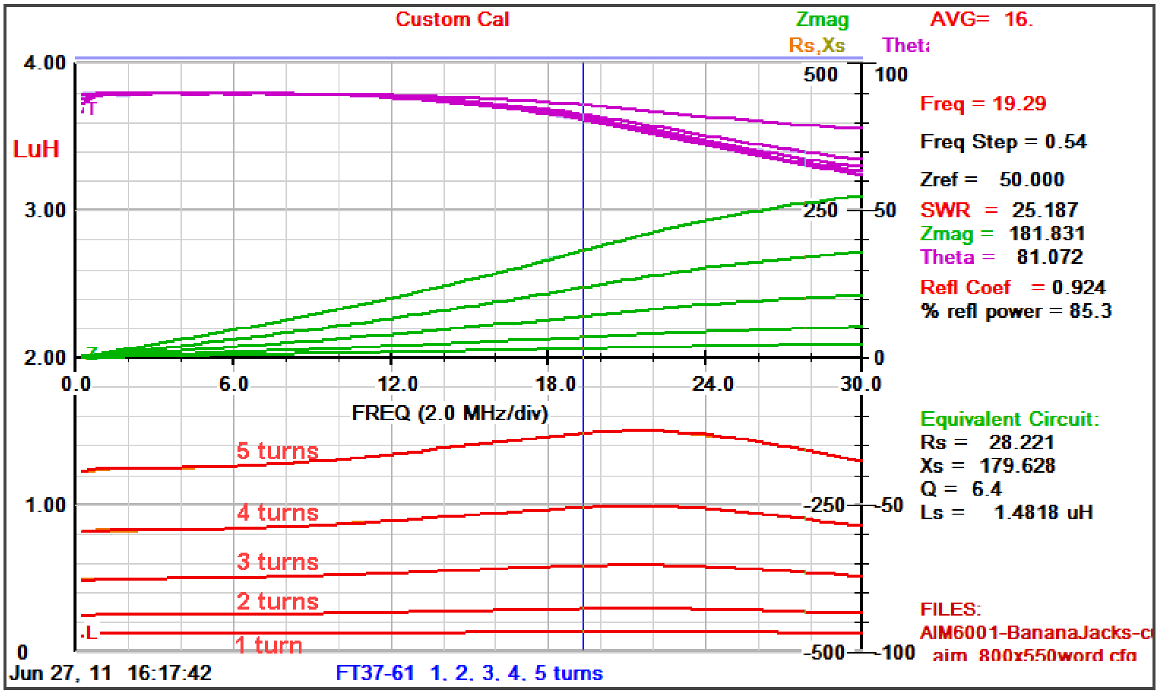
Inductance / Capacitance Measurement

When testing components it is often convenient to have a visual display of the inductance or capacitance as a function of frequency. This shows at a glance how the parameter varies without having to read the cursor data at each frequency point. When displaying L or C the vertical scale on the left side of the graph is used. Only L or C can be plotted at one time. L and Q can be plotted at the same time.

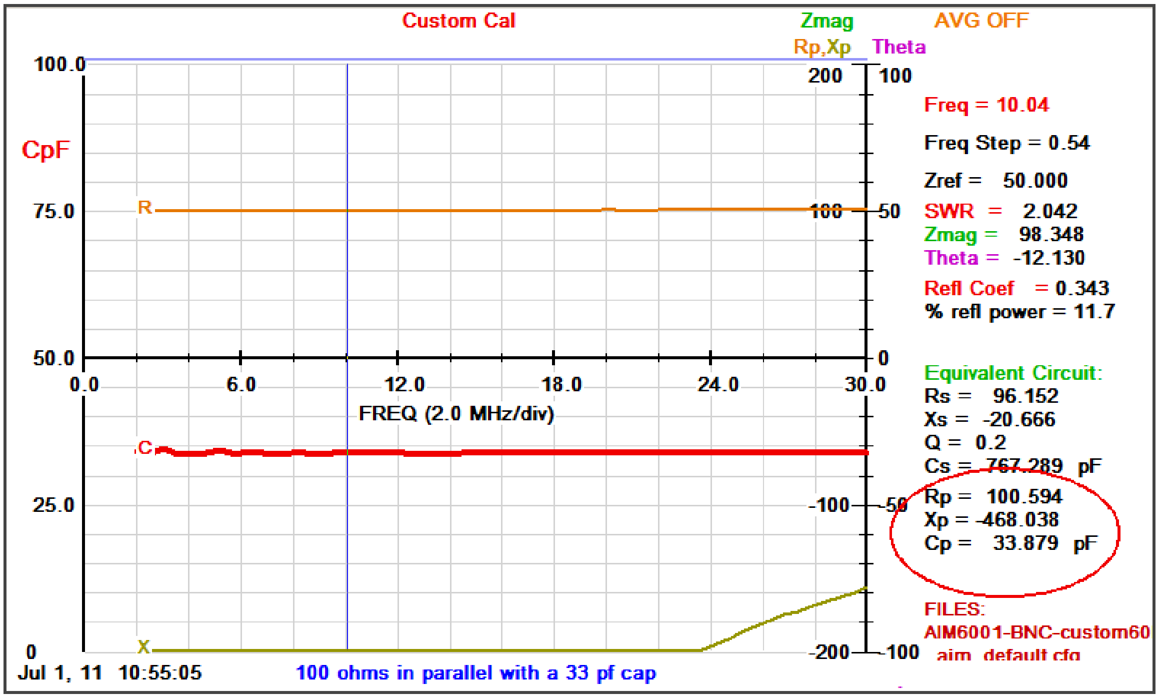
The parameter to be plotted is selected using the **Setup => Plot Parameters** menu. The data is numerically the same as the cursor data displayed on the right side of the graph. The L corresponds to **Xseries** (Xs) and C corresponds to **Xparallel** (Xp). If the sign of the reactance changes during a scan, a note appears at the bottom of the graph to indicate the component is not purely inductive or capacitive over the specified frequency range.



This figure shows a family of inductance curves for coils with 1 to 4 turns on a ferrite core of **type 43** material. The bottom red trace corresponds to 1 turn and the others correspond to 2, 3 and 4 turns. The value in microhenries is shown on the left axis. The magnitude of the impedance (green) and the phase angle (magenta) are also displayed. The Zmag and Phase traces are optional and they can be turned off if desired by using the **Setup =>Plot Parameters** menu.



This family of traces shows the inductance for 1 to 5 turns on a **type 61** core. The bottom red trace corresponds to one turn and the top red trace is five turns. The inductance is less than it was when using type 43 material because the permeability of type 61 is less. However, the inductance is flatter across the frequency range.



This plot shows a 100 ohm resistor in parallel with a 33 pf capacitor. The value of Rp and Cp are flat across the range. The trace labels (**R, C, X**) on the left are used to highlight the traces.

Appendix 1– AIMUHF Specifications

Frequency Control: Digital Synthesizer 5 KHz - 1000 MHz

Frequency Accuracy: +/- 2 ppm (TCXO settable to WWV or a counter @ 10MHz)

Frequency program step size: 0.1 Hz min to 10 MHz max

Calibration: software controlled (*no screwdriver adjustments*).

ADC resolution: 12 bits.

Measurement Ranges:

SWR: 1 to 20

Impedance: 1 ohm to 5K ohms up to 60 MHz, 2K ohm to 200MHz, 600 ohms to 1GHz

Accuracy: 1 ohm +/- 2% of reading up to 60 MHz
5% of reading up to 500 MHz
10% of reading up to 1GHz

Phase Angle: +/-90 degrees (true phase)

Parameters displayed include: SWR, Reflection coefficient, Q, Return loss, Magnitude of load impedance, Phase angle of load impedance, Equivalent series resistance and reactance, Equivalent parallel resistance and reactance. Reactance is shown as inductance (uH) or capacitance (pF) according to the phase angle.

Two Smith Chart displays with zoom, phase offset and markers.

Data can be referenced to the antenna terminals.

RF Output: Programmable 0.2 to 20 microwatts (-17dBm) max. Type-N connector standard.

Spurious output: –30dBc or better below 200 MHz

Max allowable RF input while measuring: 140mV peak (-7dBm)

Max safe RF input: 2V peak (+16dBm)

PC Interface: USB cable included

Display: Graphics output on PC screen. Mouse controlled **cursor** for digital parametric readout. **Markers** for highlighting user specified frequencies. Audible **tone** and **speech** output for SWR to assist in making adjustments without watching the PC monitor.

Power Requirements: 8 to 15 VDC at 500mA max (120VAC power supply included)

Dimensions (approx): 5” x 4” x 1.5” (12.7 x 10.2 x 3.8 cm)

Software updates are available from W5BIG.com (no cost).

AIM4170C / AIM4170D Specifications

Frequency Control: Digital Synthesizer 5KHz - 170 MHz ; Stability: +/- 30 ppm

Frequency Step Size: 1 Hz to 10MHz

Calibration: software controlled (*no screwdriver adjustments*).

ADC resolution: 12 bits.

Measurement Ranges:

SWR: 1 to 20

Impedance: 1 ohm to 5K ohms up to 60 MHz, 2K ohm to 170MHz

Accuracy: 1 ohm +/- 2% of reading up to 60 MHz
5% of reading up to 170 MHz

Phase Angle: +/-90 degrees (true phase)

Parameters displayed include: SWR, Reflection coefficient, Q, Return loss, Magnitude of load impedance, Phase angle of load impedance, Equivalent series resistance and reactance, Equivalent parallel resistance and reactance. Reactance is shown as inductance (uH) or capacitance (pF) according to the phase angle.

Two Smith Chart displays with zoom, phase offset and markers.

Data can be referenced to the antenna terminals.

RF Output: 20 microwatts max; UHF connector standard (UHF connector standard, N- optional)

Spurious output: –30dBc or better

Max allowable RF input while measuring: 140mV peak (-7dBm)

Max safe RF input: 2V peak (+16dBm)

PC Interface: RS232. Data rate = 57.6K or 115K baud. An optional USB/RS232 adapter is available when ordering the AIM. *The AIM4170D includes the usb adapter inside the case*.

Display: Graphics output on PC screen. Mouse controlled **cursor** for digital parametric readout. **Markers** for highlighting user specified frequencies. Audible **tone** and **speech** output for SWR to assist in making adjustments without watching the PC monitor.

