Product Review: The Array Solutions VNA2180 Vector Network Analyzer
Phil Salas – AD5X

Introduction

In August 2007 QST reviewed the Array Solutions AIM4170 antenna analyzer. In the ARRL review it was pointed out that "… the accuracy is exceptional …" and "… the AIM4170 is really more of a laboratory instrument…" I couldn't agree more as I've found the AIM4170 to be indispensible for my home lab work – so much so that I also wrote a review of the AIM4170 (elsewhere on this website). And while the AIM4170 has been outstanding in all that it does, I've wanted a 2-port version so I could design and analyze 2-port devices. Enter the VNA2180 Vector Network Analyzer.

Photo A: Array Solutions VNA2180 Vector Network Analyzer & Supplied Accessories

VNA2180 Description

The VNA2180 is a 2-port instrument where Port A is an enhanced version of the AIM4170 featuring increased frequency range, higher output signal with a programmable level, and the ability to handle a higher interfering signal level while making antenna measurements). The VNA2180 also has a built-in optically-isolated USB interface which reduces the effects of ground loops. As this review focuses on the Port A-to-Port B transmission path capability of the VNA2180, refer to the above referenced AIM4170 reviews for the Port A features. The complete VNA2180 specifications are show below:

Parameter	Specification
Frequency Control	Digital Synthesizer
Frequency Range	5KHz-180 MHz
Stability	+/- 25 ppm
Frequency Step Size	1 Hz minimum

Calibration	Software controlled
ADC resolution	12 bits
SWR measuring range	1 to 20
Impedance Measurement Range	1 ohm to 5K ohms
Accuracy	+/- 5% to 60 MHz, +/- 10% to 180 MHz
Phase Angle	+/-180 degrees (true phase)
RF Output	+7 milliwatts max, nominal output Z = 50 ohms.
Spurious output	–30dBc or better
Max stray RF input while measuring	2V peak (+16dBm)
Max safe RF input	5V peak (+24dBm)
S21 nominal dynamic range	100dB up to 50MHz, 80dB to 160MHz
Port B nominal input impedance	50 ohms - Return Loss greater than 30dB.
RF Interfaces (Ports A & B)	Type N connector
PC Interface	Optically isolated USB, FTDI chipset
Display	Graphics output on PC. Mouse controlled cursor for digital parametric readout. User-specified frequency markers. SWR audible tone & speech output. Displayed parameters: SWR, S11, Return loss, |Z|, Phase angle of |Z|, S21, R_S, X_S, R_P, X_P, and uH or pF. Two Smith Charts with zoom, phase offset and markers. Data can be referenced to the antenna terminals.
Power Requirements	11-15 VDC, 500mA max (power supply included)
Dimensions (approx)	7" x 5.3" x 1.5" (17.8 x 13.5 x 3.8 cm)

Preparing to use the VNA2180

The VNA2180 software has been tested with Windows 2K/XP/Vista/Win7 32/64 bit. No software installation is required - it can run directly from a flash drive or CD if desired. The VNA2180 includes three standard N-connector calibration loads (open, short, and 50Ω), a 120VAC power supply (or optional DX power supply with Australian, European, US and UK adapters), a 2.1mm DC cable, two N-male terminated cables, and a USB interface cable. You must download the VNA2180 manual and software from w5big.com. Incidentally, you can run the software in demo mode to get a feel for the product prior to purchasing.

Calibration requires no tools or adjustments, and you'll have everything up and running in minutes. However since the VNA2180 Ports A&B uses N-connectors, you must purchase BNC/F-to-N/M and UHF/F-to-N/M adapters for BNC and UHF measurements (I purchased mine from www.therfc.com). And while not absolutely necessary for many lower frequency measurements, for maximum accuracy you'll want BNC and UHF calibration loads. However these are easy to build (see the last section of this review).

Using the VNA2180

My first project was a low-pass filter needed to clean up the square-wave output of a 50 MHz TTL clock oscillator for use as a standard signal source for calibrating attenuators. The schematic of the filter is shown in Figure 1.

