Antenna Analyzer AIM430

By Bob - W5BIG
© Sept 19, 2005

Table of Contents

Quick Start

Loading the Software:

The AIM430 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 430" 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 "AIM430_xx.exe" is the actual executable file. It is ready to run without going through an installation process. When later versions of the program are released, the number "430_xx" may 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 AIM430_xx.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 needs 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 AIM430 program and click on the **Setup** menu at the top of the screen. Then click on **Comm Port** and enter the port number 1,2,3 or 4 that you want to use. This number will be saved in the setup file called *analyzer.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 AIM430 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 AIM430 can be operated on battery power for remote operation with a laptop computer. The current required is about 150ma while a measurement is in progress and about 30ma when idle.

Batteries are not included with the AIM430 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.

Be sure the maximum input voltage at the DC power connector does not exceed 18 volts. The minimum input voltage required is 6.0 volts.

Initial Operation:

Launch the AIM430_xx.exe program. You will see a graph similar to this:
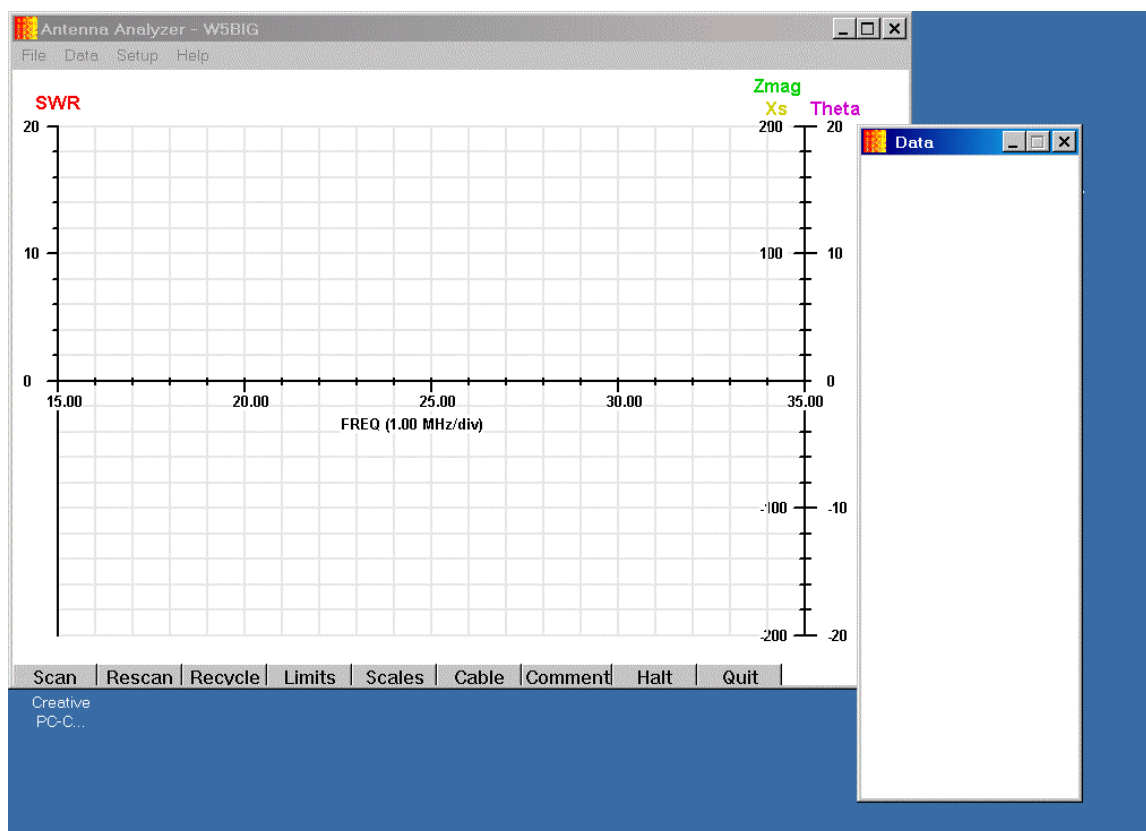
If you request a communication between the AIM430 and the PC when the AIM430 power is turned off or the RS232 cable is not connected, the program may get confused. This doesn't do any harm but you might have to close the AIM430 program on the PC by clicking the X in the upper right corner and restart it **after** the hardware is powered up.

For a quick test, 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 (roughly similar to the picture below). The actual values are not important, but this shows the AIM430 is functioning.
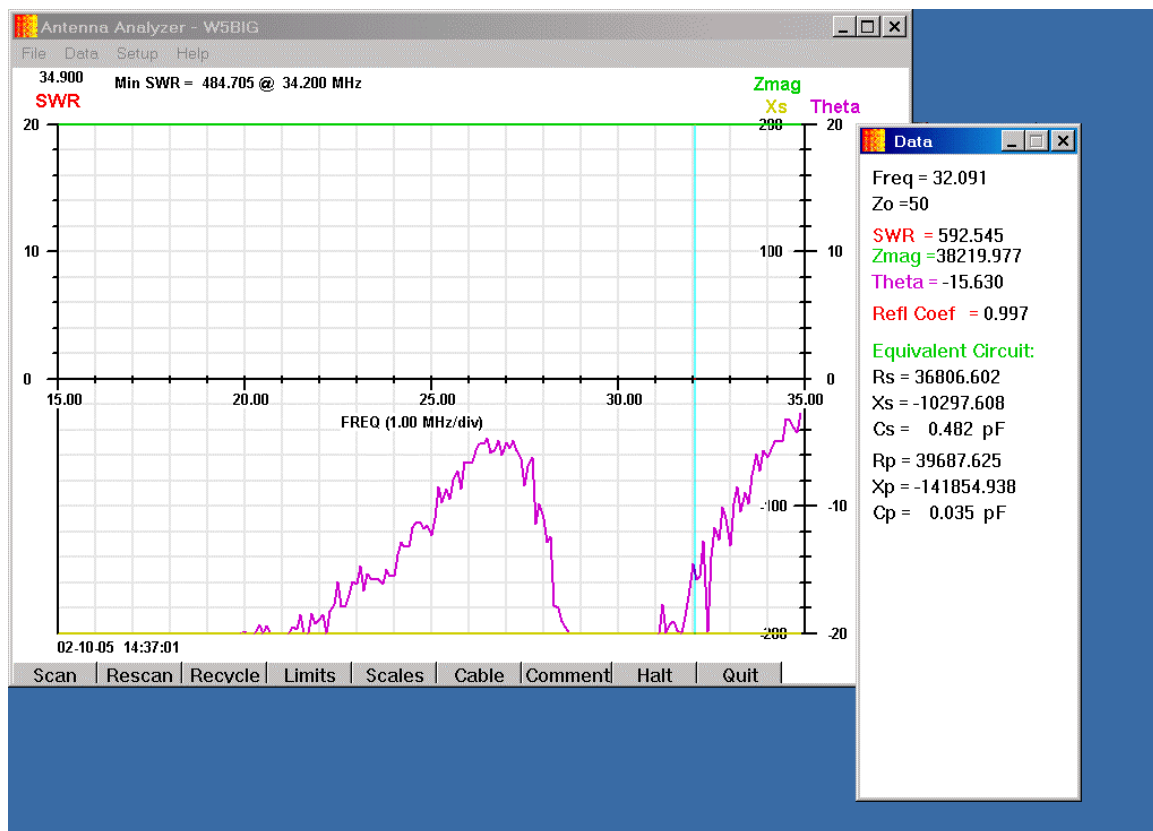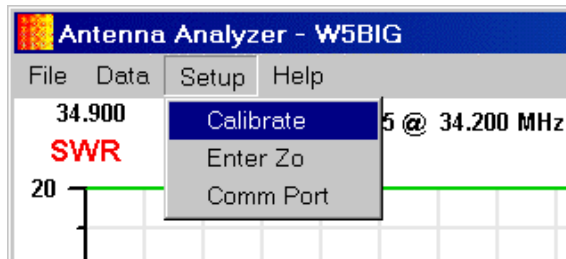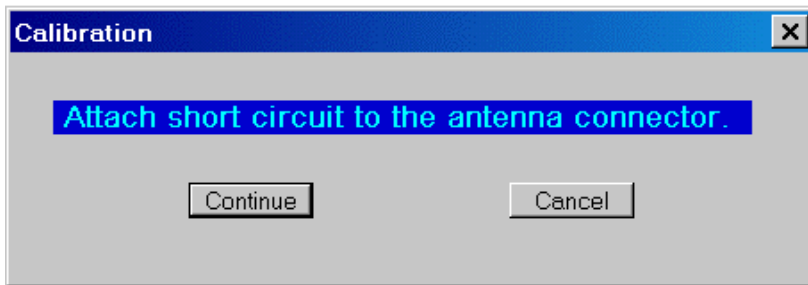

