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The Micro908 Antenna Analyst

Here's a low cost and portable microcontroller-based instrument that automatically determines SWR and reactance characteristics of an HF antenna system. Advanced features of DDS frequency control, LCD tuning display, PC data collection and plotting, numerous operating modes and easy software upgradability make this design attractive for homebrewers and antenna enthusiasts.
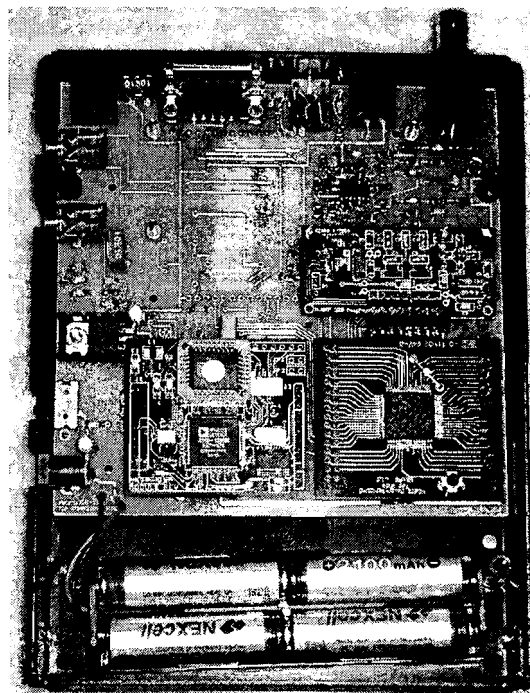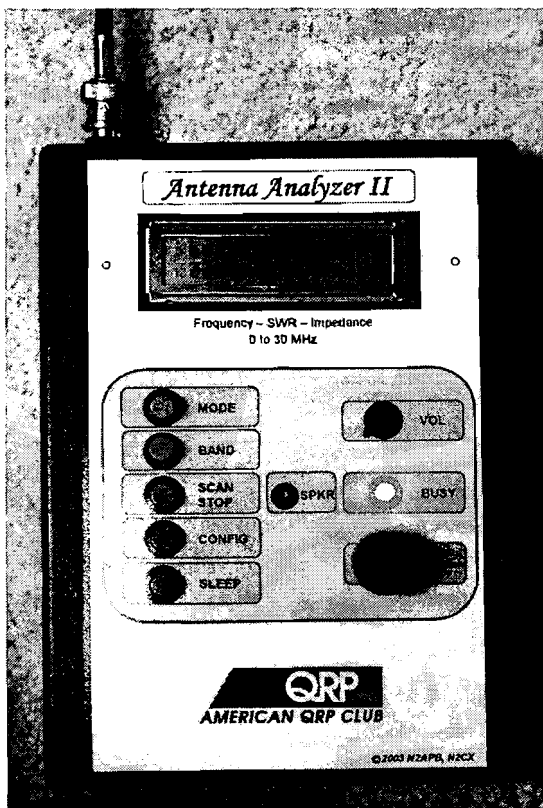
Introduction

N2APB and N2CX have been complementary halves of a design team working together in the New Jersey QRP club over the past seven years – sort of like the "Sonny & Cher" duo as applied to the world of QRP project design. We've been fascinated with opportunities that digital computing technology brings to the design of standard analog and RF radio equipment, measurement fixtures and QRP accessories. Four years ago we created a prototype of an antenna analyzer – actually the predecessor of the one described here – using relatively common components to create a very inexpensive piece of test equipment.

Since then technology has advanced in the microcontroller world as well as on the RF digital synthesis front. We've dusted off the design and augmented the approach with some precision signal generation via a DDS integrated circuit, used a ubiquitous LCD for the user display interface, and incorporated a much more flexible and powerful microcontroller unit for the computationally intense demands lying ahead.

In this paper we describe the design of an antenna analyzer that has two tremendously exciting aspects to it. One is that it is based on some pretty current technology – the AD9850 **Direct Digital Synthesis chip** from Analog Devices and a quite flexible MCU (**microcontroller unit**) from Motorola called the HC908AB32. These two technologies give QRPers considerable measurement and user interface power.

Secondly, the hardware platform on which the antenna analyzer software runs is a multi-use, reconfigurable and field-programmable instrument called the **Micro908**. For the first time QRP homebrewers have available an inexpensive-yet-powerful portable computing platform tailored to serve the specific needs in the ham shack. The concept and modules have been developed over the last several years as chronicled in QRP Quarterly magazine as the "Digital QRP Breadboard", and now is available as a kit from the AmQRP Club.

Both of these important aspects – the Antenna Analyst software and the Micro908 platform on which it runs – will be discussed in this paper. So as Sonny & Cher said back then, "I've Got You Babe" and let's dig into it all!

Overview

The Micro908 Antenna Analyst is a small and inexpensive measurement device designed to determine antenna performance across the amateur bands through use of automatically collected SWR and complex impedance readings. The figure below shows the block diagram of the Antenna Analyzer.
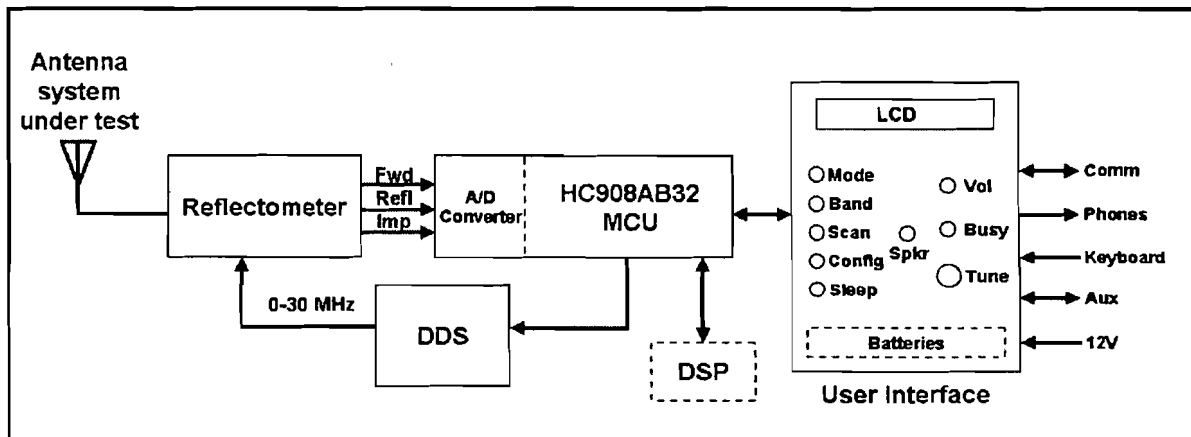

Figure 1 – Block Diagram of the Micro908 Antenna Analyzer

A very low power transmitter is swept across selected frequencies by a microcontroller. The transmitter's signal is delivered to the antenna system through a reflectometer consisting of an absorptive SWR bridge and diode-compensated buffer amplifiers. The data provided by the reflectometer are digitized and used by the microcontroller to compute SWR and impedance values. The microcontroller retains the frequency and corresponding results throughout the measurement period.

