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MFJ-994BRT and MFJ-998RT Remote Automatic Antenna Tuners

These high power matching networks mount at the antenna.

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I previously reviewed several remote automatic antenna tuners specifically for use with a 43 foot vertical antenna.[1] Those remote tuners were limited to about 200 W maximum RF power, unsuitable for stations using power amplifiers. This has now changed with the introduction of the MFJ-994BRT (600 W) and MFJ-998RT (1500 W) remote auto tuners.

A remote antenna tuner must be weatherproof and remotely powered, and it must provide automatic tuning. For a given RF power handling and impedance matching specification, a remote antenna tuner will generally be more expensive than a desktop unit because of these requirements.

With many manual and automatic desktop models available, why use a remote antenna tuner? It's an efficient way to match an antenna that has a high SWR and is fed through a relatively long length of coaxial cable. SWR-related coax cable losses can be high when the antenna SWR is high — even if an in-shack tuner provides a 1:1 SWR for your equipment. You can easily demonstrate this with antenna modeling software simulations and a coax/SWR calculator.

Overview

The MFJ-994BRT and MFJ-998RT are remote versions of the current MFJ-994B (600 W) and MFJ-998 (1500 W) switched L-network desktop auto tuners.[2] Turning these into remote auto tuners involved mounting them in weatherproof boxes and removing some of the desktop features such as A/B antenna switching and multiple memory banks. A comparison of the MFJ-994BRT and MFJ-998RT auto tuners is given in Table 1.

In addition to the higher RF power ratings, the MFJ-994BRT and MFJ-998RT include some interesting features not found in other remote auto tuners. The first is an internal bias-T for those who may not have dc power available at the antenna. (A bias-T allows you to inject dc into the coax feed line so you don't have to run a separate power cable.) An MFJ-4117 bias-T for the station end of the feed line is included with both units and it includes an ON/OFF switch for convenient power control of the auto tuners.

The MFJ-994BRT and MFJ-998RT provide SO-239 connectors and random wire outputs (only one at a time can be used). The SO-239 connector has been tested to more than 2 kV to ensure there is no possibility of arcing under high SWR conditions.

These auto tuners include an LC limit feature that provides upper limits of inductance and capacitance according to frequency and maximum power rating. This feature limits the MFJ-994BRT maximum peak voltage to 1000 V and maximum peak current to 10 A across these components. For the MFJ-998RT the maximum limits are 2100 V peak and 13 A peak. If a match could be achieved, but with settings that would result in destructive voltages or currents, the auto tuners will not permit the match.

Both auto tuners will not tune if more than 75 W is applied and the SWR is greater than 3:1, or if more than 125 W is applied regardless of SWR. This effectively locks the tuner settings when high power is applied, protecting the tuner and your RF power amplifier from damage.

Finally, both the MFJ-994BRT and the MFJ-998RT can be forced to retune on any given frequency. When *Sticky Tune* is enabled (default) these auto tuners will always retune the first time you transmit after a power cycle. So 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-994BRT and MFJ-998RT will retune and store the new tuning data for that frequency only. All other previously stored memory locations will be unaffected.

Tuner Measurements

I performed resistive matching range and loss testing with a precision setup similar to that used in the ARRL Lab.[3] This is a good way to systematically check an auto tuner's ability to match a wide variety of loads.

While resistive matching tests are great for standard antenna tuner comparison testing, remote tuners will experience maximum inductance and highest RF current with short antennas, so antenna tuner losses can be higher under these conditions. To determine auto tuner losses in more real-world conditions, I built two antenna simulator circuits. One is based on the tuners' minimum antenna length specifications for 160 meters. The other simulates the popular 43 foot vertical on 80 meters.

Note that most auto tuners, the MFJ-994BRT and MFJ-998RT included, do not

Bottom Line

The MFJ-994BRT and MFJ-998RT provide reasonably priced remote auto tuner solutions for stations with high power amplifiers.

[1] P. Salas, AD5X, "Remote Automatic Antenna Tuners and the 43 Foot Vertical," Product Review, *QST*, Mar 2010, pp 47-52. Product Reviews mentioned here are available to ARRL members online at **www.arrl.org/product-review**.

[2] The MFJ-994, an earlier version of the MFJ-994B, was reviewed in the August 2006 *QST*.