The calibration procedure is next.

Calibration

The AIM430 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 AIM430, 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**.

Then it will display a message box, shown below:
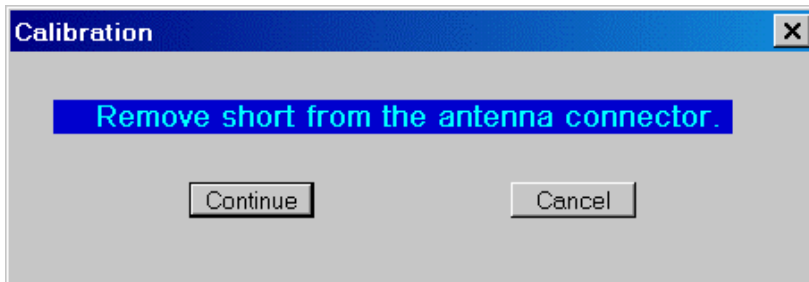
Remove the short circuit and then click **Continue**.
(The Red LED will stay ON during this process.)

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

*NOTE: If you are using the UHF/BNC adapter (or another adapter) leave it on the output connector of the AIM430 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 Red LED goes off and the cal complete message box is displayed as shown below:
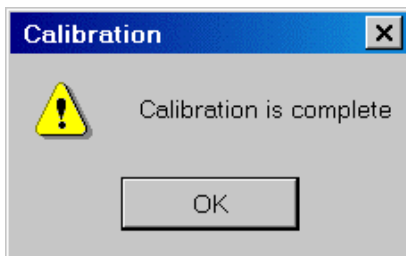
Click **OK** to continue.

The new cal data will be saved automatically in the AIM430 folder in a file called "**_cal_.txt**". Each time the AIM430 program starts, this file will be read to restore the calibration data.

 Since there are no adjustments that have to be made inside the box, 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 AIM430, 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 AIM430 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 in progress is indicated by the RED LED being 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.

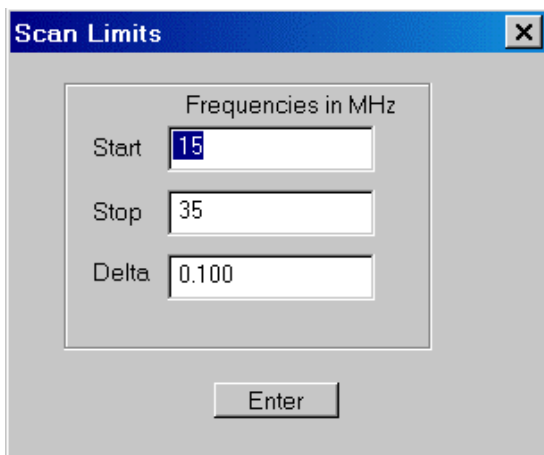The most common commands use the buttons along the bottom edge of the screen:

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.

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 (d**elta**) between measurement points. The **start** and **stop** frequencies range from 1MHz to 32MHz.
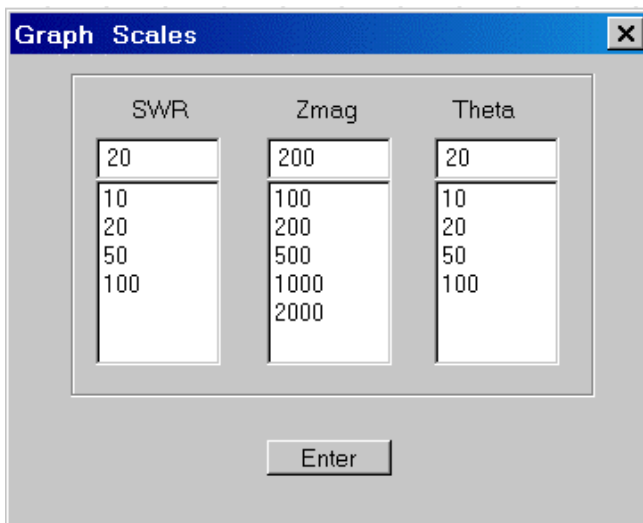
Scan Limits	☒
Frequencies in MHz	
Start	15
Stop	35
Delta	0.100
Enter	

 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 Delta (the spacing between measured points). This would result in a scan of 50 points across the band. The maximum number of scan points is 200 and the minimum number is 5. You don't have to worry about these details; the program will check the input data for reasonable values and adjust the frequency step size if necessary.

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 delta between steps 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 20 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.
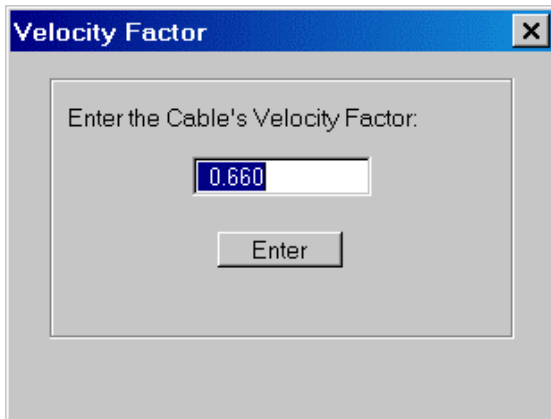
SCALES - When this button is clicked, a dialog box pops up for entering the full-scale values for: SWR, Zmag (impedance magnitude), and Theta.

Graph Scales			✕

SWR	Zmag	Theta
20	200	20
10	100	10
20	200	20
50	500	50
100	1000	100
	2000	

Enter

 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 1500 ohms at some frequencies, the cursor can still read the true value and display it in the data window.

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.

Next, enter the Velocity Factor (typically in the range of 0.66 to 1.00).

Velocity Factor

Enter the Cable's Velocity Factor:

0.660

Enter

Next, enter the length of the cable if it is known. If zero is entered, the velocity factor previously entered will be used to calculate the length. If the length value is followed by the letter "M", the length will be considered to be in meters; otherwise, it's in feet.