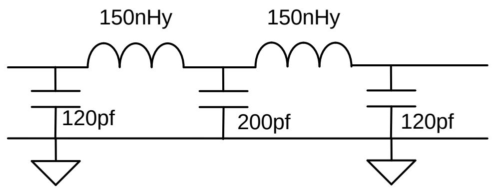

Figure 1: 50 MHz Low Pass Filter

The VNA2180-measured filter response, shown in Photo B, highlights the ability to set vertical markers (up to 20), and simultaneously display S11 and S22. I set markers at 50- and 100-MHz. The vertical cursor is placed at 150 MHz, where I wanted maximum rejection. Incidentally, Port B provides a 50Ω termination >30dB return loss.

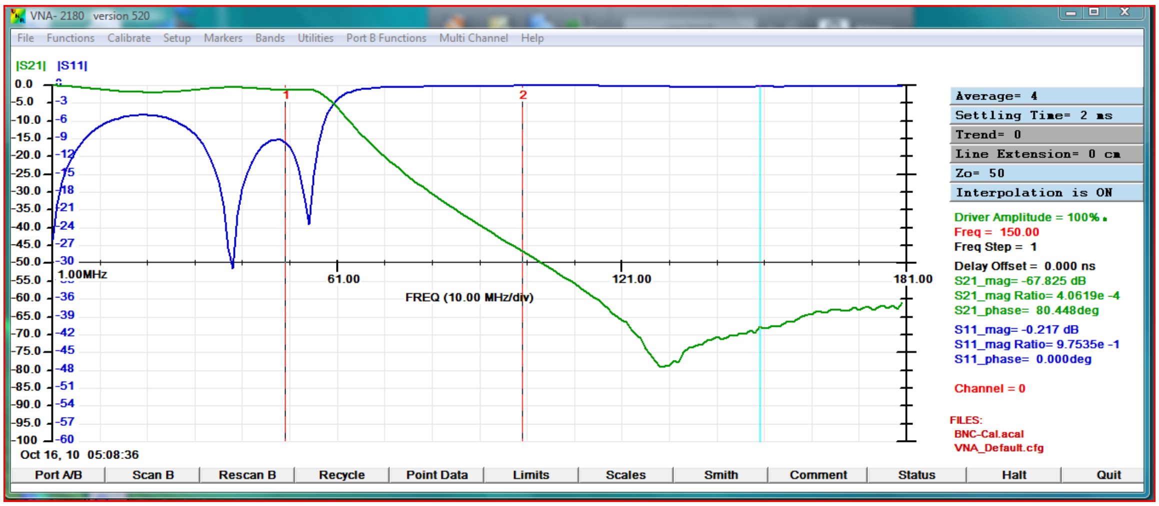

Photo B: Low Pass Filter Swept Response. Markers at 50-, 100-, and 150 MHz

My next project was a resistive 50dB tap covering 1.8-148 MHz to permit looking at a transmitter RF output on a spectrum analyzer. My original circuit is shown in Figure 2, and the final circuit is shown in Figure 3. The two paralleled 16K 2-watt metal film resistors provide the necessary power dissipation for up to a 600 watt amplifier. The VNA2180 software permits setting an offset attenuation value while simultaneously permitting a fine attenuation range. In this way you can look at fine variations in attenuation, even at the 50dB tap point. As you can see in Photo C, I set an offset of 45 dB with a measuring resolution of 0.5 dB.

