PRODUCT REVIEW

SPE Expert 1K-FA Linear Amplifier

Reviewed by Mark Wilson, K1RO
QST Product Review Editor

Not long ago, vacuum tubes ruled the world of RF power amplifiers in the Amateur Radio marketplace. Tube type amplifiers are economical to build at amateur power levels, easy to cool and tolerant of abuse. Depending on the design, one or two vacuum tubes will run comfortably at the legal power limit (1500 W output) for extended periods. Properly cared for, vacuum tubes will last for many years in normal amateur service. It's common to hear amplifiers that haven't been manufactured in decades still on the air. Replacement parts are generally available although there are fewer sources than in years past.

While tube type amplifiers are still plentiful and much loved, in recent years solid state power amplifiers have become increasingly popular. Most of these units are in the 500 to 1000 W power output range. With sophisticated protection circuitry that constantly monitors temperature, current and other key parameters, today's solid state amplifiers are far less prone to damage from excessive drive, mistuned antennas or other problems occasionally encountered during normal amateur operation. In addition, modern switching power supplies provide the required low voltage, high current power source — typically around 50 V at 30 A or more — without the size, weight and heat of a linear power supply with a massive 60 Hz transformer.

Thanks to impedance matching with broadband transformers, solid state amplifiers work over a wide frequency range and lend themselves to instant *auto-tune* band changes by switching in the appropriate output low pass filter. As a bonus, some solid state amplifiers work on 6 meters as well as 160 through 10. All this adds up to a compact, reliable, easy to use power amplifier to complement your HF or HF plus 6 meter transceiver.

The subject of this review is the SPE Expert 1K-FA, a solid state amplifier for 160 through 6 meters. Output power is typically 1 kW PEP for SSB and 900 W for CW on the HF bands. At 6 meters, it's 700 W PEP output. Maximum key-down time is 2 minutes in the FULL (full power) mode, and 5 minutes in the HALF (half power) mode. The manual recommends using the HALF setting for high duty cycle operation such as RTTY and other digital modes, SSTV, AM or FM. The amplifier is manufactured by the Italian firm SPE and currently distributed in the US by SteppIR, best known for their innovative antennas.

We purchased the review amplifier in late 2008 through Bill Leahy, KØZL, of Custom RF Solutions in Arvada, Colorado. Bill's untimely death in an industrial accident in early 2009 put SPE's North American operations in limbo for several months. In April, SPE announced that SteppIR had picked up sales and service for the US, Canada and Mexico — welcome news for current owners as well as prospective buyers. SteppIR will handle warranty issues for previous US and Canadian buyers as well as new purchasers.

Our review amplifier was shipped directly from Italy, necessitating some customs paperwork. SteppIR is stocking and shipping amplifiers from their US location, eliminating this requirement.

Overview

Ads for the SPE Expert 1K-FA call it "the smallest in the world." Although it's easy to dismiss such claims as marketing hype, there's no doubt that this is one compact package. Measuring 5.5 × 11.0 × 12.6 inches and weighing 44 pounds, it's easy to find a spot for the Expert in a "cozy" station or to bundle it up for Field Day or a DXpedition. It's roughly the same size and shape as a transceiver. SPE even provides a padded carrying case with handles for storage and transportation.

Figure 1 shows part of the interior. The power amplifier (PA) module uses six MRF-150 MOSFETs configured as three push-pull amplifiers connected through a combiner. Switchable low pass filters provide harmonic suppression well within FCC limits on all bands. A pi-L network antenna matching circuit on the output works with loads of up to 3:1 SWR on 160 through 10 meters and 2.5:1 on 6 meters, a range comparable with the internal antenna tuners in many transceivers. The internal power supply provides about 44 V dc under load for FULL operation, reduced to just over 30 V in the HALF mode. PA current is around 40 A at full output and 30 A in the HALF mode.

A 5⅛ × 1¾ inch backlit LCD displays important operating parameters, menu choices and settings. The rear panel has jacks for four antennas and connections for two transceivers.

Protection Features

To keep the amplifier safe, a microprocessor-based protection system monitors heat sink temperature, input power, PA voltage and current, reflected power and SWR, RF voltage on the output network and power combiner balance. Exceed any of the parameters and the amplifier protection springs into action.