Cable Length

Enter the Length of the Cable
(Enter zero if unknown)
(Put M at the end of the number for Meters)

0

Enter

If the length is specified (greater than zero), then the velocity factor will be calculated and the value of velocity factor that was previously entered will not be used.

Next, enter the frequency at which the cable impedance will be measured:

Enter Zo Test Frequency

7.150   MHz

Enter

Typically, this value is in the band that you're most interested in. The cable wavelength will be calculated using this frequency and displayed with the "Measurement results".

Some measurements are made and then a message box prompts to change the end of the line to the opposite condition:

Find Cable Zo ❌

⚠️   Make sure the cable is SHORTED at the far end.

OK

After the tests are complete, the results are displayed:

Measurement Results ❌

Cable Length   27.987 feet

Wavelength   0.308 @ 7.150 MHz

Velocity Factor   0.660

Impedance   50.646 –j 0.789

OK
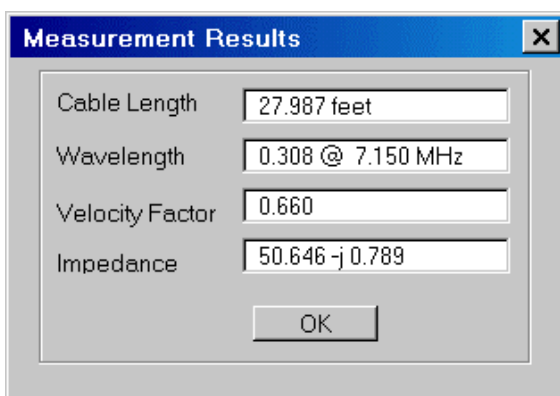
SMITH – A window is displayed with a Smith chart showing a plot of the reflection coefficient versus frequency. As the cursor is moved with the mouse over the original plot, a marker dot is displayed at the corresponding point on the Smith chart and the relevant data is displayed in this window.
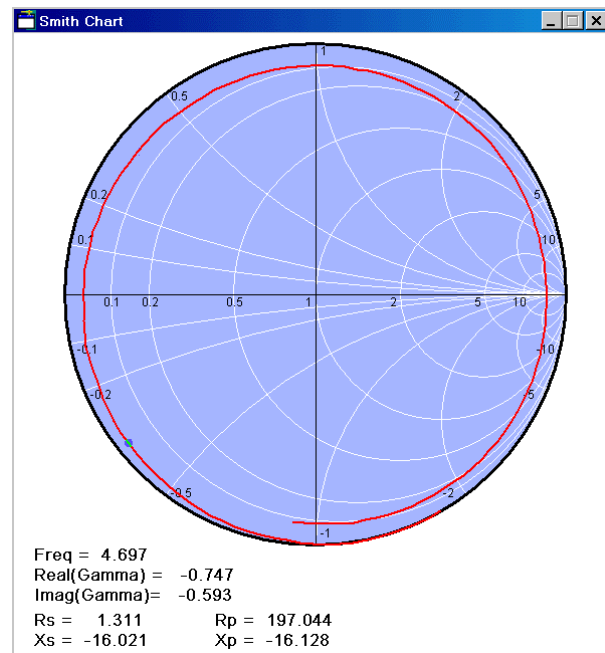
COMMENT – A dialog box pops up for you to enter a comment that will be displayed at the bottom of the graph. This is very useful for documenting the test conditions. This comment will appear in a screen capture or a screen print and it will be saved in the raw data file on disk if this scan is saved.

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.

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

DATA:

Point data (D)--   Measure the impedance at a specified frequency.   This is used for diagnostics.
                     Data can also be sounded out in Morse code (see below).

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 40mv-rms and somewhat less at higher frequencies.

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

SETUP:

Calibrate   Calibrate the AIM430 using open circuit and short circuit
Analyzer--   conditions. The calibration data is saved in a disk file that's read
                   each time the program is launched.

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

Cable Calibration Tables of data for the cable are generated to be used by the "ref to
                   antenna" mode shown below.

Refer to   The impedance readings are transformed to be equivalent to
Antenna --   readings directly at the antenna terminals. More information about
                   this feature is shown on the following pages. Click this again to
                   exit from the "refer to antenna" mode.

Average Readings- Each data point is obtained by averaging four ADC
                    readings to reduce the effect of measurement noise. When
                    this option is selected, "AVG ON" appears in red in the
                    upper right corner of the graph.

Comm Port --   Enter the RS232 port used for communication.
                   Port values can be 1,2,3 or 4. This is saved in the initialization file
                   that's read each time the program is started.

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 turn this feature off.

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.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.

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:
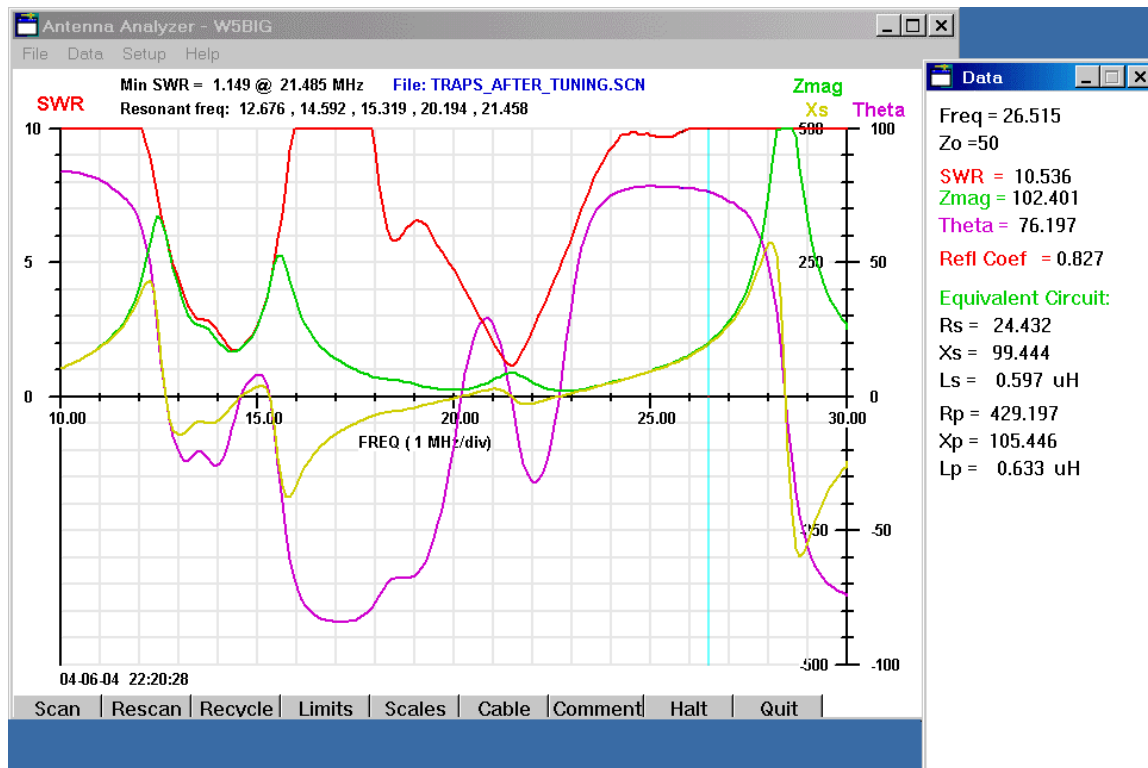
The light cyan vertical line is the cursor. It moves with the mouse whenever the mouse pointer is inside the graph area. In this example, the frequency is 26.515MHz. The frequency changes in 1-pixel increments due to the mouse resolution, so some specific frequencies may not be displayable.