During this measurement period, the microcontroller rapidly displays the individual frequency and SWR values on an LCD. When all data are collected the microcontroller statically displays selected frequencies and the associated SWR readings.

The frequency and SWR data may also be downloaded to a PC attached to the Antenna Analyst via a serial cable. A special software program for the PC collects the data pairs and graphically represents the antenna

performance. This plot clearly shows the resonant frequencies of the antenna system under test. The PC may also be used to remotely control the analyzer for manual selection of frequencies of interest.

Thus, with a press of a button the Antenna Analyst is able to automatically and quickly determine and display the frequency for which the antenna system is best matched, along with the associated complex impedance values at those frequencies.

Manual operation allows the user to control the band/frequency of operation while viewing the display of SWR results.

The analyzer also functions as a simple frequency source in manual mode. This signal may be used in troubleshooting various RF equipment.

The Micro908 Antenna Analyst has a built-in speaker to allow use of the unit when conditions do not permit easy viewing of the display. The device may be configured to sound a tone whose pitch is varied based on the value of the computed SWR. Thus the operator may manually tune for lowest pitch and be assured that the specific frequency is the point of lowest SWR. The feature may also be enabled for automatic scanning, although one's sanity will be stressed with this tone sounding all the time. Headphones may also be used to listen to the tone.

The audio output feature is useful in yet another way for limited viewing scenarios. The unit may be configured to audibly annunciate the displayed measurement results via Morse code through the speaker or headphones. The SWR reading is also audibly announced by a variable-pitch tone – the lower the tone, the lower (better) the SWR.

The Micro908 Antenna Analyst is designed to be field-usable and operator friendly. The handheld form factor lends itself to convenient operation while away from the bench by means of pushbutton controls along the left top side of the unit. The operator is able to easily select the various modes and options with the left hand while making frequency and volume adjustments with the right hand. Various interface connectors are placed along the top side of the unit, including the RF connector, serial port connector, and several other connectors (for aux, keyboard, paddles) that find use on the Micro908 in other applications. The remaining interfacing connectors are located along the right side panel of the unit – headphones, audio input for using the Micro908 as an audio filter, external power jack and the power switch. The unit can be battery operated and the enclosure was selected to hold eight rechargeable AA cells.

Another exciting aspect to the Antenna Analyzer project concerns the nature of the software used to control the microcontroller. There are a growing number of computer-controller ham radio construction projects being offered today by clubs and small companies. For the most part, however, they do not provide the source code and design details that are of great interest by a growing number of homebrewing amateurs capable of dealing with software modifications and improvements. The Micro908 Antenna Analyst project supplies fully documented source code and design methodology for the software used to control the device. The same is true for the software used for the companion remote control and display program in the PC.

The Micro908 Antenna Analyst represents a unique, inexpensive and fully functional instrument for the QRP homebrewer community. The Analyst is a project of great educational appeal - wideband transmitter design and software control of its operation. The low-cost, straightforward and modular design places construction of the Analyzer well within the grasp of a great many radio amateurs.

Antenna Analyst Features

- ➤ Automated, microcontrolled antenna network analyzer
- ➤ A powerful 8-bit microcontroller (NJQRP HC908 Daughtercard) controls all aspects of the operation
- ➤ A low power DDS signal generator (the NJQRP DDS Daughtercard) is swept across HF spectrum.
- ➤ Precise and self-calibrating reflectometer design measures forward and reflected signals and impedance data
- ➤ Automatic scanning results displayed as frequencies of lowest SWR and complex impedance
- ➤ Configurable frequency scanning limits and step sizes
- ➤ Manual control option displays SWR and complex impedance at selected frequencies
- ➤ Audible tones provided assists in eyes-free tuning for minimum SWR
- ➤ Displayed results annunciated via Morse through internal speaker or via headphones
- ➤ Serial port connects to PC for optional remote control and display/plot of antenna performance
- ➤ Battery-operated for convenient field use, or can use external 12V for bench operation
- ➤ Power-saving "sleep" feature powers down unit after presettable period of inactivity
- ➤ Full hardware and software source material freely available via GNU Public License

Other Micro908 Features

In addition to providing useful hardware modules that allow the Antenna Analyst software application to operate, the Micro908 hardware and software platform also sports capabilities that allow other applications to run.

➤ KK7P DSPx daughtercard provides signal processing services for digital modem, audio filtering, etc.
➤ Paddle input allows Micro908 to serve as memory keyer, keyed local oscillator, etc.
➤ Keyboard input port provides ability for textual data input for digital modem (PSK31, RTTY, etc.)
➤ Auxiliary port available for custom input/output needs

Micro908 Hardware Platform

The Antenna Analyst software program was designed specifically to run on the Micro908, which is an ideal computing platform for ham radio homebrewers and experimenters. Designed and developed over a 2-year period, it was chronicled in QRP Quarterly magazine as the "Digital QRP Breadboard project". Now officially named the "Micro908", the unit is ready to be rolled out in kit form by the American QRP Club and serves as the common hardware platform for a growing list of powerful applications in addition to the Antenna Analyst -- a Portable PSK31 Digital Mode Controller, a DSP-based Audio Filter, a "commander" remote controller for transceivers, a memory keyer, and other applications in development.

The Micro908 platform was designed to be easily operated on the bench as well as in hand while portable. It is comprised of a single 5" x 5" printed circuit board containing all components, connectors, controls, a 2x16 character LCD, and three daughtercards. The 5.5" x 7" x 1.5" plastic enclosure is also large enough to hold an 8-cell AA battery back enabling convenient field use.