Temporary problems that can be addressed by the operator are classified as "simple." For example, if the input power briefly exceeds the limit, a beep sounds but the amplifier resets itself automatically and continues to operate. If the problem persists, for example if the SWR is too high, the drive level remains excessive or the temperature reaches the limit, then the fault is considered "serious." For serious faults, the Expert

Bottom Line

With the SPE Expert 1K-FA, you can add power on 160 through 6 meters to your home or portable station. The built-in antenna tuner allows operation with a variety of antennas.

Mark J. Wilson, K1RO ♦ Product Review Editor ♦ k1ro@arrl.org

switches to standby. An error message with the reason for the fault flashes on the display and is stored in memory so that the operator can find and fix the problem. A "fatal" fault is declared if the microprocessor fails. In this case, the amplifier power switches off and might be restarted by cycling the power switch on the rear panel, but the manual recommends contacting the repair center.

Heat is the enemy of solid state devices, and heat buildup is of particular concern because of the Expert's compact physical design. There simply isn't much spare room inside the case. The rear panel has four small fans, and another three internal fans cool the PA heat sink. Heat sink temperature is one of the parameters always displayed on the LCD so you can keep an eye on it. (You can set the display for Celsius or Fahrenheit.)

In "normal" mode, the fans don't run until the temperature reaches 40 °C. At that point, the fans run quietly at low speed. Fan speed increases to medium at 70 °C and to high at 83 °C. Fan noise is noticeable at medium speed, and headphones are a plus at high speed. In "contest" mode (a menu choice), heavier use is assumed and the fans run at low speed all the time. The medium and high speed thresholds are reduced to 60 and 75 °C to help keep the heat from building up with prolonged use. In either mode, the protection circuit switches the power from FULL to HALF when 85 °C is reached. If the temperature keeps rising, the Expert will switch to standby until it cools down.

During routine operation (lots of listening, occasional transmitting) in my cool basement location, the temperature tended to hover around 35 to 40 °C with the fans off or running at low speed. With prolonged use during a CW contest, including a lot of CQing, I observed temperatures in the low to mid 70s. Running stations running and CQing during a RTTY contest brought temperatures to the high 70s and low 80s, but I never hit the power foldback point during normal operation. I did discover something unfortunate about the power handling capability of my "high power" manual antenna tuner and dipole fed with ladder line, though. The sudden antenna tuner failure provided an unexpected opportunity to test the Expert's SWR/reflected power protection — it worked flawlessly.

The Expert comes with a 75 page instruction manual and three page *Quick Start* guide in Adobe Acrobat PDF format on a CD-ROM. There are actually four versions — English, Italian, French and Spanish. The English version is clear and thorough, with lots of illustrations and good use of color.

Table 1
SPE Expert 1K-FA, serial number 084499569

Manufacturer's Specifications	Measured in ARRL Lab
Frequency Range: All amateur frequencies, 1.8 to 54 MHz.	As specified.
Power output: 1000 W PEP, 900 W CW for HF, 700 W PEP for 50 MHz.	As specified for SSB and CW.
Driving power required: Not specified.	28 to 32 W typical.
Spurious and harmonic suppression: Better than 50 dB HF, 60dB 50 MHz.	51 dBc worst case for HF, 60 dBc for 50 MHz. Meets FCC requirements.
Primary power requirements: 100/115 V ac, 16 A, 200/215/230 V ac, 8 A.	
Size (HWD): 5.5 × 11.0 × 12.6 inches (height, width, depth); weight, 44 lb.	
Price: $3850; transceiver interface cables, $19.	

The Expert operates from 100/115 V ac (about 16 A) and 200/215/230 V ac (about 8 A) ac lines. We requested that the review unit be set for 230 V, which allows operation from about 210 to 250 V. To change settings, remove the bottom cover and rearrange wires on a terminal block according to diagrams in the manual. It's not difficult, but a number of color coded wires are involved and you need to pay close attention.

Two Transceivers

Figure 2 shows the rear panel. Along the bottom are connections for RELAY (TR switching), ALC (automatic level control) and CAT (radio control interface) for two transceivers. At the top right are two SO-239 jacks for RF input. The transceiver connections are referred to as INPUT 1 and INPUT 2. You can select between the inputs manually with a front panel switch or automatically by transmitting with either transceiver. Antenna and tuner settings are stored independently for each input.

The ALC connection is for automatic control of the transceiver's output power to ensure proper amplifier input levels — especially useful with the Expert's low drive

Figure 1 — Inside the SPE Expert 1K-FA. The PA module and output network assembly are visible. The power supply is underneath.