Data in the data window shows the characteristic impedance, Zo, has been specified to be 50 ohms. The SWR at 26.515MHz is 10.536, Zmag=102.401 ohms, and Theta=76.197 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, Theta, is negative, the equivalent components, Ls and Lp, change to Cs and Cp automatically.

At the top of the graph in the main window, the first 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.

Data Referred to Antenna

Sometimes it is desirable to know the impedance at the antenna terminals. 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.
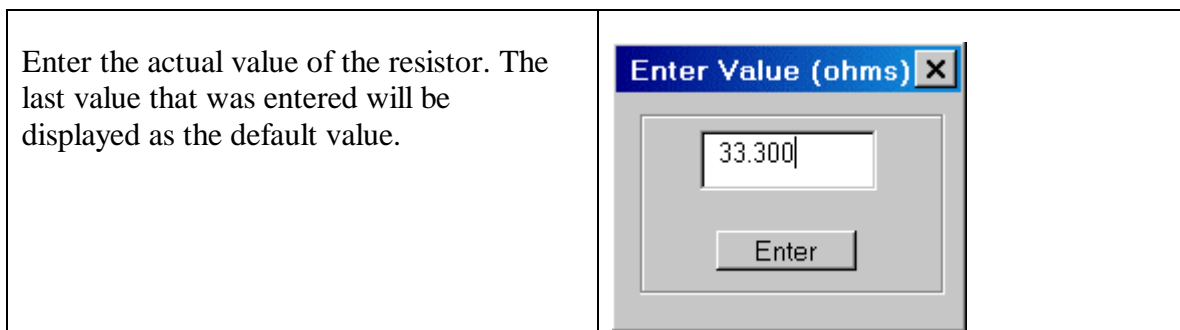
First, click the "Limits" button at the bottom the screen to specify the frequency range and the frequency increment you want to use.

|	
To select this feature, click "Setup" and "Cable Calibration".	**Calibration** [×] **Connect small resistor to cable at the antenna.** Continue Cancel
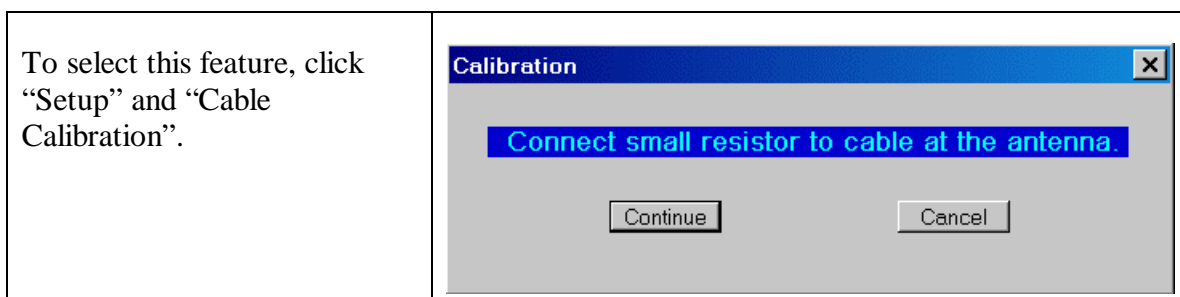
Disconnect the coax from the antenna. Then connect a small resistor in the range of 20 to 100 ohms at the antenna end of the coax. The actual value is not critical as long as you can measure it accurately with a digital ohmmeter. The resistor can be a ¼ watt size since it doesn't have to handle any power. 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 AIM430 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 much more accurate that trying to use a single value for velocity factor since the velocity factor is a complex function of frequency. This data table is saved to disk and will be recalled later whenever you click "Refer to Antenna". 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. If you want to change the scan limits, the cable calibration has to be done again with the new limits.

Next, connect a large resistor in the range of 1K 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]
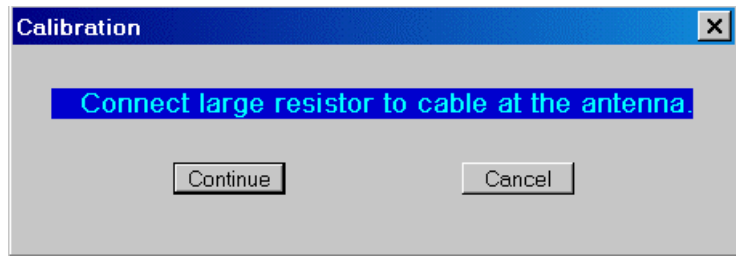
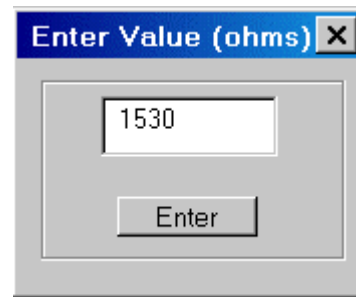|	
Enter the value of the larger resistor (in ohms). The last value that was entered will be displayed as the default value.	**Enter Value (ohms)** ☒ 1530 [Enter]

The AIM430 will now scan the specified frequency range and save another table of parameters that contains information about the cable using the large terminating resistor.

The names of the two files that are created during the cable calibration process are: **_LowRdata_. txt** and **HighRdata_.txt.** These can be saved under different names if you want to save cal data for several different test conditions (different cables or different frequency bands). The latest set of files with these names will be used automatically when the "Ref to Antenna" option is selected.

