Antenna Analyzer AIM4170

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New information is highlighted in RED.

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Quick Start

Loading the Software:

The AIM4170 software does not require a formal installation procedure. It does not interfere with any other programs or the registry on your computer.

1) Create a folder or a subfolder on any convenient hard drive.
For example, "*C:\AntennaAnalyzer*".

2) Insert the CD labeled "AIM 4170" in the CD drive.

3) Copy all the files on the CD to the folder you just created for the antenna 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. When later versions of the program are released, the number "_xxx" will be different. All versions of the antenna analyzer program can reside in the same folder at the same time. The older programs with the lower numbers will not interfere with the newest version, so they do not have to be deleted.

If you want to make a shortcut icon for your desktop, right click on the AIM_xxx.exe file (or the latest version) and select "create shortcut" from the dropdown menu. Drag the shortcut to your desktop or task bar.

When 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.

Hardware Connections:

Connect one end of the RS232 cable to the antenna analyzer and the other end to COM1 on your PC. If you want to use a different COMM port, start the AIM4170 program and click on the **Setup** menu at the top of the screen. Then click on **Comm Port** and enter the port number (1 to 8) that you want to use. This number will be saved in the setup file called *AIM_xxx.ini*. If you're using a USB to RS232 adaptor, change your USB program to match this number. For more information about setting up a USB/RS232 adapter, see Appendix 4.

Plug the DC power supply that's included with the AIM4170 into an appropriate 120V AC outlet and insert the connector into the jack on the rear panel of the analyzer.

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. If the analyzer does not receive a command from the PC for 10 minutes, it will power down automatically if it is in the AutoPwrOff mode. The default is to **not** power down automatically but if you're using batteries, the AutoPwrOff mode can be turned on with a menu selection under **Setup**.

The AIM4170 can be operated on battery power for remote operation with a laptop computer. The current required is about 250ma while a measurement is in progress and about 50ma when idle.

Batteries are not included with the AIM4170 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. The main power on/off switch controls the battery power too, so the leakage current is less than one microamp when the AIM4170 is turned off. Refer to Appendix 6 for more details.   (These pictures show an AIM4160, but the AIM4170 is electrically the same.)

Be sure the maximum input voltage at the DC power connector does not exceed 15 volts. The minimum input voltage required is 6.0 volts.

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. **Check the output voltage with no load to make sure it does not exceed 15 volts**.

Some of the pictures in this manual were taken using an AIM430 or an AIM4160. The operation of these instruments is equivalent to the AIM4170 (within their operating ranges) and this manual applies to all three instruments.

Initial Operation:

Launch the AIM_xxx.exe program. You will see a graph similar to this:
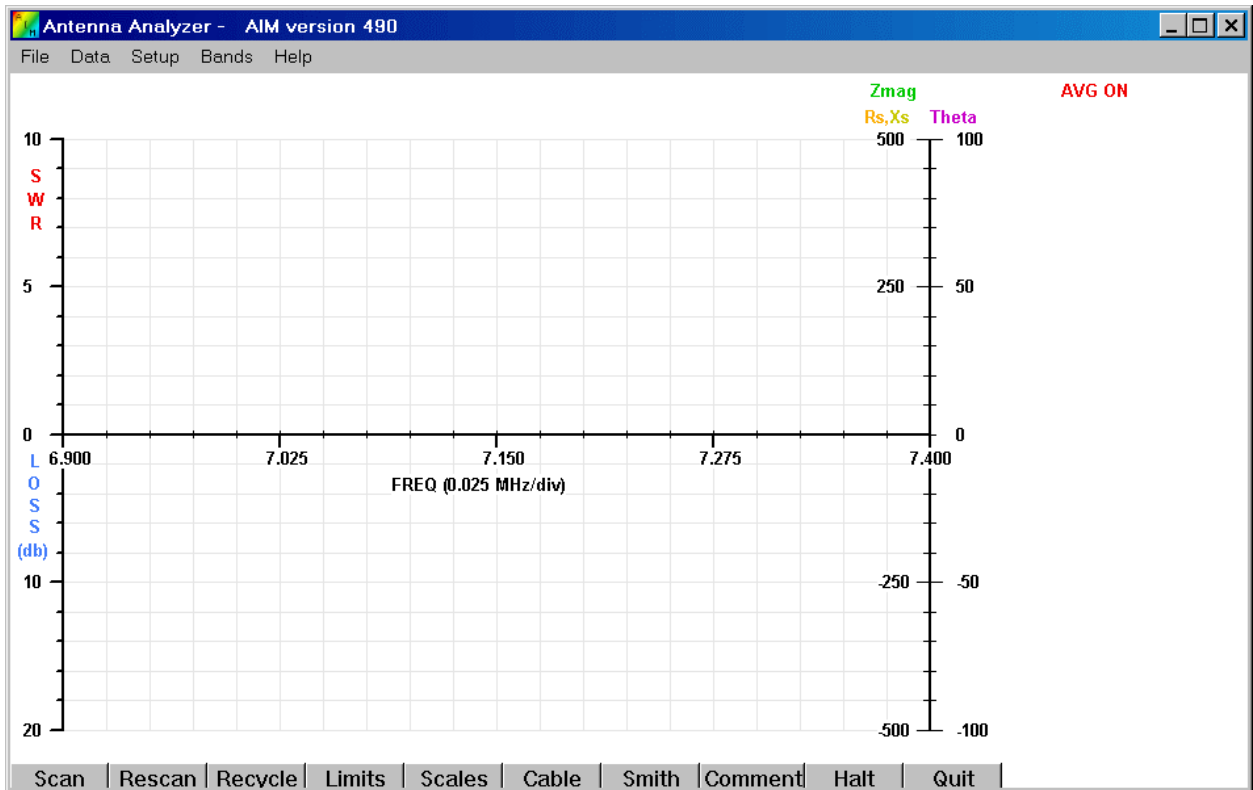
When the AIM4170 is present, it must be turned on **before** the PC program is launched. If the PC program starts when the AIM4170 is not connected and powered up, the program will automatically enter the DEMO mode.

For a quick test, connect the calibration resistor 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 AIM4170 is functioning.
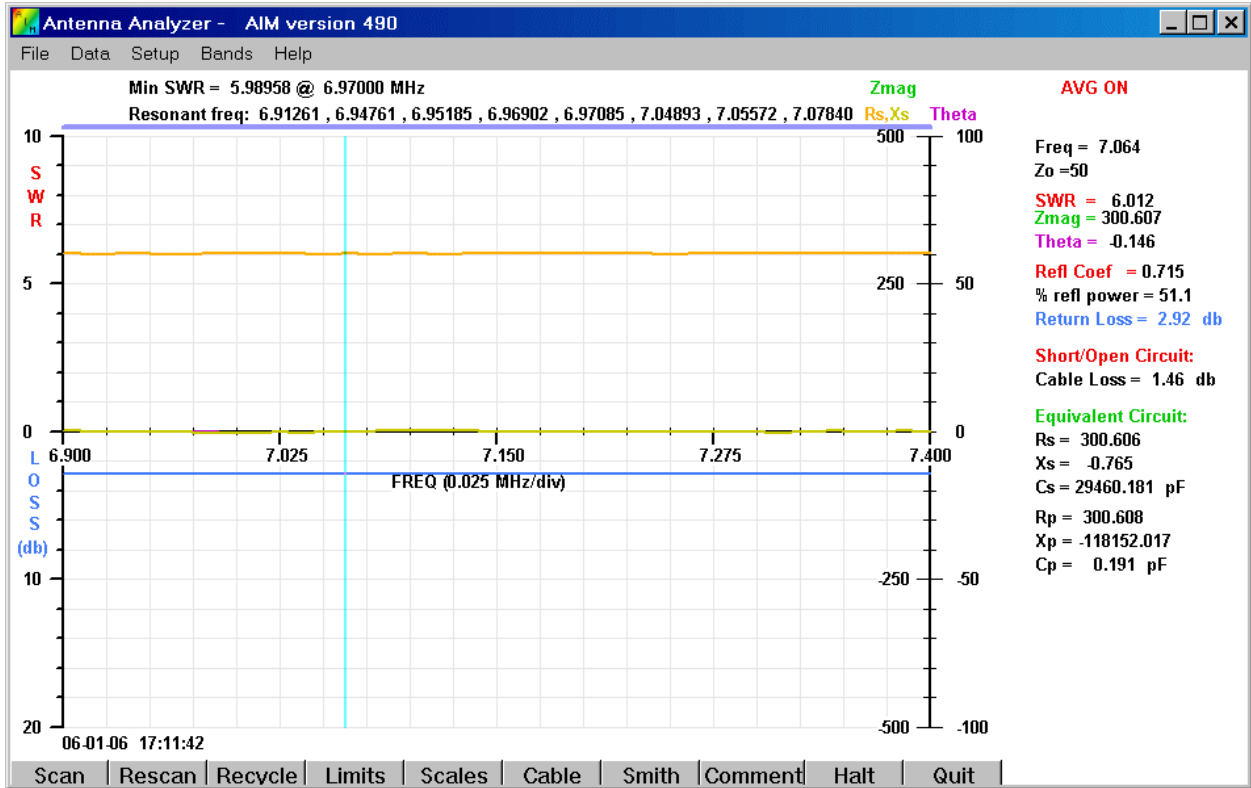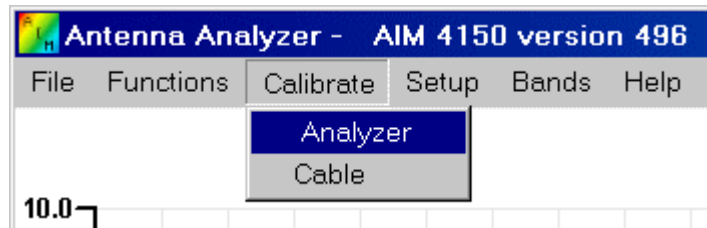
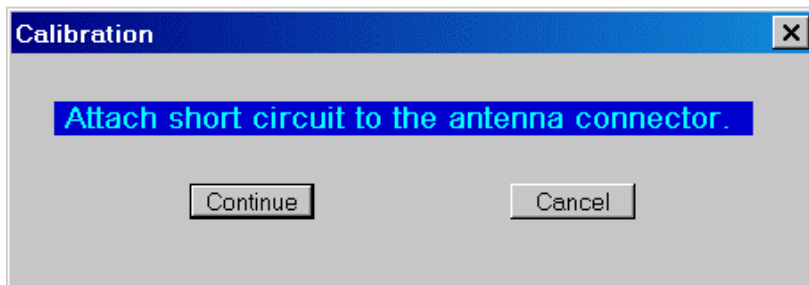Scan using a 301 ohm resistor for a test load.