Figure 2 — The rear panel includes connections for two radios and up to four antennas. The four cooling fans, plus three more inside the case, remove heat effectively.

requirements and a typical 100 W transceiver. I appreciated the smooth ALC action rather than trying to ride herd on my radio's power control manually.

The CAT jack allows the transceiver to provide operating frequency information to the Expert for seamless automatic band changes. Although you can make your own CAT cable using DB-15 connectors included with the amplifier, SPE offers cables with appropriate connectors for a variety of transceiver makes and models from Elecraft, FlexRadio, ICOM, Kenwood, Ten-Tec and Yaesu. Transceiver type and any necessary parameters are set up through menus. We ordered cables for the Elecraft K3, ICOM transceivers with CI-V and older Yaesu FT-1000 transceivers with a BAND DATA jack. The only issue encountered was with the Yaesu cable and an FT-1000D. With SPE's assistance we found that a "transmit inhibit" pin on the radio end of the cable needed to be grounded. After that everything worked as expected and SPE has changed the cable in production.

Use of the CAT control feature for band switching is recommended but not required. The Expert has a built-in frequency counter that senses RF at the input and changes bands accordingly as soon as you start transmitting. In addition, you can perform manual band selection with front panel switches.

As shipped, the amplifier operates on all bands. Lookup tables contain information on the edges of the amateur bands and are used in conjunction with the frequency counter to comply with FCC regulations prohibiting amplification between 26 and 28 MHz.

Antennas and Tuner

At the upper left are SO-239 jacks for four antennas (ANT 1 to ANT 4). During initial setup, you use a menu to select the antenna for each band. If you have more than one antenna for a band, you can enter two choices and switch between them with the front panel ANT switch. If you don't have an antenna for a particular band, select NO and the amplifier won't go into transmit if you try to operate there.

The automatic antenna tuner is always in line, and during setup you need to store the settings for your antennas for each band. The bands are divided into segments (the manual gives details) and you can store settings for each segment. Furthermore, you need to store tuner settings separately for each input, even if you are using the same set of antennas. All tuning operations are done with the amplifier in STANDBY and require only a few watts from the transceiver. Setting up the tuner for all the band segments (126 total for 160 through 6 meters) is a bit tedious, but once accomplished, everything tracks your transceiver's operating frequency and you're done until something in your antenna system changes.

The antenna tuner and switching are active whenever the amplifier is turned on, so you can use them with your transceiver even if you have the amplifier in STANDBY. With the amplifier turned off, the transceiver on INPUT 1 is connected to the antenna on ANT 1. Manual adjustment of the antenna is possible using front panel switches to adjust inductance and capacitance. For manual tuning the LCD shows inductance and capacitance values.

Single Operator, Two Radios

A popular contest strategy is SO2R, a single operator using two radios. The idea is to be able to call CQ on one radio while using a second radio to tune around for multipliers or new contacts on a different band. With the right interfaces and switching systems and some practice, it's a very effective way to boost your score by taking advantage of the time spent waiting for your computer or memory/voice keyer to send a CQ or exchange message.

Normally SO2R is accomplished with two transceivers, two amplifiers and some sort of switching system that allows flexibility to use different radios on different bands but prevents transmitting with both radios simultaneously. Effective SO2R operation requires several antennas, as well as good separation between antenna and bandpass filters to prevent interference between the stations or damage to receivers.

The Expert already has connections for two radios with independent settings for each. There's an SO2R jack on the back of the amplifier for an antenna (such as a multiband vertical) separate from the main antennas on ANT 1 to ANT 4. The transceiver connected to the active input uses the main antennas and antenna tuner. The other transceiver is connected to the SO2R antenna and can use that antenna for receiving while the active radio is transmitting.

For example, say you're running stations on 40 meters in the early evening on the main radio (INPUT 1) and tuning for multipliers on 20 meters with the radio on INPUT 2 and SO2R antenna. After finishing a 40 meter contact, you key your transmitter to call the multiplier on 20. The Expert senses the relay closure on INPUT 2 and automatically switches to that radio. The INPUT 2 CAT connection tells the amplifier to switch to 20 meters and select the appropriate antenna. The SO2R antenna switches to the radio on INPUT 1 so you can continue to listen to activity on your run frequency. When you're done working the multiplier, key the 40 meter transmitter to call another CQ and everything switches back.

