FA-VA5 Vector Antenna Analyzer and RF Explorer WSUB1G+ Spectrum Analyzer

Whitham D. Reeve

1. Introduction

The battery-operated Funk Amateur FA-VA5 Vector Antenna Analyzer and RF Explorer WSUB1G+ Spectrum Analyzer are small and light instruments that are well-suited for field measurements where portability is an important consideration (figure 1). The instruments also may be powered, operated and controlled through their USB ports. These test sets are differentiated from many other similar inexpensive instruments by having associated software applications that actually are useful and work. Also, both have decent documentation and operate reliably and consistently.

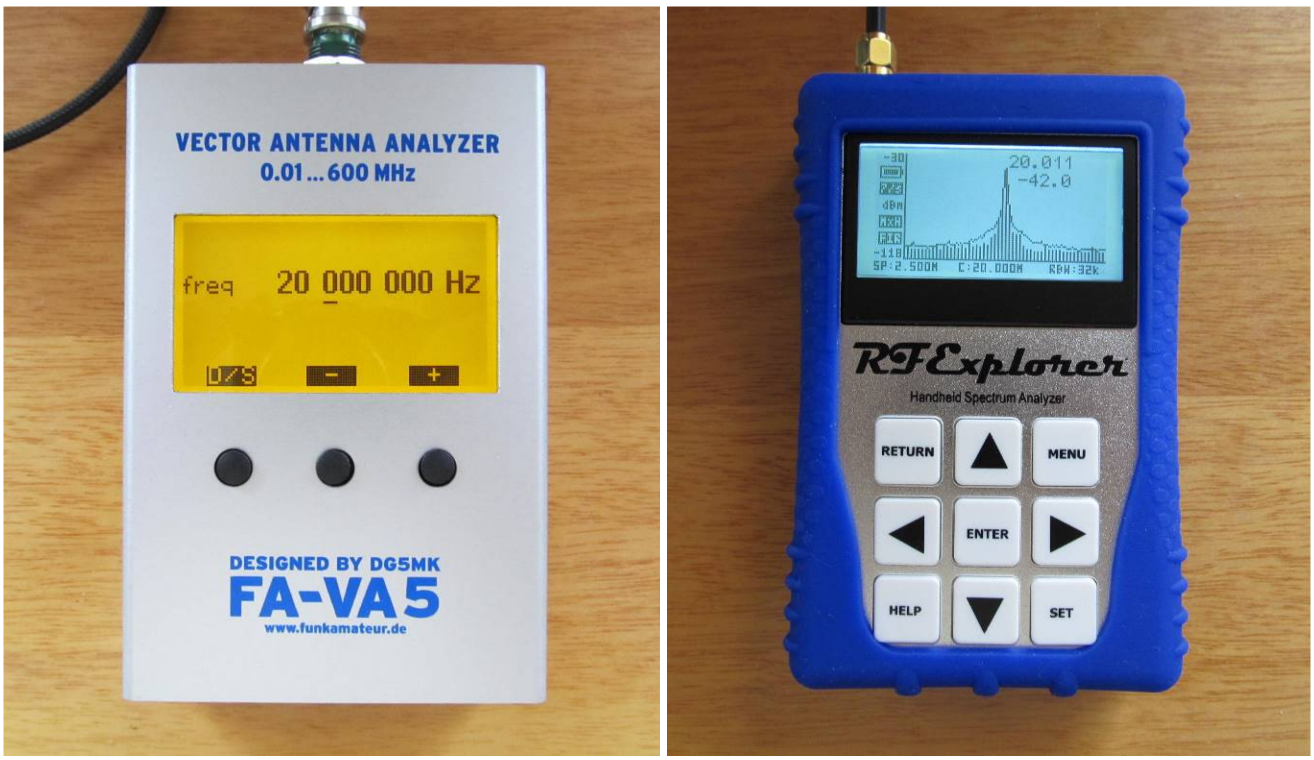

Figure 1 ~ FA-VA5 (left) and WSUB1G+ (right) in operation, shown at approximately 65% scale. The FA-VA5 is in the Frequency Generator mode with the frequency set to 20 MHz. It is connected to the WSUB1G+ through several attenuators totaling 46 dB and two short coaxial jumper cables. The output from the FA-VA5 is +5.4 dBm and is measured as –42.0 dB at the RF Explorer, an error of –1.4 dB (assuming perfect attenuators) and well within its accuracy specifications. The WSUB1G+ is shown in an optional rubber protective sheath. Images © 2020 W. Reeve

The FA-VA5 is a 1-port analyzer for measuring the complex impedance of antennas and other RF devices from 10 kHz to 600 MHz. The impedance can be displayed in terms of real and imaginary components, voltage standing wave ratio (VSWR), return loss and reflection coefficient; a Smith Chart display also is available. The reference impedance can be set to 25, 50 or 75 ohms (default is 50 ohms).

The FA-VA5 also includes LCR (inductance-capacitance-resistance) and RF signal generator functions but the upper frequency range of the latter is limited to 200 MHz. The signal generator function is very simple – there are no sweep, modulation or output power settings and when selected is always on. The signal generator output is a squarewave, so its spectra includes the fundamental frequency and harmonics. Although the FA-VA5 has several functions targeted at radio amateurs, such as the ability to simultaneously display the VSWR of five frequency bands associated with a multiband antenna (for example, five *radio amateur* bands), it can be setup for any frequency or set of frequencies within its range.

The FA-VA5 may be purchased in *semi-kit* form or fully assembled and tested. The kit is supplied with a printed circuit board that has all surface-mounted devices (SMD) preinstalled. The kit builder only needs to solder the display and a few other components and place them in the metal enclosure.

The FA-VA5 is like all vector network analyzers and requires calibration before use to take into account the measurement setup and conditions (test cables, adapters, temperature and so on). Short-Open-Load (SOL) calibration standards for use below about 100 MHz can be easily shop-built from BNC connectors; in fact, parts for just this purpose are provided with the unit. Alternately, an inexpensive (20 USD) 4-piece BNC calibration kit is available that is designed for operation up to 600 MHz.