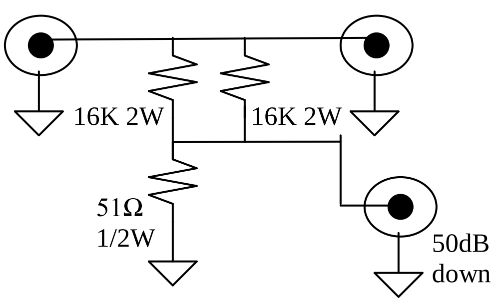

Figure 2: Original Resistive Tap

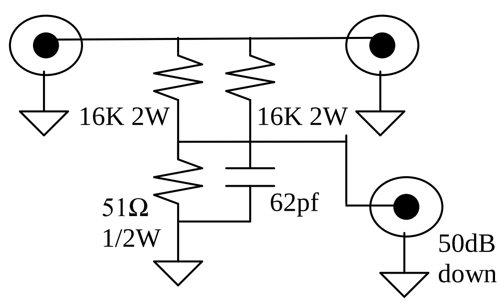

Figure 3: Final Resistive Tap

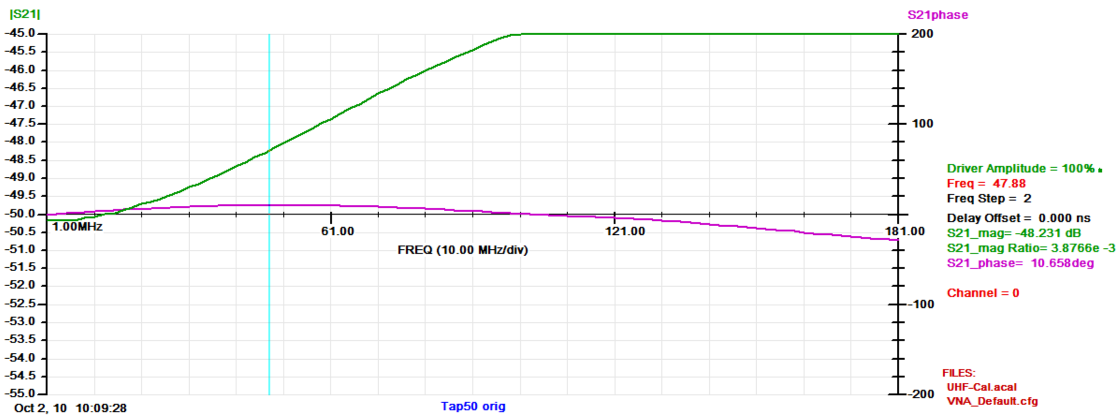

Photo C: Original Sweep of the 50dB resistive tap

As you can see, the isolation degrades at higher frequencies due to stray capacitance across the paralleled resistors (even a few picofarads impacts isolation at higher frequencies in a high impedance circuit). The 62pf capacitor across the 50 ohm resistor (Figure 3) compensates for this. Photo E shows the final swept response. The three horizontal markers are on 10-, 6-, and 2-meters. Horizontal rulers at -49dB and -51B show that the tap circuit provides 50dB +/- 1dB attenuation in all ham bands through 2-meters.

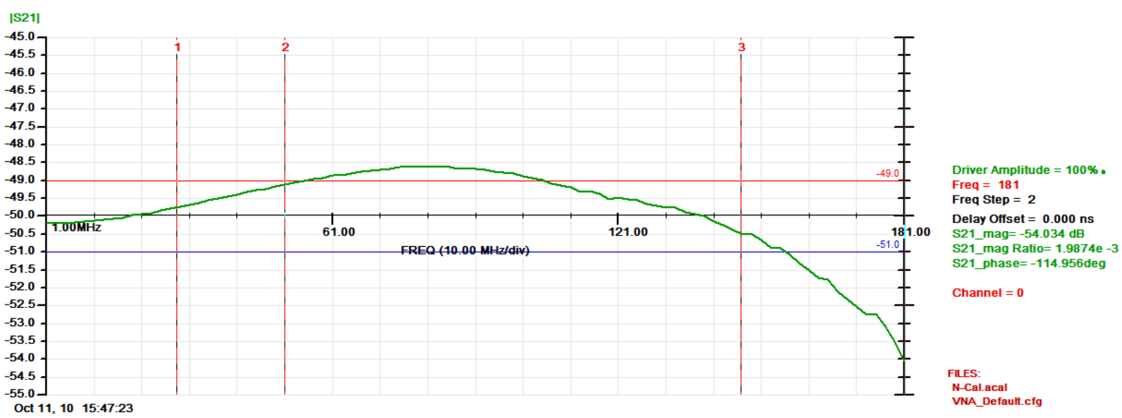

Photo D: Compensated 50dB tap. Vertical rulers on 10-, 6-, and 2-meters

Next I wanted to characterize a home-brew 4-element crystal filter. The schematic is shown in Figure 4 below.