RS-232 Port

A rear panel RS-232 port works with *Expert Console*, a *Windows* application for interfacing the amplifier with a PC, that's included on the CD-ROM. *Expert Console* replicates the amplifier front panel, including all operating parameter displays and switches. Using the software, you can turn power on and off, change bands, select antennas, operate the tuner and so on.

The CD-ROM also includes a 28 page document entitled *Expert 1K-FA Communication Protocol Specifications* for those who want to incorporate amplifier monitoring or control in their own software.

In the Lab

Lab test results are shown in Table 1. The Expert met FCC spectral purity requirements with no problems, and close-in two-tone IMD performance is good compared with other solid state amplifiers we've reviewed.

Power output ratings are "typical" which means to expect "around 900 W" on CW or "around 1000 W" PEP on SSB, depending on band selected and operating conditions. This was the case except for 40 meters, where at most we initially saw 830 W on the Lab power measurement setup. At the time we were dealing with the late Bill Leahy at Custom RF Solutions, and he suggested that we try adjusting the ALC parameters from a special service menu. That did the trick and brought 40 meters in line with the other bands.

Two other related items are worth mentioning. First, the internal power meter measures RF at the *input* to the antenna tuner. The tuner components introduce some loss, so actual power at the antenna jack can be 100 to 200 W lower. For example, the internal meter might show 1200 W PEP while an accurate meter on the output indicates 1000 W PEP. Through menu settings it's possible to apply a correction factor for more realistic readings with the internal power meter. Second, the power drifted down a bit as the amplifier components warmed up. During prolonged contest operation at higher temperatures, the output settled in closer to 800 W than 900 W. Readjusting the antenna tuner with the Expert warmed up helped some.

Using the Expert 1K-FA

The lower edge of the LCD always displays the current input, band, antenna, CAT type, FULL or HALF power mode and heat sink temperature. In STANDBY, SWR is displayed; that changes to PA gain in OPERATE. During operation the LCD can show power output and PA current, or reflected power and PA voltage.

Once the transceiver, antenna and tuner settings are selected, operation is pretty much automatic. The amplifier tracks the transceiver frequency and makes the appropriate adjustments. Drive power adjustments are handled by the ALC.

The Expert's various instruction sheets

make it clear that this amplifier is intended for SSB and CW operation or short transmissions with high duty cycle modes. That meets the needs of most amateurs. If your operating style includes extended periods of high duty cycle transmission, then it's not the right choice. I had no problems using the Expert for extended periods in SSB, CW and RTTY contests. The short breaks for listening between contacts or CQs kept the temperature well within the safe range.

Manufacturer: SPE (Societa Per L'Elettronica), Via di Monteverde, 33, 00152 Rome, Italy; **www.radio-ham.eu**. *US Distributor:* SteppIR, 2112 116th Ave NE, Suite 1-5, Bellevue, WA 98004; tel 425-453-1910; **www.steppir.com**.

Antenna Accessories from Array Solutions

Reviewed by Phil Salas, AD5X
QST Contributing Author
ad5x@arrl.net

As your antenna system evolves, you may find the need to add remote antenna switches, preamps and automatic antenna tuners (autotuners). Unless you initially planned for future accessories when you first designed your antenna system, adding these accessories may be difficult. Enter Array Solutions with their Bias-T Plus, Bias-T Master and ATD-1 Auto-Tuner Disconnect antenna system accessories.

Bias-T Plus and Bias-T Master

The Bias-T Plus and Bias-T Master pairs permit you to inject and extract a dc voltage on your antenna's coaxial feed line for controlling or powering remote equipment. This method is convenient because it eliminates the need to run a separate power cable. One unit mounts inside the station, and the other at the antenna. Included with both pairs are an ON/OFF switch assembly and power cord for the dc injection unit in the station, and a power cord for the dc extraction unit at the far end. Figure 3 shows one of the Bias-T units (Plus and Master versions look identical).[1]

The Bias-T Plus is specified to handle up to 2000 W of RF power and introduce an SWR of less than 1.1:1 from 1.8 to 148 MHz when inserted in the antenna line. It can handle dc current up to 400 mA and is probably more appropriate for remote switches and mast mounted preamps through 2 meters. The Bias-T Master is very similar, but is probably more appropriate for remote antenna tuners as it handles dc current up to 1.5 A. It's rated for legal limit power levels from 1.8 to 54 MHz at less than 1.1:1 SWR across this range.