A number of standard ham radio peripherals may be connected to the Micro908. One may plug in an antenna, paddles, a PC-style keyboard, headphones, an audio line to drive an SSB transceiver, a keyline to drive a transmitter, and custom control lines via an auxiliary jack.

The Micro908 is built around three daughtercards that are available within the homebrewing community. The **HC908 Daughtercard** plugs in as the main computing engine for the platform and provides flexible programming, field updates, powerful processing and a multitude of input/output lines for controlling all the devices in the unit.

The **NJQRP DDS Daughtercard** serves as a precise and accurate signal source that is programmable by the HC908. This plug-in module gives the Micro908 platform the ability to serve as an audio and RF signal source for testing and network analysis.

The third plug-in module is the **KK7P DSPx Daughtercard.** This optional module gives the Micro908 platform a powerful signal processing capability suitable for serving as a digital modem for PSK31, PACTOR and other digital modes of operation. Although not necessary when running the Antenna Analyzer II software, when this DSP card is coupled with the HC908 controller, the Micro908 becomes and even more formidable portable computing platform.

Referring to the schematics shown at the end of the paper, let's go through a module-by-module inventory of the Micro908 platform and see what functionality is available as a system.

HC908 DAUGHTERCARD

The HC908 Daughtercard is a modular microcontroller board that holds the powerful-yet-inexpensive Motorola 68HC908AB32. The daughtercard has lots of memory and I/O, and peripherals like counter/timers, asynchronous serial ports, and A/D converters to make the project useful for many standalone applications around the radio shack. It also contains the clock, reset pushbutton, voltage regulator and RS-232 drivers. The software supplied with the project allows for easy self-programming of the chip – just download new software programs to the chip and it burns the code into its flash memory. No need for special, expensive or complicated programming hardware with this project!

The HC908 Daughtercard was developed and made available in 2002 by the NJQRP Club. Articles describing the daughtercard have been previously published (QRP Homebrewer #9) and complete information can be found on the project's web pages at www.njqrp.org/hc908. The HC908 Daughtercard is plugged into two mating 2x34 pin connectors on the main pc board of the Micro908.

Downloading Software to the Micro908

One of the prime goals for the Micro908 was to be able to easily and inexpensively load new or updated software into the HC908 Daughtercard even after the project was built and field deployed. The daughtercard has ample onboard flash program memory; the microcontroller retains its program memory even when power is removed.

The microcontroller on the HC908 Daughtercard has the ability to be in-circuit programmed, which means that a conventional +5V power supply and proper timing is all that's required in order to burn a new program into its flash memory ... even while the daughtercard is in the Micro908. A special boot loader program was developed that allows one to download the binary image of the new software program over the built-in RS232 serial data port connected to your PC. One can even develop a custom program with the free software development tools on the PC, download it to the HC908 Daughtercard and the new or improved program can then be run. In this way you can take advantage of newer software programs that are provided for download on the HC908 and Micro908 websites, or you can develop your own customized versions of the programs and flash the daughtercard directly with your own code. Any "dumb terminal" may be used to communicate with the HC908 Debug Monitor to perform the download of the new software and burning of it into the microcontroller's flash memory. A useful public domain (freeware) terminal program called Tera Term is available to run on Microsoft Windows platforms.

DDS DAUGHTERCARD

In 2002, the NJQRP created the DDS Daughtercard in advance of coming applications like the Micro908 that would need signal generation capabilities. It is a small pc board containing just the bare DDS essentials – an Analog Devices AD9850 DDS chip, a 100MHz clock oscillator, a 5th-order elliptic filter and a monolithic RF amplifier to boost the raw 200 mV p-p DDS signal to a more usable 2-volt level. Additionally, a 5-V regulator is provided so you only need provide a single 12-V battery or power supply. The three digital control lines, the power supply, and the output signal are all available on a pin header at the board edge. Articles about the DDS Daughtercard have been previously published and full schematic and technical detail can be found on the project website at www.njqrp.org/dds. An 8-pin connector at the board edge allows the DDS Daughtercard to be plugged into the main pc board of the Micro908.

REFLECTOMETER

The reflectometer module is a basic absorptive SWR bridge driven by the computer-controlled DDS frequency source, whose output in turn drives an antenna system. The analog outputs of the SWR bridge are digitized by the built-in A/D converter on the HC908 microcontroller. By sweeping the DDS frequency across a given ham band and computing the SWR of the antenna system at various points along the way we have a rudimentary antenna analyzer.

SWR Bridge & Diode Detector -- A Wheatstone bridge is composed of 49.9-ohm resistors with the antenna as the "unknown" leg of bridge. When the antenna is at resonance, presenting a minimum impedance with a pure 50-ohm resistive "real" component, the bridge is balanced and the AC voltages on each side of the bridge are identical. No AC current flows between the legs.

Figure 2: Conceptual analyzer bridge
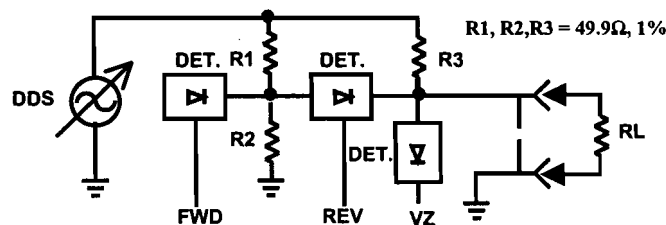
Figure 3: Schematic of the SWR bridge and diode detectors

However when the antenna system is not resonant, the complex impedance of the antenna is not 50-ohms but something greater, which creates a bridge imbalance. The 1N58711 diode samples that AC signal imbalance, rectifies it, and after filtering, the DC signal is directly analogous to "reflected" sample of more familiar SWR

bridges. We then sample the "forward" power using another diode detector on the original incoming signal. These forward and reflected DC signals are presented to the next stage for compensation, buffering and amplification.

The basic equations used by the analyzer for SWR computations are:

$$SWR = (FWD+REV)/(FWD-REV)$$

$$Z = 50 * VZ/(FWD - VZ)$$

And further, an estimate of the resistive and reactive parts of Z can be determined.

$$R = (2500+Z^2) * SWR/(50 * (SWR^2 + 1))$$
$$X = SQRT (Z^2 - R^2)$$

Note that in the above equations the only inputs are DC measurements so the computations are straightforward – no messy complex algebra or trigonometry involved!