Power Requirements: 7 to 15 VDC at 250mA max (120VAC power supply included)

Dimensions (approx): 5” x 4” x 1.5” (12.7 x 10.2 x 3.8 cm)

Software updates are available from W5BIG.com (no cost)

PowerAIM Specifications

Frequency Control: Digital Synthesizer 0.1 - 120 MHz ; Stability: +/- 30 ppm

Frequency Step Size: 1 Hz to 10MHz

Calibration: software controlled (*no screwdriver adjustments*).

ADC resolution: 12 bits.

<u>Measurement Ranges:</u>

SWR: 1 to 20

Impedance: 1 ohm to 2K ohms

Accuracy: 1 ohm +/- 5% of reading up to 60 MHz
10% of reading up to 120 MHz

Phase Angle: +/-90 degrees (true phase)

Parameters displayed include: SWR, Reflection coefficient, Return loss, Magnitude of load impedance, Phase angle of load impedance, Equivalent series resistance and reactance, Equivalent parallel resistance and reactance. Reactance is shown as inductance (uH) or capacitance (pF) according to the phase angle.

Two Smith Chart displays. One can be phase shifted with respect to the other.

Data can be referenced to the antenna terminals.

RF Output: 2 milliwatts max; type-N connector standard.

Spurious output: –30dBc or better

Max stray RF input while measuring: 25V peak.

Max safe RF input: 50V peak.

PC Interface: RS232. Data rate = 57.6K or 115K baud. An optional USB/RS232 adapter is available when ordering the PowerAIM .

Display: Graphics output on PC screen. Mouse controlled cursor for digital parametric readout. Morse code output for selected parameters. Up to 20 markers for user specified frequencies.

An audible tone related to SWR can be output to assist in making adjustment without watching the PC monitor.

Power Supply: 12 VDC at 500mA max (12V battery and 120VAC battery charger included)

Battery power source can range from 11 to 16V. Required current is approximately 500mA when a measurement is in process, 100mA when idle. Auto-power-off after 10 minutes of inactivity.

Dimensions (approx): 5” x 4” x 2” (12.7 x 10.2 x 5.1cm)

Appendix 2 – Complex Numbers

A complex number has two parts: a real part that we are accustomed to using for most everyday problems, and an imaginary part. The imaginary part was introduced to handle the square root of negative numbers. In ordinary circumstances, any number squared is positive, so it seemed unreasonable for a negative number to have a square root. This was resolved by defining a special value called "the square root of minus one". This is usually symbolized by **"i"** in math books and by "**j**" in engineering books. Using "j" avoids confusion in an engineering context with the symbol "**i**" that is usually used for current.

Complex numbers came into use about 500 years ago for solving algebraic equations, including the familiar second order equation: ax^2 + bx + c = 0.

(note: the symbol x^2 means "the value of x squared"= x times x.)

Let's look at a specific example: x^2 – x – 2 = 0.
In this case the coefficients are: a = 1, b = -1, c = -2

The solutions using the quadratic equation are:

x = [- b + SQRT(b*b – 4ac)] / 2a

and

x = [- b - SQRT(b*b – 4ac)] / 2a

Inserting the coefficients of the equation, we get:

x = [1 + SQRT(1 + 8)]/2 = 2

and

x = [1 – SQRT(1+8)]/2 = -1

Now, if we go back and insert x = 2 into the equation, the equation is equal to zero and we also get zero by plugging in x = -1.

There is no problem here since we didn't have to worry about the square root of a negative number.

A small change of one coefficient changes the mathematical problem considerably, as we will see now:

Let the equation be: x^2 – x + 2 = 0

a = 1, b = -1, c = +2

Changing “c” from –2 to +2 gives us:

x = [1 + SQRT(1 – 8)]/2

and

x = [1 – SQRT(1-8)]/2

Now we have to deal the problem of evaluating the square root of –7.

We write this as: -7 = (-1) * (+7)

*Note the SQRT(A*B) = SQRT(A)*SQRT(B), so SQRT(-7) = SQRT(-1)*SQRT(+7).*

The SQRT(+7) is 2.646 and SQRT(-1) we define as “**j**”, so SQRT(-7)=**j***2.646.

One solution to the equation is:

x = [1 + j2.646]/2 = 0.5 + j1.323

To confirm that the value x=0.5+j1.323 actually does cause the equation to equal zero, we have to do some arithmetic with complex numbers.

Addition is straightforward:

The real part of one number is added to the real part of the second number.
Similarly, the imaginary part of one number is added to the imaginary part of the second number.

(a + jb) + (c + jd) = (a+c) +j(b+d)

For example: (1 + j4) + (5 + j8) = (5+1) +j(4+8) = <u>6 + j12</u>

Multiplication is a little tricky:

The two complex numbers have to be multiplied term by term:

(a+jb)*(c+jd) = a*c + jb*c + a*jd + jd*jb

We get 4 terms. Note that j*j = -1, so the last term = -d*b (this is a real number)

The first and fourth terms are real, so we can add them directly to get: (a*c – d*b)

The second and third terms are imaginary, so we can them to get: j*(b*c + a*d)

The final result is:

(a+jb)*(c+jd) = (ac – db) + j(bc + ad)

This is tedious. Fortunately, the computer is good at this sort of thing, so we usually don't have to worry about the details.

Now we'll finish checking our equation by plugging in one of the answers that we found:

Let x = 0.5+j1.323

x*x = (0.5+j1.323)*(0.5+j1.323) = - 1.50 + j1.323

Then, the whole equation = (-1.50+j1.323) - (0.5+j1.323) –2 = 0 (good)

To relate complex numbers to electrical circuits, we make the following observations:

Resistance is a **real** number.

Inductive reactance is a positive **imaginary** number.

Capacitive reactance is a negative **imaginary** number.

The impedance of a circuit is:

Z = R + jX, X = reactance and it can be positive (inductor) or negative (capacitor)

For example, suppose we have a 100pF capacitor (100*10^-12 Farad) in series with a 500 ohm resistor and the frequency is 7 MHz.

At 7 MHz, the capacitive reactance X= -1/(2*pi*7000000*100*10^-12) = -227 ohms

*Note: the **minus** sign is very important.*

Z = 500 – j227 = impedance of the series R-C circuit.

Real_part_of_Z = Re(Z) = 500
Imaginary_part_of_Z = Im(Z) = -227

The magnitude of a complex number is the square root of the sum of the squares of the real part and the imaginary part:

Magnitude_of_Z = SQRT(500*500 + 227*227) = 549 ohms

The phase angle, Phase, associated with this complex number can be calculated by:

Phase = ArcTangent(Imaginary_part / Real_part)
= ArcTangent(-227/500) = - 24.4 degrees

The negative angle is characteristic of a capacitive circuit. It means the voltage is **trailing** (or lagging) the current. In an inductive circuit, the phase angle is positive since the voltage **leads** the current.

Appendix 3 – Hot Keys

The following keyboard keys can be used instead of clicking buttons with the mouse:

S – Scan (same as Scan button)

R – Rescan (same as Rescan button)

L – Enter new Limits (same as Limits button)

D – Get raw data in Point Data mode (S, Z and T can be output in Morse code if desired).

U – Do a scan and save the data in a file named $AutoScan$.csv for off-line processing by a program such as Excel.

Q – Exit the program

Left Arrow – Move the cursor to the left on the graph.

Right Arrow – Move the cursor to the right on the graph.

Up or Down Arrow – Swap the last two scans. *(either key can be used)*

Control+UpArrow will overlay the last two scans if the scan limits are the same.

Left mouse button – Disable the cursor movement (reverse this action with a flag in Setup Menu.)

Right mouse button – Enter markers.

Appendix 4 – RS232/USB Operation

Because some newer computers don't have RS232 ports, it may be necessary to use an RS232 to USB adapter with the AIM. The AIM's RS232 port uses only three wires. Pin 2 is the data from the AIM to the computer, pin 3 is the data from the computer to the AIM and pin 5 is ground. Hardware handshaking is not used. The signal amplitude on the I/O lines (pins 2 and 3) is approximately +/-5V.

The comm port assigned to the USB adapter can be found using the Windows Device Manager: Click Start → Settings →Control panel → System → Hardware → Device Manager.

If there seems to be a problem with the USB adapter, here are some tips for checking it.

First, make sure another accessory in the computer or another program is not tying up the comm port. For example, if the AIM program is started two times without closing it the first time, the second copy cannot use the comm port. This can happen when the first AIM window gets hidden behind another window so it's not obvious that it is still active.

When the AIM hardware first powers up, it sends out a character string that can be received by any **terminal emulation program**, such as **HyperTerminal**. To use HyperTerminal, which is a standard accessory in Windows, click on the **Start** button in the lower left corner of the Windows desktop. Then, click "Programs" -> "Accessories" -> "Communications" -> "HyperTerminal". Set HyperTerminal for the following parameters:

Baud rate=57600; 8 data bits; 1 stop bit; no parity; echo typed characters locally.

When HyperTerminal is ready, turn on the AIM power. The green LED on the AIM front panel will turn on and the text displayed on the computer terminal is the following (or similar):

Antenna Analyzer AIM
from Array Solutions
Oct 13, 2006

If this is displayed, it means the data from the AIM to the computer is okay. If the text is *not* displayed, a scope or logic probe can be used to check for pulse activity on pin 2 of the RS232 connector with the PC cable disconnected. Pin 5 of this connector is the Ground pin. The normal voltage at pin 2 is about –5V and it pulses to about +5V several times during a 1 second interval while the text string is output right after the power is turned on. The PC doesn't have to be present at all, so this output test is completely independent of the PC or the operating system.

To check data from the computer to the AIM, type **K1** (**K** and a **one**). Note the **K** is **upper case**. The command **K1** will cause the AIM to turn on its Red LED. There is **no**

character space between the **K** followed by a **1**, but the time interval between typing the **K** and the **1** is not critical. Then, type **K0** (K followed by a zero). The Red LED should go off. This indicates the AIM is able to receive commands from the computer; therefore, the I/O data link is working properly.

