Remote Automatic Antenna Tuners and the 43 Foot Vertical

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QST has previously reviewed in-shack and remote automatic antenna tuners designed for various applications and power levels.[1,2] Recent interest in 43 foot multiband vertical antennas available from several vendors has led to a corresponding interest in remote auto tuners used specifically with these antennas. This is because the 1:4 unun (unbalanced to unbalanced transformer) typically mounted at the vertical's base for matching to 50 Ω coaxial cable provides a compromise SWR on 60 through 10 meters. SWR is very high on 160 and 80 meters resulting in corresponding coax and unun losses.

This review will focus on three 200 W auto tuners and specifically their suitability for remote outdoor use at the base of a 43 foot multiband vertical antenna. The units reviewed (from lowest to highest cost) are the MFJ-927, CG Antenna CG-3000 and SGC SG-230.

43 Foot Antenna Measurement Methods

According to the *EZNEC* antenna modeling program, a 43 foot vertical has an impedance of 3 –*j*620 Ω on 160 meters when installed over a perfect ground and not in close proximity to other objects. For bench testing a tuner's ability to match this load on 160 meters, I built a simulator circuit with an impedance of 14 –*j*590 Ω. I used 20 Ω and 50 Ω Caddock thick film resistors in parallel to give the total real resistance of 14 Ω. This simulates 3 Ω of radiation resistance plus 11 Ω of ground loss, which is probably better than most hams have on 160 meters. To simulate the reactive component, two 300 pF, 1 kV silver-mica capacitors in series provide –*j*590, a compromise reactance between the theoretical –*j*620 and the –*j*550 that I measured on my own 43 foot vertical.

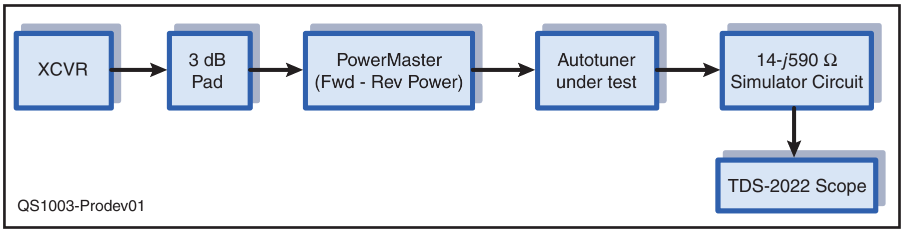


Figure 1 — Test setup used by the author for measuring expected tuner loss with a load that simulates the impedance of a 43 foot vertical antenna on 160 meters. See text for details.

Because maximum inductance and highest RF current occur on 160 meters due to the antenna's high capacitive reactance and low resistive impedance, this simulator circuit also permits the measurement of expected auto tuner loss when used with a 43 foot vertical on 160 meters. To measure the loss, I used an Array Solutions PowerMaster power/SWR meter and Tektronix TDS-2022 digital sampling oscilloscope as shown in Figure 1. I first compared the TDS-2022 and PowerMaster by feeding a 50 Ω resistive load directly and comparing the computed power level from the TDS-2022 display to the PowerMaster readings. The worst case measurement difference between the two instruments was 3%.

I set the PowerMaster to read net (forward minus reflected) power and inserted a high power 3 dB attenuator at the transceiver output to ensure that reflected power from a less than perfect auto tuner match is attenuated 6 dB further if re-reflected by the output circuitry. Actual power delivered to the load is measured by the TDS-2022, which displays not only the normal oscilloscope waveform but also digitally displays the frequency, RMS voltage and peak-to-peak voltage.

Resistive matching range and loss testing was performed in the ARRL Lab with a precision setup similar to that described in February 2003 *QST* and used in tuner reviews since then.[3] In the course of testing, ARRL Test Engineer Bob Allison, WB1GCM, noted that mounting the CG-3000 and SG-230 to a metal plate improved auto tuner efficiency. It also eliminated interaction with nearby metal objects. Without the plate, SWR changed dramatically with tuner movement on the metal test bench. Bob suggests bolting the mounting bracket of either of these tuners to a metal plate if the unit is installed on a nonconductive surface. (The MFJ-927, which is

[3]M. Tracy, KC1SX, "Antenna Tuner Testing Methods vs Accuracy," Product Review, *QST*, Feb 2003, p 75.