Buffer Amp -- There are two reasons for employing the op amp circuits in **Figure 4**. The first amplifier in each path (FWD and REV) compensates for the nonlinearities in the diode detectors when the bridge is operated at very low power levels. These first stage op amps employ 1N34 diodes (or 1N5711 diodes as now used) in their feedback paths to counteract these nonlinearities in the bridge diodes. This action essentially moves the natural knee of the curves closer to zero, thus improving the accuracy of the readings FWD and REF readings ultimately presented to the A/D input on the microcontroller.
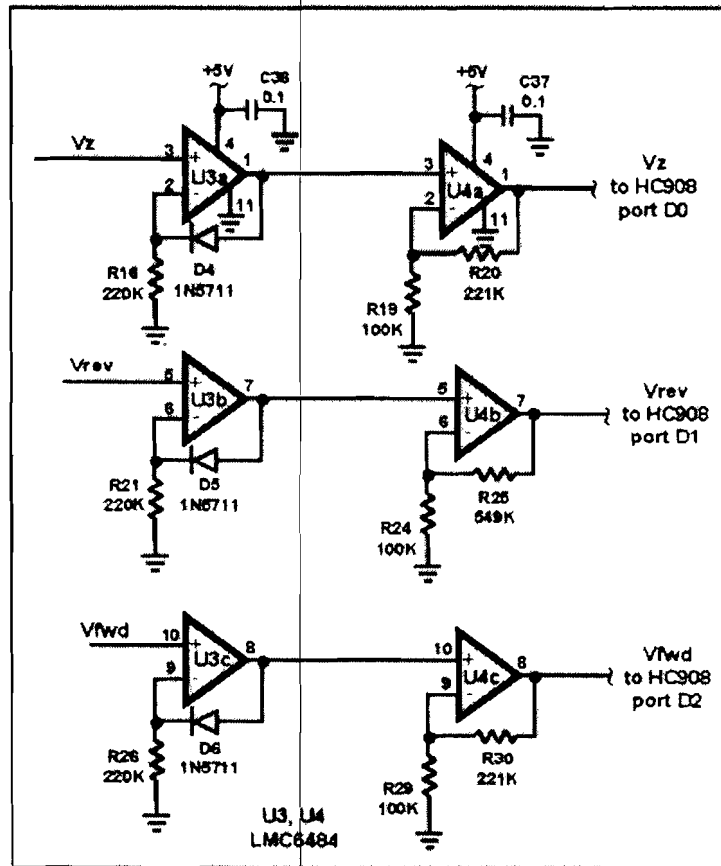

Figure 4: Schematic of the LMC6485 buffer amp.

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The second purpose for the op amps is to amplify. The DC signal levels coming from the bridge, and through the unity gain of the first compensation stage, are fairly low. In order to make the most use of the 8-bit A/D, we need to amplify the detector voltage up to the 5V range of the A/D. Further, the output of the op amp circuits is quite low which provides a better condition when presenting signals to the 10K input impedance of the A/D. (The output impedance of the diode detectors themselves is approximately 100K-ohm. If those signals were directly input to the A/D, they would be greatly affected by the lower impedance of the A/D.)

Liquid Crystal Display

LCDs have become commonplace in our microcontroller projects. The Micro908 platform uses an inexpensive 2-line by 16-character/line device to display status and measurement information to the user. The software driver for this display assumes that a common HD44780 controller-based LCD is used, so one could actually use larger or smaller LCDs fairly easily instead of the specified one. One could also upgrade the Breadboard's capabilities to use a graphic LCD with an appropriate software driver in place. The Micro908 pc board was designed to accommodate a specific 128-by-64 pixel graphic LCD from Seiko: model number G1216. Although slightly more expensive as compared to character-based LCD modules, the advantages of using a graphical display downstream become obvious when considering the types of data representations typically used for displaying SWR, frequency spectra, and tuning aids.

Keyboard

A standard PS2-style keyboard, similar to many keyboards used on PCs these days, can be used with the Micro908. The utility of this input device comes about when we develop "digital modem" software programs for support of PSK31, RTTY, PACTOR, PSK63, et al. This combination of DSP co-processing and fast alpha-numeric input by the operator is the basis for PSK31 and other digital modes intended to be supported by this project. The small Dauphin keyboard in the photos is particularly well-suited for portable use with the project.

DSPx Daughtercard

One of the many goals for the Micro908 continues to have it perform as a stand-alone digital mode controller, allowing the user to communicate using PSK31 (et al) without the need for a completely dedicated PC. To do this, and other audio filtering functions, a signal processing is required and we designed the Micro908 platform to accommodate the KK7P "DSPx" daughtercard. This DSP card, containing an Analog Devices ADSP-218x digital signal processor and mating codec (integrated A/D and D/A converter), is provided as a completely assembled and tested 2" x 2" plug-in board designed by Lyle Johnson, KK7P. Developed initially to replace a discontinued Analog Devices DSP evaluation board, it is the main embedded computing engine within the DSP-10 project. Further, the same DSP algorithms (i.e., software) are used to provide audio filtering in the Elecraft K2 transceiver. The DSPx daughtercard is powerful enough to demodulate the digital mode audio baseband signals coming from your transceiver's speaker to ultimately display PSK31 data being received, for example. Similarly, it can simultaneously modulate the data you type on the Micro908 alpha keyboard and send that audio out as audio tones suitable for input to your SSB rig. There are truly some real exciting applications coming along for the Micro908 platform based on use of the KK7P DSPx daughtercard.

Miscellaneous Circuits

A shaft encoder provides ultimate flexibility to the operator as a continuous rotation menu selector, numeric dial setting, frequency tuning, and so on. A Morse paddle may be connected to an input jack of the Micro908 and software performs as an iambic keyer, which in turn drives an external transmitter through the Keyline output on the Aux connector. A tone is also sounded, under control of the HC908, and is output through an LM386 audio amplifier. This audio tone can be the sidetone for the keyer, the output for an Audio Voltmeter, or mode confirmation beeps. Finally, room is provided within the Micro908 enclosure for an eight-AA cell pack, thus providing portable power for the field use of the unit.