The following pictures show the effect of using the impedance transformation feature.
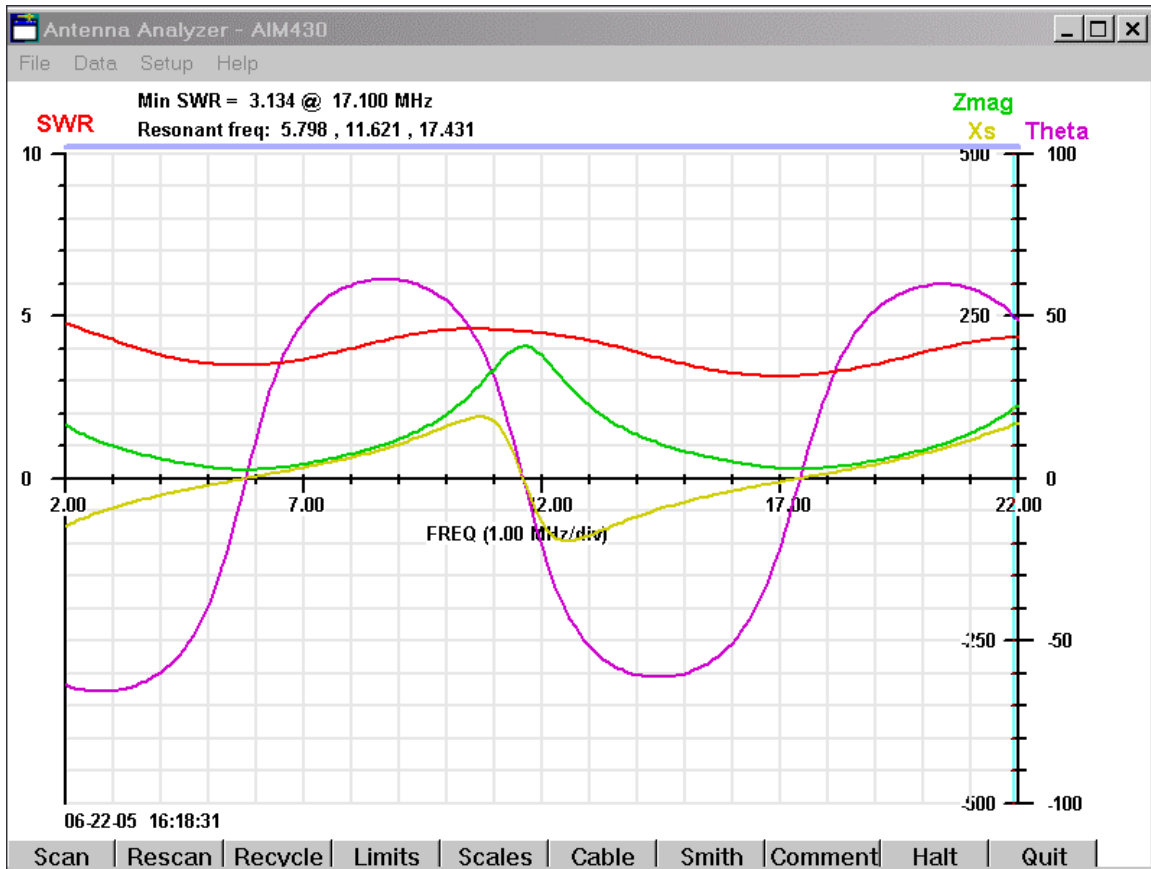
This picture shows an **ordinary** scan with the 243-ohm resistor at the end of 28 feet of RG58 coax. The Green trace is the magnitude of the measured impedance. As expected, this is a complex function of frequency.

Now we click "Setup" and "Ref to Antenna". The legend "Ref to Antenna" is displayed in Red at the top of the graph when this feature is enabled.
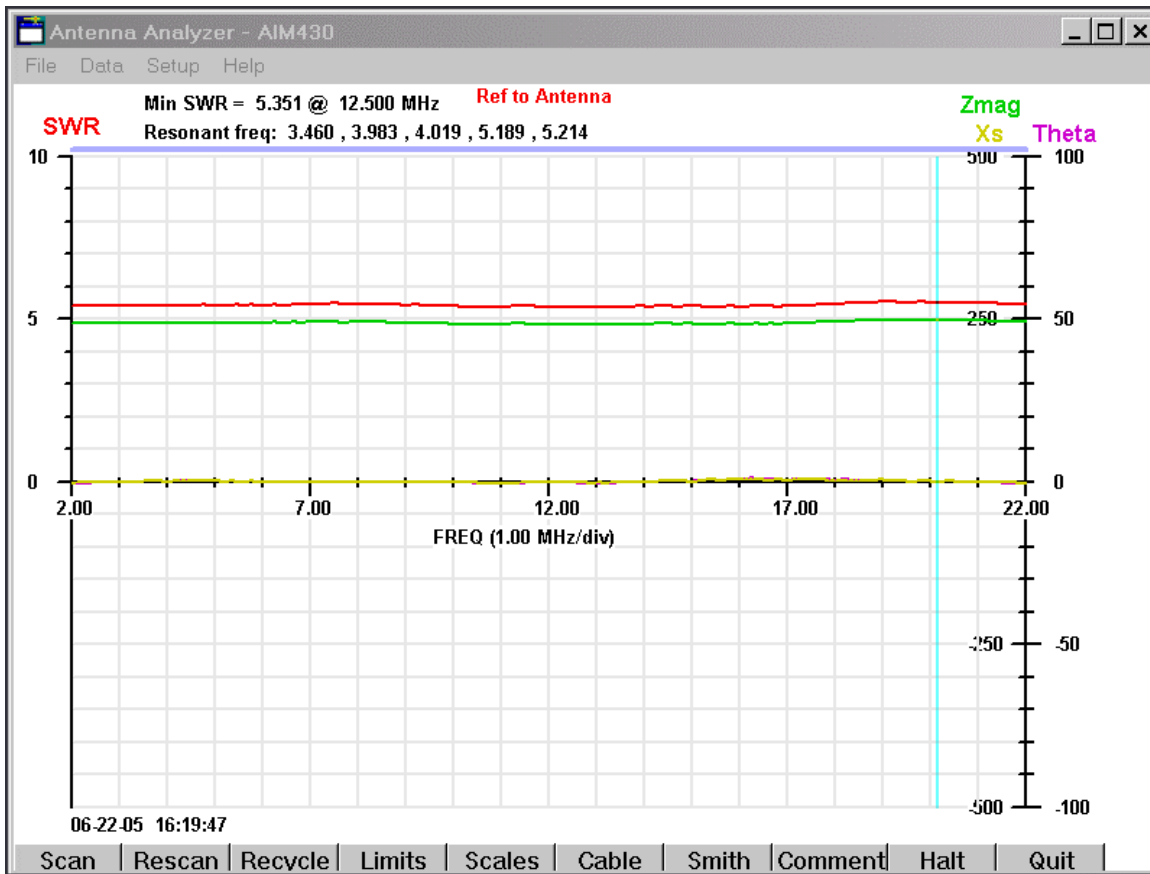
This picture shows the results when the "Refer to antenna" function is selected. The resistor (243 ohms) and the cable are the same as used in the previous graph. The Zmag plot (shown in green) is relatively flat across the frequency range. The measured resistance now varies only from 243 to 248 ohms, a range of 2 percent.