Both the Bias-T Plus and Bias-T Master sets handle up to 50 V dc and are polarity insensitive, so you can inject either a positive or negative voltage on your coaxial cable. This is handy for antenna switches or other devices that use different polarity dc power sources for various remote control functions. For example, an antenna switch might require no voltage for position A, +12 V for position B and –12 V for position C. If you do inject a negative voltage or want to flip your voltage polarity, you should use a dedicated wall transformer with both polarities isolated from your normal station power supply. Figure 4 shows a typical application.

Both Bias-T pairs are mounted in weatherproof plastic boxes. Because the RF paths inside the units use microstrip design, a metal box is unnecessary for good broadband impedance performance. Three specially selected high-current inductors provide the RF-to-dc isolation in the Bias-T Plus and Bias-T Master. These inductors are chosen to keep resonances out of the ham bands for the specific ranges covered. Additionally, the Q of the inductors is such that there is little or no power dissipation in the inductors even at full legal limit. Internal views of the Bias-T Plus and Bias-T Master are shown in Figures 5 and 6, respectively.

I swept both units with my AIM-4170C antenna analyzer, and the results are shown in Figures 7 and 8. As these devices are normally used in pairs, the sweeps include two cascaded units terminated in precision 50 Ω loads. The two important curves to look at are the SWR (red) and return loss (blue) curves. As you can see, performance is excellent across their individually specified frequency ranges.

Bottom Line

The Bias-T Plus and Bias-T Master from Array Solutions offer a way to get power to a remotely mounted autotuner, antenna switch or preamplifier without running an additional cable. The ATD-1 Auto-Tuner Disconnect can help protect a valuable autotuner at the antenna base from damage.

ATD-1 Auto-Tuner Disconnect

Another interesting accessory is the Array Solutions ATD-1 Auto-Tuner Disconnect shown in Figure 9. Several years ago lightning struck a cable television box about 100 feet from my house. The energy from that strike exploded the ceramic doorknob capacitors used in matching section of the Butternut vertical I had at the time. A major reason I've been hesitant to use an outdoor remote automatic antenna tuner is that I've

[1]If your coax cable passes through a lightning arrestor on its way outside, make sure you have one that can pass dc. Most manufacturers make models that can pass dc, as well as ones that shunt dc to ground.

Figure 3 — The Bias-T Master and Bias-T Plus are housed in a weatherproof NEMA enclosure. The system uses two of these units — one in the shack and one at the antenna.

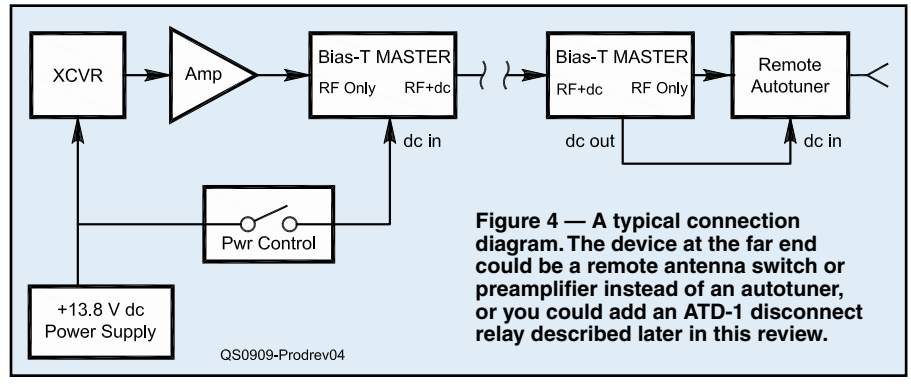

Figure 4 — A typical connection diagram. The device at the far end could be a remote antenna switch or preamplifier instead of an autotuner, or you could add an ATD-1 disconnect relay described later in this review.

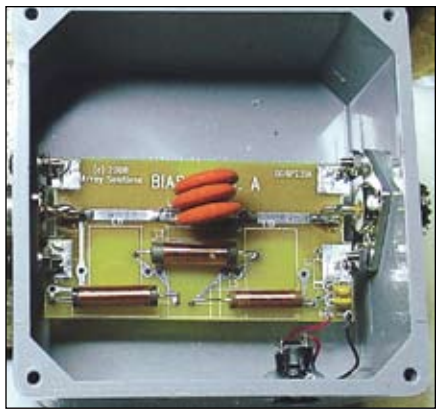

Figure 5 — Bias-T Plus internal view.