It has been found that sometimes the computer operating system will say the USB driver is properly installed when it really isn't. Deleting the driver and then starting over and specifying that the driver must be reloaded from the CD may work.

A problem has also been found where Windows may not properly keep track of which comm port is in use. Some problems with the comm port can be solved by removing the port numbers that have been assigned in the past but which are no longer in use. This link has information for cleaning up the port assignments.

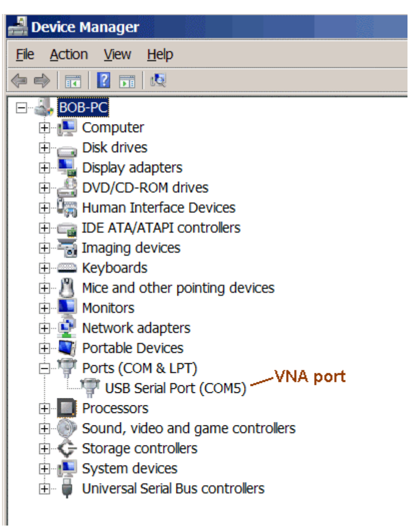
Check this web page for the latest information on the interface:
www.w5big.com/FAQ.htm

The following information on the USB interface applies to the ***AIMuhf****, the* ***AIM*** *and the* ***VNA2180****.*

Connect one end of the USB **cable** to the AIM (or VNA) and the other end to a USB port on your PC. You many need a new USB driver. (Many computers will already have the appropriate driver.) The USB interface chip used in the VNA2180 is made by FTDI (www.ftdichip.com). The chip is called FT232R and the recommended driver for several versions of Windows is 2.04.16. A link to it is on this page:
http://www.ftdichip.com/Drivers/VCP.htm

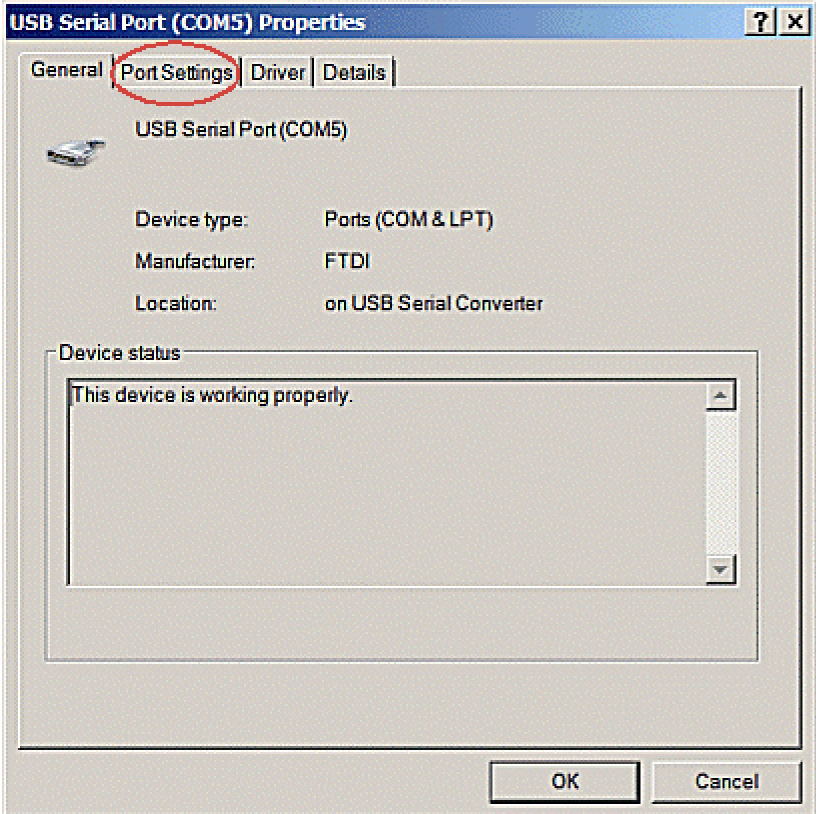
If your computer is connected to the internet at the time you first plug in the USB cable, Windows XP, Vista and Win7 may be able to find the driver automatically on the internet. This may take two or three minutes.

After the driver is installed and it has assigned a port number to the AIM, use the Windows Device Manager to find the comm port number. Click "**Start**" in the lower left corner of the screen, then click "**Control Panel**", "**System**", "**Hardware**", "**Device Manager**". The comm port number will be shown in a list of i/o ports similar to this:

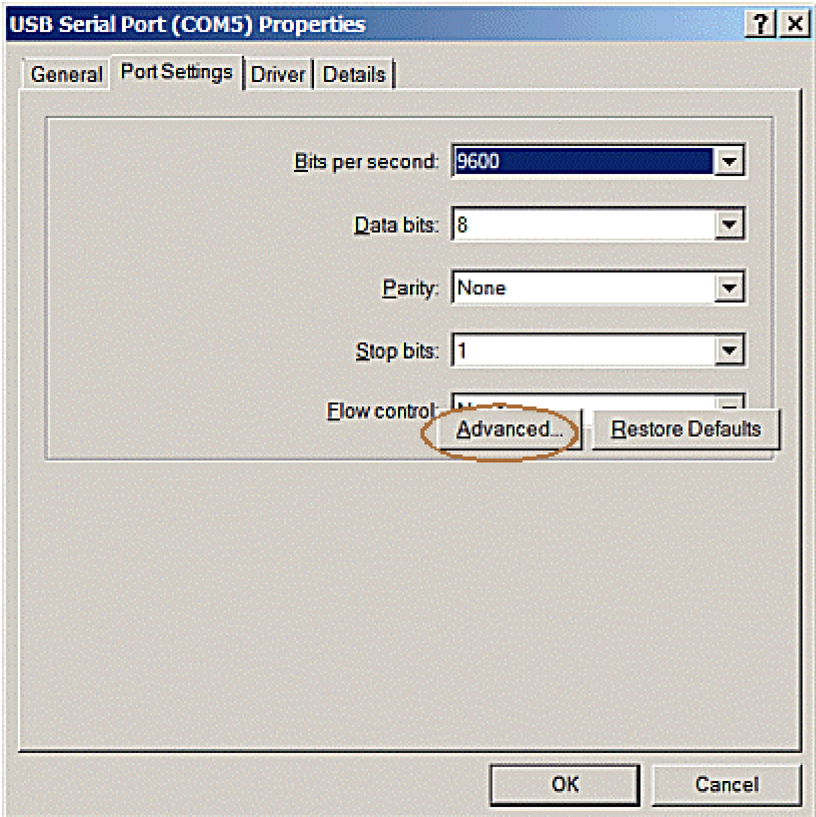


Under the AIM **Setup** menu tap at the top of the AIM program screen, click on **Enter Comm Port** and enter the port number that was assigned by Windows. This number will be saved in the setup file called *AIM_xxx.ini*. The default comm port number may be **6** or 5.

The usb interface can be customized for improved performance. Double click on the line that says "USB Serial Port (COMxx)". The **General Properties** dialog will pop-up:

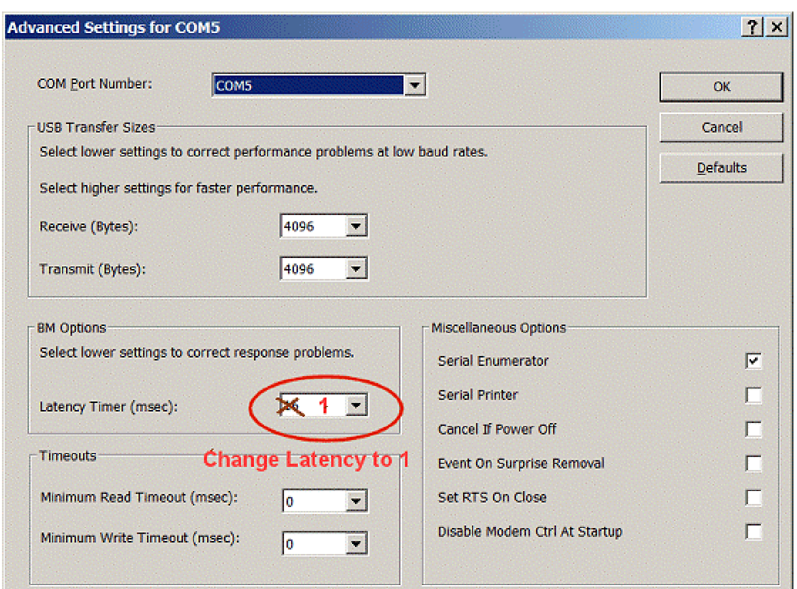


Click on the tab that says "Port Settings".



The Bits per second (baud rate) does not matter.

Click on the button labeled "Advanced" (this button may be overlapping the Flow Control edit box). Click on the outer edge of the Advanced button.



The COM Port Number can be changed, if desired. **Make a note of this number**; this is the value that will be entered into the AIM program for the comm port. Change the parameter called "Latency Timer" from 16 to 1. This will speed up the communication.

It has been found that sometimes the computer operating system will say the USB driver is properly installed when it really isn't. Deleting the driver and then starting over and specifying that the driver must be reloaded from the CD may work. Sometimes, deleting the device manager for this port and then plugging the cable back into the computer will cause the PC to reinstall the correct driver.

Check this web page for the latest information on the interface:
www.w5big.com/FAQ.htm

The AIM programs has been used with Windows 2000, XP, Vista and Windows 7. They have also been used with the MAC.

Appendix 5 – Scan Data File Format

The scan data can be saved in two different formats that are suitable for importing into spreadsheets or plotting programs.
In one file with the extension ".csv", only the basic data is saved in the following order:

Frequency in MHz, SWR, Rseries, Xseries, Zmag, Phase(deg), Reflection coefficient, Return loss(dB), Percent reflected power.

The data values for one frequency are all on one line and are **comma** delimited.
This file can be easily imported into a spreadsheet for detailed analysis.