A *Master Calibration* requires about 20 min and covers the full frequency range. The Master Calibration data are stored in non-volatile memory. The instrument also supports a *Current Calibration* that the user can do at individual frequencies or frequency ranges but the data are non-volatile. Current Calibration is used to compensate for temporary changes in the measurement setup that was used for the Master Calibration, for example, using the FA-VA5 outdoors after the Master Calibration had been made indoors.

RF Explorer is a family of ready-to-use portable spectrum analyzers that have the same form factor but different frequency ranges. RF Explorer also makes two signal generator versions, one of which has a frequency range of 100 kHz to 6 GHz. The spectrum analyzers are primarily designed for locating RF signal sources (*sniffing*) and radio frequency interference. The RF Explorer WSUB1G+, which is the specific model discussed here, has a frequency range from 50 kHz to 960 MHz. The unit can be set to display a frequency span as narrow as 112 kHz (resolution of 1 kHz for each of the 112 displayed datapoints) or as wide as 960 MHz. The resolution bandwidth of the WSUB1G+ is set automatically based on the displayed frequency span and cannot be set manually.

The minimum displayed noise level of the WSUB1G+ is –125 dBm, making it useful for weak signals. The internal low noise amplifier (LNA) must be enabled to achieve levels this low. The LNA provides 25 dB gain and is supposed to be usable with signals below –40 dBm. For strong input signals, an internal 30 dB attenuator may be switched in. The WSUB1G+ can display two types of markers, automatically display the frequency and power of the Peak signal and display the signal power at a Manual frequency setting.

Although both instruments operate for many hours on their internal batteries, the USB ports on both can be connected to a 5 V *battery brick* for extended portable operating time (figure 2). The FA-VA5 does not use rechargeable batteries but the WSUB1G+ battery may be recharged through the USB port from a PC, battery brick or dedicated power supply.

The remainder of this article describes the technical aspects of both the FA-VA5 and WSUB1G+ (section 2) and then describes some field applications (section 3). Included are comments (section 4), and weblinks and references (section 5).

2. Descriptions

The characteristics of the FA-VA5 and WSUB1G+ are summarized in table 1. Although the FA-VA5 primarily is an analyzer, it also can be operated as a stable, variable frequency RF signal generator as noted in section 1.

Table 1 ~ FA-VA5 and WSUB1G+ characteristics as given by the manufacturers

Parameter	**FA-VA5 (a)**	**WSUB1G+ (b)**	**Remarks**
Frequency range (MHz)	0.010 – 600	0.050 – 960	
Frequency span (MHz)		0.112 – 960	Datasheet shows minimum is 100 kHz
Measurement range – VSWR	≤ 100:1		
Measurement range – Impedance (ohms)	≤ 1000		Lower accuracy at higher impedances
Frequency resolution (Hz)	1	1000	
Amplitude resolution (dBm)		0.5	
Resolution bandwidth (kHz)		2.6 – 600	Automatic, no manual setting
Display size (pixels)	128 x 64	128 x 64	W x H
RF impedance (ohms)	50	50	
Maximum input power (dBm)		+30	
Dynamic range (dB)	80 (≤ 200 MHz)		50 dB (200 – 600 MHz)
Dynamic range (dBm)		–125 ... +10	
Signal generator output power (dBm)	+5.4		Reduced above 100 MHz; datasheet specifies 1 $V_{pk\text{-}pk}$
Signal generator frequency range (MHz)	0.010 – 200		
Measurement accuracy (%)	≤ 2		0.01 MHz ≤ f ≤ 200 MHz, Z < 1000 ohms
Frequency accuracy (ppm)	Not specified	±10	a. & b. Can be calibrated
Frequency stability (ppm)	±0.5	±10	
Amplitude accuracy (dBm)		±2	
Amplitude stability (dBm)		±2	
Amplitude resolution (dBm)		0.5	
Internally selectable LNA/Attenuator (dB)		+25/–30	
Controls	3 push-buttons	9 push-buttons	
Dimensions (mm)	127 x 86 x 23	113 x 70 x 25	H x W x D
Weight (kg)	0.280	0.185	
Power	1.5 V battery 2 x AA or USB	Li-Poly battery 1 x 1000 mAh or USB	5 V USB. a. Non-rechargeable batteries; b. Rechargeable battery
Battery operating time	Not specified	16 h	
RF Connector	BNC-F	SMA-F	
Firmware	Updateable	Updateable	
Software (Windows)	VNWA	RF Explorer	Free
Purchase configuration	Partial kit or ready to use	Ready to use	a. All SMDs preinstalled in kit version
Cost	167 USD	165 USD	a. & b. Not including shipping
Vendor	{SDR-Kits}	{RFExplorer}	b. Also available from others

The FA-VA5 is compatible with the free *DG8SAQ VNWA* software (figure 3) that originally was designed for the VNWA-series of vector network analyzers sold by {SDR-Kits}. This software can fully control the FA-VA5 and significantly extends its usefulness by providing plots and data capture in scattering parameter format (*.s1p) among many other features. No direct Linux support is provided for the VNWA software but many users have made it can run as a virtual application under Linux.

Figure 2 ~ *myCharge – Adventure Max* portable charger is typical of battery power supplies that may be used for powering the instruments through their USB ports. The battery in this unit is advertised as 10 050 mAh. It is charged through a micro-USB port and it has two USB-A output ports that supply 5 Vdc. Dimensions are 1.0 L x 2.4 W x 4.4 H in (25.4 x 61.0 x 112.3 mm) and weight is 0.55 lb (0.25 kg) – approximately the same size as the RF Explorer WSUB1G+.