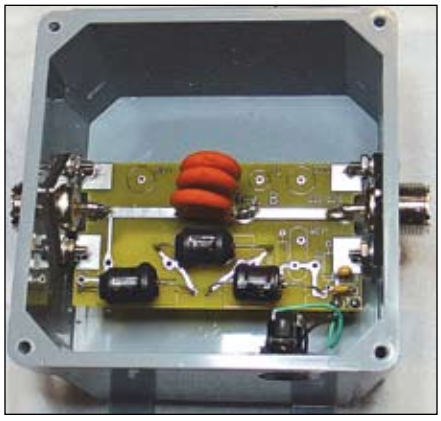

Figure 6 — Inside view of the Bias-T Master.

worried about nearby lightning hits causing damage to such an expensive device. Of course, I could always run outside and disconnect and ground the autotuner output when it is not being used. I'm not sure I'd always remember or take the time to do this, and it is an inconvenience.

The ATD-1 solves this problem. It incorporates a special relay that shorts the autotuner output and antenna input to ground when power is removed. The ATD-1 has a 3.1 kV peak voltage breakdown rating. A standard coaxial dc jack provides the control voltage input to the ATD-1 (11.5-14 V dc at 125 mA). A 6 foot dc power cord is provided with the unit. Screw terminals are used to connect the unit between the antenna tuner and antenna feed point, and grounding is accomplished through the aluminum mounting plate. Figure 10 shows the ATD-1 mounted with a remote autotuner at the base of my 43 foot vertical antenna.

The power-handling capability of the ATD-1 will vary as a function of the actual antenna impedance. In most cases the ATD-1 can handle full legal limit power even with a high antenna SWR. However, highly reactive antennas can have a very high feed point voltage. As the antenna becomes shorter, the capacitive reactance becomes higher and so the resultant voltage drop across the magnitude of the impedance increases. With an electrically short 43 foot vertical on 160 meters, the capacitive reactance is approximately 600 Ω and the radiation resistance is approximately 3 Ω. Adding in 10 Ω of ground loss (probably better than most hams can achieve), the peak voltage breakdown of the ATD-1 will occur at about 200 W. If the ground or matching losses increase, the frequency is increased or the antenna length is increased, more power can be applied before breakdown occurs. As an example, on 80 meters the ATD-1 can easily handle 1500 W when used with a 43 foot antenna.

If you can measure your antenna's SWR (using an SWR meter or antenna analyzer) then the ATD-1 can handle 1500 W of power. If the antenna SWR is so high that it is not measurable, you should determine the power handling capability of the ATD-1 for your untuned antenna. To do this, first use readily available antenna modeling software such as *EZNEC* to determine the input impedance of your antenna.[2] Next add your approximate ground loss into the resistive portion of the impedance. Now calculate the current into the total resistive part of the impedance at your power level. (When properly matched, there is no reactance.) Once you know this, calculate the peak voltage across the antenna impedance and compare it to the 3.1 kV peak breakdown rating of the ATD-1. Here's an example:

A 43-foot antenna has an impedance of

[2]Several versions of *EZNEC* antenna modeling software are available from developer Roy Lewallen, W7EL, at **www.eznec.com**.