Another file with the extension ".scn" is saved with more information about the conditions of the scan. A detailed example is show below.

```
// The comments are not included in the actual file.
// Parameters included in this file:  SWR, Rseries, Xseries,
// Zmagnitude, Phase
//
// If the equivalent parallel load circuit is needed:
//  Rparallel=Zmag*Zmag/Rseries
//  Xparallel=Zmag*Zmag/Xseries
//
09-08-05  10:57:33    // first line, date and time of the scan
 110                  // program version (changes if the data format
                      // changes)
 20                   // number of data points minus 1 :
                      // (there are 21 data blocks below)
 12                   // scan start frequency (MHz)
 22                   // scan end frequency
 0.500000000000000    // step frequency between test points
 12                   // freq at left side of graph plot (MHz)
 22                   // freq at right side of graph plot (may not be
                      // the same as "scan end freq"
 10                   // swr full scale
 1000                 // z magnitude full scale
 100                  // phase full scale (degrees)
 22.500000000000000   // not used
 0                    // not used
 0                    // not used
 0.500000000000000    // freq spacing between major vertical lines on
graph
 1                    // plot_swr flag (1=true)
 "comment string"     // graph comment string, if any.
1010.010620117187500  // SWR :  Start of data blocks; 5 items per block
                      // repeated 21 times in this example
 0.892523407936096    // Rseries : equivalent series resistance of load
 206.328903198242190  // Xseries : equivalent series reactance of load
 206.330841064453120  // Zmagnitude : magnitude of load impedance
 1.566470623016357    // Phase : angle of load impedance, radians
 440.064605712890620  // next SWR
 2.952029705047607    // next Rseries, etc
 249.890869140625000
```

```
249.908309936523440
1.558983564376831
284.346221923828120  // SWR
7.125505924224854
314.254211425781250
314.334991455078120
1.548125863075256
202.912612916039060  // SWR
17.597200393676758
419.200958251953120
419.570159912109370
1.528843045234680
158.592254638671870
49.341548919677734
621.562377929687500
623.517761230468750
1.491579294204712
134.716033935546880
205.956863403320310
1158.638305664062500
1176.801147460937500
1.394876122474670
123.570953369140620
4566.038085937500000
2713.321289062500000
5311.385742187500000
0.536173224449158
114.446578979492190
421.559051513671870
-1494.078613281250000
1552.411987304687500
-1.295792102813721
108.322395324707030
105.496887207031250
-746.862121582031250
754.276245117187500
-1.430471181869507
102.702613830566410
49.549240112304688
-499.510437011718750
501.961944580078120
-1.471924185752869
97.688926696777344
29.741893768310547
-376.700836181640620
377.873107910156250
-1.492006182670593
91.975608825683594
20.779895782470703
-304.370910644531250
305.079406738281250
-1.502630472183228
88.663787841796875
15.381784439086914
-255.856430053710940
256.318389892578120
-1.510749816894531
```

```
80.219047546386719
12.850700378417969
-221.102661132812500
221.475799560546870
-1.512740731239319
76.584655761718750
10.647170066833496
-195.356231689453120
195.646148681640620
-1.516348838806152
68.956077575683594
9.652303695678711
-175.194458007812500
175.460159301757810
-1.515757203102112
65.095878601074219
8.543374061584473
-158.872634887695310
159.102188110351560
-1.517073035240173
61.215835571289063
7.745326042175293
-145.441238403320310
145.647323608398440
-1.517592549324036
58.022541046142578
7.089697837829590
-134.253402709960940
134.440475463867190
-1.518036961555481
53.652206420898437
6.746065139770508
-124.731056213378910
124.913352966308590
-1.516764044761658
50.906970977783203      // last SWR (21 data blocks in all)
6.325359821319580       // last Rseries
-116.475082397460940    // last Xseries
116.646713256835940     // last Zmagnitude
-1.516543030738831      // last phase
50                      // real part of transmission line
                        //impedance (ohms)
0                       // imaginary part of transmission line
                        // impedance
0                       // transmission line type
0.660000026226044       // transmission line velocity factor
0                       // cable length
1                       // meters or feet scale factor
1                       // plot Xseries flag
1                       // plot Rseries flag
0.000000045816051       // Next five values are calibration data, not
                        // needed by spreadsheet
0.000000000007380
-0.025273719802499
1.023359417915344
100.599998474121090     // last line
```

Appendix 6 - Battery Operation

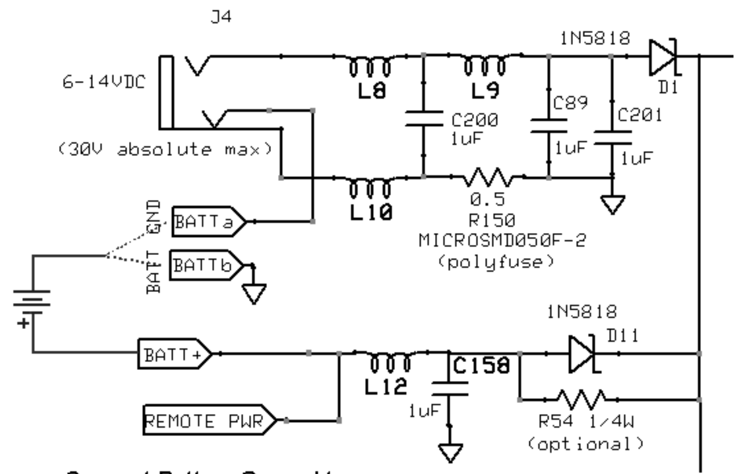
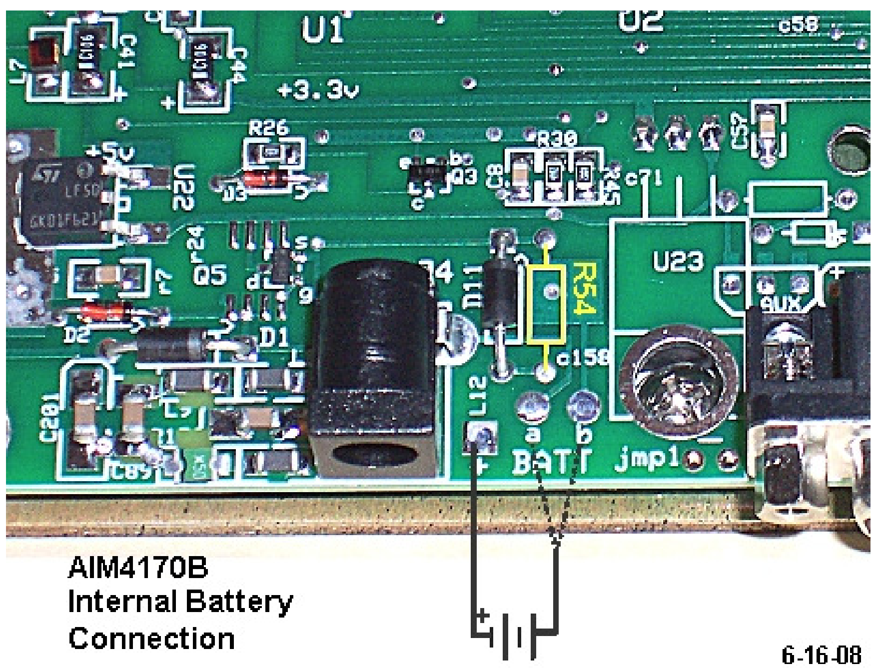
The AIM can be powered with a battery for portable operation. Battery voltage can range from 8.0 to 15V. The required current is 250mA (400mA for the AIMuhf) when a measurement is in process and 50mA when idle. The power is turned off automatically after 10 minutes of inactivity when the Auto-Power-Off feature is enabled (this is an option in the SETUP menu at the top of the screen).

Suitable batteries include a conventional 9V battery or a 12V car battery. The easiest way to connect the battery is to use a barrel connector like the wall power supply uses. This is a 5.5x2.1mm barrel connector. The Mouser part number is: 1710-2120.

When using the AIM to test a mobile antenna on a motor vehicle, it is better to use a separate battery and **not** the 12V battery in the vehicle. A 9V battery will power the unit for several hours or a small 12V gel cell (sealed lead acid) battery can be used for extended operating periods. This avoids the problem of sneak paths through the ground between the DC power input and the antenna ground connection. It will also help reduce measurement noise if it's necessary to run the engine while taking data (such as to operate the air conditioner). **If it's essential to get power for the AIM from the vehicle, be sure to put 500 ma fuses in BOTH the +12V lead and the power ground lead.** A small voltage drop across the fuses will not affect the AIM since the battery voltage is much more than the required minimum operating voltage. The laptop computer being used should remain **floating** for the best measurement accuracy.

A 9V battery can be installed inside the AIM. There are diodes on the card to automatically select either the wall power supply or the internal battery. The power on/off switch will disconnect the battery too, so the off-state current drain is only about 1 microamp.

Refer to the **Applications** file under the **Help** menu for more information on battery operation.

J4 is the power connector on the rear panel. The wall power supply (or external battery) plugs in here. D1 and D11 are a cross-over circuit to select either the external or internal power source, whichever is more positive. The battery positive and negative connections are labeled on the pc board. R54 is an optional resistor for trickle-charging a rechargeable battery. This is a user-selected resistor. It is not included in the AIM but there is a space on the PCB for mounting a through-hole resistor.	 Connect Battery Ground to "BATTa" if the charger voltage is not great enough to charge the battery. The battery will be disconnected when the charger is plugged in. Connect Battery Ground to "BATTb" if the charger voltage is greater than battery voltage. Then battery can be trickle charged through R54 (optional).
This photo shows how an optional battery or battery pack can be connected to the printed circuit board.	

Appendix 7 – Saving Screen Shots

Pictures of the scan can be very useful for documentation. The easiest way to paste a screen into a program, such as **Microsoft Word**, **Photo Shop**, or **Paint Shop Pro** is:

1: Press **Alt-PrtScr** to copy the image to the clipboard

2: Move the cursor to the desired document or paint program and press **Control-V**.

A nice **freeware** utility is called "**PrintScreen**" from Gadwin:
http://www.gadwin.com/printscreen/

This utility installs very easily. It can save the whole screen, the current window (the one with its top banner highlighted), or a rectangular area that you can select. For saving shots of the AIM data, the ***current window*** is probably the most useful choice. This should be saved in **gif or png** format, not jpg. Gif and png formats save a better quality **graphic image** than jpg. (jpg is better for photographs.)

Newer versions of **Windows** have a utility called **Snipping Tool** that can be used to save screen shots too. Look in the list of **Accessories** files.