Calibration

The AIM4170 has **no internal adjustments**. There are no trim pots or caps inside. All the calibration is done with the following software procedure.

Click on the **Setup** menu and select **Calibrate Analyzer**.

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

Attach the BNC connector with an internal short circuit (this is included with the AIM4170, it is labeled "short").

If this shorting connector is not handy, then a piece of wire, like a resistor lead, can be used with good results too.

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

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

Sometimes when calibrating with a coax stub or an external filter connected to the AIM RF port, the impedance may appear to be significantly difference from a short circuit at 1MHz 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 YES. Otherwise, click NO to abort the cal procedure. Then after connecting the desired load, restart the calibration.

Then it will display a message box, shown below:
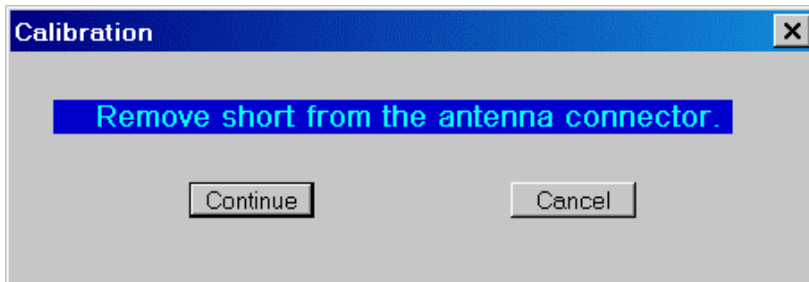
Replace the short circuit with an **open connector** (included with the AIM4170) and then click **Continue**.

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

For the best accuracy, especially at VHF 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 the UHF/BNC adapter (or another adapter) leave it on the output connector of the AIM4170 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 calibration procedure can also cancel the effect of a piece of coax that is used as a jumper to connect the AIM4170 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.

Calibration

Connect a standard resistor.

Continue   Cancel
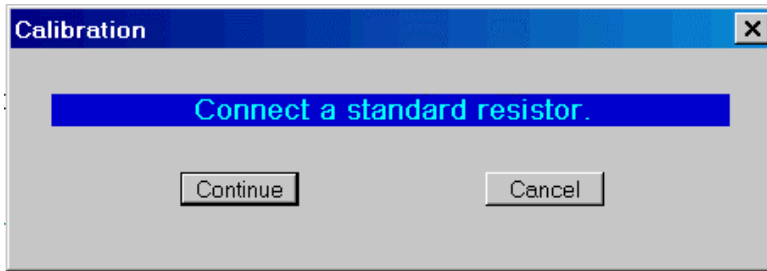
After taking several reading of the open connector, the program will prompt for the standard resistor with a value between 50 ohms and 500 ohms. This resistor should be mounted on a connector like those used during the open and short calibration steps. The exact value is not critical. Enter the value you measured with a digital ohmmeter and click Continue. If you are using the cal resistor that is included with your AIM, the number printed on it should be entered. If you have a different cal standard, use that value.

After reading the standard resistor, the Red LED goes off and the prompt for a calibration data file name appears:

Save Cal Data

Save in: Antenna Analyzer

_cal_AIM_490_50ohm.acal
_cal_AIM_490_200ohm.acal
_cal_AIM_490_301default.acal
_cal_AIM_490_default.acal

File name: Save

Save as type: Calibration files   Cancel
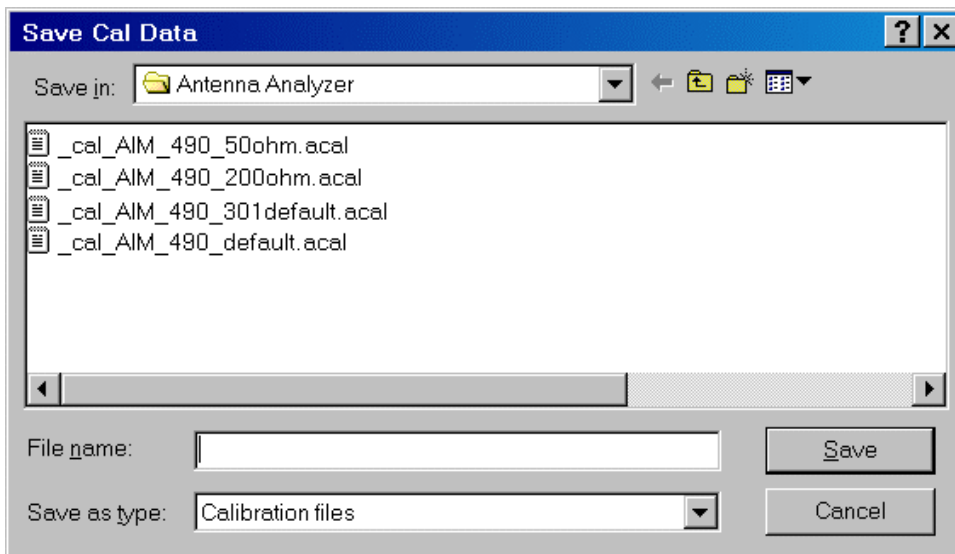
Enter the name of the calibration file and click "Save". There is no restriction on the name of the cal data file. It's extension is automatically set to .acal ("**a**nalyzer **cal**"). Any of these cal files can be recalled latter using the menu option "File" → Load Cal File.

Then the cal complete message box is displayed as shown below:
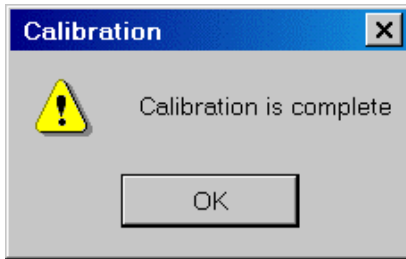
Click **OK** to continue.

Each time the AIM4170 program starts, the last calibration file that was used will be read to restore the cal data.

 Since there are no adjustments that have to be made inside the case, the calibration is very stable.

This completes the calibration procedure. Now you are ready to begin testing your antenna.

NOTE: Before connecting a transmission line to the input of the AIM4170, 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 AIM4170 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.

Commands

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 most common commands use the buttons along the <u>bottom edge of the screen:</u>

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.

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.

 POINT DATA (D) - Measure the impedance at a specified frequency.   This is used for diagnostics. The measurement can be a single-shot reading or repeated about 2 times per second until the point data window is closed.

In the recycle mode, a set of buttons appear in the data window to allow the **test frequency** to be incremented or decremented.

 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 0.1MHz to 170MHz for the AIM4170.
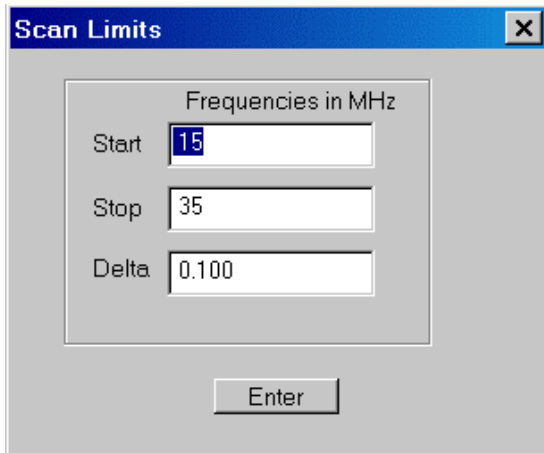
 For example, to scan the 40-meter band, you might enter 6.9MHz for the Start frequency, 7.4MHz for the Stop frequency and 0.01MHz for the frequency Step (the spacing between measured points). This would result in a scan of 50 points across the band. The maximum number of scan points is 300 and the minimum number is 5.
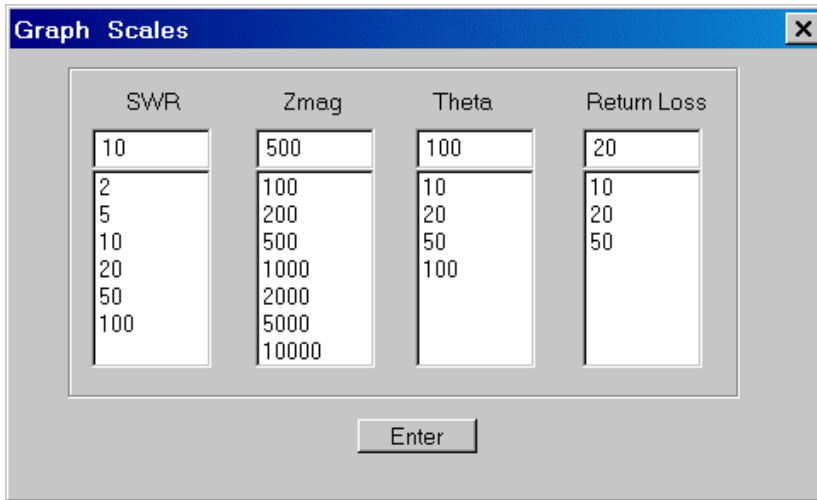
You can also enter a number in the Step (delta) box and follow it with the letter **"p"** for "points" and the scan will use that many data points. If the number in the Step box is followed by a percent sign "%", the step size will be that percentage of the total scan width.