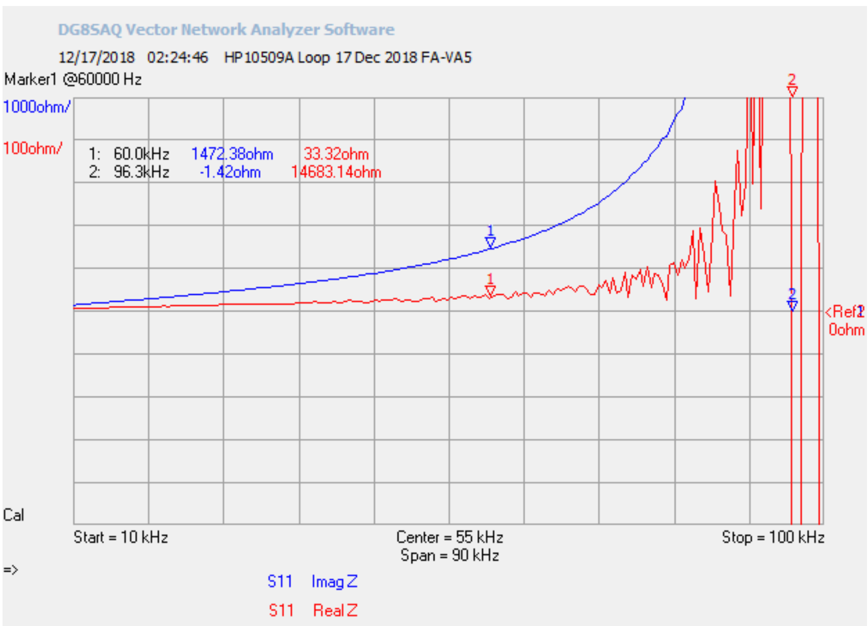

Figure 3 ~ VNWA software screenshot after a reflection coefficient (S11) measurement run from 10 to 100 kHz with the FA-VA5 analyzer connected to an HP 10509A loop antenna. The traces have been set to display the reflection coefficient as real and imaginary components of the antenna impedance. Marker 1 is set at 60 kHz (corresponding to the frequency of the time-frequency station WWVB) and Marker 2 is set to the loop self-resonance point.

The WSUB1G+ may be operated with the free *RF Explorer* software available from {RFExplorer} (figure 4). This software is available for Windows, Macs, and Linux and specific versions are available for the Raspberry Pi. There are two versions of RF Explorer for Windows, a regular version with a waterfall display in addition to the spectrum display and another version labeled *no OpenGL*; the latter version does not include the waterfall and the window size scales better than the other version. The *no OpenGL* version appears to be offered to get around problems with graphics display drivers in Windows. Both versions of the software have data logging capabilities and can fully control the WSUB1G+. Other vendors offer software applications for the RF Explorer instruments such as Touchstone (free) and Touchstone Pro (paid), Clear Waves and WiFi Surveyor available from {NutsNets}.

The FA-VA5 has limited internal data capture capabilities and the WSUB1G+ has none. Up to ten FA-VA5 screens may be saved with a timestamp and recalled. Also, up to 16 FA-VA5 datasets (measured values) may be saved but they cannot be recalled on the instrument – the VNWA software is used to download and view the data on a PC.

A useful feature that is available on both instruments is the *Preset* function. The FA-VA5 can store up to five numbered preset measurement modes and the WSUB1G+ can store up to 100 setups with limited text description (12 characters). Nobody can remember the details for 100 different setups, so RF Explorer provides a software tool called *Preset Manager* for managing them; thus, the Preset feature is most useful when the WSUB1G+ is connected to a PC (the Preset Manager is installed along with the main RF Explorer software).