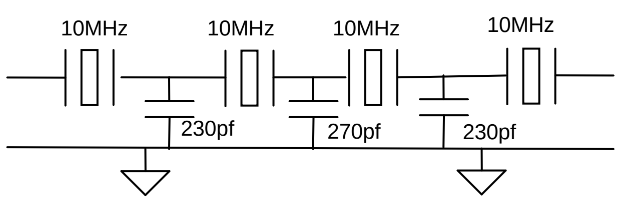

Figure 4: 10 MHz Crystal Filter

I ran two scans. The first (Photo E) shows the ultimate rejection of this crystal filter which is in excess of 100dB just 5 kHz to either side of the 9.998MHz center frequency.

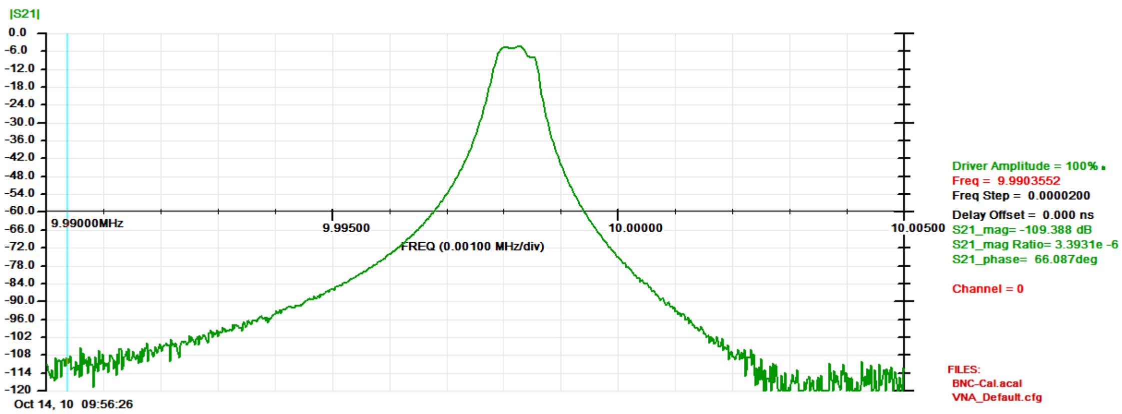

Photo E: Crystal Filter ultimate rejection

The second scan has a narrowed pass-band and increased vertical resolution to better see the pass-band response. The VNA2180 software calculates the shape factor of the filter for you when you insert horizontal rulers at the desired measuring points. Because the filter loss is approximately 4.5dB, horizontal rulers were set at -10.5dB and -64.5dB so as to calculate the standard 6/60dB shape factor. The results are shown in Photo F below.