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 15 to 25 points per second, depending on the speed of the PC. The program can be run on older, slower computers with Windows 95 but the scan rate may be slower.

After a scan, new start and stop limits can be set by pressing the **control key** and holding the **left mouse button** to set the start frequency. Drag the cursor to the right while holding the left mouse button. Release the mouse button to set the new stop frequency. The frequency step size will be automatically set for 100 data points in the new scan interval.

To restore the original scan limits, press the **shift key** and click the **left mouse button** one time. The scan limits will switch back and forth each time the left mouse button is clicked.

SCALES - When this button is clicked, a dialog box pops up for entering the full-scale values for: SWR, Zmag (impedance magnitude), Theta (deg), and Return Loss (db).

 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.

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

SMITH – A window is displayed with a Smith chart showing a plot of the reflection coefficient versus frequency. As the cursor is moved with the mouse over the original plot, a marker dot is displayed at the corresponding point on the Smith chart and the relevant data is displayed in this window.

Note, the point that is highlighted on the Smith chart corresponds to the frequency on the horizontal frequency axis of the *original* graph. This graph is under the Smith chart and the horizontal axis may not be completely visible, but the actual frequency that the cursor is pointing to is displayed on the Smith chart itself.
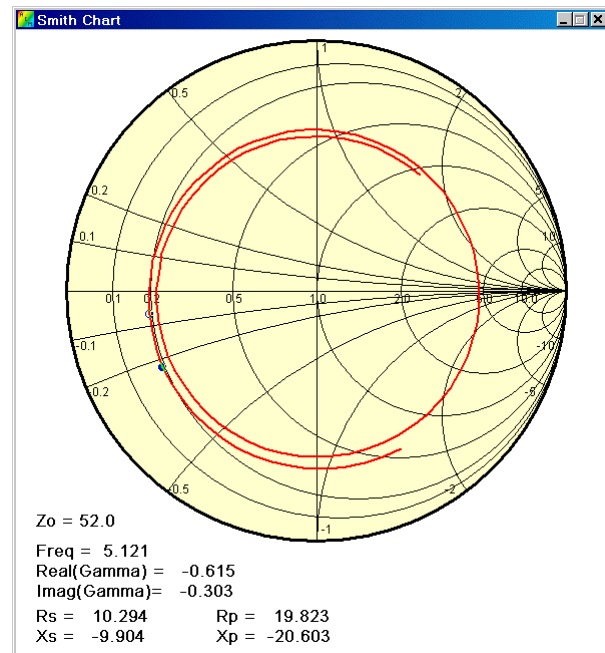
This particular plot corresponds to the scan shown on page 23 which uses 28 feet of RG58/U terminated with 301 ohms.

[The center of the Smith chart corresponds to 52 ohms in this example. The Zo value is specified using the Setup Menu.]

```
Smith Chart

Zo = 52.0

Freq =  5.121
Real(Gamma) =   -0.615
Imag(Gamma)=  -0.303

Rs =   10.294          Rp =   19.823
Xs =   -9.904          Xp =  -20.603
```

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.

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.

Commands on the menu bar at the top of the screen:

FILE:

Load -- Load a raw data file from a previous scan. After this file is loaded, its data is just like the original scan. The 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.

Save -- 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 **last** scan. 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 .scx. The .scx file has data in a format that can be read into a spreadsheet. The format of this file is shown in Appendix 5.

Print -- Print the graph on the system printer.

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

Load Config -- One of several configuration files can be loaded. A selection window will show all the files in this folder with the .cfg extension.

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

FUNCTIONS:

Measure Cable -- This command is used to measure several parameters related to the transmission line. A message box pops up to prompt that the cable should be either **open** or **shorted** at the far end for these tests to be valid. After this is ready, click OK to continue.

Other dialog boxes prompt for the velocity factor and the length of the cable, if known. If the length is entered as Zero, the length will be determined using the velocity factor that was entered. If the length is non-zero, the length is assumed to be accurate and the velocity factor will be determined.

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.

Refer to Antenna --   The impedance readings are transformed to be equivalent to readings directly at the antenna terminals. Select either Method A or Method B from the drop-down menu. Click OFF to exit from the "refer to antenna" mode.

Constant Freq --   Output a constant frequency that can be used as a test signal. Initial frequency accuracy is +/-30ppm. At 1MHz, the output amplitude into 50 ohms is about 25 to 30mv-rms (-18 dBm) and somewhat less at higher frequencies.

Measure Crystal --   Measure the parameters of a quartz crystal automatically. Details are in a later section.

¼ Wave Stub --   Adjust a coax line to be 1/4 wavelength at a given frequency. The target frequency and the initial length (in feet) of the coax are entered in the dialog box. Then the graph runs in recycle mode and displays the amount of the line that needs to be cut off ("Excess Length") to reach 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.

CALIBRATE:

Analyzer--   Calibrate the AIM4170 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.

Cable --   Data for the cable is generated to be used by the "ref to antenna" mode when reference Method A is selected.

SETUP:

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

Enter Zo --   Enter the nominal impedance of the transmission line. This is used to calculate the SWR. This is a real number, there is no imaginary part.

Average Readings-   Each data point is obtained by averaging two or more ADC
                       readings to reduce the effect of measurement noise. 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 2 and 16.

Smoothing --   Smooth data by averaging the specified number of scans. This is a
                      running average and will continue until it's turned off or until
                      new scan limits are entered.

Enter Comm Port --   Enter the RS232 port used for communication.
                      Port values can be 1 to 65K. This is saved in the initialization file
                      that's read each time the program is started.

Find Comm Port --   Automatically scan from comm port 1 to port 64 to find the one
                      that is working. This is useful with USB adapters since it isn't
                      always easy to tell which comm port they are assigned to.

Morse --   Three values can be sounded out:

                        Sxx.xx= SWR,   Zxx.xx=Zmag, Txx.xx=Theta.

                       The decimal point is coded as "R". This is active when
                       the "Measure Point" function is used (see above). Morse output
                      is
                      enabled by clicking the "ON" button and disabled by the "OFF"
                      button.

AutoPwrOff   This button enables/disables the automatic power down feature of
                       the analyzer. The enable/disable flag is saved in the analyzer
                       initialization data when you exit from the program (QUIT) and
                       restored each time the program is started again. The green LED
                       on the front panel of the analyzer blinks when this command is
                      executed. The default timeout delay is 10 minutes.

                       If you never use batteries, you may want to leave this feature
                      turned off.

BANDS:

Highlight --   Highlight the amateur radio frequency bands. These frequencies
                       are specified in the configuration file (*.cfg). The start/stop limits
                       do not have to be the actual amateur bands. The highlight color

can also be specified in the config file.

160..2 meters   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.

Band A..D   User specified band limits. Same as above.

UTILITIES:

L-C Matching   This program which is available on the web takes the impedance
Networks by WY2U   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.

HELP:

Help --   A help file pops up in the local browser. This is in html format
                       and can be edited by the user if desired. The file name is
                       "help_xx.htm".