The next graph shows the transformation works quite well with a complex load. A series L-C tuned circuit was used for the load. In one case, it was connected directly to the BNC connector on the AIM430. Then a "rescan" was done with the load at the end of 28 feet of coax. The impedance and reactance curves almost coincide. There is a small difference in the two phase angle traces shown in Violet.
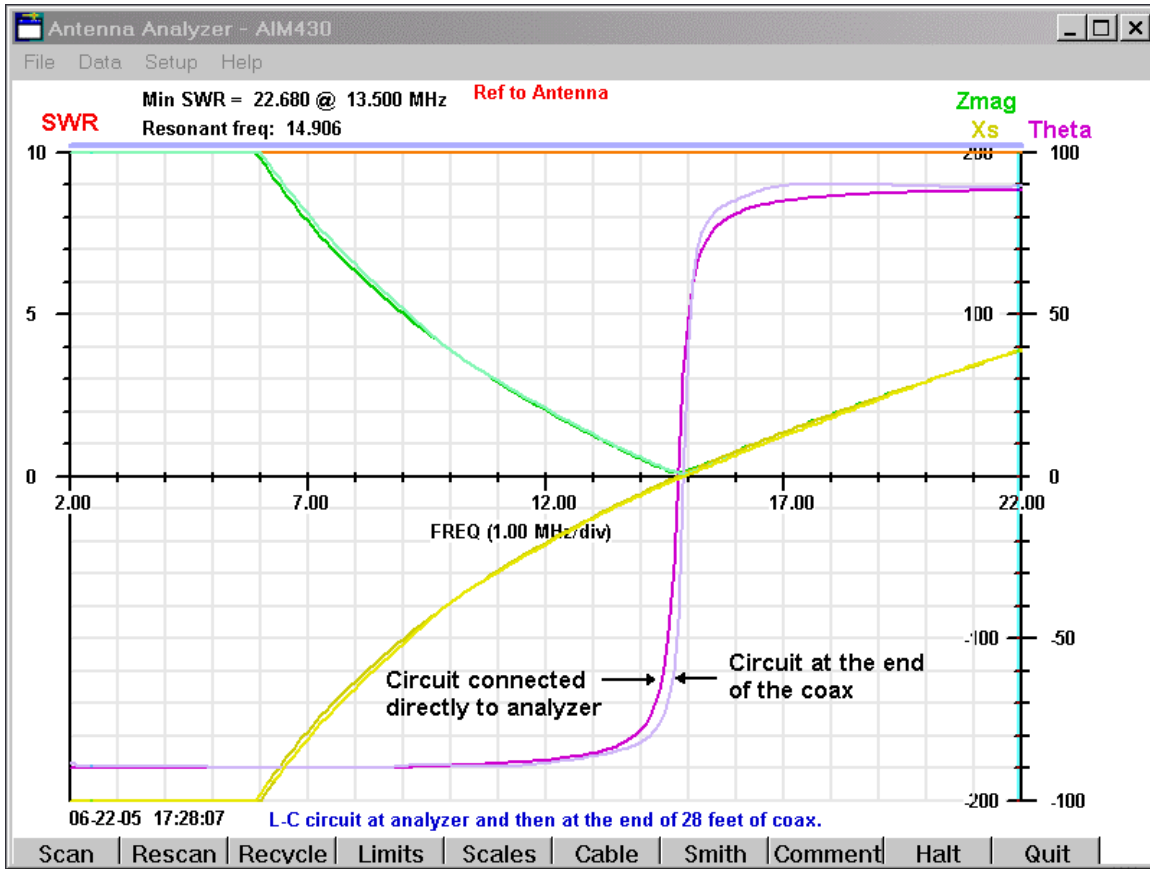
To exit from this mode, click "Setup" and "Ref to Antenna" again.

AIM430 Principles of Operation

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 only 50 microwatts (-13dBm).

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 AIM430 does not use any RF transformers). The current sensing resistor does not have to be adjusted and it has excellent long-term stability.
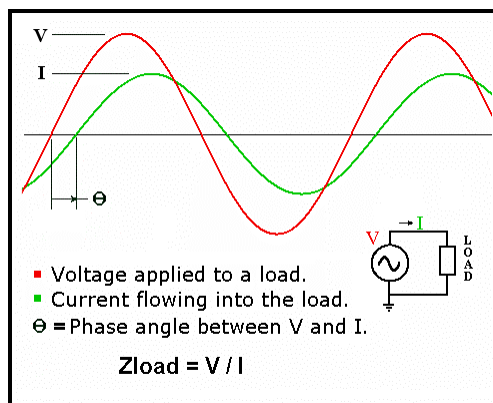
3. Calculate the magnitude and phase of the input impedance. The magnitudes and phases of the applied voltage and resultant current are measured with an analog to digital converter (12-bit ADC) and their ratio determines the magnitude of the impedance. The sign of the phase is also measured so that capacitive 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 AIM430:
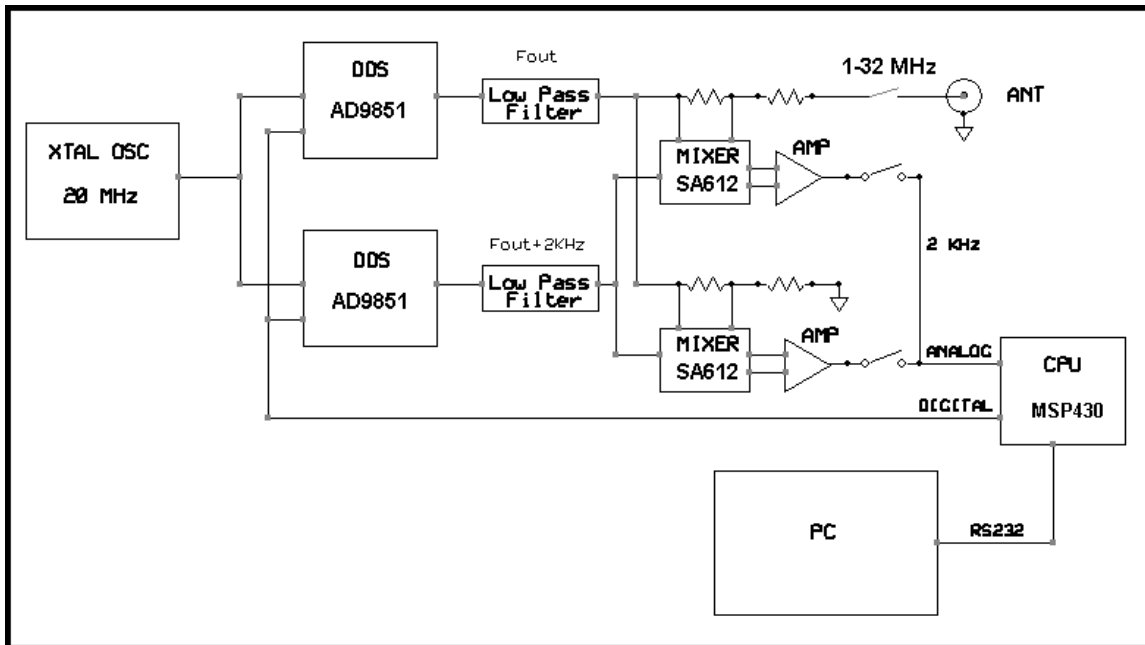
The AIM430 uses two Direct Digital Synthesizer (DDS) chips. One generates the test signal and the other acts as a local oscillator to heterodyne the RF signals to the audio range. You can read about the basic principles of the DDS at this address:
http://www.analog.com/library/analogDialogue/archives/38-08/dds.pdf

A 20 MHz crystal controlled oscillator drives both of the DDS chips. Inside the DDS, the clock is multiplied by a factor of 6, so the effective clock rate is 120 MHz. Program frequency resolution is a fraction of a Hertz. The output of each DDS goes to a 45 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 1 MHz to 32 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 2KHz. Audio amplifiers boost the 2KHz 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 AIM430 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
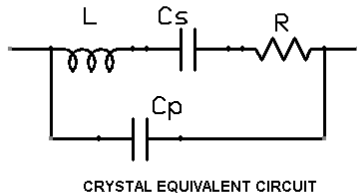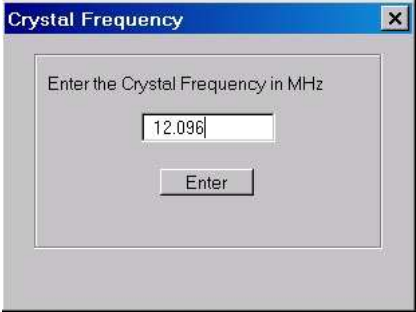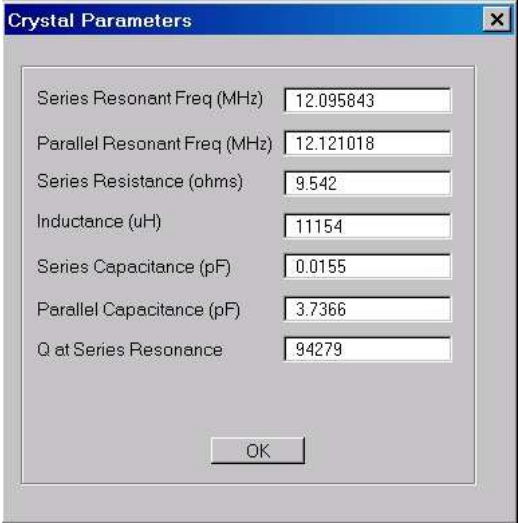
The series resonant frequency is the lower of the two frequencies. It's determined by L and Cs. The higher parallel resonant frequency is determined by L and Cp+Cs.