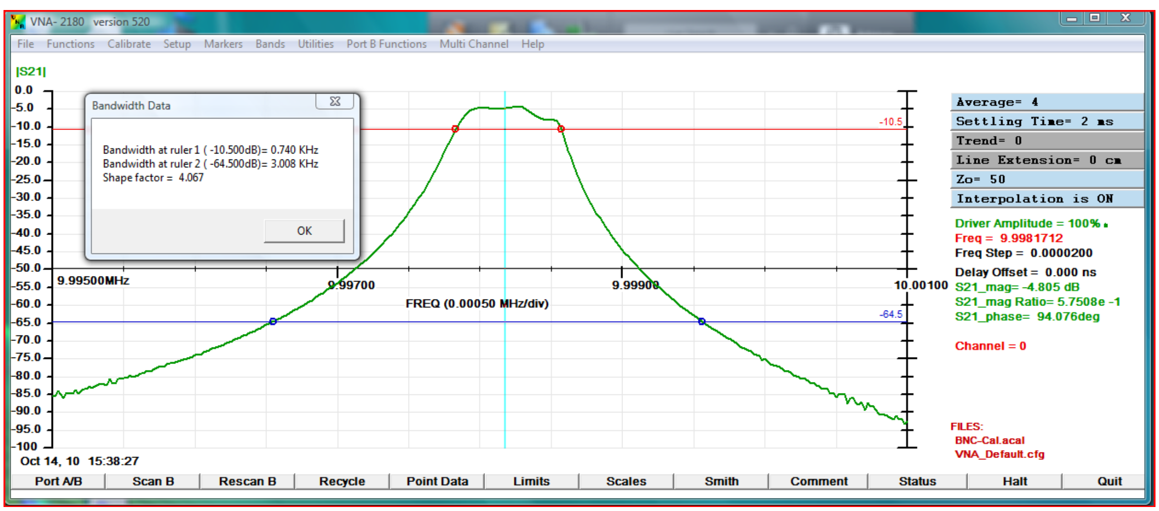

Photo F: Determination of Crystal Filter Shape Factor

Finally, I looked at a commercially available 40 meter band-pass filter used in contest environments to protect a receiver from high-power adjacent band transmitters and nearby antennas. A broadband scan is shown in Photo G. This filter has rejection specifications of 42dB (horizontal red ruler) on 80 meters, and 70 dB (horizontal blue ruler) on 20 meters. Note the simultaneous display of both S11 (dark blue scan) and S22 (dark green scan). Vertical markers are set at 4 MHz and 14 MHz. The vertical curser is placed within the 40 meter band to show the in-band insertion loss (0.430dB).

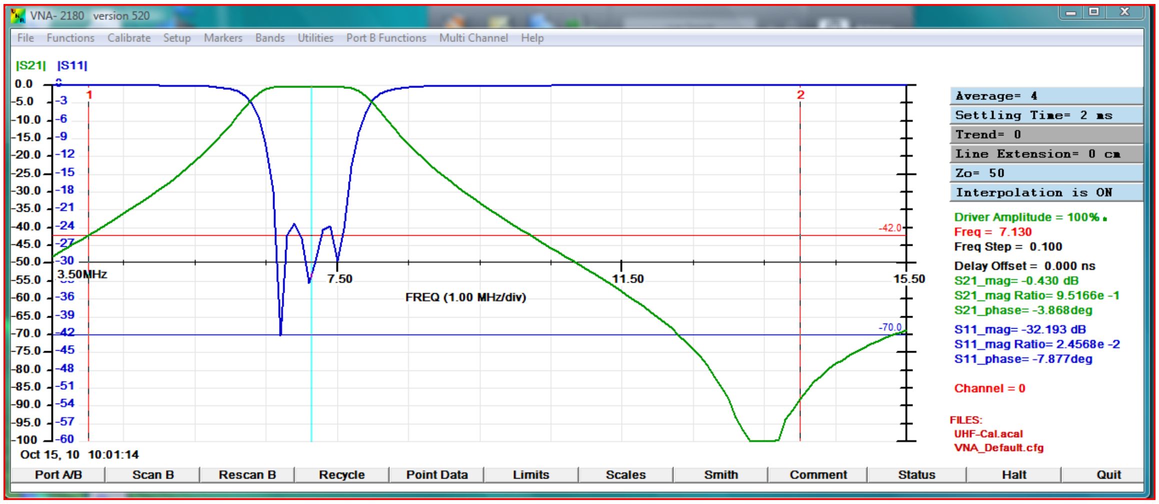

Photo G: 40 Meter Band-Pass Filter Response

<u>Conclusion</u>

The VNA2180 is a lab-grade analyzer that you will find to be an indispensable item for both home and industrial lab environments. And with software and firmware updates continually available for download at no charge, you don't have to worry about product obsolescence. I've only touched on some of the transmission capabilities of this instrument. As an example, group delay measurements permit you to determine the length of cables and potential distortion in filters. There is also an external port with both digital I/O and analog input capability for possible control and monitoring of other accessories. Finally, there is a wealth of measuring and analysis capabilities associated with Port A. Detailed information is readily available for further investigation at w5big.com. The complete manual is included with the program zip file.

The VNA2180 is available from Array Solutions (www.arraysolutions.com).
Price - US Version: VNA-2180 @ $1495. With DX supply: VNA-2180-1 @ $1524.

Addendum: Building BNC and UHF Calibration Loads for the VNA2180
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For maximum accuracy, BNC and UHF calibration loads should be used when making measurements on equipment and components with these connectors.

BNC calibration loads are easily built into RG-58 BNC crimp-on connectors. The parts list is shown in Table 1. Mouser (www.mouser.com) part numbers are shown.

Table 1: BNC Calibration-Loads Parts List

QTY	Description	Part Number
3	BNC crimp-on connectors	601-27-9208
1	49.9Ω 1% ¼-watt resistor	71-CMF5549R900FHEK
1	Buss wire or resistor lead	
1	Toothpick	
1	Dab of epoxy	

For the BNC 50 ohm load, clip one 49.9 ohm resistor lead just long enough to go into the BNC center pin and solder the resistor lead to the pin. Slide the center pin/resistor into the BNC plug, fold the resistor lead over the BNC collar, and solder the lead to the collar. The short circuit is assembled the same way, using just a resistor lead or buss wire.