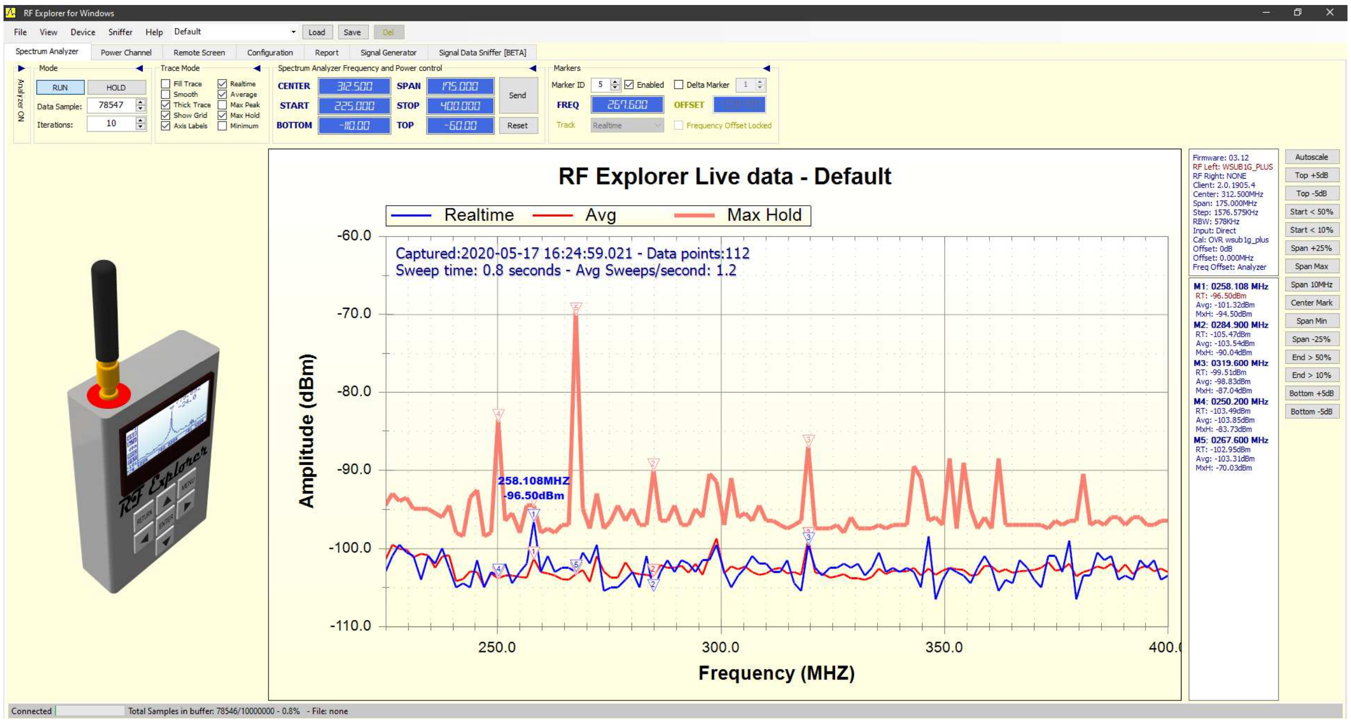

Figure 4 ~ RF Explorer (*no OpenGL* version) screenshot while running the WSUB1G+ analyzer setup for a frequency range of 225 to 400 MHz (military aviation band) and resolution bandwidth of 578 kHz. The analyzer was connected to an outdoor discone antenna, and the traces were set to *thick* to improve visibility Three traces are seen – real-time sweep (blue), average sweep (lower red) and max hold sweep (upper red). Markers have been set at several frequencies with marker data listed along with analyzer setup information in the frame to the immediate right of the spectrum. The signals seen in the upper red trace are from the nearby Joint Base Elmendorf Richardson (JBER) and associated military aircraft traffic. The instrument image left of the plot indicates the antenna port in use (some RF Explorers have two antenna ports).

---

3. Field Application Examples and Measurements

All of the application examples in this section are based on standalone field operation of the two instruments using their internal batteries. After the FA-VA5 was calibrated with the 4-piece BNC calibration kit that I purchased with the unit, the resulting Master Calibration was used throughout the measurements. The FA-VA5 was used in its *Single Frequency* mode. The frequency was stepped from 1 to 500 MHz in the sequence 1, 2, 5, 10 ... 500. In Single Frequency mode, the measurements apply to a single preset frequency (the FA-VA5 also supports multifrequency and sweep modes). Also, only the fundamental frequency power levels (no harmonics) were measured by the spectrum analyzer.

The WSUB1G+ was used in its *Direct* mode in which its internal low noise amplifier or attenuator was not used. I used a professional field test set, a Keysight N9917A Microwave Analyzer, to measure various parameters for comparison and these measurements are assumed to be *error-free*. Examples of the N9917A measurements are FA-VA5 fundamental frequency output level at the measurement frequencies, coaxial cable section lengths, coaxial cable insertion loss, VSWR of the cable with a termination, amplifier gain and bias-tee characteristics.

The instruments all were read and recorded exactly as displayed (no rounding), and no software or PC was used. It should be noted that some types of measurements, such as long-term measurements or detailed measurements of numerous frequencies or wide frequency spans, are easier to make when the instruments are controlled by a PC through their USB ports, but all the measurements in this section were done manually.

3.1 Coaxial cable insertion loss: End-to-end insertion loss measurements at various frequencies with the FA-VA5 at one end and the RF Explorer WSUB1G+ at the other (figure 5). It is shown that while the FA-VA5 can accurately generate a test signal up to 200 MHz, the WSUB1G+ cannot display the signal level with enough accuracy and resolution for detailed insertion loss measurements; however, the WSUB1G+ is very useful where approximate measurements of signal coupling are adequate.

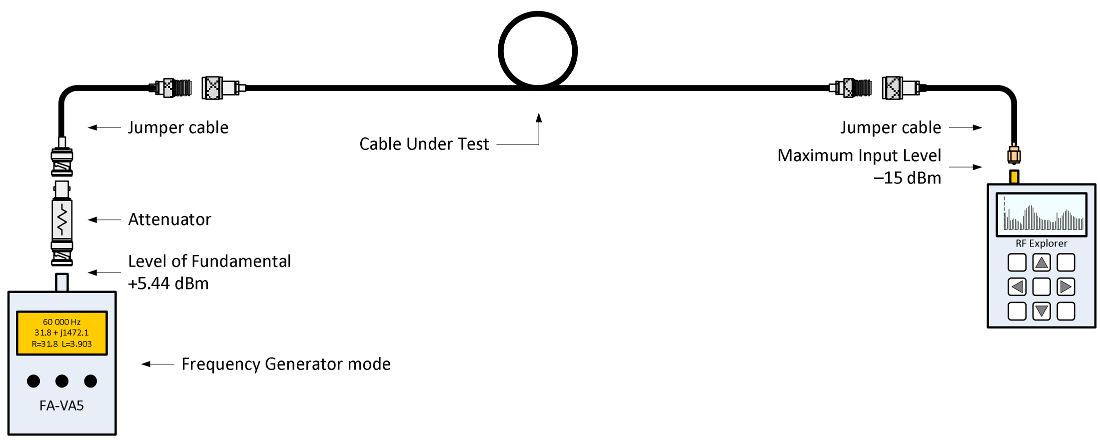

Figure 5 ~ Setup for end-to-end cable insertion loss measurements using the FA-VA5 (left) and WSUB1G+ (right). Attenuation must be used on the FA-VA5 output to prevent overload of the WSUB1G+ analyzer. For the measurements in this section 40 dB was used. The WSUB1G+ is setup for the same frequency as the FA-VA5, minimum span (112k kHz), Marker set to Peak, sweep Calculator mode set to Average and Iterations (averaging count) set to 16.

In this application example, the FA-VA5 was connected to high-quality RG-213/U coaxial cable (figure 6) and set to *Frequency Generator* mode. At lower frequency settings, the fundamental frequency output level as measured by the N9917A in Spectrum Analyzer mode is +5.44 dBm, which slowly decreases as the frequency is increased. The cable loss was first measured at various frequencies with the N9917A in Spectrum Analyzer-Tracking Generator (SA-TG) mode and these values were then compared to subsequent measurements with the WSUB1G+.

Initial measurements were made with a 10 dB attenuator on the FA-VA5 output. In this case, the WSUB1G+ measurements showed very high errors when the cable loss was low or, equivalently, when the signal input to the WSUB1G+ was high. For example, the errors at 1 and 2 MHz were –6.7 dB and –6.1 dB, respectively. The input signal levels throughout the frequency range were approximately –5 to –11 dBm, well below the maximum for the specified dynamic range (+10 dBm), but the errors were obvious.

I then added another 30 dB of attenuation on the FA-VA5 output (for a total of 40 dB). With the added attenuation giving lower input signal levels, the WSUB1G+ measurements were in line with its accuracy and resolution specifications (table 2).