You can save the screen in .bmp format by clicking: File ->Save Image Bitmap

The Windows operating system also includes a standard accessory program called "**Paint**" that's already available on all computers.

To run "**Paint**", click the **Start** button in the lower left corner of the screen.

Then click "**Programs**"

Scroll to find "**Accessories**"

Click "**Paint**"

Click **Control-V** to insert the screen shot into the working page.

Then save the file as a **.gif** , **.png**, or **.jpg**. (.gif or .png are preferable since the quality of the line drawing is better than it is in jpg)

Now your screen shot can be inserted into a document file or attached to an email.

Appendix 8 – Configuration File

The configuration file (*.cfg) is used to set the screen colors and some other display parameters. The config file can be edited with any text editor, including Notepad. There is an editor included with the AIM program, click **Help -> Edit Config File** to call it up.

A utility called ***colors.exe*** is included with the AIM software to aid in selecting screen colors. Move the sliders to get the desired color combination. Note the numeric values for red, green, and blue and then enter these values in the config file using a text editor. Several different config files can be resident in the same folder. They are selected using the menu option: **File -> Load Config File.**

The following comments are included in the config file itself.

==

This is a comment line that is displayed when the config file is loaded from the menu.

// The user-supplied comment above will be displayed when the config is loaded from the
// menu.

// The comment line does not have to start with the // symbols.

// There can be several config files in the same folder. The comment in the first line is

// helpful to differentiate them.

// April 23, 2006

// AIM configuration file

// The parameters must remain in the same sequence.

// When new parameters are added, they will be placed at the end of the file.

// Comments or blank lines can be inserted freely.

// Comments are indicated by a double-slash //

// The double-slash should start in column 1.

// If the config file is not found in the same folder as the exe file,

// default values will be used.

// COLORS for PLOTTING:

// Colors are entered as RED, GREEN, BLUE with values 0-255

// 0=no color, 255=maximum color (max red, max green, or max blue)

// Examples: 0,0,0 = black (no red, no green, no blue)

// 255,255,255=white (max red, max green, max blue)

// 255,0,0=bright red 0,255,0=bright green 0,0,255=bright blue

// The included utility file: colors.exe can be used to help select the colors.

```
// The numbers should be in decimal format.
// A space or comma can be used to separate the three numbers.

// Only the first number (or set of 3 numbers for colors) on each line is used.
// The rest of the line is a comment.
// A double-slash on a line means the whole line is a comment.

// When experimenting with colors, the new set of colors can be entered on the same
// line and the old ones are pushed to the right.
// The old ones will be ignored by the program but they are handy for reference.

// There are two sets of colors for each parameter:
// The brighter color is used for the main scan (first scan)
// A fainter shade of that color is used for the rescan (second scan)

  240,0,0      //RED=SWR (or reflection coefficient) main scan and Smith Chart trace
  240,120,0  //light red=SWR (or reflection coefficient) rescan

  0,200,0        // Green=Zmagnitude main scan
  130,240,180  //light green=Zmagnitude rescan

  200,0,200      // Magenta=Phase main scan
  200,180,240  // light magenta=Phase rescan

  0,200,200   // Cyan=vertical cursor that is moved with the mouse.

  64,122,252    //Blue=Return Loss main scan
  160,160,250  //light blue=Return Loss rescan

  200,200,0    //Yellow=Xs or Xp (whichever is selected) main scan
  255,255,0   // light yellow=Xs or Xp rescan

  255,174,0     // Orange=Rs or Rp main scan
  255,195,125  //light orange=Rs or Rp rescan

  250,250,200    //smbackground=Smith Chart background color

  230,230,230 // grid color=color of gridlines on the graph
```

```
 200, 0,  0   //file name color (cal,config,cable_cal file names displayed on screen)

// Cursor enable:
   1   // = (default) cursor is enable whether left mouse button is pressed or not.
//     ( 0 means cursor is enabled only when left mouse button is pressed. )

// Graph line width:
   2  //= Line width of the plotted data (can be 1,2,3,4,5)

// Halt:
   2  //=  Halt if right mouse button is pressed )
//      ( 0 = Halt if Halt button at bottom of screen is clicked )
//
//  BAND SELECTION:   Start_freq, Stop_freq, Step_freq (all in MHz)
//  The actual "Stop_freq" on the graph will be equal to or greater than the
//  value specified here.
//  The frequencies specified DO NOT have to correspond to ham radio bands.
//  The frequencies and the step freq can be any value within the range of the AIM.

// Example of defining a band for an AM radio station:
//          0.520,  0.620, 0.001,  station=KLIF_570
// The string after "station=" is a user supplied string to identify the band
// on the menu. It can be up to 12 characters long but it cannot have any spaces.
// Use an underline or a dash character instead of a space.

   1.7,     2.1, 0.01  // 160 meters  all of these values can be user specified.
   3.4,     4.1, 0.02  //  80 meters
   6.9,     7.4, 0.01  //  40 meters
   13.9,   14.5, 0.01  //  20 meters
   20.9,   21.6, 0.01  //  15 meters
   27.9,   29.8, 0.05  //  10 meters
   49.5,   54.5, 0.10  //   6 meters
   143.5, 148.5, 0.10  //   2 meters

   5.25,  4.25,  0.05  //  60 meters
   10.0, 10.20,  0.005 //  30 meters
   18.0, 18.20,  0.005 //  17 meters
```

```
24.7,  25.1,  0.01   //  12 meters

1.00, 160.00, 2.0   //  Band A
1.00,  21.00, 0.2    //  Band B
5.00,  45.00, 0.25  //  Band C
13.00, 43.00, 0.2   //  Band D

240, 240, 240  // highlight color for bands
1000  //max number of data points. This can range from 20 to 1000.
0    //meters/feet (1 means use meters as default length, 0 means use feet as default)


                    1000  //Max delay in milliseconds for external hardware

              //     (for example, Bluetooth) to respond to the RS232 data link.

   //**************************************************************

              // Parameters to set graph and font sizes: (new with version 600)

            // If the max width and height are larger than the actual screen size,

            // the full screen size will be used.

   // The earlier versions of the AIM program used a max graph size of 950 x 600.

      950  // max graph width in pixels  (original AIM graph width was 950 pixels)

      600  // max graph height in pixels (original AIM graph height was 600 pixels)

           7 // Default font size. 5 is very small, 6 and 7 are medium, 8 is large.

                   //   minimum font value=3, maximum font value=10
1    //Bold Data display ( 0=not bold data )

//*******************************************************************

            0    // Do not clear each screen during recycle mode ( 1= do clear )
300   //Delay in milliseconds while recycling. Several seconds may be useful in some
      cases.
```

```
//**** versions 621 and higher:

 1    //RS232 baud rate  1=high,  0=low   (may need to be 0 for bluetooth)

 0       // (1=issue cal warning if long stub is attached while calibrating)

 2.0  //parameter 3

 0.1  //parameter 4

 32    // averaging for crystal's parallel resonant frequency measurement

   1  // = don't enable external program control,
      // 2=enable but don't show counter
      //  3=enable external control and show counter.

 1   // auto save graph after each scan,     0=don't save

// The next two lines are path names for the external control  files:

// The names controlfile= and outputfile= must appear first on the line.

// The exact position on the line is not critical.

// The file and path names can be anything, they don't have to be on the C drive.

// Don't enclose the path name in quotes.

// Use double back-slashes for folder delimiters.

// The path names CANNOT have spaces in them. Use dashes or underscores.

// All valid filename characters are ok except spaces.

 controlfile=  hkey_current_user\software\AIMAIM\    // input control initiates scan

 outputfile= C:\\temp\\AutoScan.csv    // output data csv file


// Voice output parameters:

 // Folder for voice sounds (wav files):

 voicefilefolder=Sounds_1\\       // (two back slashes follow "Sounds_1" )

  1    //num_digits=1 or 2 in fractional part for voice output
```

0 // 0=Don't repeat the same number, 1=Repeat the same number.

1 // parameter_10 // if Zmag changes too much between data points, issue an alert:

4 //= Freq resolution tolerance as a percentage of full scale, e.g, 4=4% of full scale, 5=5%, 10=10%, etc.

// the alert can be made less sensitive by entering a larger number, e.g., 100 will disable it.

// The data will be valid even when the alert appears.

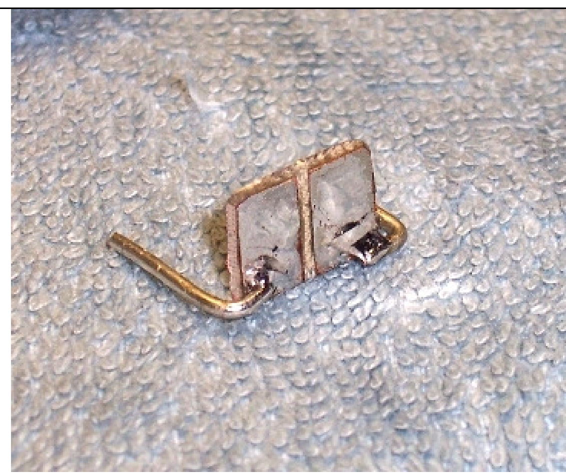
// END of config file

Appendix 9 – Component Test Fixture

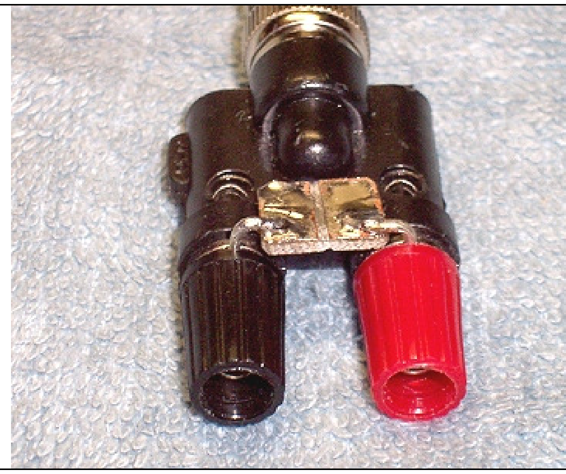
The AIM can be used to measure small discrete components over a specified frequency range. A convenient way to hold them is with a BNC to binding post adapter. Even though the adapter has significant stray capacitance and inductance, these stray parameters can be cancelled by the calibration procedure. The adapter shown here is from Jameco, part number 99355, which costs about $5.30 in the U.S.A.
(ref: www.jameco.com)

When calibrating, insert a piece of wire between the binding posts for the **short circuit**. Then remove the wire for the **open circuit**. The **resistor** that is used can be any 1/4W or 1/8W carbon or metal film resistor with an accurately known value. A resistor in the range of 50 to 500 ohms can be used.