For the open circuit, insert the BNC center pin into the plug. Coat a toothpick end with epoxy and push the toothpick into the BNC plug so it is snug against the center pin. When the epoxy cures, snip-off the excess toothpick.

When complete, put heat-shrink tubing over the BNC collars and mark with a silver Sharpie™ pen (∞, 0, and 50). Photo A shows parts prior to assembly, and Photo B shows a 50 ohm marked load.

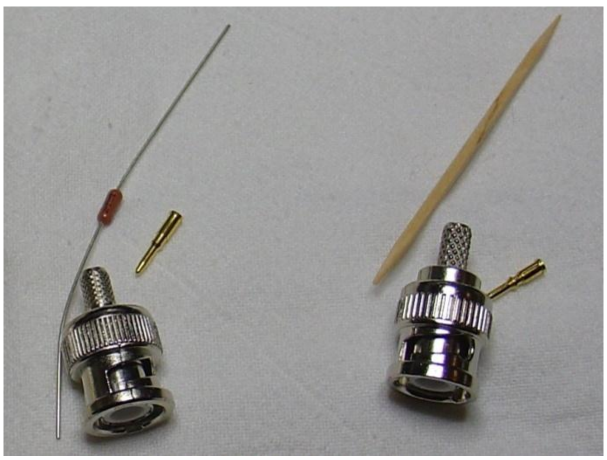

Photo A: 50 Ohm Load & Open BNC parts

Photo B: Final BNC 50 ohm load

The UHF calibration loads are also easy to build. The 50 ohm load consists of two 100 ohm resistors in parallel. Begin by putting a slight bend in the end of one lead of each resistor. Slide one resistor through the UHF center pin, bent lead end first, and feed the resistor lead through one of the shield holes in the connector. Pull the resistor through so it clears the pin inside the connector but with minimum lead length on both ends. Do the same for the second resistor. Solder the resistor leads in the UHF connector center pin, and then solder the ground ends of the resistors to the UHF body. The UHF short is built the same way, only use two pieces of bus wire or resistor leads. An empty UHF connector is used for the open circuit. The parts list is shown in Table 2. Photos of the before and after UHF 50 ohm load is shown in Photos C & D below. The connectors were marked with Casio labeling tape.

Table 2: UHF Calibration-Loads Parts List

QTY	Description	Part Number
3	PL-259 connector	523-83-1SP-1050
2	100Ω 1% ¼-watt resistor	660-MF1/4D52R1000F
1	Bus wire or resistor lead	

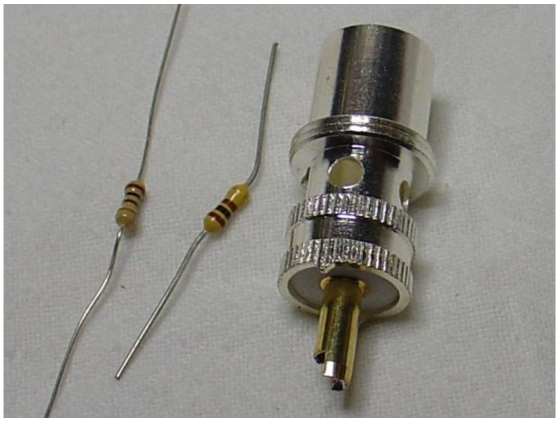

Photo C: PL259 and two 100 ohm resistors Photo D: Final 50 ohm load

The return loss of the 50 ohm loads was measured at 180 MHz with a spectrum analyzer/tracking generator and MiniCircuits ZFDC-20-5 directional coupler. N adapters were used for the BNC and UHF connectors. The results are shown in Table 3. As you can see, the performance of the homebrew loads is quite good.

Load	Return Loss/VSWR
Supplied Array Solutions N-load	36dB/ 1.03
Precision Array Solutions N-load (optional)	42dB/1.01
BNC homebrew	30dB/ 1.07
UHF homebrew	40dB/ 1.02