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

Data Window

After a scan (or after loading a file from disk), the mouse can move a 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:
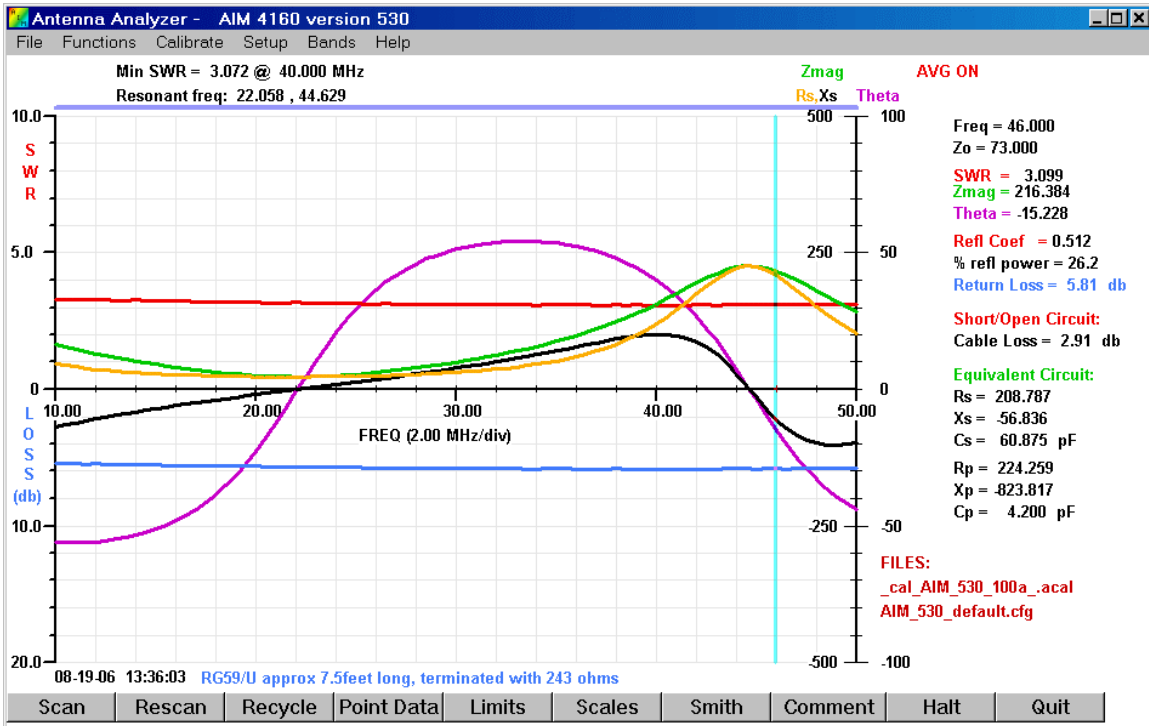
The light cyan vertical line is the cursor. It moves with the mouse whenever the mouse pointer is inside the graph area. In this example, the frequency is 46.000 MHz. The frequency changes in 1-pixel increments due to the mouse resolution, so some specific frequencies may not be displayable. The data 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. There is an option in the *configuration file t*o enable the cursor only when the left mouse button is pressed.

Data in the window shows the characteristic impedance, Zo, has been specified to be 73 ohms. The SWR at 46.000 MHz is 3.099, Zmag=216.384 ohms, and Theta= -15.228 degrees. Note how the SWR decreases slowly as the frequency increases. This is due to loss in the coax. Less energy arrives back from the reflection at the far end, so it appears to the measurement system (or the transmitter) that the reflection is not as bad as it really is.

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, Theta, is <u>negative</u>, the equivalent components, Ls and Lp, change to Cs and Cp automatically.

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. At these frequencies, the magnitude of the impedance is a maximum or a minimum.

The names of the calibration and configurations 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.
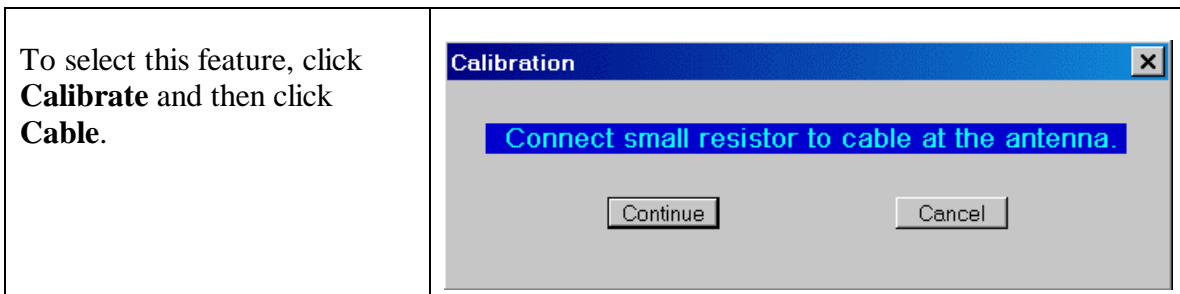
Data Referred to Antenna

Sometimes it is desirable to know the impedance at the antenna terminals. Two different methods can be used with the AIM4170. The method described first is more accurate but it requires a careful calibration phase. The second method described later is not quite as accurate but it only requires data from the manufacturer's spec sheet.
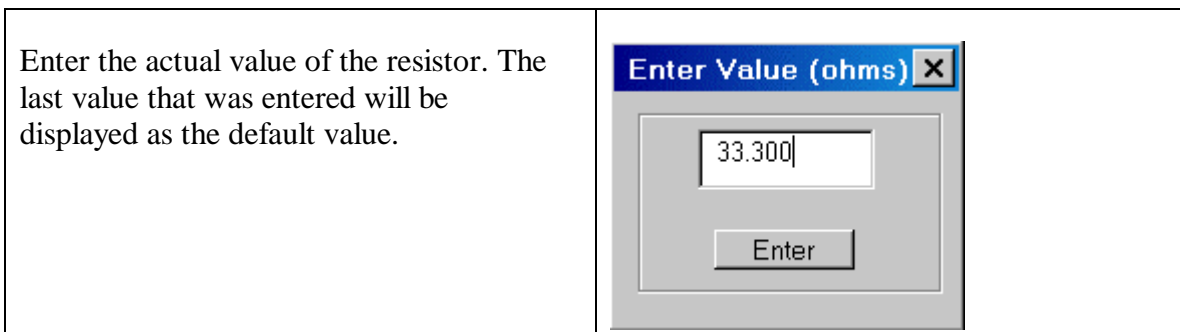
METHOD A:

After a calibration phase where the properties (length and loss) of the cable are determined at each measurement frequency, the measurement made at the transmitter end of the line can be transformed to the antenna terminals. This is done in real-time during the scan and the displayed data is very close to what would be measured if the analyzer were actually mounted at the antenna. The transmission line can be **any length**.

First, click the "Limits" button at the bottom of the screen to specify the frequency range and the frequency step you want to use.

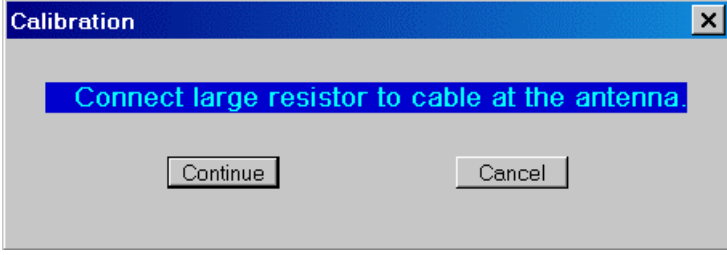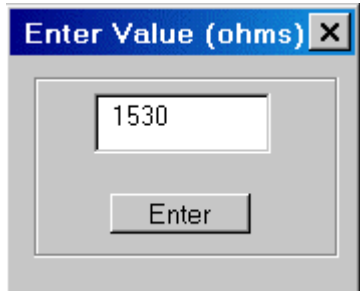|	
To select this feature, click **Calibrate** and then click **Cable**.	**Calibration** ✕ Connect small resistor to cable at the antenna. [Continue] [Cancel]

Disconnect the coax from the antenna. Then connect a small resistor in the range of 20 to 100 ohms at the antenna end of the coax. The actual value is not critical as long as you can measure it accurately with a digital ohmmeter. The resistor can be a ¼ watt size since it doesn't have to handle any power. Click "continue" after the resistor is in place.

Enter the actual value of the resistor. The last value that was entered will be displayed as the default value.	**Enter Value (ohms)** ✕ 33.300 [Enter]

The AIM4170 will now scan the specified frequency range and save a table of parameters that contains information about the cable at each measurement frequency. This is more

accurate than using a single value for velocity factor since the velocity factor is a complex function of frequency.

Next, connect a large resistor in the range of 200 ohms to 2K ohms across the coax. Again, the actual value is not critical as long as it is known accurately. Click "Continue"	**Calibration** ⊠ Connect large resistor to cable at the antenna. [Continue] [Cancel]

Enter the value of the larger resistor (in ohms). The last value that was entered will be displayed as the default value.	**Enter Value (ohms)** ⊠ 1530 [Enter]

The AIM4170 will now scan the specified frequency range and save another table of parameters that contains information about the cable using the large terminating resistor.

After the cable calibration is complete, the data is saved in a user-specified file. Later whenever you turn this feature on, there is an option to use any of the cable-calibration (*.ccal) files that have been saved.

When the reference data is restored from disk, the scan limits will be set to the same values they had when the cable was calibrated.

After calibration, Method A is enabled by clicking:

 Functions -> **Refer to Antenna** -> **A**. **Use cable cal data**.

METHOD B:

An alternative 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.

To select this feature, click **Functions** -> **Refer to Antenna** -> **B. Use cable Zo**.

Then enter the transmission line data in the dialog box.

Cable data	
Length (ft or m)	27.750
Loss dB/100ft @ 1 MHz	0.350
Impedance Z0	53
Velocity factor	0.660

OK   Cancel

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 AIM4170. Put a **short circuit** across the antenna terminals (or disconnect the coax from the antenna) and scan from 1 to 32 MHz 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:

Electrical_length = 0.25*(299.8/F1) meters

= 0.25*(984/F1) 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 very important. 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.