Bottom Line

There are pros and cons to using a remote automatic antenna tuner with an untuned antenna such as the popular 43 foot vertical. On the plus side are operating convenience and reduced SWR related coax losses. Cons include limited reactive tuning range and tuner losses. If you plan your remotely tuned antenna system properly, a remote auto tuner can be an excellent answer for multiband operation.

[1]J. Hallas, W1ZR, "Automatic Antenna Tuners — A Sample of the Field," Product Review, *QST*, May 2004, pp 71-76. *QST* Product reviews are available on the Web at **www.arrl.org/members-only/prodrev/**.

[2]J. Hallas, W1ZR, "Medium to High Power Auto Antenna Tuners — The Evolution Continues," Product Review, *QST*, Aug 2006, pp 56-61.

Table 1
Tuned SWR with Short Circuit or Open Load

	----- *MFJ-927*-----		----- *CG-3000* -----		----- *SG-230*-----	
Band	*Short*	*Open*	*Short*	*Open*	*Short*	*Open*
160	No tune	No tune	No tune	No tune	No tune	1.4:1
80	No tune	No tune	No tune	1.3:1	No tune	1.0:1
40	2.9:1	No tune	No tune	1.7:1	No tune	2.3:1
30	No tune	No tune	No tune	2.4:1	1.2:1	1.2:1
20	4.0:1	5.0:1	1.1:1	2.2:1	1.7:1	3.0:1
17	4.0:1	No tune	1.6:1	No tune	1.9:1	1.3:1
15	No tune	3.8:1	1:4:1	1.3:1	1.6:1	1.7:1
12	No tune	No tune	No tune	1.3:1	No tune	No tune
10	1.3:1	1.9:1	1.8:1	No tune	No tune	2.0:1

Figure 2 — Each auto tuner was tested at the base of the author's 43 foot vertical antenna.

Table 2
Testing with AD5X 43 Foot Vertical

	MFJ-927	CG-3000	SG-230
Band	*SWR*	*SWR*	*SWR*
160	No tune	No tune	1.4:1
80	1.3:1	2.0:1	1.4:1
60	1.0:1	1.2:1	1.2:1
40	1.0:1	1.2:1	1.3:1
30	1.5:1	1.1:1	1.5:1
20	1.5:1	1.3:1	1.0:1
17	1.2:1	1.5:1	1.4:1
15	1.1:1	1.3:1	1.9:1
12	1.2:1	1.7:1	1.8:1
10	1.2:1	1:9:1	1.3:1

built on a metal plate with integral mounting tabs, did not exhibit this behavior.)

The ARRL Lab also tested the auto tuners with open and short circuit loads. With *lossless* tuner components, an open/short tuning solution is not possible. But no practical antenna tuner is lossless because it is built with components of finite Q. The Lab discovered that an antenna tuner can sometimes tune into its own internal losses and present a matching solution to the transmitter. Results of these tests are shown in Table 1. Generally, fewer cases where this happens indicates lower intrinsic tuner losses.

Tuning sensitivity was also measured. This is the RF power and SWR required to automatically initiate a retune. All three auto tuners specify a "must start a retune" when the SWR exceeds 2:1.

For final testing, each auto tuner was connected to the base of my 43 foot vertical and tested on each band (Figure 2) with my 100 W transceiver. Sixty feet of ½ inch Andrew Heliax connects my transceiver in the shack to the auto tuners at the base of the 43 foot vertical. Three ground rods and approximately 20 radials provide my RF and dc grounding at the antenna — certainly not a perfect ground, but probably not atypical. As a reference, I measured the resonant impedance of my 43 foot vertical on 60 meters as 48 $-j0\ \Omega$, which implies my ground loss is 12 Ω on that band. Once the tuner found a match, I recorded the SWR measured in my shack with the PowerMaster, as shown in Table 2.