[3] J. Parise, W1UK, "*QST* Reviews Five High-Power Antenna Tuners," Product Review, *QST*, Feb 2003, pp 69-75. See the sidebar, "Antenna Tuner Testing Methods vs Accuracy" by Michael Tracy, KC1SX, on p 75.

have enough internal inductance to tune a 43 foot vertical on 160 meters. MFJ offers the MFJ-2904 external inductor assembly that can be manually strapped in line at the auto tuner output to enable 160 meter tuning capability with a 43 foot vertical. In addition, I developed a remotely switched range extender for 160 meter operation and improved 80 meter operation that will be the subject of a future *QST* article.

For final testing, I connected each auto tuner to the base of my 43 foot vertical and recorded the tuned SWR on different bands. I measured the SWR in my shack with an Array Solutions PowerMaster. Seventy feet of Andrew FSJ4-50B ½ inch Heliax low loss coax connects my transceiver and amplifier in the shack to the auto tuners at the base of the 43 foot vertical. Three ground rods and approximately 20 radials provide 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.

Details of my test setup are available in the digital edition of *QST* and online at **www.arrl.org/qst-in-depth**.

MFJ-994BRT Remote Auto Tuner

The MFJ-994BRT, with its 600 W SSB/CW capability, is perfect for the many medium power amplifiers on the market. The photos accompanying Table 2 show the outside of the unit and the internal circuitry. Note that the inductors consist of a mix of toroidal and wide-spaced air-wound inductors.

ARRL Lab test results are given in Table 2. As you can see, the MFJ-994BRT matched all resistive loads presented to it that were within its specified tuning range. And while there were a few cases in which the SWR didn't reach the 1.5:1 target, in most cases the target specification was met.

I measured the MFJ-994BRT tuner losses using the 160 and 80 meter short antenna simulator circuits described earlier. Approximately 10 Ω of real resistance was added to simulate ground losses. The MFJ-994BRT was able to match a simulated 43 foot vertical for 80 meters and a simulated 100 foot antenna for 160 meters with power loss less than 10% and minimum SWR of 1.3:1 on 80 and 1.7:1 on 160.

MFJ-998RT Remote Auto Tuner

The MFJ-998RT handles a full 1500 W PEP on SSB or CW. Construction is similar to the MFJ-994BRT with a mix of toroidal and wide-spaced air-wound inductors.

Table 1
MFJ-994BRT and MFJ-998RT Specifications

	MFJ-994BRT	MFJ-998RT
Frequency range:	1.8-30 MHz	1.8-30 MHz
RF power capability:	600 W CW/SSB	1500 W CW/SSB
Resistive matching range:	12-800 Ω	12-1600 Ω
Capacitance range:	0-2950 pF	0-3900 pF (input side) 0-970 pF (output side)
Inductance range:	0-17 µH	0-24 µH
12-15 V dc current required:	850 mA max	1.4 A max
Size (HWD, approx):	2.8 x 10.1 x 9.2 in.	3.25 x 13.75 x 17 in.
Weight:	3.7 lb	9.5 lb
Price:	$400	$770

Table 3 shows the results of resistive load tuning range and loss measurements in the ARRL Lab. In most cases the 1.5:1 target specification was met. As with the MFJ-994BRT, the high impedance tuning range is significantly broader than the low impedance range. The low impedance limit is specified at 4:1 SWR.

I measured the MFJ-998RT tuner losses using the 160 and 80 meter short antenna simulator circuits described earlier, again with approximately 10 Ω of real resistance added to simulate ground losses. The MFJ-998RT was able to match a simulated 43 foot vertical for 80 meters and a simulated 90 foot antenna for 160 meters with power loss less than 10% and minimum SWR of 1.2:1 on 80 and 1.6:1 on 160.

Open/Short Circuit Testing

Ideally a tuner should not be able to match an open or short circuit load. If it does, this means that it is tuning into its own internal losses. However, no antenna tuner is lossless due to components with finite Q. From past experience I've found that most antenna tuners — manual and automatic — can find a match on one or more frequencies when connected to an open or a short.

In the ARRL Lab, neither tuner could find a match into an open circuit or a shorted PL-259 connector. At my station, I found some noteworthy short circuit match occurrences. With both the MFJ-994BRT and MFJ-998RT, on 20 meters I found a short circuit match with an SWR less than 2:1. If you have a shorted antenna feed line on 20 meters and the tuner finds a match, all your power will be dissipated within the tuner. You will probably damage the auto tuner if you transmit into it with full power. So if you don't hear any signals either before or after a tune-up, you might want to check your antenna system before you start transmitting.