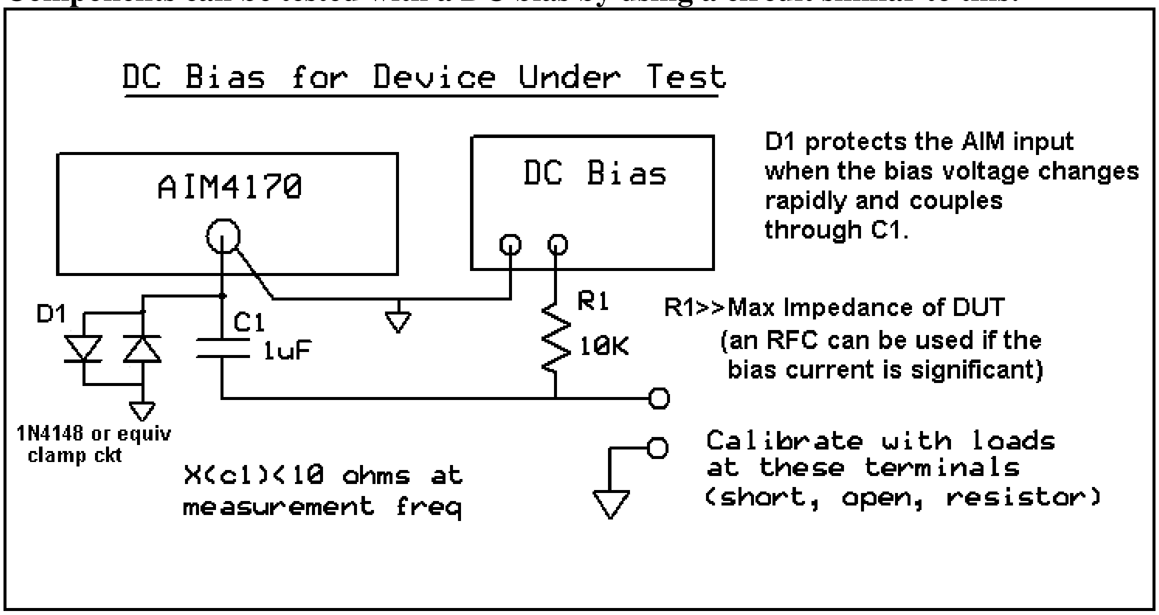
For testing very small surface mount components, another adapter can be made from a small piece of printed circuit board material. A cut down the middle isolates the two side. A similar cut is also made on the back side if the printed circuit board has copper on both sides. Two heavy wires (#16 - #20) can be used to connect it to the binding posts. The chip component being tested can be held securely by pressing it against the board with the eraser of a pencil or a plastic screwdriver.



Here we see the surface mount adapter combined with the binding post adapter. The stray capacitance of this combination adapter will also be compensated by the calibration procedure. Capacitors in the picofarad to nanofarad range and inductors in the nanohenry to microhenry range can be measured.



Components can be tested with a DC bias by using a circuit similar to this:



Appendix 10 – External Program Control

In Nov 2011 a new method was developed for controlling the AIM with functions in a DLL. These functions can be employed in any language and they give the user full control of the data collection, processing and display. A separate document is available with the title: **AIM_Software_Guide.pdf.** This document (with a link to the demo program) is included in this zip package to show how the DLL functions can be used.

A description of the ***original external control*** *method follows:*

The AIM can be integrated with a test system so that measurements are done under the control of a "**Master**" program. A new procedure has been incorporated in program version 700B which is more robust than the earlier version.

By using this procedure, the calibration and data processing in the AIM program are employed automatically and the user can focus on analyzing the final data that is output to a file in CSV (comma separated values) format. This file can be read by Excel or the user's custom program.

The Master program communicates with the AIM by data strings in the registry. The scan data from the AIM is written to a CSV file in the same format that it was before.

The three parameters sent from the Master to the AIM are: **Start_freq, End_freq**, and **Delta_freq**. The frequency values are in megahertz. After these parameters are written to the registry, the AIM will read them, perform the scan and write the csv file. It then puts the name of the csv data file in the registry so the Master knows the scan is complete and the data is ready.

To enable external control, set the flag in the config file to 2 or 3:

3 external program control: 1=disable 2=enable-don't display time, 3=enable & show time

If the flag is set to "3", a one second timer is displayed in the upper left corner of the screen.

The names of the registry key and data file are specified in the AIM config file:

controlfile= hkey_current_user\software\AIMAIM\ : input control key initiates scan (this is new in
: AIM version 700B and later)

outputfile= C:\\temp\\AutoScan.csv : output data csv file

A sample file called "External_Control.eba" is included with the zipped AIM files to illustrate the communication process. A compiled version of this sample program can be run to get a feel for how the process works.

While the AIM is in the external control mode, the other features operate normally. It still responds to mouse and keyboard commands.

The external control scenario is:

1. Turn on the AIM power and then start the AIM program.

2. Change focus to the Master program.

3. Master program writes control parameters for setting the frequency range.

4. AIM does a scan with the specified scan limits.

6. Master program waits until C:\Temp\AutoScan.csv (output data file) is created by the AIM. This data file name can be specified in the config file.

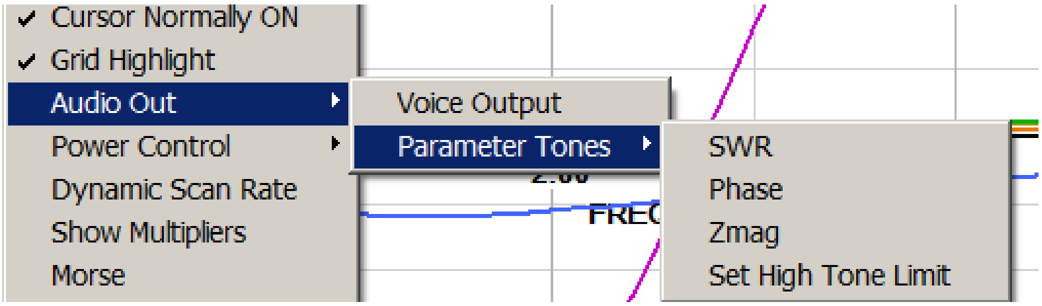
7. Master program processes the scan data.

8. Loop back to step 3.

This new external control procedure only works with AIM program versions 700 and later. It works with any model of the AIM hardware.

Appendix 11 - Tone and Voice Output

Setup Menu:



TONES:

While in the **Point Data *Tune Mode,*** a tone related to the **SWR, Phase**, or **Zmag** can be played through the PC speaker to assist in making adjustments without watching the monitor. When the Point Data window is open, click the button labeled **Tone On** to start the tone. (Later, click **Tone Off** to stop the tone.) The magnitude of the parameter that corresponds to the highest pitched tone can be changed using the setup routine called "**Set High Tone Limit**" under the **Setup** tab on the main menu at the top of the screen. For example, to make the highest tone correspond to SWR=5, click Set High Tone Limit and enter 5 in the dialog box. This dialog box also appears when the parameter is first enabled. SWR is converted to a log scale for better resolution at the low end. The Phase and Zmag outputs use linear scales between zero (lowest tone) and the HighToneValue (highest tone). For Phase, the maximum limit is 90 degrees. For Zmag the maximum limit is 10K ohms.

SWR can be sounded out verbally. Use the Setup menu to enable this function.

The tone or speech output can be played over an extension phone or cell phone while making remote adjustments to an antenna.

Voice Output:

The SWR value can be sounded out verbally in the **Point Data Mode**. This feature is enabled using the **Setup menu -> Voice Output**. This makes it possible to make adjustments without looking at the computer monitor. It's also possible to send the readings to another location using telephones, cell phones or portable radios. For example, the AIM can be located in the lab and you can hear the SWR readings while up on a tower.

The numbers are saved in **wav** files. Each number is a separate file. The program breaks up the swr reading into its separate digits and plays the appropriate wav file for each digit. For example, the number one is a file called: **one.wav**. The number two is a file called: **two.wav**, etc. The decimal point is a file called **point.wav.** There are 11 separate files. These are in a folder whose name is specified in the config file. The default folder is **sounds_1** but the name can be anything you like. It has to be a subfolder of the folder where the program is located. By changing the folder name, you can have different sets of files with different voices and different languages. The content of the wav file does not matter at all, only the name is use by the AIM program.

There is an option in the config file to select either one or two digits for the fractional part of the reading. Using a single fraction digit will make the repetition rate faster.

Another config file option controls **repeating** the same reading. For example, if the swr reading is a steady 1.25, you may not want to listen to this over and over. If the flag is zero, the same reading will not be repeated twice in a row. If this flag is some value greater than **zero**, the same reading will be repeated every **Nth** pass. For example, if the flag is equal to 5, the same reading will be repeated after 5 measurements. Larger or smaller numbers can be used too. This way you can tell if the system is still working, even when the reading doesn't change for a long time.

To get started, I made the wav files myself. This leaves a lot of room for improvement. I'm sure some people can improve on the quality of these files and perhaps share them with other AIM users. Since the wav files are completely independent of the AIM program, it's not hard to create a new set in a new folder. Then change the folder name in the config file. With the menu option: **Help -> Edit Config File** you can switch between voice file sets quickly. If you're interested in an audio editor, try **www.wavosaur.com**.

Appendix 12 - Band Skipping

When testing a multiband antenna, the scanning process can be speeded up by jumping over the spaces between the bands of interest. The bands to be scanned are defined in the config file in the same format that is already being used. On one line, there are three numbers: Start_freq, End_freq, Delta_freq. These are in **MHz**. The Start and End frequencies define a particular band that will be scanned. These values do not have to correspond to a ham band. When scanning a ham band, the entire band does not have to be scanned. You can scan just the CW band or the phone band if you want to.