MFJ-927 REMOTE AUTOMATIC ANTENNA TUNER

The MFJ-927 is the smallest of the three auto tuners tested here. It is enclosed in a weather protected container, but is not O-ring sealed. For extended outdoor operation, it would be a good idea to place the tuner under a protective cover, such as an inverted plastic storage bin.

Coaxial and random wire outputs are provided, along with an SO-239 UHF jack for the station feed line and a ground post. The MFJ-927 receives dc power on the coax feed line via an internal bias-T, so you won't need to run a separate cable for power. MFJ supplies an MFJ-4117 bias-T for inserting +12 V dc on the coax in the shack. The outside of the unit and internal circuitry are shown in the accompanying photos. Note that the inductors consist of a mix of toroidal and wide spaced air wound inductors.

Unlike the CG-3000 and SG-230, the MFJ-927 does not specify minimum antenna lengths for tuning the ham bands, but instead specifies a resistive tuning range on all bands. A little calculator work shows that with the 25 μH maximum inductance available in the MFJ-927, the minimum length antenna for 160 meters would need to be about 80 feet. Therefore the MFJ-927 does not have the inductance range required for using my 43 foot vertical on this band. I verified this by connecting the simulator circuit to the MFJ-927. The MFJ-927 tried to find a match for about 10 seconds, and then gave up.

Open/short test data is shown in Table 1. Only on 10 meters did the MFJ-927 find an open and short circuit tuning solution below a 2:1 SWR.

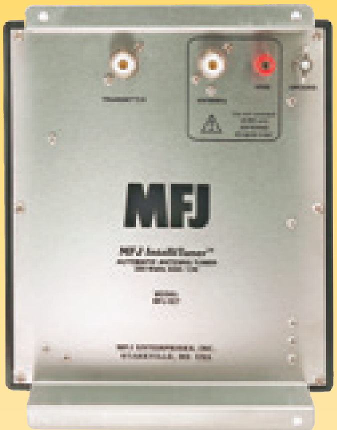
Next I connected the MFJ-927 to the base of my 43 foot vertical. Tuning was very fast, with initial tuning typically occurring in less than 2 seconds and tuning from memory essentially instantaneous. As expected, the MFJ-927 could not tune the 43 foot vertical on 160 meters but found a 1.5:1 or better match on 80 through 10 meters. Note that an external inductance can be used to allow 160 meter operation (see sidebar on page 52). The results are shown in Table 2.

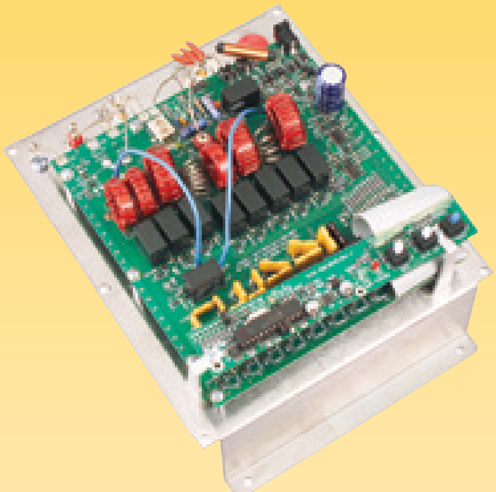
Last came the ARRL Lab testing of the resistive load tuning range and loss measurements. As you can see in Table 3, the MFJ-927 matched all resistive loads the Lab presented to it. While there were a few cases where the SWR didn't reach the 1.5:1 target,