It is probably a good idea to record your antenna's untuned SWR in your shack on your bands of interest so you can check that nothing changes over time. This is easily done by turning off auto tuner power, which bypasses the tuner.

43 Foot Vertical Antenna Testing

My final tests involved connecting both the MFJ-994BRT and MFJ-998RT antenna tuners to the base of my 43 foot vertical (Figure 1). Tuning was very fast, with initial tuning typically occurring in less than 2 seconds and tuning from memory essentially instantaneous. The results are shown in Table 4. I have two solid state

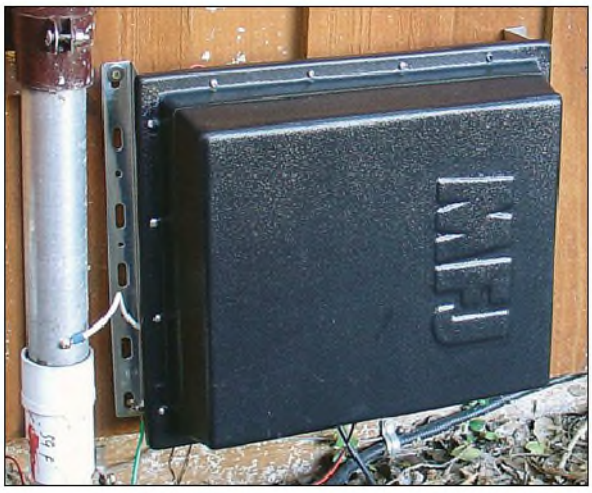


Figure 1 — The MFJ-998RT mounted at the base of the author's 43 foot vertical.

Table 2
MFJ-994BRT Resistive Load and Loss Testing

Manufacturer's Specifications

Matching range:	Up to 4:1 for <50 Ω, up to 16:1 for >50 Ω.
Minimum power for tuning:	2 W.
Maximum power for tuning:	20 W (100 W with foldback).
Target SWR:	1.5:1 (default) or 2:1 (selectable).
Tuning threshold:	0.5 to 1.5 above target SWR, 0.5 default.

ARRL Lab Testing

SWR	Load (Ω)		160 m	80 m	40 m	20 m	10 m
4.3:1	11.5	Power Loss (%)	*	*	*	*	*
		SWR	1.6	**	**	**	1.7
2:1	25	Power Loss (%)	*	*	*	*	*
		SWR	**	**	1.9	**	**
1:1	50	Power Loss (%)	*	*	*	*	*
		SWR	**	**	**	**	**
2:1	100	Power Loss (%)	*	*	*	*	*
		SWR	**	1.6	1.7	**	1.6
4:1	200	Power Loss (%)	*	*	*	*	14
		SWR	1.7	1.7	**	**	2.0
7.6:1	380	Power Loss (%)	*	*	*	*	20
		SWR	**	**	1.6	**	**
16:1	800	Power Loss (%)	11	12	*	*	28
		SWR	2.0	2.0	**	**	2.0

*Power loss less than or equal to 10%.
**Matched SWR less than or equal to 1.5:1.
Measured current usage: 2.4 A peak during tuning, 214 mA idle.

amplifiers — an Ameritron ALS-600 and an Elecraft KPA500. Both amplifiers put out full power into the tuned antenna system on all bands from 80 to 10 meters (I did, of course, limit power to 200 W on 30 meters).

As pointed out in both manuals, I found occurrences in which both auto tuners would not tune when changing bands. This can occur if the tuning solution for the previous band results in a very high SWR on the new band, and more often happens when going from a lower frequency band to a higher frequency band especially when using a highly reactive antenna. This very high SWR can reflect all input power from your transceiver, so the auto tuner cannot sense RF input power. The solution is to simply cycle power to the auto tuner when changing bands. This drops the auto tuner to bypass prior to tuning so some forward power is sensed thus permitting a tune to occur.

On the Air with the Remote Auto Tuners

Each auto tuner was installed on my 43 foot vertical for about one week. During this time I enjoyed numerous QSOs on 80 through 15 meters primarily using my Elecraft K3 transceiver and KPA500 amplifier. In all cases I would start anew on each band by pressing the TUNE button on my K3 (my K3 TUNE output is set for 15 W) with the amplifier off line. It was interesting to watch the PowerMaster SWR readout in the shack as the remote tuners did their thing. Once tuning stopped, usually less than 5 seconds on an initial tune, or instantaneously for a previously memorized tune, I would enable the amplifier and operate with no worries. Changing bands or making large frequency changes within a band required a trivial effort. And I never had an occurrence of either auto tuner trying to tune while operating at high power. It was a very pleasant experience indeed!