The calibration procedure, either standard or custom cal, is not affected at all by band skipping. The custom cal procedure (if used) is performed at all the frequencies between the Start and End points. The only difference is that raw data points are not read at frequencies between the selected bands during a scan. Therefore, the whole freq range can be covered in much less time.

The S**tart** and E**nd** frequencies for the scan are set by clicking the **Limits** button. The **Step size** is specified here and the delta_freq in the config file is not used. All bands are scanned with the same frequency step size, regardless of the value in the config file.

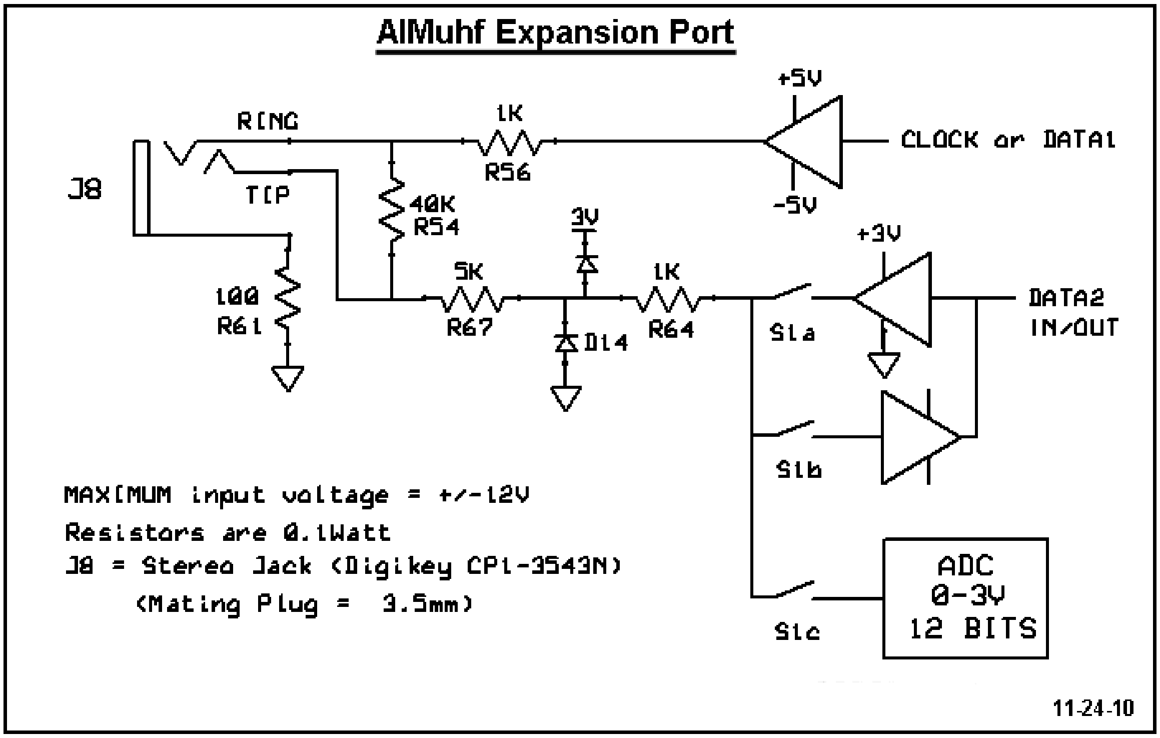
After setting up the Start and End frequencies, go to the **Bands menu** and click on **Band Skip**. This flag will alternate between on/off each time you click it. There will be a check mark beside Band Skip when it is enabled.

To compare the performance with and without skipping, first highlight the bands. Then click on Scan for a regular scan. Now set Band Skip and click Rescan. The whole scan over the bands of interest will be much faster and the data inside the highlighted bands will be essentially the same as before, when skipping was off.

Markers can be very helpful when adjusting multiband antennas or filters. The SWR for each band can be displayed by analog gauges which make it easier to visualize when the optimum points are reached. See the Marker section of this manual for details.

Appendix 13 - AIMuhf Expansion Port

The AIMuhf has an I/O port with two signal lines. One line is an output driver that can be used as a **clock** or a **data output**. The other signal line can be a *data output*, *data input* or an *analog input* to the ADC. Connection to this port, **J8**, is made with a regular stereo plug (3.5mm).



This diagram shows the equivalent circuit of the I/O port. The ground is isolated from the chassis. Only low currents should flow in this path. The **Ring** of the stereo plug is connected to the **output** pin which can be a clock or a data line. The functioning of this line can change from one data cycle to the next. The other data line is connected to the **tip** of the stereo plug. The three functions of this line: **Output, Input, Analog Input** can change for each data cycle too. Both of the lines can be used as outputs if desired. They should be buffered in the external accessory with a transistor or a logic gate with a low input bias current. There are resistors in series with these lines to protect them from external voltages up to plus or minus 12V.

R54 is only used for diagnostic tests.

The Ring signal swings from -5V to +5V. This is an output only. The current is limited by R56.

The Tip line can be digital in/out, or it can be connected to an analog output signal (such as an op amp) in the accessory and then read by the ADC in the AIM. This is a 12 bit

ADC with an input range of 0 to 3.3V. A full-scale input voltage generates an ADC reading of 4095.

Data Format:

Signal Line Setup Conditions:

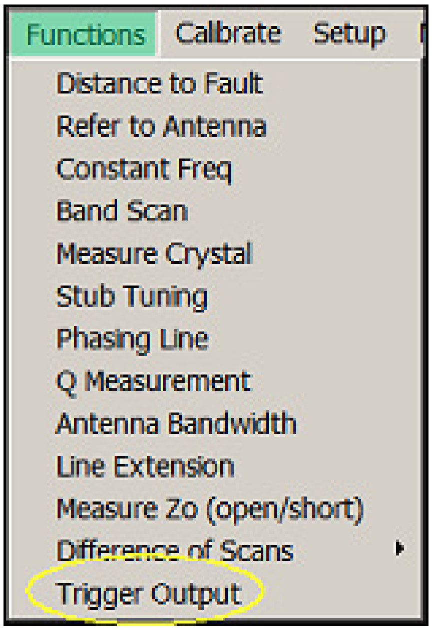
Data 1 - output only. This defaults to a SYNC output that pulses at the start of a scan. Functionally it is similar to the sync output described in Appendix 14.

Data 2 - output (default), input, ADC input.

Appendix 14 - Trigger Output

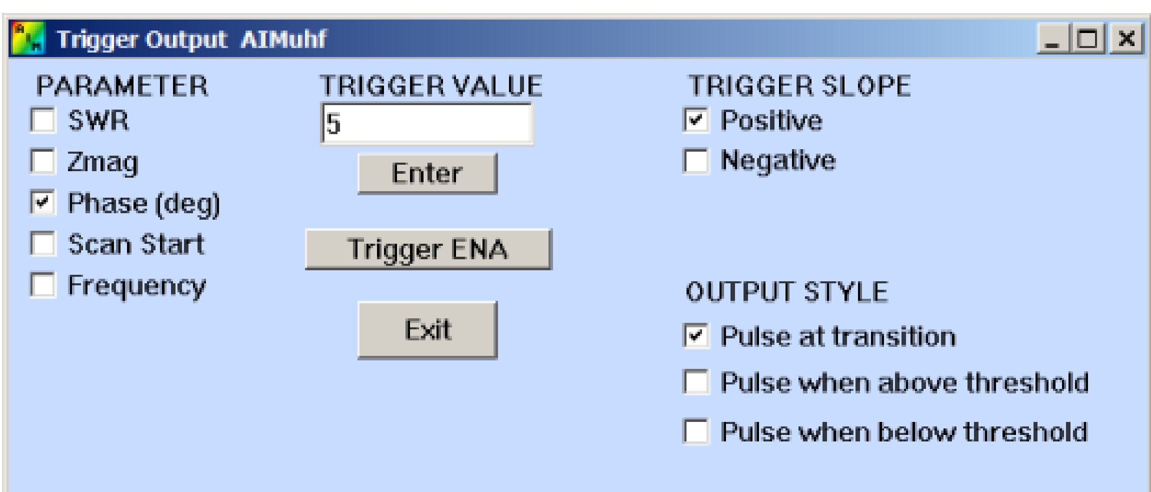
Newer models of the AIM4170B,C&D, AIMuhf and PowerAIM have a **Trigger output** (Sync) on the rear panel. *Hardware details are shown below*. This pulse can be used to trigger a scope or a controller when a measured parameter (**Zmag, Phase, SWR, Frequency**) passes through a specified **threshold** value. The trigger can also be programmed to occur when the scan starts.

Click the **Functions** menu at the top of the graph.



Click **Trigger Output**.

The Trigger Window pops up to enter the desired trigger conditions:

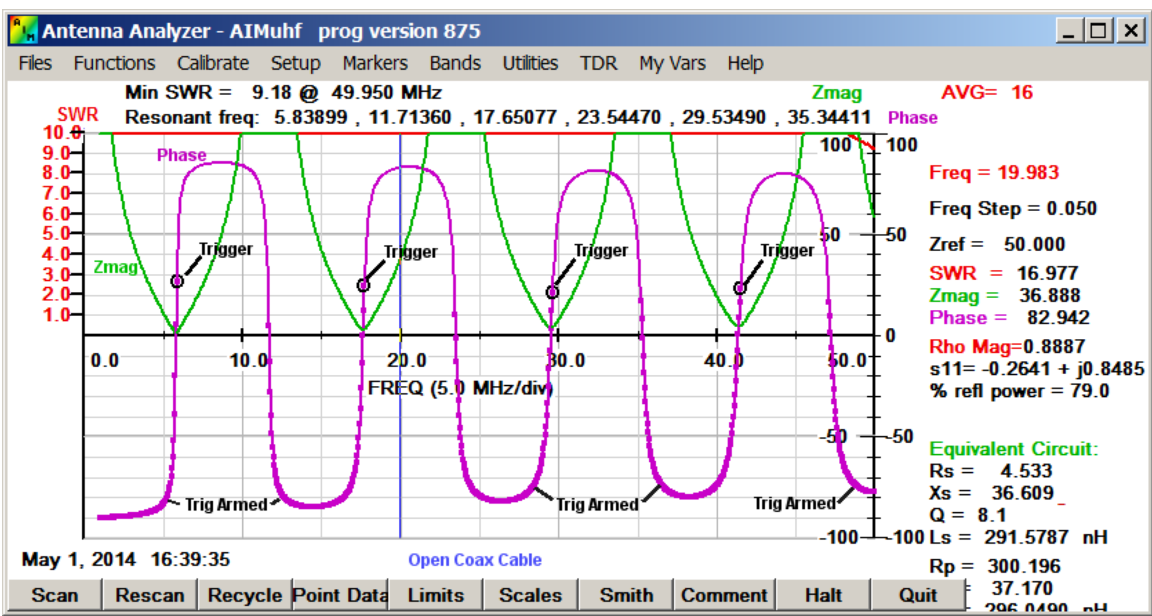


One of the **parameters** listed on the left side of the window can be used to generate the trigger event. The threshold value is entered in the **Trigger Value** box. This value will represent **ohms** if Zmag is selected, **degrees** if Phase is selected, and **MHz** if frequency is selected.