Figure 6 ~ Stack of four interconnected hand-coils [approximate diameter 24 in (610mm)] of RG-213/U coaxial cable with a total length of 136.5 m (448.0 ft). This cable was salvaged during Fall 2018 from the decommissioned imaging riometer at Poker Flat Rocket Range near Fairbanks, Alaska. Each section length was measured with the N9917A setup in CAT/TDR (Cable and Antenna Test/Time Domain Reflectometer) mode. Short flexible jumpers are connected to the test instruments (not shown in this image). Image © 2020 W. Reeve

Table 2 ~ Expected and measured coaxial cable insertion loss from 1 to 200 MHz
Cable: RG-213/U, 136.5 m (448.0 ft)

Freq (MHz) (1)	**Cable Loss (dB) (2)**	**Cable Unit Loss (dB/100 ft) (3)**	**FA-VA5 Output (dBm) (4)**	**Expected Level (dBm) (5)**	**Measured Level (dBm) (6)**	**Δ (dB) (7)**
1	0.515	0.1150	–4.296	–34.8	–36.0	–1.2
2	1.029	0.2297	–4.339	–35.4	–37.0	–1.6
5	1.744	0.3893	–4.409	–36.2	–36.0	–0.2
10	2.498	0.5576	–4.461	–37.0	–38.0	–1.0
20	3.626	0.8094	–4.537	–38.2	–39.5	–1.3
50	5.824	1.3000	–4.623	–40.4	–41.0	–0.6
100	8.340	1.8616	–5.047	–43.4	–43.0	+0.4
200	12.130	2.7076	–5.572	–47.7	–46.0	+1.7

Column definitions:
(1): Measurement frequency;
(2): Cable loss measured with N9917A in SA-TG normalized mode with a 6 dB pad and 3 m LMR-240 jumper on tracking generator output (port1) and spectrum analyzer input (port 2);
(3): Unit loss = Column (2)/4.480 and is for reference;
(4): FA-VA5 output with 10 dB pad and 610 mm LMR-240 jumper cable as measured with an N9917A in SA mode;
(5): Expected level = Column (4) – 30 dB – Column (2). See text;
(6): Measured level is as displayed WSUB1G+ at each frequency with 300 mm RG-316 jumper cable on the analyzer input;
(7): Difference Δ = Column (6) – Column (5).

3.2 Impedance matching measurements: Voltage standing wave ratio (VSWR), return loss and reflection coefficient are parameters used to indicate the degree of impedance matching of two RF interfaces, such as between a receiver and a cable or antenna or termination. These parameters provide equivalent information, and if one is known the others may be calculated from it. In this application example, the VSWR of a 50 ohm coaxial cable connected to a 75 ohm termination is measured and compared (figure 7). The 75 ohm resistive termination was used to approximate the impedance of a resonant dipole antenna at each measurement frequency.

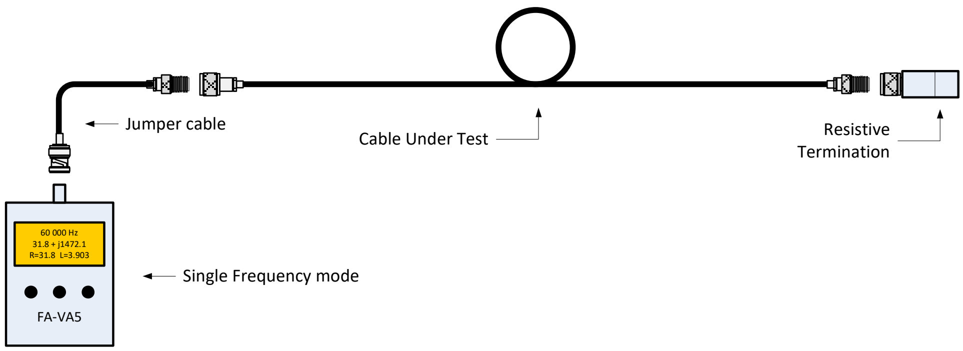

Figure 7 ~ Setup for cable impedance measurements with the FA-VA5. The termination normally matches the cable characteristic impedance but for the measurements described here, the cable impedance is 50 ohms and the termination is 75 ohms (see text). Image © 2020 W. Reeve

To establish a baseline, I first measured the terminated cable VSWR with the N9917A Microwave Analyzer in 1-port Network Analyzer (NA) mode from 1 to 500 MHz with markers set to specific test frequencies. Prior to use, the N9917A was calibrated with HP 85032B type N calibration standards at the end of a 3 m long LMR-240 jumper cable. The FA-VA5 was then connected and setup in Single Frequency mode to display VSWR using its Master Calibration. The FA-VA5 was stepped through the same test frequencies for comparison (table 3). This data also includes the measured complex impedance displayed along with the VSWR.

Table 3 ~ Terminated cable VSWR from 1 to 500 MHz
Cable: RG-213/U, 26.0 m (85.3 ft), 75 ohm resistive termination

Freq (MHz) (1)	**N9917A VSWR :1 (2)**	**FA-VA5 VSWR :1 (3)**	**Δ (%) (4)**	**FA-VA5 Z (ohms) (5)**
1	1.460	1.45	–0.7	48.0 – j18.0
2	1.444	1.37	–5.1	36.6 + j1.6
5	1.414	1.40	–1.0	41.9 – j13.2
10	1.401	1.35	–3.6	41.2 + j10.5
20	1.381	1.39	+0.7	45.3 – j15.1
50	1.345	1.38	+2.6	53.6 – j16.1
100	1.298	1.31	+0.9	40.9 – j8.4
200	1.249	1.25	+0.1	48.4 + j11.0
500	1.183	1.15	–2.8	51.3 + j6.8

Column definitions:
(1): Measurement frequency;
(2): VSWR measured with N9917A in NA mode through a 3 m long LMR-240 jumper on port 1;
(3): VSWR measured with FA-VA5 in Single-Frequency mode through a 230 mm long jumper;
(4): % Difference Δ = [Column (3) – Column (2)]/Column (2);
(5): Impedance measured with FA-VA5, real and imaginary components

3.3 Amplifier measurements: A low-noise preamplifier often is installed at or near an antenna. The signal chain also may involve intermediate amplifiers and other components such as bias-tees used to supply power to the amplifier, all of which require operational verification (figure 8). The example application described here is an end-to-end measurement that includes an amplifier at the far end, connecting cables and bias-tees. This application combines example applications 3.1 and 3.2 above to include these additional components.