The following pictures show the effect of using the impedance transformation feature. These graph illustrate the results using reference Method A.
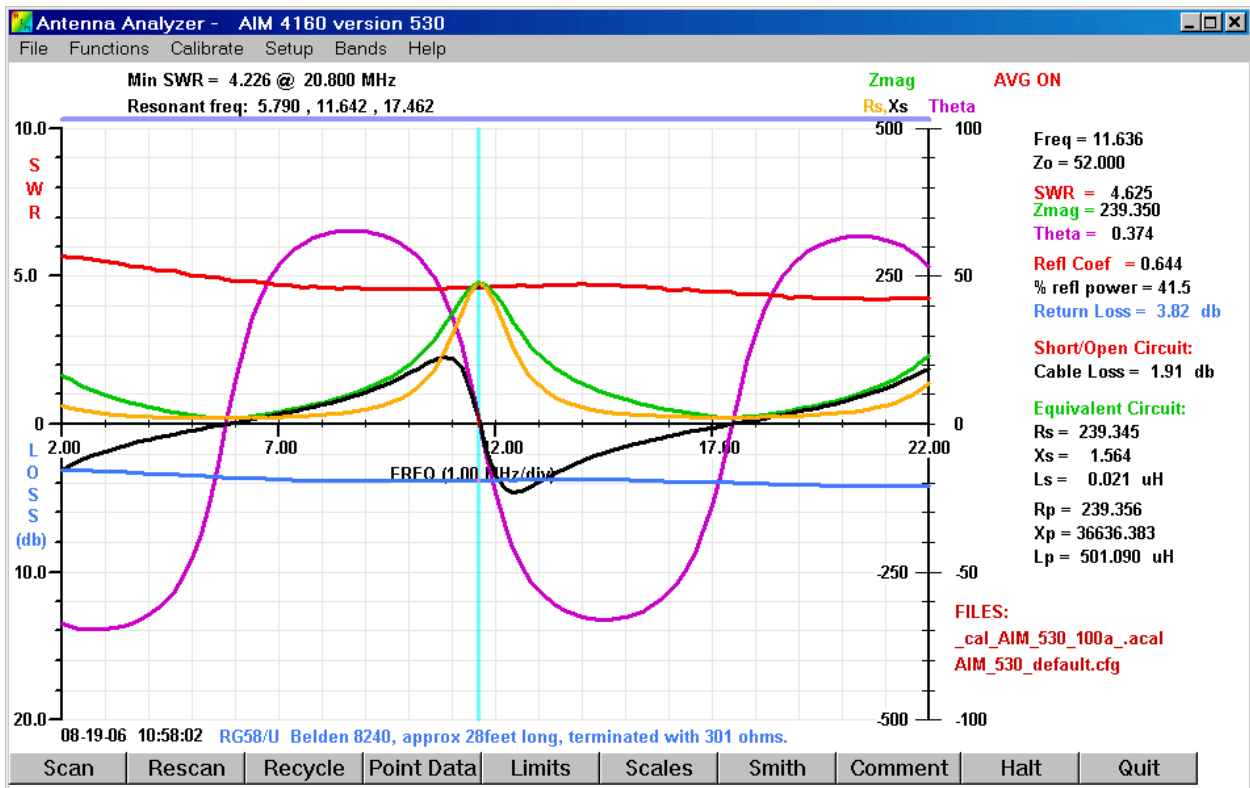

This picture shows an **ordinary** scan with a 301-ohm resistor at the end of 28 feet of RG58 coax. The Green trace is the magnitude of the measured impedance. As expected, this is a complex function of frequency. The magnitude of the impedance at the half-wavelength frequency is only 239 ohms instead of the expected 301 ohms because of loss in the cable.

Now we click **Functions** on the top menu line and **Refer to Antenna**. The legend "Ref to Antenna" is displayed in Red at the top of the graph when this feature is enabled.
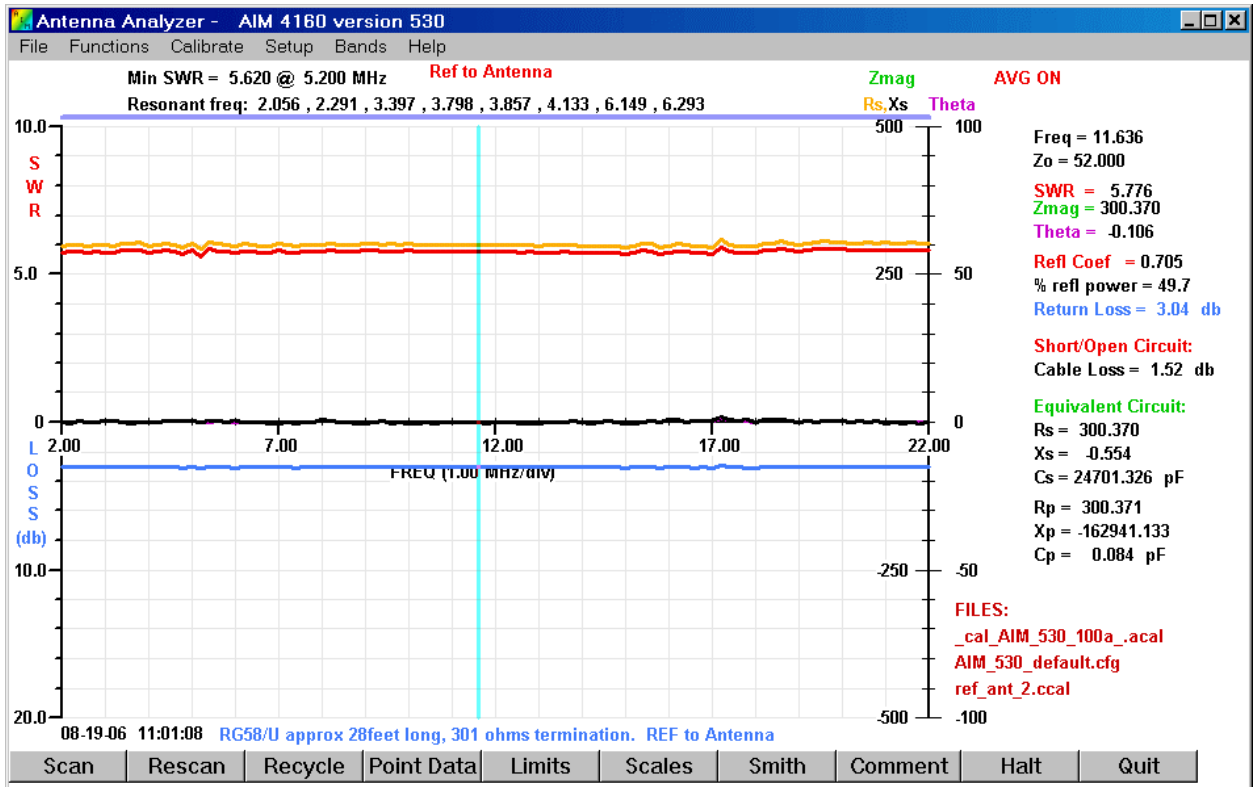
This picture shows the results when the **Refer to antenna** function is selected. The resistor (301 ohms) and the cable are the same as used in the previous graph. The Rs plot (shown in orange) is relatively flat across the frequency range. (The magnitude of the impedance is plotted in green but it is overlaid by the orange plot since the values of Zmag and Rs are so close in numeric value.) The measured resistance at 11.363MHz is 300.4 ohms. It's very close to the true value now because the cable loss has been compensated by the calibration procedure.