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.
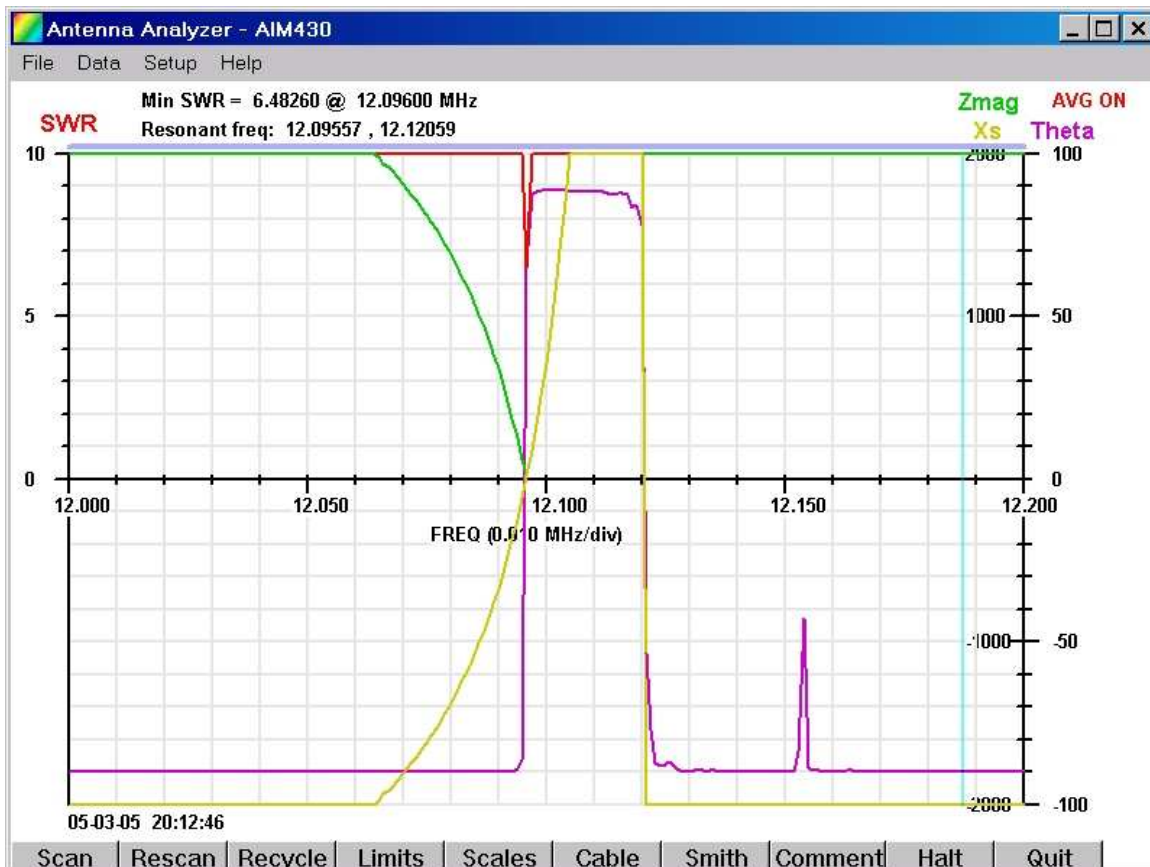
Automatic Crystal Parameter Calculation

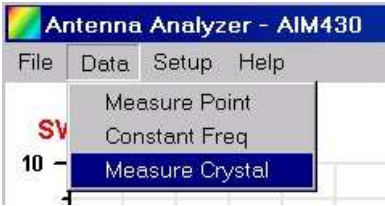|	
The calculations to find the crystal parameters are tedious so they have been combined into a procedure than can be called from the Data menu. First click "Measure Crystal":	**Antenna Analyzer - AIM430** File **Data** Setup Help Measure Point Constant Freq **Measure Crystal**
Then enter the resonant frequency:	**Crystal Frequency** Enter the Crystal Frequency in MHz 12.096 Enter
After a few seconds the crystal parameters will be displayed:	**Crystal Parameters** Series Resonant Freq (MHz) 12.095843 Parallel Resonant Freq (MHz) 12.121018 Series Resistance (ohms) 9.542 Inductance (uH) 11154 Series Capacitance (pF) 0.0155 Parallel Capacitance (pF) 3.7366 Q at Series Resonance 94279 OK

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.
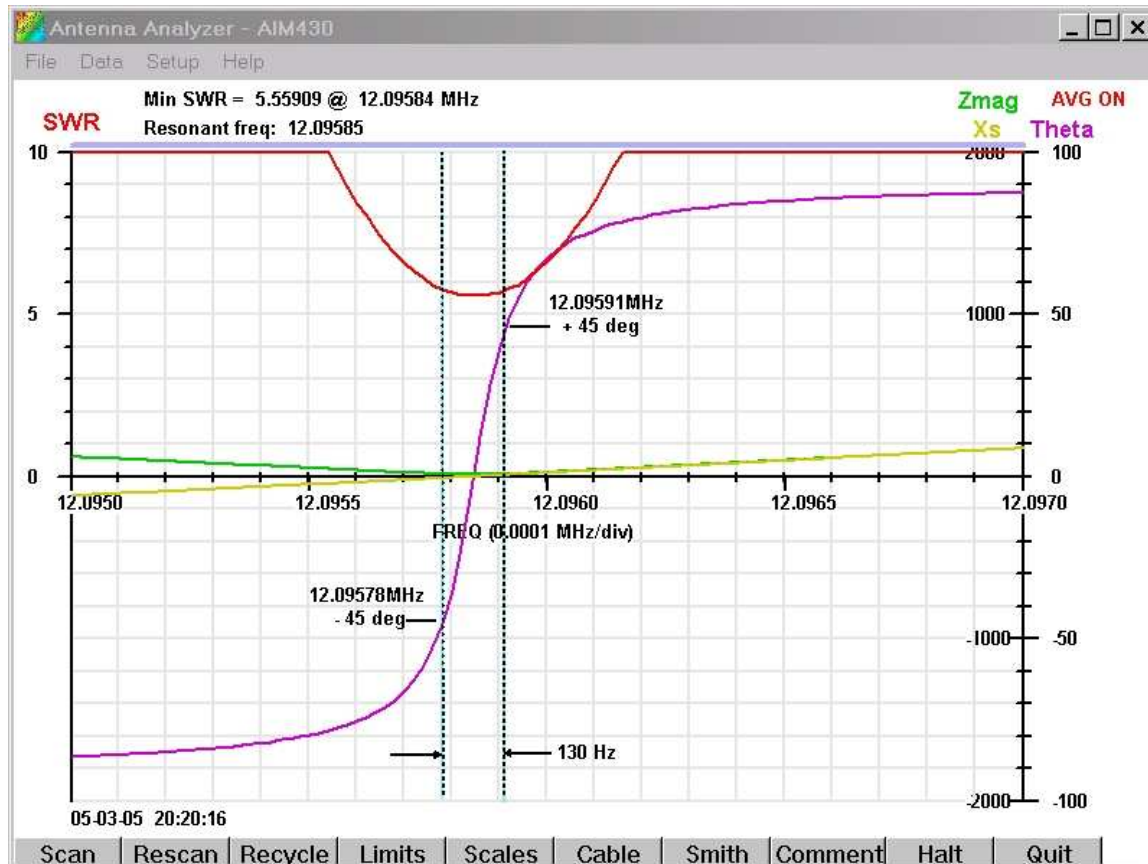
At frequencies well below the series resonant point, the impedance value is the total capacitance, Ctotal, which is essentially equal to Cparallel.