Antenna Analyst Software

The real heart of any project running on the Micro908 hardware platform is the software controlling it. This is certainly the case for the Antenna Analyst, as the system components are controlled and operated in unison to create a fine-tuned measurement system. Let's walk through the program logic a bit to see how things are accomplished.

The main operation of the Antenna Analyst is achieved as a sequence of five basic operations that repeatedly occur within in the main program loop ...

- Set the DDS frequency
- Display the frequency on the LCD
- Read the analog signals from the reflectometer
- Compute the SWR and impedance
- Store the results in list for later display and post-processing

When the scan is complete, the program analyzes the list of scan data to determine antenna resonance (the frequency of the minimum data point) and the Q of the antenna system (how sharp the dip is).

Setting the DDS Frequency – The DDS frequency, phase and control bits are serially delivered to the device via three I/O lines coming from the HC908 Daughtercard: data, clock and load. Per the details provided in the AD9850 data sheet, the HC908 delivers these 40 bits of programming information by repeatedly setting the data line to the desired value, and toggling the clock line in order to move the data bit into the DDS chip. After 40 such bit clocks, the load line is toggled which instructs the DDS chip to put that 40-bit programming word into effect. At that point, the output of the DDS changes and the new frequency is present on its output.

Display Frequency on LCD – The frequency is displayed to the LCD by placing the binary coded decimal (BCD) value of each digit into seven sequential locations LCD_dat+0 through LCD_dat+6. These digits represent the 10 MHz position through the 10 KHz position in the frequency display. The LCD driver routines take these BCD numbers and display them to specific locations in the LCD memory, thus making them appear on the display itself. The numbers contained at these locations represent the start of increment/decrement functions (used in scanning), and in subsequent calculation of the DDS programming 40-bit word (used in setting the DDS frequency.)

Read Analog Signals – The forward voltage FWD, reverse voltage REV, and impedance voltage IMP are read as 0-5V analog signals by the A/D converters built into port D of the HC908. These 8-bit converters quantize the analog signal to one of 256 values, based on the analog signal presented on the respective port D input pin. Thus a granularity of 19.531 mV is achieved. This level of precision is entirely adequate for determining even the low-end knee of the diode detectors primarily because of the compensation diode placed in the second op amp circuit for each signal path.

Compute the SWR -- Using measured values to calculate SWR means that instrument is self-calibrating. This is a good thing in test equipment! The following simple equations are coded in the software, using the FWD and REV signals read by the A/D.

P = FWD/REV

SWR = (FWD+REV)/(FWD-REV)

Store the data in list – Each frequency sample's computed SWR and impedance value is stored in a list in RAM memory for processing at the conclusion of the scan. Further, the raw data may uploaded to a PC for additional processing, plotting, display and storage.

Operating the Antenna Analyst

The Analyzer has three Modes – manual, automatic and remote. In **Manual Mode** the unit is operated by direct user manipulation of the **Tune** control (rotary encoder) to change the frequency of the signal being delivered. This operation is analogous to that of a standalone VFO, however in addition to the frequency being displayed in the LCD, the SWR and impedance measurements are also continuously computed and displayed. This allows the user to go to a specific location to see the antenna's performance there, or to manually "diddle" the frequency (i.e., move it back and forth about a center frequency) to determine approximate bandwidth of the network response.

While in Manual Mode, the user may press the **Band** control to cycle through the list of ham bands. Each time the Band control is actuated, the lowest frequency of the next band is set into the DDS and displayed on the LCD. Using this control allows the user to quickly change frequency to take manual measurements on different bands.

In **Automatic Mode**, the unit sweeps the DDS frequency from the **Start** setting to the **End** setting, incrementing the frequency each time by the **Step** amount. Each of these settings is settable by pressing the Config pushbutton to get into the Configuration sequence. Settings are already present for each band, but the user has the option of saving the newly-specified settings for default operation thereafter.

The **Step** setting is also used in Manual mode. Thus the user may specify how fast the frequency changes when the **Tune** control is rotated.

Scanning is started in the Automatic Mode by pressing the **Scan/Stop** pushbutton. This actuation initiates the frequency scanning and measurement sequence and turns on the **Busy** LED. During the scan, the frequency, SWR and impedance values are displayed on the second line of the LCD. One is able to optionally turn off this display of data during the scan, as it will greatly increase the speed of the overall scan. If the user wishes to stop or abort the scan while in progress, the **Start/Stop** pushbutton may be actuated.

Once the automatic scan is complete, the **Busy** LED is turned off and a list of **resonant frequencies** and their associated SWR and impedance values will be displayed. A resonance is determined to be located at the points in the collected data where the SWR experiences a "monotonic minimum" – that is, when the SWR is detected as decreasing in a monotonic fashion (unchanging direction), then increasing in a similar monotonic way. This algorithm can detect multiple resonance points in an antenna system even when some resonances are more pronounced than others. In this results display mode, the resonant frequencies are presented individually to the LCD with an indication in the rightmost position that there is **More Data** to be viewed. Pressing Scan button advanced through the list of resonant frequencies until the list is exhausted, whereupon the More Data indication is no longer displayed.

If the Micro908 device is inactive for more than the default time of 60 seconds, the unit is put to sleep – i.e., it is placed in extreme low power mode – until the **Sleep** pushbutton is actuated to resume operation at the same point. The inactivity timer is configurable within the Configuration user interface.

One can enable/disable the **Tones** within the Configuration user interface. When enabled, a tone whose pitch is determined by the current SWR reading is annunciated via the internal speaker and through the headphone jack. Lower SWR readings produce lower tones. In this way, the unit may be used in situations when the LCD is not easily viewable.

One may also enable/disable **Morse Readout** of the frequency data within the Configuration user interface. When enabled, the frequency and SWR results are annunciated via the internal speaker and through the headphone jack. In this way, the measurements and computations are accessible when the LCD is not easily viewable.

Whenever Tones are enabled, the volume is adjustable with the **Volume** potentiometer on the front panel.

In the **Remote Mode**, communication is established with a PCLink program running on a PC for the purpose of uploading/downloading of data, and for establishing a link for remote control.