When performing measurements involving gain, it is necessary to prevent the amplifier and WSUB1G+ from being overloaded and also to recognize that the WSUB1G+ is inaccurate when its input level exceeds about –15 dBm (as discussed previously in 3.1). Attenuators are used to reduce the signal generator output level accordingly. For example, assuming the signal generator output level is +5 dBm and the amplifier gain is 24 dB, then a 60 dB attenuator would reduce the amplifier input to –55 dBm and its output would be –31 dBm. Losses in the coaxial cable and bias-tees will further reduce this level. Note that all measurements and calculations below that involve attenuators assume the attenuators are perfect (in other words, a 60 dB attenuator is exactly 60 dB).

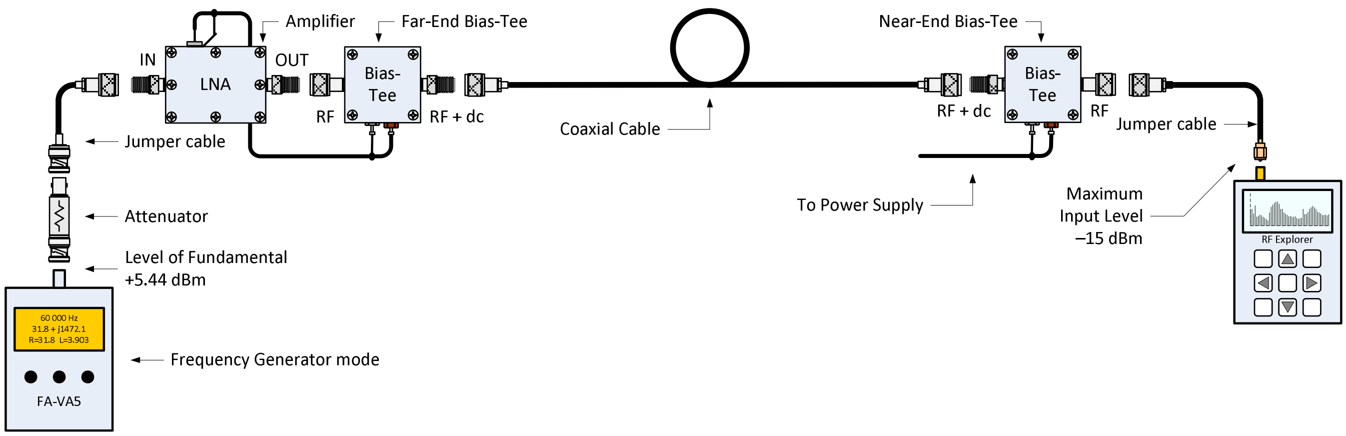

Figure 8 ~ Setup for amplifier measurements with the FA-VA5 (left) and WSUB1G+ (right). Attenuation must be used on the FA-VA5 output to prevent overload of the amplifier and WSUB1G+ analyzer. The WSUB1G+ is setup for the same frequency as the FA-VA5, minimum span (112k kHz), Marker set to Peak, sweep Calculator mode set to Average and Iterations (averaging count) set to 16.

A Mini-Circuits ZFL-500 amplifier was used along with two unbranded bias-tees (figure 9) and a 26.0 m (85.3 ft) long RG-213/U coaxial cable. The ZFL-500 is not a particularly low noise device but that is not important for the demonstrations discussed here. The insertion loss of each bias-tee is < 0.25 dB across the frequency range from 1 to 200 MHz and, for purposes of calculation, is assumed to be zero at all frequencies.

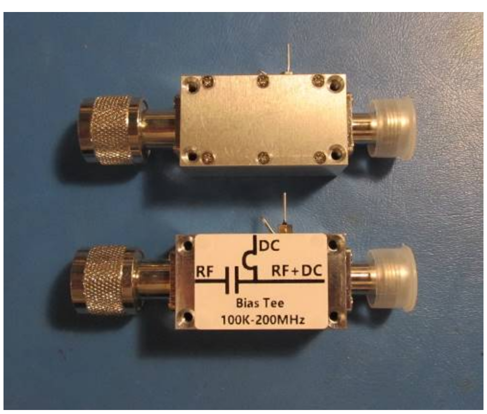

Figure 9 ~ Two unbranded bias-tees used in the amplifier measurements have an advertised frequency range of 100 kHz to 200 MHz. Measurements show these units have negligible insertion loss throughout their specified frequency range but their impedance degrades above 100 MHz – see text for additional details. A type N-male connector is used on the RF port and a type N-female connector on the RF + dc port. Voltage and current ratings are 50 Vdc and 1000 mA. Dimensions are 92 L x 30 W x 27 H mm including the connectors. Image © 2020 W. Reeve

The amplifier was powered through the bias-tees with a 15 Vdc power supply. Its gain was measured previously with the N9917A in SA-TG mode and determined to be 24 ±0.5 dB throughout the frequency range 1 to 500 MHz. Various RF adapters were used for interconnection. All components have compatible frequency ranges for use with the FA-VA5 signal generator (200 MHz maximum). The power levels measured by the WSUB1G+ at the near (receiver) end are compared to the expected levels based on calculations (table 4). The results were as expected for the WSUB1G+ accuracy and resolution and in line with the previous measurements of the cable insertion loss after compensation for the amplifier gain.