Table 3
MFJ-927

Manufacturer's Specifications

Maximum power: 200 W PEP SSB/CW, 125 W continuous.
Minimum power for tuning: 2 W.
Frequency range: 1.8 to 30 MHz.
Tuning time: 6 seconds (initial tuning), <0.2 second if memorized.
Impedance matching range: 6 to 1600 Ω.
Matching network: Reversible-L (series L/shunt C or shunt C/series L).
Capacitor range: 0-3961 pF (256 tuning steps).
Inductor range: 0-24.86 µH (256 tuning steps).
Tuning start: 2:1 SWR
Tuning target: Less than 1.5:1 SWR
Memory channels: 2500
Memory resolution: 2 kHz on 160 meters, scaling to 28 kHz on 10 meters
Size: 7.5 × 5.5 × 9 inches; weight 3 pounds.
Power supply: 13.8 V dc ±10% at less than 750 mA.
Price: $230.





ARRL Lab Testing

Current draw: 200 mA when tuning, 13 mA static
Tuning sensitivity: At 10 W or higher, 2:1 SWR starts a retune.

Measured power loss into resistive loads (%) / Input SWR at match.

SWR	Load (Ω)	160 m	80 m	40 m	20 m	10 m
16:1	3.125	47	21	26	13	*
		1.6	**	1.6	**	1.6
8:1	6.25	31	14	27	15	*
		**	**	**	1.7	**
4:1	12.5	*	*	*	*	16
		**	**	**	**	1.8
2:1	25	*	*	*	*	*
		**	**	**	1.6	**
1:1	50	*	*	*	*	*
		**	**	**	**	1.6
2:1	100	*	*	*	*	27
		**	**	**	**	1.6
4:1	200	11	13	*	*	22
		**	1.7	1.6	**	1.6
8:1	400	12	*	*	*	20
		**	**	**	**	1.6
12:1	600	*	12	17	14	24
		**	1.6	**	**	**
16:1	800	30	12	17	14	24
		**	1.8	1.8	**	1.6

*Power loss less than or equal to 10%.
**Matched SWR less than or equal to 1.5:1.

in most cases the 1.5:1 target specification was met. The ARRL Lab also verified the 2:1 "must start tuning" specification.

The MFJ-927 has the ability to be remotely forced to retune on any given frequency with its *Sticky Tune* feature. In software version 2.4 or greater, if Sticky Tune is enabled, the MFJ-927 will always retune the first time you transmit after a power cycle. This feature is convenient if the SWR doesn't settle as low as you like and you'd like to force a retune. If you want to try for a lower tuned SWR on a given frequency, simply cycle power and then transmit on that frequency. The MFJ-927 will retune on that frequency only. Other memory locations will be unaffected.

MFJ-927 Summary

The MFJ-927 is a fast-tuning, inexpensive remote auto tuner that will give good performance from 80 to 10 meters when used with a 43 foot vertical. Its Sticky Tune feature provides a simple way to remotely force a retune on any frequency without affecting other memories. In a permanent installation, some sort of cover for weather protection would be a good idea.

Manufacturer: MFJ Enterprises, PO Box 494, Mississippi State, MS 39762, tel 800-647-1800; **www.mfjenterprises.com**.

CG ANTENNA CG-3000 REMOTE AUTOMATIC ANTENNA TUNER

The CG-3000 is enclosed in an O-ring sealed ABS plastic weatherproof container. It includes attached stainless-steel mounting brackets as well as two U bolts should you wish to mount the CG-3000 on a mast. The provided power cable, about 12 feet long, plugs into the CG-3000 via a four pin connector included on the cable. Next to the power connector is an SO-239 for the station feed line and a metric wing nut ground connection that fits a #10 solder lug. The CG-3000 antenna output is a single ceramic-insulated terminal that is also a good fit for a #10 solder lug. As seen in the accompanying photo, all inductors are close wound air-core inductors.

CG Antenna specifies a minimum antenna length of 8 meters (26 feet) for 1.8 to 30 MHz operation, or 2.4 meters (8 feet) for 3.5 to 30 MHz. Those specifications, along with the specified inductance range, indicate that the CG-3000 will provide full coverage from 160 through 10 meters with a 43 foot vertical. Testing showed this was not the case. When I connected the simulator circuit, the CG-3000 was unable to find a match. This implies that either the CG-3000 does not have the advertised inductance range, or the tuning algorithm fails to do the job on 160 meters.