Basic Uses for an Antenna Analyst

Antenna analyzers are extremely useful devices to have around any ham shack or homebrewer's workbench. A small list of the things that many frequently want to do includes:

Antenna SWR measurements -- The antenna is simply connected to the analyzer antenna terminal and the analyzer is set to the desired frequency. The readout gives the resultant SWR. If the frequency is tuned across a ham band, the minimum SWR point (resonance) can be found as well as the SWR end points (usually 2:1).

Measure feed point impedance of antenna -- Connecting the analyzer directly at the antenna terminals or remotely through a half-wavelength of transmission line allows direct measurement of the antenna terminal impedance. This is often useful with vertical antennas. A matching network may also be connected to the antenna and then adjusted for best SWR on the analyzer.

With short vertical antennas measuring the impedance directly at the feedpoint allows estimation of ground loss or loading coil loss. For example a ¼ wave vertical will have a resistance of about 36 ohms at resonance. Any higher reading indicates ground loss. Similarly shorter antennas (when resonated) will have lower resistance values. Reading a good SWR may mean excess loss and measuring the actual impedance allows gauging just how much loss.

The analyzer can be used to adjust an antenna tuner for a perfect match without the need to transmit a strong signal from the station rig. The analyzer sources only milliwatts of power, thus lessening the possibility of interference.

The analyzer can measure the values of inductors and capacitors connected across its antenna terminal.

Series resonance of a tuned circuit can be accurately measured. The series combination is connected across the analyzer antenna terminal and the analyzer is tuned for the lowest resistance. The frequency where this occurs is the resonant frequency.

Advanced Uses for an Antenna Analyzer

The analyzer is an instrument that can be used for a number of uses well beyond simple SWR and impedance measurements. The following list outlines some of the uses. Detailed methods are available in a number of references including the MFJ-259B manual which can be found on-line. See the list of references for the URL

Determine characteristic impedance of transmission line. -- Using an electrically long length of the line connect a non-inductive resistor or about the correct resistance at the far end and the analyzer at the near end. Measure impedance while tuning the analyzer across the HF range. Note the observed impedance indication. If it varies with frequency try another value. When it matches the transmission line characteristic impedance it should remain approximately equal over a wide frequency range.

Determine length of ¼ and ½ wave phasing lines -- Half wave lines are easy – terminate the far end in the 50 ohms and read the near-end SWR. It will be 1:1 at the frequency where the line is ½ wavelength. A quarter wavelength is half this length. There are more sophisticated means for direct ¼ wave line determination.

Coaxial Cable Loss – Leave the far end of a transmission line open while measuring SWR. A table of feedline loss versus SWR in the ARRL Antenna Book can be consulted for the corresponding value

Determine antenna tuner loss – An excellent method for using an analyzer to measure tuner loss was published in QSR by Frank Witt, AI1H. See the references for the publication information. In addition the articles can be downloaded from the ARRL Member's Only site. The same method can be used to measure balun loss.

Measure inductor Q – The series impedance and inductance of an inductor can be measured and used to calculate coil Q. For high-Q inductors a series resistance can be used to get an in-range resistance value and the known resistance is subtracted from the reading to calculate Q.

Estimate quartz crystal parameters – Since the Analyzer can be tuned precisely the series resonant frequency and series resistance of a quartz or ceramic resonator can be measured. An off-resonance measurement of the parallel capacitance can also be estimated.

Measure magnetic loop resonance and SWR -- As with quartz crystal measurements, the high-Q characteristics of magnetic loops make their measurement difficult with analog-tuning analyzers. The precision DDS in this analyzer overcomes that difficulty.

Of course, since the Antenna Analyzer II software is easily able to be updated though quick 'n easy downloads from the project website.

PCLINK

PCLink is an optional program from your PC that connects to the Micro908 Antenna Analyst to upload, display and save data collected by the instrument. The Micro908 connects to the serial port of a PC for uploading raw measurement data for graphical display and plotting, and for remote control of the unit. The mode is entered merely by connecting a standard RS-232C serial cable between the Micro908 and a PC that is running the companion PCLink software provided with the project.

Data Display -- After the Analyst has completed a manual or automatic data collection scan, it may be connected to a host PC which is running software that uploads the frequency and SWR data from the unit and displays a graphical plot of that data on the video monitor. This view of the data can present a more detailed and visually-intuitive representation of the antenna system performance. Options are also present in the PCLink software package to allow data storage, retrieval and hard copy printout.

Remote Control – The PCLink software running on the host PC allows all operations of the Analyzer to be run from the PC keyboard and display. This mode is useful when the analyzer is located in an inconvenient or slightly remote location from the operator's bench. Thus, the host PC is a virtual control panel for the Analyzer.

Calibration – The PCLink software package also provides the user with a precise way to calibrate the analyzer. Specific parameters to be set include: the transmitter frequency, the low and high edges of each band, specific bands of interest (i.e., an ability to select only certain bands to be scanned by the analyzer), and SWR readings.

There are default values for each of these parameters, so the Calibration function (and hence the PC) is not mandatory. However, great flexibility comes about through use of this facility.