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 AIM430 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 AIM430 with a 68 ohm resistor before connecting the 50 ohm coax to the circuit under test. If the interconnecting cable is 75 ohms, the AIM430 terminating resistor should be 120 ohms. If flatness is not important, the coax can be connected directly to the AIM430.

The nominal signal delivered to a 50-ohm load is about 50mv rms. If an extra 68 ohm terminating resistor is used, the signal level will be about 25mv rms.

Appendix 1 – Specifications

Frequency Control: Digital Synthesizer 0.5 - 32 MHz ; Stability: +/- 30 ppm

Frequency Step Size: 0.1 Hz to 1MHz

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

Measurement Ranges:

SWR: 1 to 100

Impedance: 1 ohm to 10K ohms

Accuracy: 1 ohm +/- 5% of reading up to 2K; 10% of reading from 2K to 10K.

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

Parameters displayed include: SWR, 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: 50 microwatts max; BNC connector (UHF female adapter included)

PC Interface: RS232 (6 foot cable included)

Display: Graphics output on PC screen. Mouse controlled cursor for digital parametric readout. Morse code output for selected parameters.

Power Supply: 6 to 15 VDC at 150ma max (120VAC power supply included)

Battery power source can range from 6.0 to 15V. Required current=150ma when a measurement is in process, 30ma when idle. Auto-power-off after 10 minutes of inactivity. (Batteries are not included.)

Dimensions: 5.3" x 5.3" x 2.2" (13.5 x 13.5 x 5.6cm)

Software for the analyzer hardware controller and the PC data analysis is upgradeable in the field. The controller is loaded through the RS232 port. No additional hardware is required. The new software is in a text file format and a utility to load the controller is included with the AIM430 program. Software updates are available from the W5BIG web site and they are **free** for life.

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

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 AIM430. 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 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 AIM430 power.

The text displayed on the computer terminal is the following (or similar):

Antenna Analyzer AIM430
by W5BIG
July 04 2005

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** and the **1**, but the time interval between them is not critical. Then, type **K0** (K and 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

```
// Example of a .scx file with data suitable for importing into a
// spreadsheet.
// 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      // delta 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"       // 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
 202.912612915039060    // 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
```
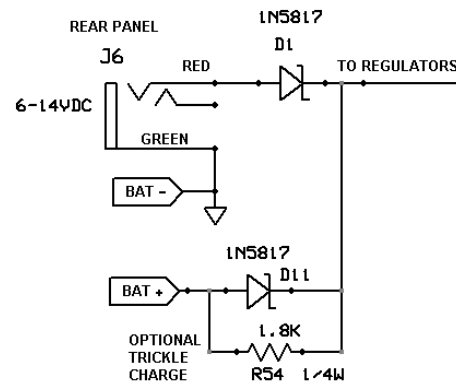
Battery Operation

The AIM430 can be powered with a battery for portable operation. Battery voltage can range from 6.0 to 15V. The required current is 150ma when a measurement is in process, 30ma when idle. The power is turned off automatically after 10 minutes of inactivity when the Auto-Power-Off feature is enabled.

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 AIM430. There are diodes on the CPU card (the bottom 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 standard in the AIM430.	
This photo shows how a battery or battery pack can be mounted inside the AIM430. The battery shown is not included with the AIM430.	
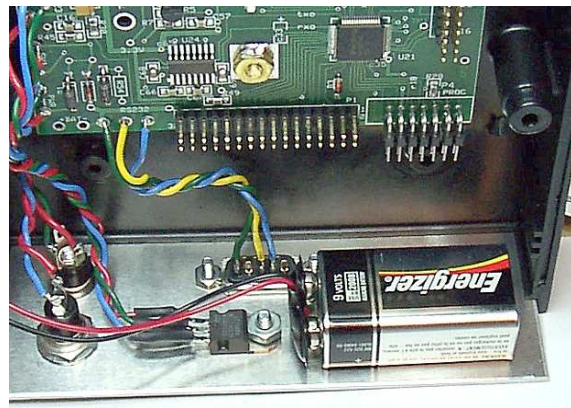
In the lower left corner of the board are shown the pos(+ RED) and neg(- BLUE) battery connections.

There is an open space to install R54 for optionally charging a battery. All of the other components, including D1 and D11 are standard.
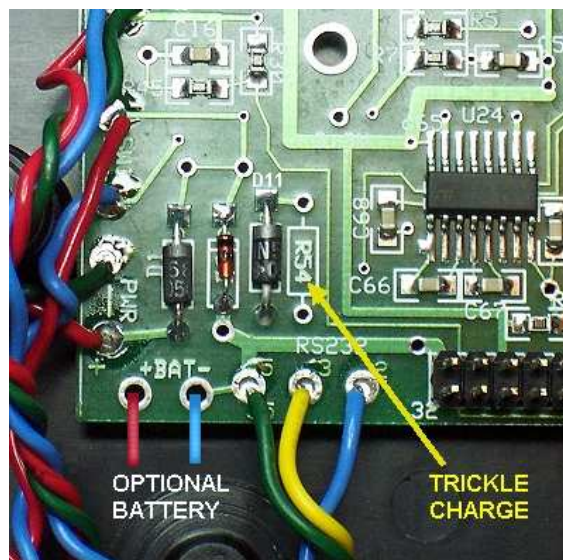
Terms and Conditions

ORDERING: E-mail to: W5BIG@comcast.net. Payment can be made by Paypal, money order, or certified check.

SHIPPING: We ship most orders for delivery in the U.S. within two business days via USPS Priority Mail. The package will usually be delivered to you within three days after shipping.

PRICES: Prices and specifications are subject to change. We reserve the right to make improvements to the products.

UPGRADES: Software upgrades are available at our website at no cost. This includes programs for both the analyzer controller and the PC. Check the website: W5BIG.home.comcast.net/prog_update.htm for the latest version of the programs.

LIMITATIONS OF LIABILITY: Except as expressly stated herein, R&R Technology makes no representations or warranties, either expressed or implied, of any kind with respect to products sold, including but not limited to, merchantability and fitness for a particular purpose. You agree that the sole and exclusive maximum liability arising from any product sold shall be the price of the product. R&R Technology, its employees or its representatives shall not be held liable for special, indirect, consequential, or punitive damages related to the product sold.

RETURNS: Returned items must be received in the original condition including the program CD, power supply, cable, and accessory connectors. Returns must be within fourteen days of receipt. If the original box is not available, suitable boxes can be obtained from the post office without charge. Use the original packing materials if available or the equivalent. For maximum protection of your equipment, insure the package and request a signature when it is received. Shipping cost is not refundable. We will pay the return shipping for warranty repairs.

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.