During resistive load testing in the ARRL Lab (Table 4), you can see that the resistive tuning range on 160 meters is limited compared to the other bands. There were also some resistive impedances on 40 and 10 meters that could not be matched. ARRL Lab open/short test results are shown in Table 1. As you can see, tuning solutions at or below 2:1 SWR are found on most of the HF bands for opens or shorts.

Under some conditions the SWR settles close to 2:1, which is the target SWR. In those cases, I found that once the CG-3000 is tuned I could exceed a 2:1 SWR by moving frequency within that band, but a retune won't occur until the SWR increases to

Table 4
CG Antennas CG-3000

Manufacturer's Specifications

Maximum power: 200 W PEP, 125 W continuous.
Minimum power for tuning: 10 W.
Frequency range: 1.8 to 30 MHz.
Tuning time: 6 seconds (initial tuning), <0.2 second if memorized.
Impedance matching range: Not specified.
Matching network: Low-pass pi or reversible-L as needed (C-L-C)
Input capacitor range: 0-6300 pF (100 pF increments).
Output capacitor range: 0-775 pF (25 pF increments).
Inductor range: 0-64 µH (0.25 µH increments).
Tuning start: 2:1 SWR.
Tuning target: Less than 2:1 SWR.
Memory channels: 200.
Memory resolution: 5 kHz on 160 meters, scaling to 200 kHz on 10 meters.
Size: 12.2 × 9.5 × 2.8 inches; weight 13 ounces.
Power supply: 13.8 V dc ±10% at less than 800 mA.
Price: $330.

ARRL Lab Testing

Current draw: 750 mA when tuning, 413 mA static
Tuning sensitivity: At 10 W, 3.2:1 SWR starts a retune; at 50 W, 2.5:1 SWR.

Measured power loss into resistive loads (%) / Input SWR at match.

SWR	Load (Ω)	160 m	80 m	40 m	20 m	10 m
16:1	3.125	No tune	*	No tune	48	No tune
		n/a	**	n/a	2.0	n/a
8:1	6.25	13	18	20	36	No tune
		**	**	**	**	n/a
4:1	12.5	12	20	17	20	25
		**	1.9	**	**	**
2:1	25	29	17	27	19	12
		1.9	1.9	2.0	**	**
1:1	50	24	*	*	13	*
		**	**	**	**	**
2:1	100	24	*	14	31	15
		2.1	**	**	1.9	**
4:1	200	No tune	11	12	11	22
		n/a	**	**	**	**
8:1	400	No tune	11	14	14	18
		n/a	**	**	**	1.6
12:1	600	No tune	20	14	15	35
		n/a	1.8	**	**	2.0
16:1	800	No tune	38	23	24	42
		n/a	**	**	1.6	1.9

*Power loss less than or equal to 10%.
**Matched SWR less than or equal to 1.5:1.

above 3:1. Unfortunately there is no easy way to force a retune. The only way I could force a retune was to short the output of the CG-3000, let it try to tune, then reconnect the load and let it tune again. I found one other issue. The CG-3000 does not time out if it cannot find a tuning solution. It just continues to tune until you either remove RF drive, or turn off power to the unit.

After completing bench testing, I connected the CG-3000 to the base of my 43 foot vertical and measured the tuned SWR. Except for 160 meters, tuning solutions were found quickly. In most cases, the final match was better than the 2:1 target. Results are shown in Table 2.

The optional CG-CTU control unit adds power and reset switches, along with power and tuning LEDs. The reset switch puts the tuner in bypass, but does not erase memories or force a retune

CG-3000 Summary

The CG-3000 can reliably be used on 80 through 10 meters with a 43 foot vertical, but not on 160 meters as advertised. The solution presented in the sidebar may work for the CG-3000 but this was not verified. Its inability to time out when a match cannot be found is an irritant, but not really a problem. Its failure to meet its 2:1 "start tuning" specification is an issue, however, especially since there is no easy way to force a retune.