Summary

There are definite benefits to using a remote auto tuner with an untuned antenna. First, of course, is operating convenience. And second, the remote auto tuner will reduce SWR related coax losses. In the past, we have been limited to barefoot operation with the remote auto tuners available. Now, with the introduction of the MFJ-994BRT and MFJ-998RT high power remote auto tuners, we can realize these benefits when using a high power amplifier. The MFJ-994BRT works well with medium-power HF ampli-

Table 3
MFJ-998RT Resistive Load and Loss Testing

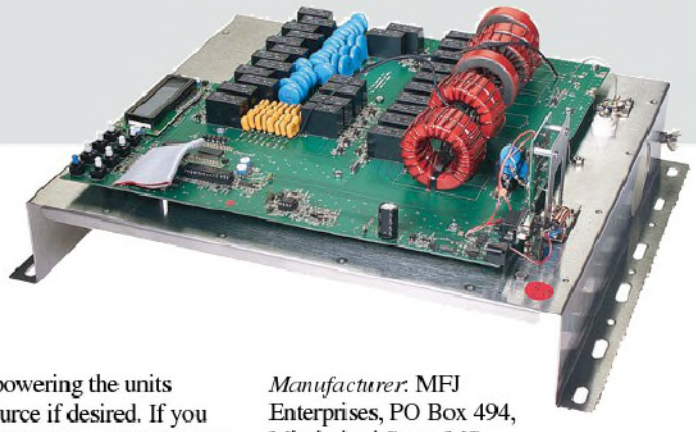
Manufacturer's Specifications

Matching range:	Up to 4:1 for <50 Ω, up to 32:1 for >50 Ω.
Minimum power for tuning:	5 W.
Maximum power for tuning:	20 W (100 W with foldback).
Target SWR:	1:1 to 2:1 selectable; 1.5:1 default.
Tuning threshold:	0.5 to 1.5 above target SWR, 0.5 default.

ARRL Lab Testing

SWR	Load (Ω)		160 m	80 m	40 m	20 m	10 m
4.3:1	11.5	Power Loss (%)	*	*	*	*	*
		SWR	**	1.8	1.6	1.7	1.6
2:1	25	Power Loss (%)	*	*	*	*	*
		SWR	**	1.6	**	**	1.9
1:1	50	Power Loss (%)	*	*	*	*	*
		SWR	**	**	**	**	**
2:1	100	Power Loss (%)	*	*	*	*	*
		SWR	1.9	1.8	**	1.6	2.0
4:1	200	Power Loss (%)	*	*	*	*	*
		SWR	1.7	**	2.0	1.6	1.6
7.6:1	380	Power Loss (%)	*	*	*	*	*
		SWR	**	**	1.6	**	**
16:1	800	Power Loss (%)	*	*	*	12	12
		SWR	1.6	**	1.6	1.6	1.6

*Power loss less than or equal to 10%.
**Matched SWR less than or equal to 1.5:1.
Measured current usage: 2.8 A peak during tuning, 277 mA idle.



fiers feeding less than perfect antenna systems. But if you are running more than 600 W or plan to do so in the future, the MFJ-998RT is the way to go.

Product Update

Since these review units were received, MFJ has improved the design by adding static and lightning protection to both the MFJ-994BRT and MFJ-998RT outputs, and an external dc jack for powering the units directly from a dc source if desired. If you have an early MFJ-994BRT or MFJ-998RT and wish these improvements, contact MFJ for pricing and availability of an upgrade kit.

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

Table 4
AD5X 43 Foot Vertical Testing

Band	Shack SWR untuned	Shack SWR with tuning MFJ-994BRT	Shack SWR with tuning MFJ-998RT
160	>20:1	NT	NT
80	11:1	1.53:1	1.12:1
60	2:1	1.38:1	1.14:1
40	3.8:1	1.21:1	1.32:1
30	6.7:1	1.47:1	1.61:1
20	5.4:1	1.59:1	1.55:1
17	2.5:1	1.39:1	1.42:1
15	4.3:1	1.35:1	1.64:1
12	3.1:1	1.32:1	1.35:1
10	2.3:1	1.06:1	1.27:1

NT = no tuning solution (as expected)

Click here to see a video overview of these MFJ automatic antenna tuners.