The next graph shows the transformation works quite well with a complex load. A parallel R-L-C tuned circuit was used for the load. The first plot shows a scan with the circuit connected directly to the BNC connector. The second plot shows the same circuit at the end of 28 feet of RG58/U after calibrating the cable and enabling the **Refer to Antenna** mode.
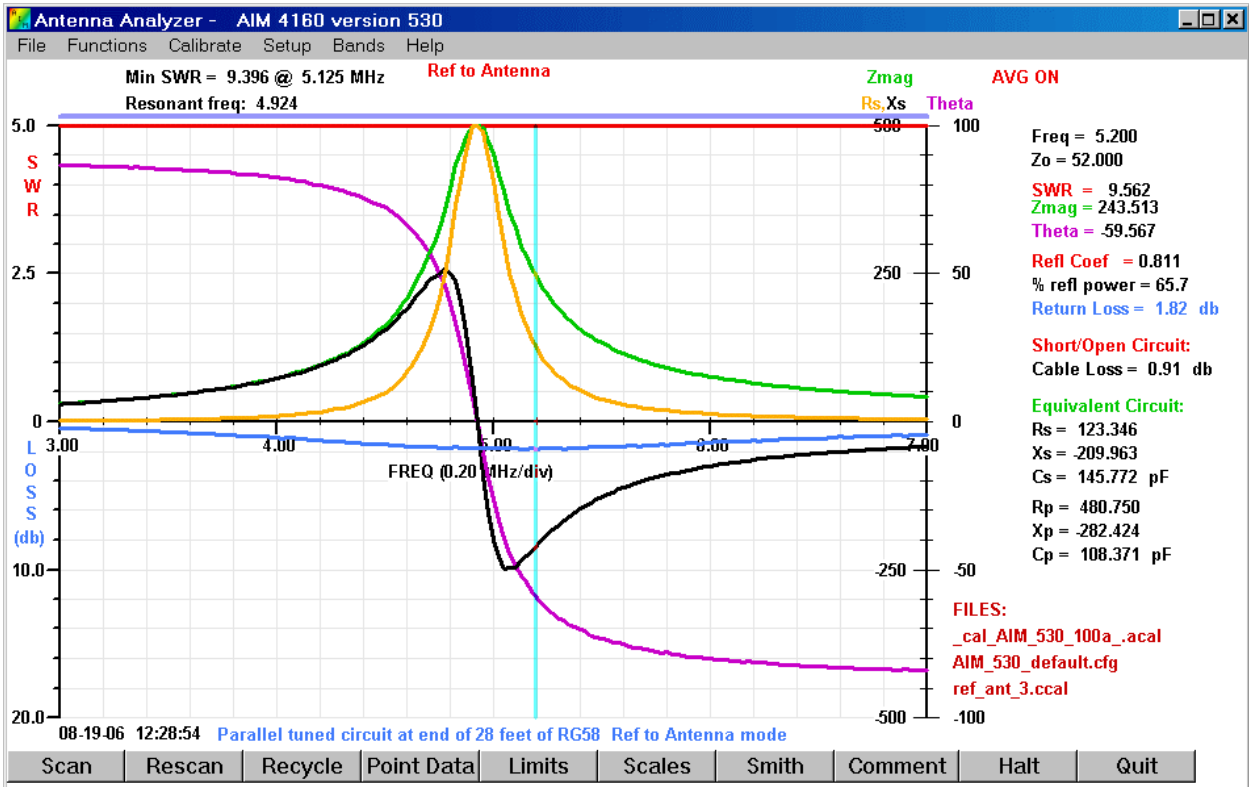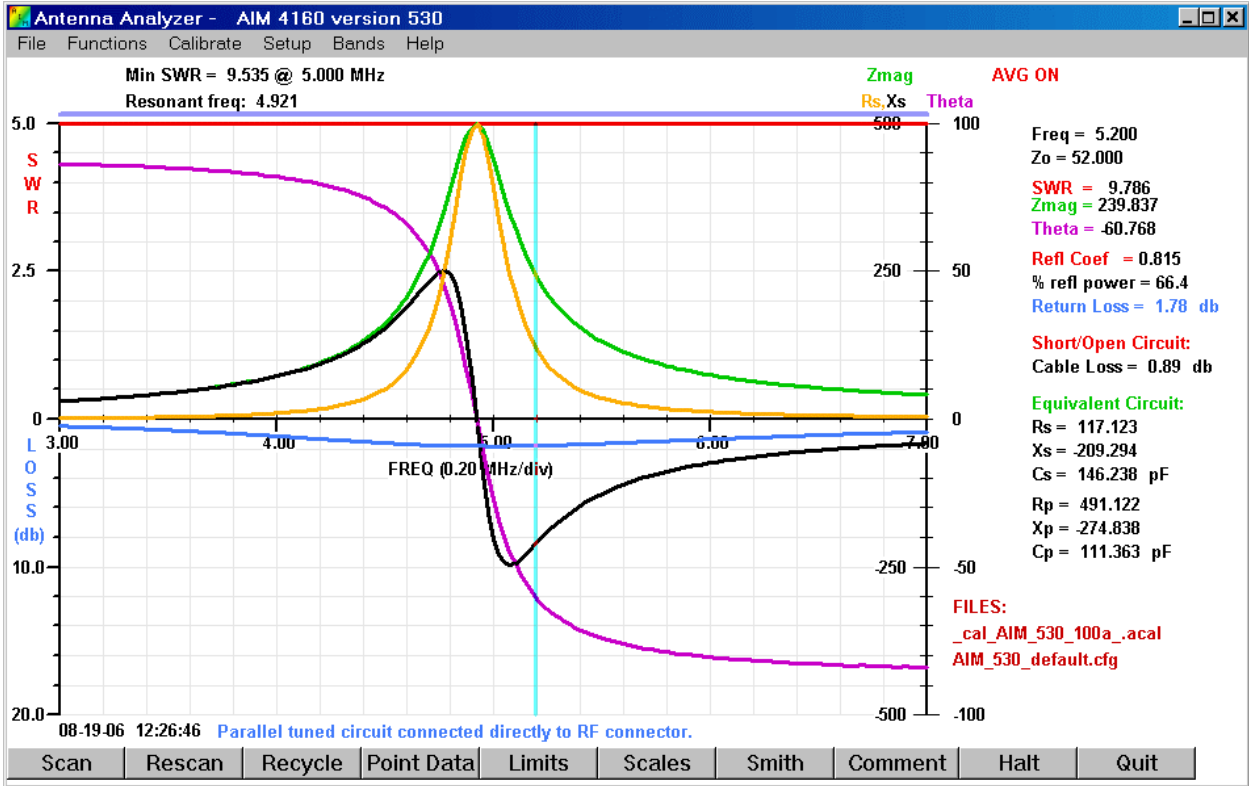
The cursor data at 5.200 MHz is very close for both plots. To exit from this mode, click "Functions" and "Ref to Antenna" again.

AIM4170 Principles of Operation

The AIM4170 is based on the same technology used in the AIM430 and AIM4160.

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 AIM4170 does not use any RF transformers). The current
    sensing resistor does not have to be adjusted and it has excellent long-term
    stability.
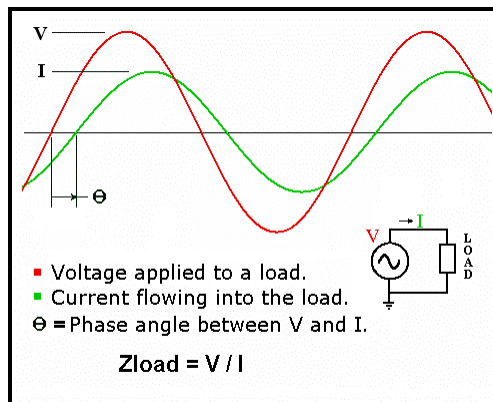
3. Calculate the magnitude and phase of the input impedance. The magnitudes and
    phases of the applied voltage and resultant current are measured with an analog to
    digital converter (12-bit ADC) and their ratio determines the magnitude of the
    impedance. The sign of the phase is also measured 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:
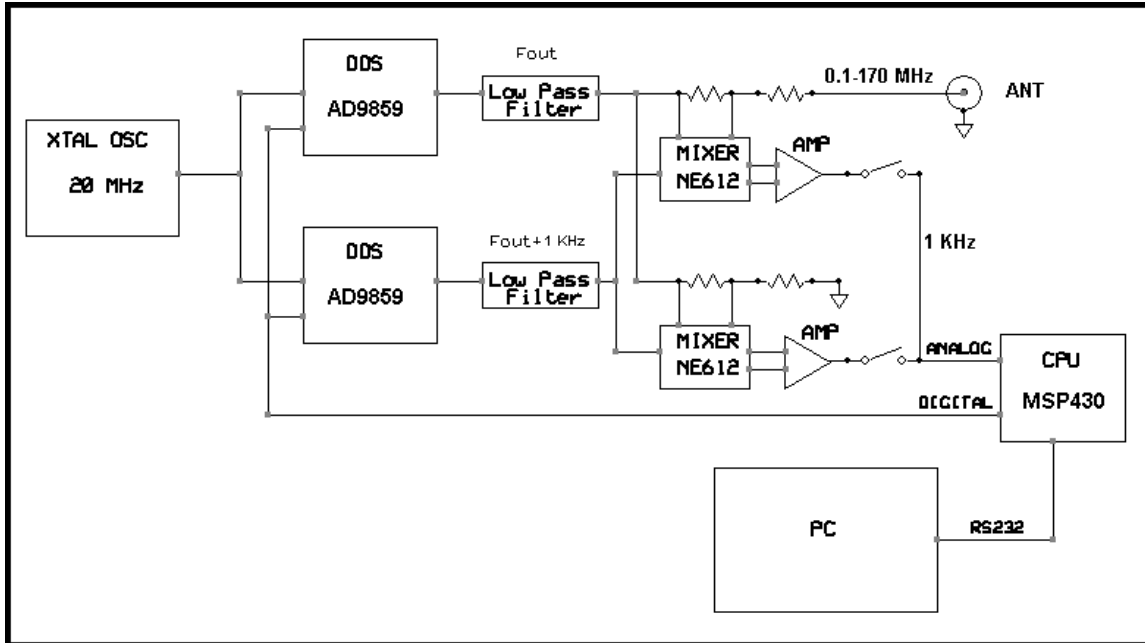
The AIM4170 uses two Direct Digital Synthesizer (DDS) chips. One generates the test signal and the other acts as a local oscillator to heterodyne the RF signals to the audio range. You can read about the basic principles of the DDS at this address:
http://www.analog.com/library/analogDialogue/archives/38-08/dds.pdf

A 20 MHz crystal controlled oscillator drives both of the DDS chips. Inside the DDS, the clock is multiplied by a factor of 20, 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 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 1KHz. Audio amplifiers boost the 1KHz 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 AIM4170 case. The raw data is sent from the microprocessor to the external PC via the RS232 port. The PC calculates the various data values and displays them graphically.

Reflection Coefficient:

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 complex numbers 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 signal is inverted, 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*, Theta, 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(Theta)

Imaginary_part_of_Rho $= rho_b =$ Magnitude_of_rho * SIN(Theta)

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).