Table 4 ~ Expected and measured amplifier circuit gain from 1 to 200 MHz
Amplifier: MCL ZFL-500; Cable: RG-213/U, 26.0 m (85.3 ft)

Freq (MHz) (1)	**Unit Loss (dB/100 ft) (2)**	**Cable Loss (dB) (3)**	**Input Level (dBm) (4)**	**Amplifier Gain (dB) (5)**	**Expected Level (dBm) (6)**	**Measured Level (dBm) (7)**	**Δ (dB) (8)**
1	0.1150	0.10	–54.296	+24.06	–30.3	–32.0	–1.7
2	0.2297	0.20	–54.339	+23.95	–30.6	–33.0	–2.4
5	0.3893	0.33	–54.409	+24.32	–30.4	–31.5	–1.1
10	0.5576	0.48	–54.461	+24.36	–30.6	–33.0	–2.4
20	0.8094	0.69	–54.537	+24.03	–31.2	–33.5	–2.3
50	1.3000	1.11	–54.623	+24.06	–31.7	–33.5	–1.8
100	1.8616	1.59	–55.047	+23.85	–32.8	–33.5	–0.7
200	2.7076	2.31	–55.572	+23.62	–34.3	–34.5	–0.2

Column definitions:
(1): Measurement frequency;
(2): Cable unit loss from table 1;
(3): Cable loss = Column (2) x 0.853;
(4): Input level is FA-VA5 output from table 1 – 50 dB. The values from table 1 already include a 10 dB attenuator, so the total attenuation on the FA-VA5 output is 60 dB;
(5): Amplifier gain measured with 60 dB attenuation on amplifier input using the N9917A in SA-TG mode;
(6): Expected level = Column (4) + Column (5) – Column (3). Bias-tee losses are assumed to be zero;
(7): Measured level is read from the WSUB1G+ at each frequency;
(8): Difference Δ = Column (6) – Column (5).

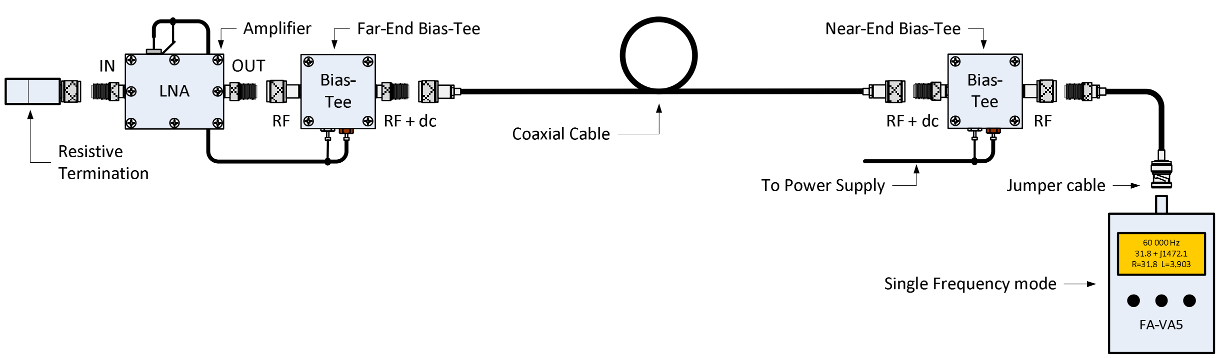

Figure 10 ~ Setup for impedance measurements at near (receiver) end with the FA-VA5. The impedance and thus the VSWR is influenced by the impedance of the two bias-tees, coaxial cable, connectors, amplifier and amplifier termination, the latter having no practical effect in a well-designed amplifier.

The impedance measurements were made from the near (receiver) end toward the amplifier – the reverse of the gain measurements (figure 10). Although the measurements with the FA-VA5 signal generator are limited to 200 MHz, the impedance measurements go to 500 MHz (beyond the range of the bias-tees) (table 5).

The amplifier input was terminated in 50 and then 75 ohms just to see if different terminations on the amplifier input affect its output impedance. The input terminations on a well-designed amplifier should not affect its output impedance, and this was found to be true with the ZFL-500 amplifier. At lower frequencies, the VSWR was very low regardless of termination, but I was surprised that the VSWR increased above 100 MHz. Further investigation showed that the VSWR of the bias-tees starts to worsen above 100 MHz and they determine the circuit VSWR above that. The amplifier itself has consistently low VSWR.

Table 5 ~ Terminated amplifier circuit VSWR from 1 to 200 MHz
Amplifier: MCL ZFL-500; Cable: RG-213/U, 26.0 m (85.3 ft)
Resistive terminations on amplifier input 50 and 75 ohms

Freq (MHz) (1)	**VSWR (50 ohm) :1 (2)**	**VSWR (75 ohm) :1 (3)**	**Δ (%) (4)**	**Z (ohms) (5)**	**Notes (6)**
1	1.13	1.15	+1.8	56.8 – j3.3	
2	1.03	1.08	+4.9	46.4 – j0.9	
5	1.05	1.11	+5.7	48.2 – j4.9	
10	1.03	1.07	+3.9	50.2 – j3.4	
20	1.10	1.16	+5.5	45.3 – j5.5	
50	1.22	1.29	+5.7	40.8 – j6.7	
100	1.02	1.05	+2.9	49.4 + j2.4	
200	2.43	2.49	+2.5	21.9 – j13.6	See text
500	2.84	2.66	–6.3	20.0 + j12.6	See text

<u>Column definitions</u>:
(1): Measurement frequency;
(2): VSWR measured with 50 ohm termination on amplifier input;
(3): VSWR measured with 75 ohm termination on amplifier input;
(4): % Difference Δ = [Column (3) – Column (2)]/Column (2);
(5): Impedance measured with FA-VA5, real and imaginary components

3.4 <u>Radio Frequency Interference location</u>: For locating interference, the WSUB1G+ may be connected to various antennas such as a collapsible whip antenna, handheld directional antenna, vehicle mobile antenna or loop antenna (figure 11).