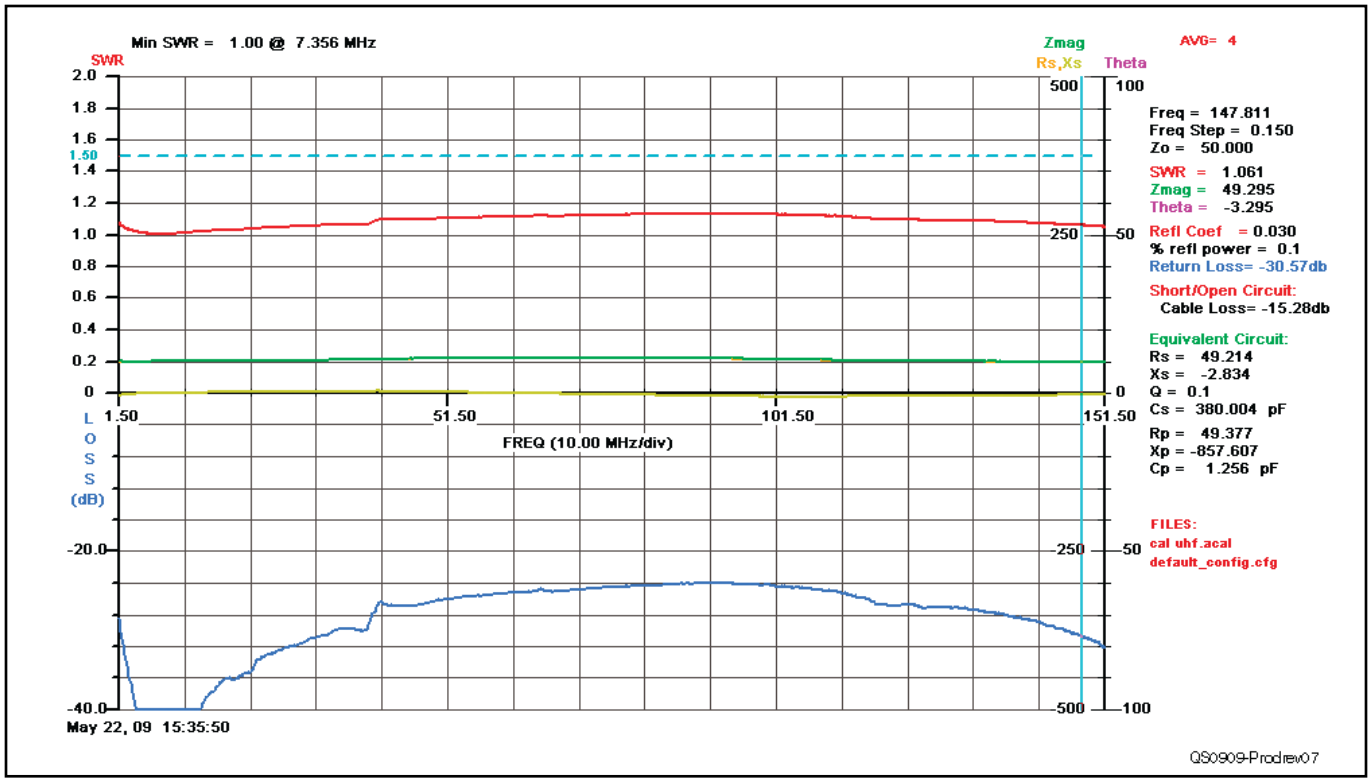

Figure 7 — Swept response through 151.5 MHz of two Bias-T Plus units cascaded. This display shows SWR (top, red line) and return loss (bottom, blue line).