Manufacturer: CG Antenna, 5/501, Lane 1800, Hanri Rd, 200336 Shanghai, China; **sales@cgantenna.com**; **www.cgantenna.com**. We purchased the review unit from Array Solutions, which is no longer handling CG antenna products. At press time, CG Antenna was working on details for distribution of its products in the US.

SGC SG-230 REMOTE AUTOMATIC ANTENNA TUNER

The SG-230 is enclosed in a rugged O-ring sealed ABS plastic weatherproof container. Transceiver RF and power interface through a 9 foot combination 4 conductor/RG-58 cable that is permanently attached to the SG-230. On the coax input side you will find a ¼ inch diameter bolt for the ground connection, and the antenna output is a single ceramic insulated terminal with a #10 screw interface. Antenna and ground solder lugs are provided with the SG-230. All inductors are close-wound air-core inductors.

SGC specifies a minimum required antenna length of 23 feet for operation below 3.3 MHz, and 8 feet for operation above 3.3 MHz. With its specified 64 µH maximum inductance, the SG-230 should be able to match a 43 foot vertical on 160 meters. As before, I first tried tuning on 160 meters with the simulated load. This time I was successful — the SG-230 found a match within a few seconds, just as it should. At 1.85 MHz, I measured an SWR of 1.46:1 and 2.1 dB loss (38% loss).

Table 5 shows the results of the ARRL Lab testing. All resistive loads were matched. In most cases the final tuned SWR was less than 1.5:1, though there were two cases where the tuned SWR settled close to the 2:1 SWR target. Open/short test results are shown in Table 1. As with the CG-3000, the SG-230 can find an open/short tuning solution of less than 2:1 SWR on most of the HF bands.

Just like the CG-3000, tuning doesn't restart if the SWR changes unless the SWR

Table 5
SGC SG-230

Manufacturer's Specifications

Maximum power: 200 W PEP, 80 W continuous.
Minimum power for tuning: 3 W.
Frequency range: 1.8 to 30 MHz.
Tuning time: 6 seconds (initial tuning), <0.2 second if memorized.
Impedance matching range: Not specified.
Matching network: Low-pass pi or reversible-L as needed (C-L-C)
Input capacitor range: 100-6400 pF (100 pF increments).
Output capacitor range: 25-800 pF (25 pF increments).
Inductor range: 0.25-64 µH (0.25 µH increments).
Tuning start: 2:1 SWR.
Tuning target: Less than 2:1 SWR.
Memory channels: 170.
Memory resolution: 10 kHz on 160 meters, scaling to 1500 kHz on 10 meters.
Size: 16 × 12 × 3.5 inches; weight 8 pounds.
Power supply: 10-18 V dc at less than 900 mA.
Price: $540.

ARRL Lab Testing

Current draw: 900 mA when tuning, 450 mA static
Tuning sensitivity: At 10 W, 3.2:1 SWR starts a retune; at 50 W, 2.5:1 SWR.

Measured power loss into resistive loads (%) / Input SWR at match.

SWR	Load (Ω)	160 m	80 m	40 m	20 m	10 m
16:1	3.125	14 **	19 **	29 2.1	13 **	25 **
8:1	6.25	* **	22 **	13 **	14 **	29 1.6
4:1	12.5	17 **	27 **	13 **	12 **	22 **
2:1	25	21 **	11 **	11 **	* **	28 1.8
1:1	50	* **	* **	* **	* **	13 **
2:1	100	* 1.6	* **	* **	* **	23 **
4:1	200	* **	* **	* **	* **	11 **
8:1	400	* **	* **	* **	* **	32 1.6
12:1	600	* **	* **	* **	17 1.6	30 **
16:1	800	* **	* **	12 **	22 **	42 **

*Power loss less than or equal to 10%.
**Matched SWR less than or equal to 1.5:1.

increases to over 3:1. Unlike the CG-3000, the SG-230 has an internal strapping option that defeats memory tuning. Internal jumper JP2 bypasses the SG-230's memories, which means that the SG-230 will always retune rather than use previously stored data. This setting will cause the SG-230 to retune every time you transmit on a new frequency.