Measurement of Crystal Parameters

Quartz crystals can be modeled as shown below:

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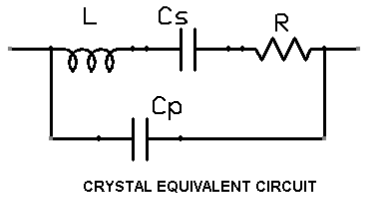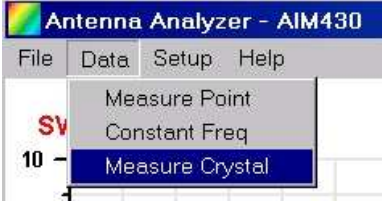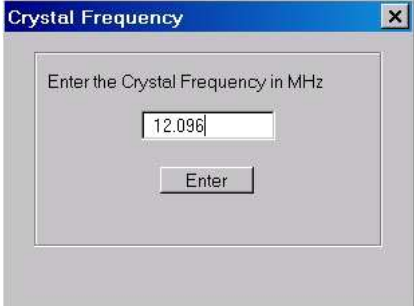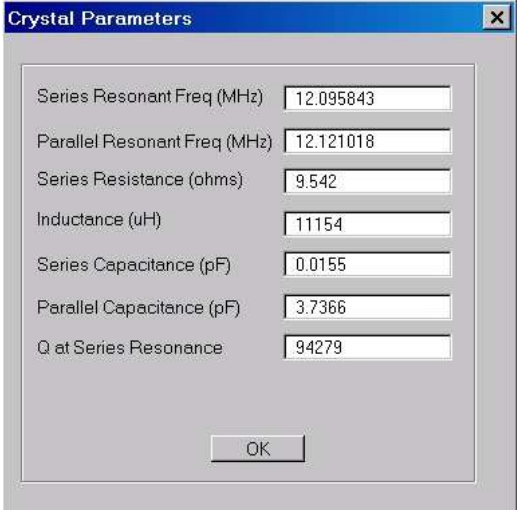
The series resonant frequency is the lower of the two frequencies. It's determined by L and Cs. The higher parallel resonant frequency is determined by L and Cp+Cs.

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.

(The screen pictures in this section were taken using an AIM430. The same features are included in the AIM4170.)
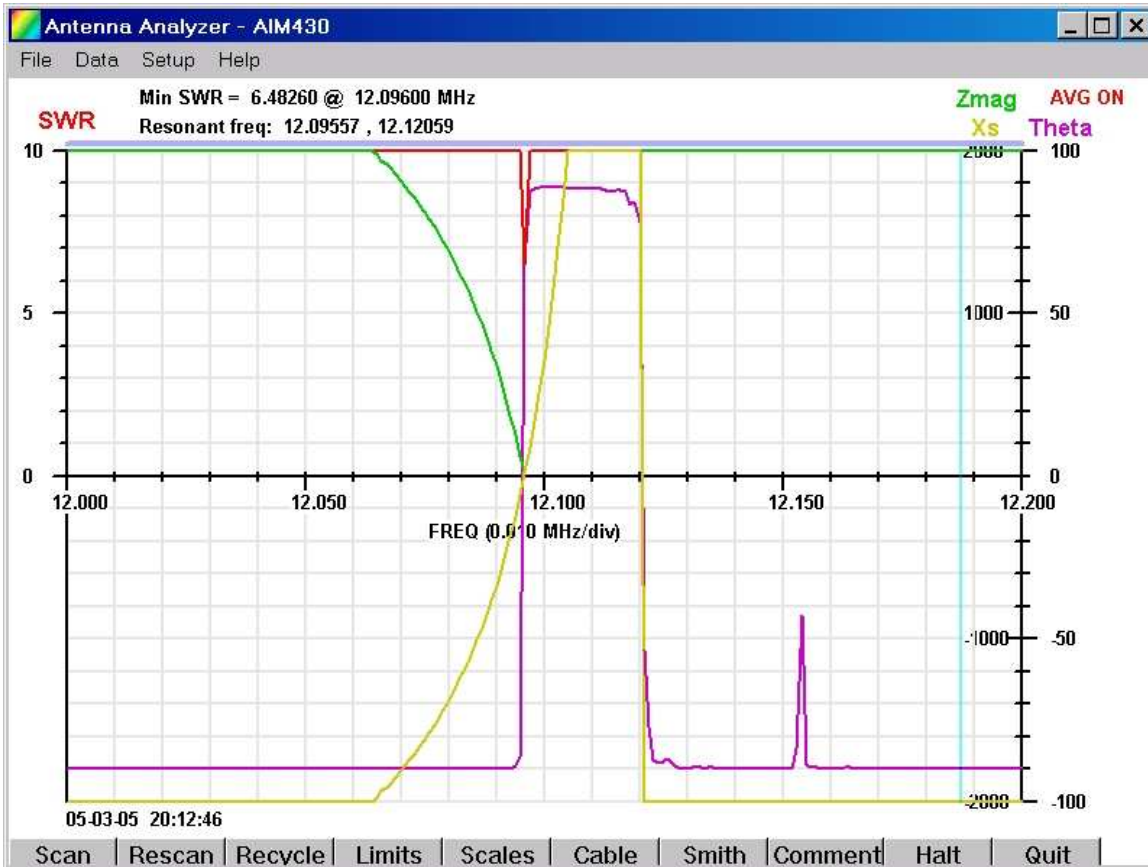
Automatic Crystal Parameter Calculation

The calculations to find the crystal parameters are tedious so they have been combined into a procedure than can be called from the Data menu. First click "Measure Crystal":	
Then enter the resonant frequency:	
After a few seconds the crystal parameters will be displayed:	

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; the numeric value is Rs in the Data Window.
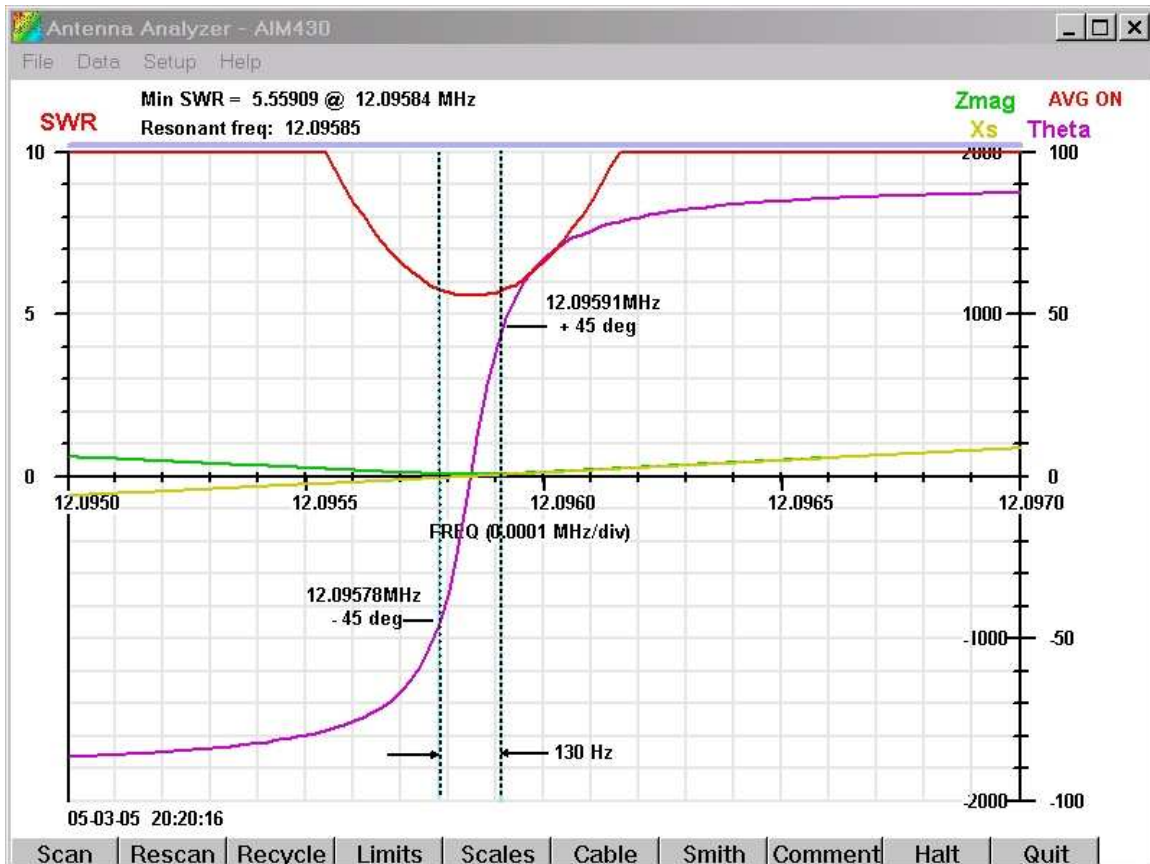
At frequencies well below the series resonant point, the impedance value is the total capacitance, Ctotal, which is essentially equal to Cparallel.

Ctotal approx = 4.5 pf

The value of Cseries is given by:

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

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

Cseries = 4.5pf * 2 *(12.12059 – 12.09557)/12.12059 = <u>0.0186pf</u>

The inductance L is given by:

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

L = 1/(4*pi*pi*12.09557MHz^2*0.0185pf) = <u>9308 uH</u>

The **Q of the crystal** is found by measuring the two frequencies F1 and F2 on either side of the Freq_series where the **phase angle** is +/- 45 degrees.