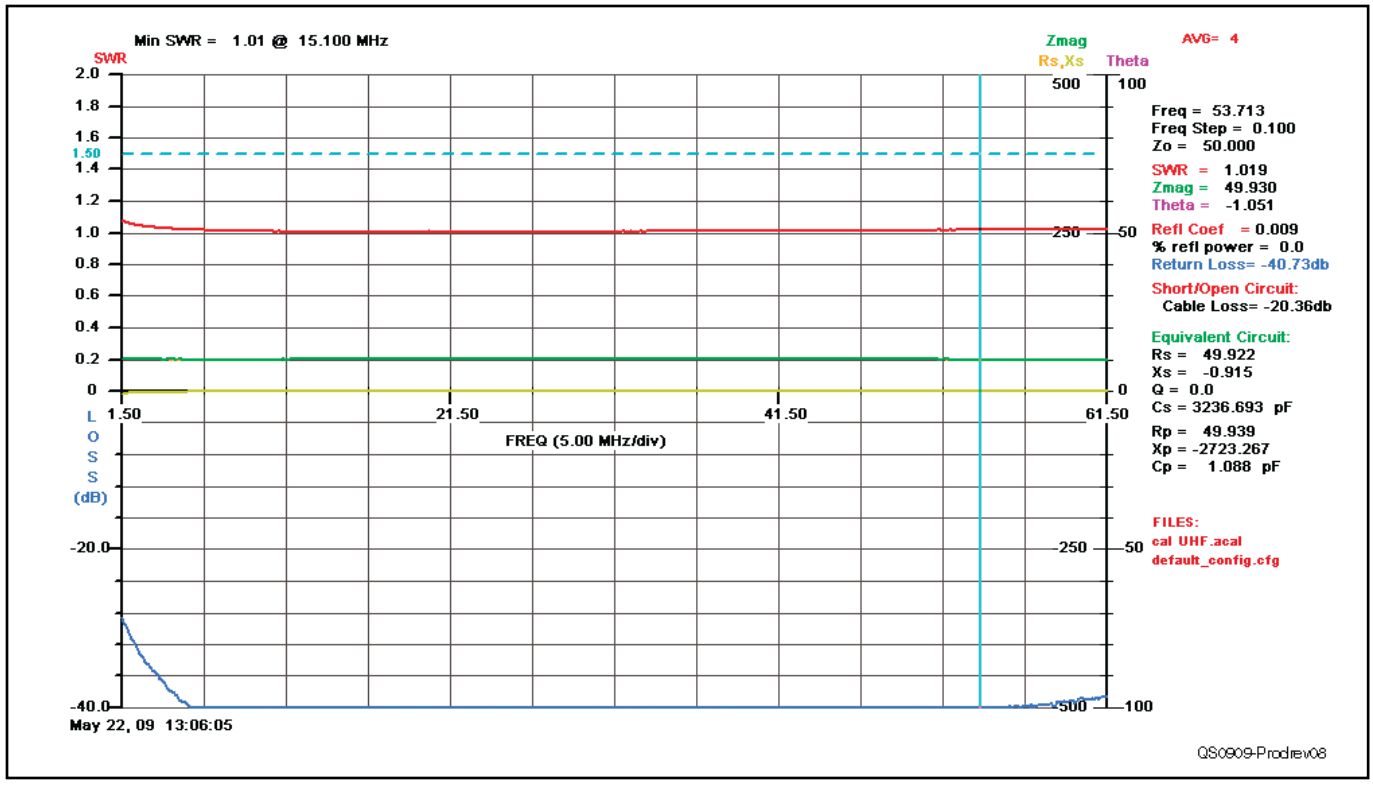

Figure 8 — Swept response through 61.5 MHz of two Bias-T Master units cascaded. This display shows SWR (top, red line) and return loss (bottom, blue line).

Figure 9 — The ATD-1 is also housed in a weatherproof NEMA enclosure and is slightly larger than the Bias-T units. The two screw terminals are for connection between the autotuner and antenna, and the metal plate on the back attaches to ground. There's a coaxial jack for power on the left side.

about 12 –*j*200 Ω on 80 meters. Assuming 10 Ω ground loss, the impedance becomes 22 –*j*200 Ω. If this is properly matched with a lossless remote autotuner or lossless matching network, all power will be delivered into the real 22 Ω portion of this impedance.

At 1500 watts, $I = \sqrt{P/R} = \sqrt{1500/22} = 8.3$ A RMS. The magnitude of the impedance is $|Z| = \sqrt{222 + 2002} = 201$ Ω. Therefore, the

Figure 10 — The ATD-1 mounted with an autotuner at the base of the author's 43 foot vertical antenna.

voltage at the base of the antenna (and across the ATD-1) can be determined:

$$V_{RMS} = I \times |Z| = 8.3 \times 201 = 1670\ V_{RMS}$$

$$V_{PEAK} = \sqrt{2} \times 1670 = 2360\ V_{PEAK}$$

The calculated 2360 V_{PEAK} is less than the 3100 V_{PEAK} breakdown rating of the ATD-1. And, of course, autotuners or even discrete matching networks are not lossless, which means there is even more margin.

To see how the ATD-1 really performed, I ran a breakdown test on 160 meters by connecting the ATD-1 in series with an inductive matching network placed at the base of the antenna. I drove this from my ALS-600 amplifier in the shack and gradually increased power until the amplifier tripped out because of the sudden SWR increase when the relay arced-over (the ALS-600 protection circuitry works well.). This occurred consistently at about 400 W. As the calculated breakdown was 200 W, this implies that my ground loss is higher than 10 Ω, or the ATD-1 relay breakdown voltage is conservative, or my matching network is not lossless, or probably a combination of all these factors. In any case, there is plenty of design margin for most remote autotuners on the market.

Summary

Powering and protecting remote devices can be an issue, especially if an unplanned remote device such as a preamp, remote switch or remote autotuner is added to an existing antenna system. The Array Solutions Bias-T Plus, Bias-T Master, and ATD-1 Auto-Tuner Disconnect accessories can make installation of these devices relatively painless and might just be part of the solution for your updated antenna system.

Manufacturer: Array Solutions, 2611 North Beltline Rd, Suite 109, Sunnyvale, Texas 75182; tel 214-954-7140; **www.arraysolutions.com**. Price: Bias-T Master, $150; Bias-T Plus, $150; ATD-1, $165. QST