Final testing occurred with the SG-230 attached to the base of my 43 foot vertical. I was able to find a matching solution on all bands from 160 through 10 meters with no tuning gaps. In all but two cases the final match was under 1.5:1. Results are shown in Table 2.

The optional Smartlock accessory provides power and reset switches, a tuning lock function and power and tuning LEDs. The reset switch puts the tuner in bypass but does not erase memories or force a retune.

SG-230 Summary

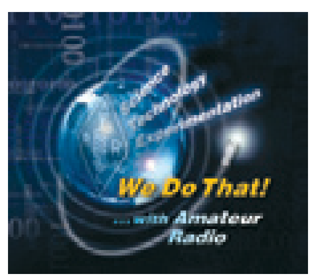
The SG-230 is the only auto tuner of the three reviewed here that will match a 43 foot vertical on 160 meters. While it did not meet its "must start retuning at 2:1 SWR" specification, it can be set to disable memory tuning. This setting forces a retune upon frequency change at the expense of tuning speed but in some cases is necessary to keep the transceiver happy when moving around a band. Tuning is almost instantaneous when recalling previously stored memory data.

Manufacturer: SGC Inc, 13737 SE 26th St, Bellevue, WA 98005; tel 425-746-6310; **www.sgcworld.com**.

Some Final Thoughts

I found this exercise to be very enlightening. Besides learning more about tuner reactive tuning ranges and tuner losses, I also had never considered that remote auto tuners could possibly match an open or a short. This means that you could have a failed connection at the antenna without even knowing it! Since there is probably at least one frequency or band where you may have a high but measurable untuned SWR, it would probably be worthwhile to record the untuned SWR so that you can verify connection integrity if you suspect there might be a problem. All three auto tuners discussed here come up in the bypassed mode when power is cycled, so this is an easy test to make from your shack with an antenna analyzer (if you apply RF power the auto tuners will start tuning).

There are definitely benefits to using a remote auto tuner with an untuned antenna such as the popular 43 foot vertical. First, of course, is operating convenience. You simply transmit a low power carrier for tuning and then operate. And second, you will reduce SWR related coax losses. There are always trade-offs to consider, such as reactive tuning range and tuner losses. If you plan your remote-tuned antenna system properly, a remote auto tuner can be an excellent answer for multiband operation.



Extending the MFJ-927 to 160 Meters

As discussed in the review, additional inductance is needed to allow the MFJ-927 to match a 43 foot vertical on 160 meters. I decided to add some external inductance to see if this would help the MFJ-927 tune the antenna on 160 meters. I chose to add around 30 µH, by using a 2.5 inch length of MFJ 4004-0008 coil stock. This is an air core coil of #16 AWG tinned copper wire, 2.5 inches in diameter, wound 10 TPI in series between the tuner output and the antenna base. If you order this product, you will get a 10 inch length, so there is plenty left over for other projects.

I mounted the coil in a 4 × 4 × 4 inch plastic outdoor electrical box available from most home improvement stores. I used #8 stainless steel hardware for the IN and OUT RF connections. Two binding posts (MFJ 606-0014) permit shorting the coil for normal 80 through 10 meter auto tuner operation.

I made a simple shorting wire using a pair of spade lugs. For mounting, I bolted the assembly to one of the MFJ-927 mounting holes and then connected everything to my 43 foot antenna as shown in the photo.

How does this work? Absolutely great! The MFJ-927 now easily tunes 160 meters just as on other bands. The only disadvantage is that you must manually select 160 meters or 80 to 10 meters by adding or removing the shorting strap. Finally, while this was built for use with my MFJ-927 this same assembly can be used with any auto tuner that needs additional inductance for matching low frequency, electrically short antennas. — *Phil Salas, AD5X*