Q = Freq_series / (F2 - F1)

Q = 12.09585/(12.09591 – 12.09578) = <u>93045</u>

Frequency Source

The AIM4170 can be used as a signal source for testing electronic circuits, such as radio receivers. The programmed frequency has a nominal accuracy of +/-30ppm and it can be calibrated with respect to WWV at 10MHz. The amplitude of the output is not regulated by an AGC circuit but it is flat within 1 db across any amateur band.

The flatness can be improved by terminating the output of the AIM4170 with a 90 ohm resistor before connecting the 50 ohm coax to the circuit under test. If the interconnecting cable is 75 ohms, the AIM4170 terminating resistor should be 225 ohms. If flatness is not important, the coax can be connected directly to the AIM4170.

The nominal signal delivered to a 50-ohm load is about 30mv rms. If an extra 90 ohm terminating resistor is used, the signal level will be about 7mv rms across 50 ohms.

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

To calibrate the frequency to WWV, tune in WWV at 10MHz and adjust the AIM4170 output to zero beat with it. Then click the "cal" button shown in the dialog box below. This will apply a correction to all frequencies that are programmed later. The correction is also saved in the .ini file and automatically recalled each time the program starts up.
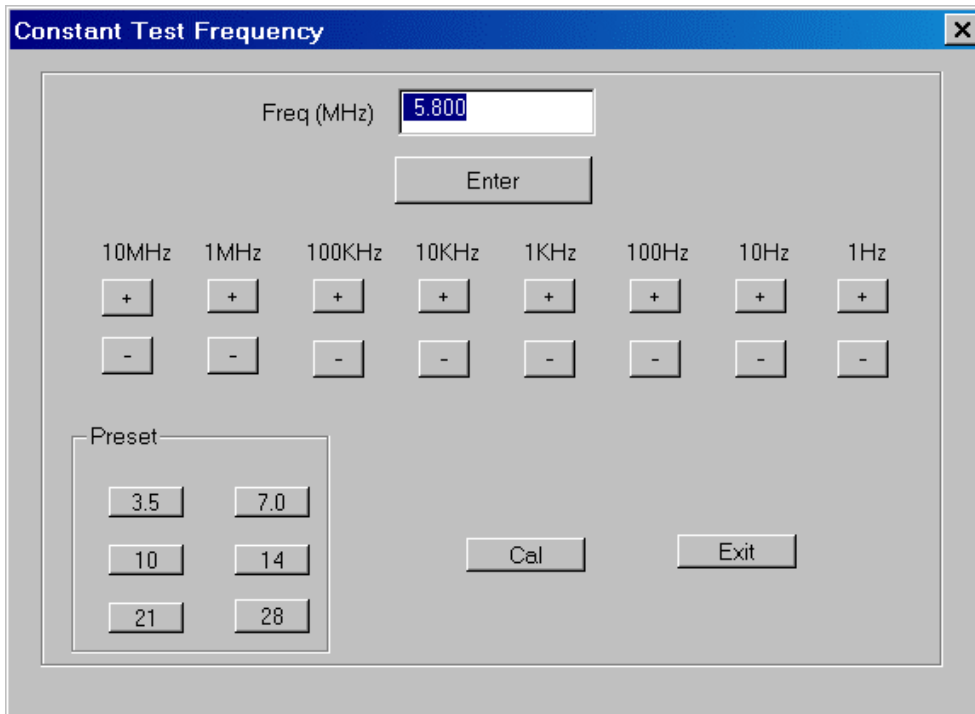
Appendix 1 – AIM4170 Specifications

Frequency Control: Digital Synthesizer 0.1 - 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 2K ohms

Accuracy: 1 ohm +/- 5% of reading up to 60 MHz
                   10% of reading up to 170 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.

Smith Chart display.

Data can be referenced to the antenna terminals.

RF Output: 20 microwatts max; BNC connector (UHF female adapter included)

Spurious output: –30dBc or better

Max stray RF input while measuring: 150mv peak (-3.4dBm)

Max safe RF input: 2V peak (+19dBm)

PC Interface: RS232 (6 foot cable included). Data rate = 57.6K baud

Display: Graphics output on PC screen. (A 1024x768 or larger screen is recommended.) Mouse controlled cursor for digital parametric readout. Morse code output for selected parameters.

Power Supply: 6 to 15 VDC at 250ma max (120VAC power supply included)

Battery power source can range from 6.0 to 15V. Required current is approximately 250ma when a measurement is in process, 50ma when idle. Auto-power-off after 10 minutes of inactivity. (Batteries are not included.)

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

Software for the analyzer hardware controller and the PC data analysis is upgradeable in the field. Software updates are available from W5BIG.com and they are **free**.

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) = 6 + j12

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, Theta, associated with this complex number can be calculated by:

Theta = 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 (S, Z and T can be output in Morse code if desired).

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.

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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 AIM4170. 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.

If the comm port assigned to the USB adapter is not known, try using the "Find Comm Port" command under the "Setup" menu. This will scan from comm 1 to comm 64 to find which port is working. The comm port assigned to the USB adapter can also 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.

When the AIM 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 AIM4170 power. The green LED on the AIM front panel will flash and the text displayed on the computer terminal is the following (or similar):

Antenna Analyzer AIM4170
from Array Solutions
  Oct 13, 2006

If this is displayed, it means the data from the AIM to the computer is okay.

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.

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, Theta(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, Theta
//
// 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                   // theta 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     // Theta : 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 theta
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
```
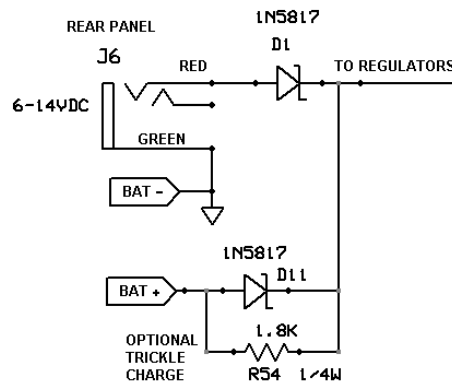
Appendix 6 - Battery Operation

The AIM4170 can be powered with a battery for portable operation. Battery voltage can range from 6.0 to 15V. The required current is 250ma 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 tab 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.

Alternatively, the battery can be installed inside the AIM4170. 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.

J6 is the power connector mounted 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 AIM4170 but there is a space on the PCB for mounting a through-hole resistor.	
This photo shows how an optional battery or battery pack can be mounted inside the case. (An AIM4160 is shown here, but the AIM4170 is electrically the same. The battery can be mounted on the top cover of the AIM4170.)	
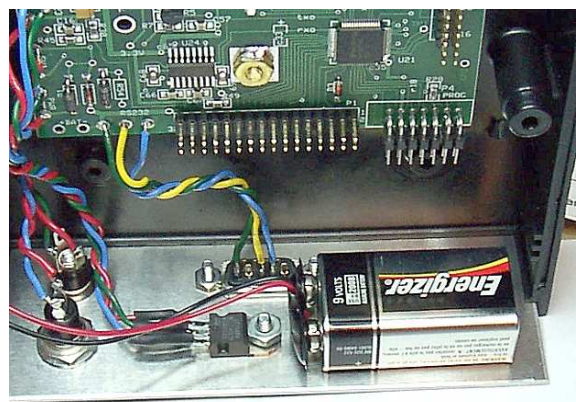
In the lower left corner of the board are shown the pos(+ RED) and neg(- BLUE) battery connections.

D1 and D11 are included on the PCB. There is an open space to install an optional R54 for charging a battery.
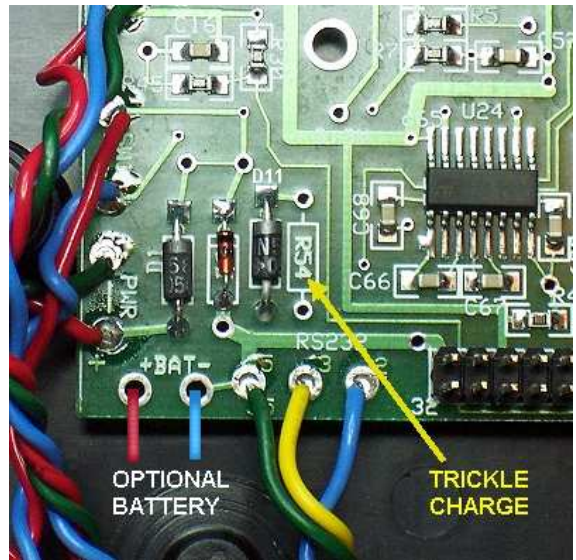
Appendix 7 – Saving Screen Shots

Pictures of the scan can be very useful for documentation. The first step is to copy the screen image to the clipboard by pressing the **ALT** key and then the **Print Screen** key. This will transfer the **active** window to the clipboard. If you want to copy the entire screen, just press the **Print Screen** key.

The screen image can now be inserted into a program, such as **Microsoft Word**, **Paintshop** or **Paint Shop Pro** by pressing **Control-V**.

The Windows operating system also includes a standard accessory program called "**Paint**" that's 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** or **.jpg**. (.gif is preferable since the quality of the line drawing is better than .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. Several 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=Theta main scan
200,180,240 light magenta=Theta 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.

   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)
// END of config file

Appendix 9 – Component Test Fixture

The AIM4170 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 99354, 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.

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