Shown below is a screen shot of the PCLink application being run on a standard PC. The display indicates the collected SWR readings as a red line on the graph. Here you can see the antenna system showing a better (lower) SWR in the 21 MHz region of the spectrum. This data had just been uploaded from the Antenna Analyst.
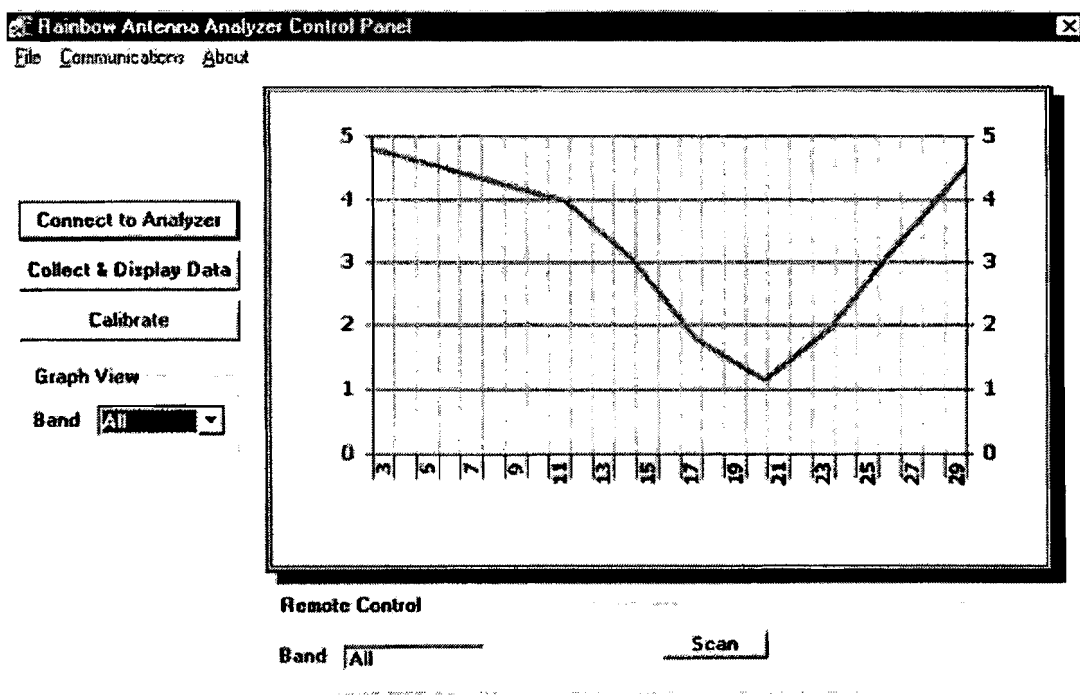
The controls on the PCLink screen allow the user to Connect to the analyzer for subsequent manual control, Collect and Display the Data, Calibrate the system, set the Band for either graph view or for manual control, and to initiate a Scan.

The PCLink program was written in Microsoft Visual BASIC. The project source code and forms files are posted on the AmQRP website for those interested in modifying the code and experimenting with customized programs.

Notes

1) If you have any questions concerning this project, please contact either of us - we'd be happy to help you along in understanding our rationale and design approach.

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2) The **Micro908 Antenna Analyst software** may be freely downloaded from the project website at www.amqrp.org/kits/micro908. Both source and object (loadable) files are placed in the public domain under the GPL license and may be freely used by others for non-profit purposes. The GPL license, included in the download, directs that modifications and/or improvements made to this software be similarly made available again to the public domain.

References:

1. ARRL Antenna Book, ARRL, Newington Ct.

2. ARRL Radio Amateur Handbook, ARRL, Newington, CT

3. Jan 1987 QST p. 18, The Tandem Match--An Accurate Directional Wattmeter, John Grebenkemper, KA3BLO

4. Aug 1990 QEX p. 3, Calibrating Diode Detectors, John Grebenkemper, KI6WX

5. Feb 1990 QST p. 19, A Simple and Accurate QRP Directional Wattmeter, Roy Lewallen, W7EL

6. Oak Hills Research wattmeters: www.ohr.com/wattmeter.htm

7. Feb 1995 QEX p. 3, A UHF+ VSWR Bridge Paul Wade, N1BWT

8. Apr 1995 QST 30 How to Evaluate Your Antenna Tuner--Part 1, Frank Witt, AI1H

9. May 1995 QST 33 How to Evaluate Your Antenna Tuner--Part 2, Frank Witt, AI1H

10. MFJ-259B Operator Manual www.mfjenterprises.com/man/pdf/MFJ-259B.pdf
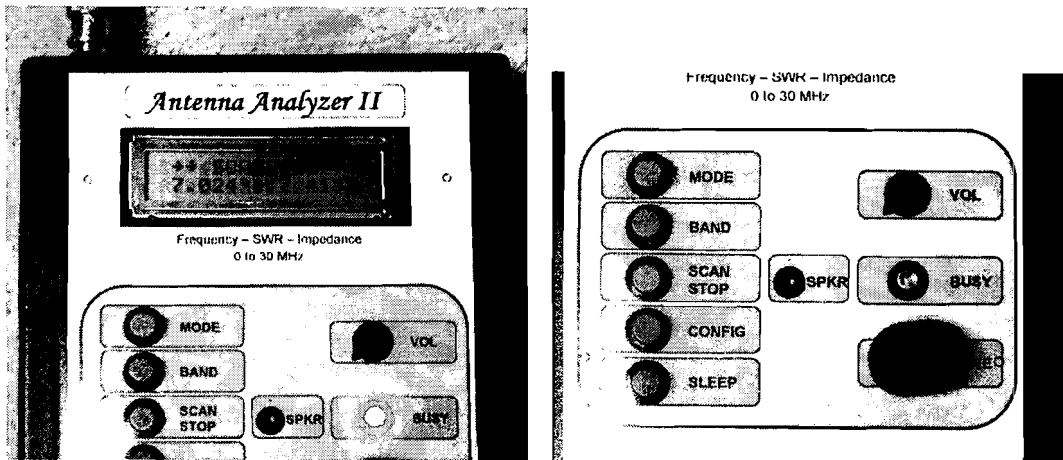
Close-up photos of the front panel user interface.
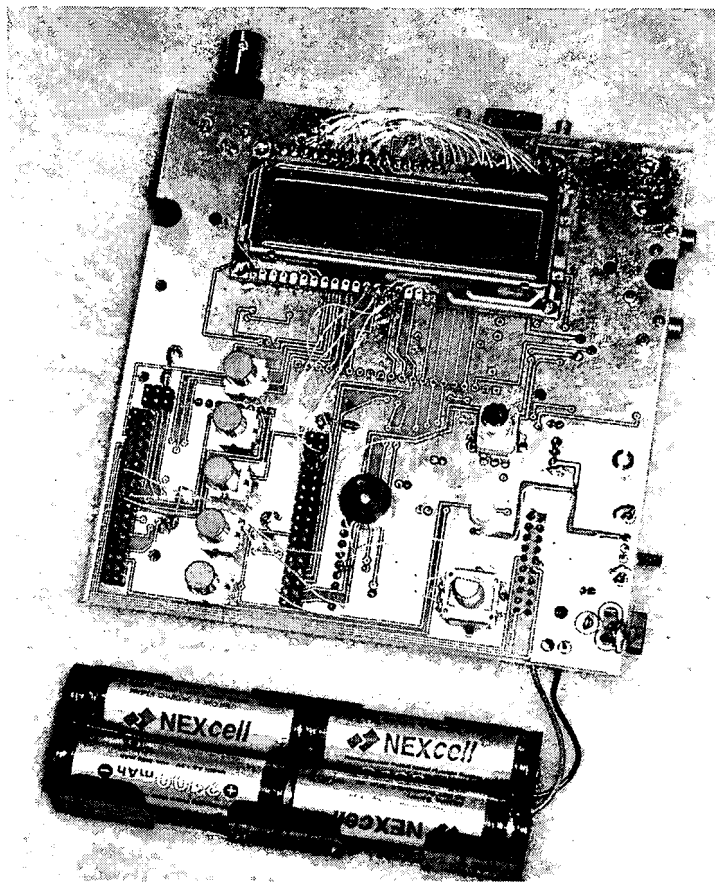
Photo of the Micro908 circuit board without the enclosure. This pc board is one of the prototypes and has a number of "cuts & adds", predominantly in the area of the LCD. The prototype board layout mistakenly had an orientation reversal of the LCD connector pins and it was necessary to hard-wire in the proper connections. An interesting point about this is that this same technique would be used to wire an LCD that is not of the type or dimensions specified. Just attach the LCD to the main board with standoffs of some sort and use thin wires to connect the LCD connector pads down to the proper pads on the Micro908 pc board.