The trigger value can be changed any number of times during a test session without having to close and reopen the trigger window. Click the **Enter button** for a new value. The trigger can be enabled or disabled without having to reprogram the trigger data. This makes it easy to perform some adjustments with the trigger turned off, run some scans and then enable the trigger again very quickly.

The slope for triggering can be positive or negative. The hysteresis for the trigger threshold is **+/-5 percent** of the trigger value. When the trigger is programmed to occur on the **positive slope**, the trigger is armed when the parameter is **95 percent** of the threshold. When the trigger is programmed to occur on the **negative slope**, the trigger is armed when the parameter is **105 percent** of the threshold.

Multiple trigger events can be generated during a single scan. The scan waveform is **highlighted** with a small dot when the trigger is armed. When the trigger occurs, a black circle indicates the time on the triggering waveform and the trigger data on the right side of the Trigger window is updated with the time and the frequency.



This scan shows **phase** being used to generate the trigger. Four triggers are generated during this scan. In this case the trigger occurs on the positive slope. It could also be programmed to occur on the negative slope. The trigger is armed on the negative slope of the phase when it drops more than 5 percent below the trigger threshold. This region is shown by highlighting the purple phase trace. If the parameter does not go more than 105 percent below the threshold, the trigger will not be armed.

The trigger can also be programmed to occur anytime the trigger parameter is **greater** than or **less** than the trigger threshold.

If the trigger event is programmed for **Frequency**, the trigger occurs only once during the scan and it is indicated by a green vertical line on the graph. *The positive/negative slope parameter is not used for the frequency trigger event.*

The trigger can be set to occur at the beginning of a scan. This takes the place of the sweep function that was formerly available in the AIM. The new Trigger Output is much more general.

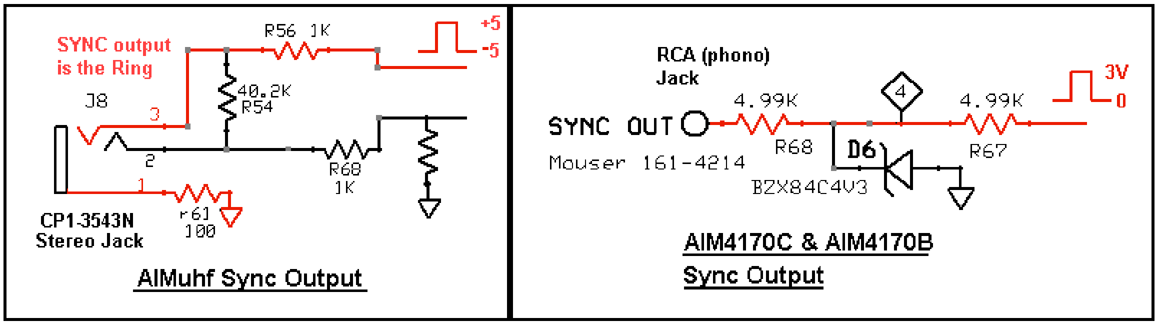
The sweep procedure is:
Set the scan limits to the range you want.
Set Delta Freq to give about 50 to 100 data points (more is ok if you want too).
Note that any number greater than 20 in the Delta Freq box is considered to be the number of measurement points, not the frequency step size in MHz. *For example, to get 100 measurement points, just enter 100 in the Delta Freq box.* The program will convert this to MHz for you.

Set **Averaging** to zero.
Set the **Recycle Depth** = zero (using the Setup menu.) This provides an unlimited number of recycle scans.
Set the **Trigger Output** to occur at Scan Start.
Now in the **Recycle mode**, you will get a trigger pulse at the sync connector at the start of each scan.

The AIM will do a regular scan in the Recycle mode, so you can see a plot of the input impedance of a filter during this procedure as well as get a driving signal for adjusting the filter.

The horizontal axis normally represents frequency. In special cases it can be **equivalent to time** by making the Start and End frequencies very close together and making the Step size very small. The test frequencies are nearly constant and the spacing between samples corresponds to time. If necessary, choose a value of averaging to adjust the horizontal time scale factor. In this way the frequency is nearly constant and the measured value corresponds to a time varying parameter.

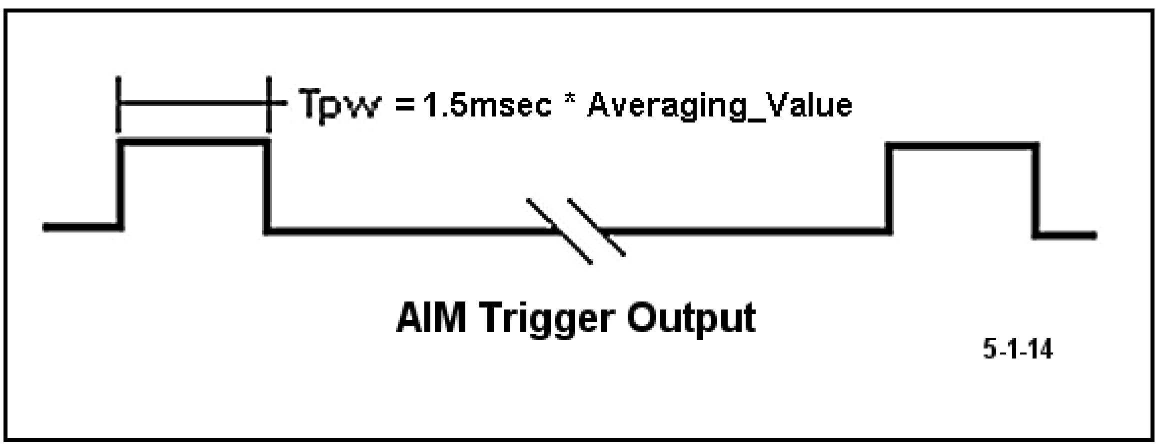
The **AIMuhf**, **AIM4170B,C,D** and the **PowerAIM** have an output on the back panel called SYNC that generates a pulse when the trigger event occurs.



The pulse from the **AIMuhf** model switches between **-5V** and **+5V**. If this goes to a TTL or CMOS circuit, the level should be clamped with a series resistor and a zener diode to ground. Instead of a zener, the clamping can be done with two computer diodes like the 1N4148 or 1N5811. One diode connects to ground, the other to the positive supply voltage. Alternatively, a large series resistor can be used and the voltage will be clamped by the internal diodes of the integrated circuit that's being driven. Check the data sheet of the device to find the maximum value of clamp current that is allowed. The **Sync** output is on the **Ring terminal** of the stereo jack.

The output signal on the **Tip terminal** of the stereo jack corresponds to the trigger pulse too. It's source impedance is about 40K ohms. This can be used to drive a high impedance circuit, like the base of a high beta transistor or a CMOS gate.

The pulse from the **AIM4170B,C or D** switches between **0** and **+3V**. The series impedance is 10K ohms, so the external load should require less than 300 ua of input current. This is a conventional RCA jack (often called a phono jack).



The trigger pulse is normally at a <u>low level</u>. It pulses <u>high</u> when the trigger occurs. For the AIM4170B,C,D and PowerAIM, the width of the pulse, Tpw, is approximately 1.5 msec times the Averaging value. The width of the pulse can be changed by using different values of averaging. For the AIMuhf, the width of the pulse is about 1.5 msec.

Only the **leading edge** of the pulse should be used for controlling external circuits because the width of the pulse may vary.

Different trigger pulse widths from the AIM4170B, C and D can be used for control purposes with an external microprocessor or one-shot logic circuits. For example, a very wide pulse could be used to reset the external hardware to prepare for the next series of measurements. This can be generated by setting the averaging value to 64x or 128x.

The trigger output from the AIM4170 includes a series resistor. This protects the output port and it can be used by external circuits for a filter. The 4.3V zener is part of the protection circuit and it does not affect normal operation of the sync output.

Appendix 15 - Measuring Cable Parameters

The AIM can be used for measuring several basic parameters of coaxial cable:

1. Impedance

2. Velocity Factor

3. Length

4. Loss

The **Distance to Fault** function will measure these parameters at the same time.

Clicking on the **Functions** menu and selecting **Distance to Fault**.

If the velocity factor (VF) of the cable is not known, enter a value of **zero**. Then enter the exact physical length of the cable that you measured with a ruler or tape measure. The program will calculate the VF.

If the velocity factor of the cable is known, enter it and then the program will determine the physical length of the cable and Zo. The function will display the length of the cable, quarter wavelength frequency (90 degree phase shift), characteristic impedance (Zo), the velocity factor and the cable loss at the quarter wave frequency.

If you need to know the cable loss at other frequencies, enable the **Return Loss** display using the **Setup** menu and click **Plot Parameters -> Return Loss** and then do a regular scan of the cable over the desired frequency range with the far end of the cable open . Move the blue vertical cursor along the scan and the cable loss will be displayed on the right side of the graph for each frequency point.

Note the one-way cable loss is numerically equal to one-half of the return loss. The return loss is the loss that the signal experiences in two passes, down and back along the open cable.

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WARRANTY SERVICE: Products have a one year limited warranty. This includes parts and labor. We will repair or replace the unit at our discretion.

CIRCUITS AND PROCEDURES used by this vector impedance measurement system are covered by one or more patents pending.