Figure 11.a ~ The RF Explorer WSUB1G+ is quite sensitive and is most useful when paired with a directional antenna, unlike the three mostly useless non-directional stub antennas shown here. The black collapsible whip antenna on the instrument extends to 15.5 in (390 mm), corresponding to a 1/4-λ at 200 MHz. The silver collapsible hinged whip antenna on the right extends about the same length. The hinged antenna at top is designed for 2.4 GHz applications (it was supplied with the instrument along with the black antenna). For lower frequencies, physically larger antennas are required unless the interfering signals are extremely strong and their source is nearby. Image © 2020 W. Reeve

Figure 11.b ~ Laird P4063, 3-element Yagi antenna for the 406-430 MHz radio bands. The advertised gain is 6 dB and the 3 dB beamwidth is 100 H x 65 V degrees. It includes a mast clamp (lower-right) that may be mounted to a piece of non-conductive pipe or wood dowel for a hand-hold. An antenna like this can be useful for locating interference produced by arcing in powerline insulators and hardware. Image © 2020 W. Reeve

Figure 11.c ~ Tram magnetic antenna mount for vehicle roof installation (base can be seen in center of image). The mount is shown with a Procomm PCF15 antenna, which is a mobile vertical antenna designed for the 15 m (21 MHz) radio amateur band. It has a 44 in (1.1 m) long fiberglass lower section (visible on the mount) and adjustable stainless-steel upper section (not visible). The lower section has conformally coated integral inductors for modifying the antenna current distribution and effectively extending its electrical length. The antenna is roughly 1/8-λ at 20 MHz and may be used for locating powerline interference in the HF band. The WSUB1G+ is visible at center-right leaning on the luggage rack rail. Image © 2020 W. Reeve

Figure 11.d ~ Shop-built loop antenna specifically made for locating HF band interference. A loop like this is not very sensitive but still useful if the interference source is nearby. The main loop has 1-turn of 3/8 in (10 mm) diameter copper tubing mounted on a mast made from a piece of PVC pipe. The main loop diameter is 24 in (610 mm). The small coupling loop is made from 1/4 in (6 mm) diameter copper tubing and has a diameter of 6 in (152 mm). A variable tuning capacitor is mounted in a small plastic box at the base of the loop and is used to resonate the main loop in the HF band. A balun couples the small loop to a BNC-F connector for connection to the analyzer via a short jumper cable. In this image, the loop support mast is temporarily installed on an EMC testing antenna tripod. The WSUB1G+ is lashed to the mast with a small bungee cord and is visible in the center of the image. Image © 2020 W. Reeve

4. Comments

The two instruments performed consistently and predictably but some operating details are worth noting:

1. The WSUB1G+ signal power measurements are inaccurate if its input signal level is higher than approximately –15 dBm (25 dB lower than the dynamic range specifications);
2. The WSUB1G+ has a scan averaging feature that is useful for marker measurements and is indicated by reverse text *AVG* on the left side of the screen when active. Anytime a change is made to the marker frequency or other conditions, the averaging counter is restarted. However, there is no indication of the averaging count so the user does not know if the displayed marker value is yet valid. When the resolution (and frequency span) is low, the scan times are relative high and an averaging count of, for example, 16 requires several seconds;
3. It is easy to corrupt the FA-VA5 Master Calibration by accidentally selecting the calibration menu. The user is not prompted to confirm any changes, and a calibration could be run accidentally without a calibration standard connected. Once started the calibration run cannot be stopped before some of the stored calibration values are corrupted. This can be prevented by being careful to never select any menu item that says *SOL* (for Short-Open-Load calibration) unless the intent is to actually calibrate the instrument;
4. The 9-button menu system in the WSUB1G+ is easier to use than the 3-button menu system in the FA-VA5. For example, setting the FA-VA5 frequency in the impedance modes requires repeatedly pressing the + or – buttons or holding them down for accelerated incrementing. Even with accelerated incrementing, the process can be tedious for large frequency changes. On the other hand, the frequency is easily changed in the WSUB1G+ by selecting the menu and then using the arrow keys to quickly scroll through the digits;

5. Making large frequency changes in the Frequency Generator mode with the FA-VA5 can be tedious. When selecting the frequency digit to change, the cursor moves only left-to-right so, if the cursor is on the hundred thousands (XXX XXX Hz) digit and the user wishes to change the millions (X XXX XXX Hz) digit, the cursor must be stepped all the way through the ones (X Hz) digit to get back to the millions digit.
6. Like all test equipment, the FA-VA5 and WSUB1G+ are best learned by actually using them. The user guides for the two instruments provide a good starting point but nothing is better than performing measurements. For practice, the user can connect the FA-VA5 to known impedances such as those provided by the *Testboard Kit* available from {SDR-Kits} and then experiment with the settings. Since the FA-VA5 requires calibration when used in its impedance modes, the *BNC Calibration Kit* is a useful accessory. Similarly, the user can connect the WSUB1G+ to one of the included stub antennas and tune to the AM and FM broadcast bands or other known strong signals and then experiment with the settings.

---

5. Weblinks and References

{NutsNets} http://nutsaboutnets.com/
{SDR-Kits} https://www.sdr-kits.net/VA5-Antenna-Analyzer-Kit
{RFExplorer} http://j3.rf-explorer.com/buy-online

Author: Whitham Reeve is a contributing editor for the SARA journal, Radio Astronomy. He obtained B.S. and M.S. degrees in Electrical Engineering at University of Alaska Fairbanks, USA. He worked as a professional engineer and engineering firm owner/operator in the airline and telecommunications industries for more than 40 years and now manufactures electronic equipment used in radio astronomy. He has lived in Anchorage, Alaska his entire life. Email contact: whitreeve@gmail.com

---

Document information

Author: Whitham D. Reeve

Revision: 0.0 (Original draft started, 15 Apr 2020)
0.1 (Revised scope, 14 May 2020)
0.2 (Added description images, 16 May 2020)
0.3 (Completed cable insertion loss measurements, 17 May 2020)
0.4 (Completed amplifier/cable insertion loss measurements, 19 May 2020)
0.5 (Completed amplifier VSWR measurements, 20 May 2020)
0.6 (Added antenna images, 21 May 2020)
0.7 (Added diagrams, 22 May 2020)
0.8 (Added antenna images and conclusions, 23 May 2020)
0.9 (Completed 1st draft, 31 May 2020)

Word count: 5516
File size: 1110528