Micro908 — Sheet 1/2

+5V

R4 10K   R5 10K

J12 Paddle

P1-9   C3
P1-7   C1

C38 0.1   C39 0.1

+5V

J11 Keyboard
5   1
3   2
Data   P2-25   A7
Clk   P2-34   A0

ENC Rotary Encoder
+5V   R2 10K
R1 10K   R3 10K
A   P1-21   F5
B   P1-18   F4
Com
PB   P1-17   F3

C1 0.1   C2 0.1   C3 0.1

P3 Monitor
1   2   P1-20   F7

+V   R28 18.2K
P2-21   B3
R41 10.0K

SWR Bridge   Buffer Amp
Vfwd   P2-24   B2
Vz   P2-23   B1
Vrev   P2-26   B0

See sheet 2

DDS D'card
load   P1-16   F2
clock P1-15   F1
data   P1-14   F0

DSP RST   P2-28   A6
See sheet 2   DSP RXD   P2-27   A5
DSP TXD   P2-30   A4

+V (in)   Gnd
J1-34   J1-19   J1-33

HC908 Daughtercard

P2-5   14   D7
P2-8   13   D6
P2-7   12   D5
P2-10 11   D4
J2-11 10   D3
P2-14   9   D2
P2-15   8   D1
P2-18   7   D0
P2-29   6   E
P2-32   5   R/W
P2-31   4   D/I

D7
D6
D5
D4
D3
D2
D1
D0

W1

LCD
Vd   2
Va   3
Vs   1

W1   +5V
R6 4.3K
R7 330

E6   P1-29   9   SI
E5   P1-28   2   SO
E7   P1-30 10   SCK
E4   P1-27   1   CS/

Vcc   16   +5V
HLD/WP/ 15
7
Gnd   8

U2 SEEPROM 512 kb (64Kx8)

E2   P1-25   Tones (See Pg. 2)

C0   P1-6   R8 1K   LED-1   +5V   Busy

+5V
R17, 18, 22, 23, 27 10K (ea)

H1/KBD4   P2-9   PB-1 Mode
H0/KBD3   P2-12   PB-2 Band
G2/KBD2   P2-33   PB-3 Scan
G1/KBD1   P1-32   PB-4 Config
G0/KBD0   P1-31   PB-5 Sleep

C11-C15 0.1uF (ea)

E0/TxD   P2-3
E1/RxD   P2-4
1 6 2 7 3 8 4 9 5
J2 Comm Port

GND   P2-2

+5V
VrefH   P1-4
Vddaref P2-16
VrefL   P2-13

1 2 3 4 5 6 7 8
Currently unused
J14 AUX

J4 External Power (12-13.6V)

D7 1N5817
D9 1N5817   R47 12 1/2W   D8 1N5817
P4 NiMH
B1
J3

S2 Power

C4 0.1   +V   C5 10uF   U1 I O G   C6 0.1   +5V   C7 1uF

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DDS Daughtercard

from HC908 port F2 → J10-1 Load
from HC908 port F1 → J10-2 Clock
from HC908 port F0 → J10-3 Data
N/C → J10-4 5V out
J10-5 Gnd
J10-6 RF Out A
N/C → J10-7 RF Out B
+V → J10-8 +V

J1 RF Out

Compensation & Buffer Amplifiers

Vz → U3a → U4a → Vz to HC908 port D0
C36 0.1, C37 0.1
R16 220K, D4 1N5711, R20 221K, R19 100K

Vrev → U3b → U4b → Vrev to HC908 port D1
R21 220K, D5 1N5711, R25 549K, R24 100K

Vfwd → U3c → U4c → Vfwd to HC908 port D2
R26 220K, D6 1N5711, R30 221K, R29 100K

U3, U4 LMC6484

Reflectometer

D1 1N5711, R12 49.9, C19 0.1, D2 1N5711, R14 49.9
R10 47K, R11 49.9, R13 47K, C21 0.1
C17 0.1, R15 47K, R34 1M
C20 .01, D3 1N5711
R32 1M, C18 .01, R33 1M, C22 .01

KK7P DSPx Daughtercard

+5V → J9-1 VCC5
J9-2 DGND
C35 0.1, D11 1N5711
DSP RXD (HC908 port A5) → J9-10 RXD
DSP TXD (HC908 port A4) → U6 TC7SET08 → J9-11, J9-12 TXD TXD
DSP RST (HC908 port A6) → D10 1N5711 → J9-20 RES

J8-1 RLINEIN, C29 0.33
J8-2 LLINEIN, C30 0.33
J8-3 AGND
C31 560, R37 5.1K, C32 560, R38 5.1K
J8-6 RHPOUT, C33 1uF
J8-7 LHPOUT, C34 1uF
J8-8
J8-12 AGND
R39 5.1K, R40 5.1K

J6 Audio IN
J7 Audio OUT

Audio Amp

SPKR 32-OHM
R43 10 1/2W, +V, C27 47uF
C23 .01, R42 10K, C26 10uF, C24 100uF, U5 LM386, R44 4.7K
R46 10, C25 0.1
R45 10K, C28 .01
Audio
TONES from HC908 Port E2, C40 .01

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