The Elecraft KAT500 Automatic Antenna Tuner
By Phil Salas – AD5X

Introduction

Unless you have an almost perfect antenna and feedline system you will need some sort of antenna tuner, especially if you have a solid-state amplifier. The autotuner will extend the "no-tune" capability of your station to many, if not all, HF ham bands. A recent entry into the high-power autotuner market is the Elecraft KAT500.

Figure 1: Front and Back views of the KAT500

KAT500 Overview

The KAT500 is a switchable-L autotuner that can match a large variety of loads. It completes the Elecraft K-Line as it currently exists, and is designed to interface seamlessly with the K3 transceiver and KPA500 amplifier. However, the KAT500 is also designed to interface with any transceiver and amplifier of 500-watts output power or more, depending on the matching range necessary. I.e., the KAT500 can handle higher RF power at loads that provide lower VSWR mismatches. Table 1 lists the KAT500 specifications.

Table 1: KAT500 Specifications

Frequency Range: 1.8 to 54 MHz, continuous.
Power Supply Req'd: 11 to 15 VDC at 1A max, 200 mA typical.
Matching Range & Power Limits (Power rating is ICAS):

3 - 30 MHz:	600W into 5 Ω to 500 Ω (10:1 VSWR). 1000W into 16 Ω to 150 Ω (3:1 VSWR).
1.8 - 2 MHz:	600W into 10 Ω to 500 Ω (5:1 Low Impedance, 10:1 High Impedance VSWR).
30 - 60 MHz:	500W into 5:1 VSWR (10 Ω to 250 Ω).

Note: Matching specified to a 1.0:1 to 1.6:1 SWR. Power rating is ICAS (Intermittent Commercial and Amateur Service: equal time on and off, 5 min., max. at full power.)

Auto-tune Power: 10W —100W. For best matching accuracy, tune with ≥20W.
Antenna Interfaces: Three, front panel and auto selectable.
Weight: 4.6 lbs (2.1 kg).

Size:	Enclosure only: 1.5 x 10.8 x 10.0 in. (3.8 x 27.4 x 25.4 cm). With projections (bottom feet and rear connectors): 1.75 x 10.8 x 11.8 in. (4.4 x 28.4 x 30.0 cm). Length and width dimensions are exactly the same as the K3 and KPA500. Designed to mount directly on top of, or under, the K3 or KPA500 if desired.

KAT500 Features

The KAT500 provides automatic or manual (user initiated) tuning. If you select AUTO, it will begin a tune whenever it senses a VSWR above the start-tuning 1.8:1 VSWR threshold (default). If you select MAN, tuning is initiated only when you press the TUNE button and apply approximately 20 watts of RF carrier. However, even in the manual mode, if the band/frequency/antenna has been previously memorized the KAT500 will automatically select this solution once the frequency is determined. You can also select BYP, which bypasses the tuner, if your antenna does not require tuning or if you want to see your untuned VSWR. Bypass is also as a tuning solution if it results in a VSWR of 1.2:1 or less (default). The KAT500 modes (AUTO, MAN and BYP) are not remembered on a per-band basis – i.e., if you select a specific mode, that will be the operation mode on all bands until you change it.

The KAT500 determines the band by reading K3 or Yaesu BCD (binary coded decimal) band data, so it will switch bands automatically with these transceivers when using the correct interface cable. The KAT500 also includes RF sensing for band switching so it can operate with any transceiver. Of course, RF sensing requires that you transmit a signal for band sensing, antenna switching, and memory recall to occur.

The KAT500 includes amplifier-keying pass-through connectors (RCA jacks). This permits the KAT500 to interrupt the amplifier key-line during a tune or sudden high SWR condition. The KAT500 utility lets you set a power level whereby the amp-key line will NOT open if RF is present to protect your transceiver, amplifier, and KAT500 from damage due to hot-switching.

The KAT500 includes a 3-port antenna switch. Each port includes a 1-meg ohm static-drain resistor and a 1KV gas discharge tube for secondary lightning and static protection (primary protection should always be provided by approved external methods). Feedlines connected to these ports can be memorized, along with tuning data, on a per-band basis.

The KAT500 is protected against high power under high VSWR conditions. The KAT500 analyzes the untuned VSWR, the tuned VSWR, and the incident power to determine if any internal components may be damaged. If there is a potential problem, the KAT500 will open the amp-key line and drop to bypass.

Finally, there are a number of software settings to consider. You can set the "start-tuning" VSWR threshold (default is 1.8:1), the power level above which the amp-key line will not be interrupted (default is 31 watts), bypass as a tunng solution (default is 1.2:1) and the VSWR above which the amp-key line will not be re-enabled after a tune (default is 2:1). You can also set preferred antenna ports per band. And your preferences can be

saved so they can be recalled at a later date should you lose or corrupt the KAT500's memory.

Building the KAT500

This KAT500 was a no-solder kit - like my previously built K3, KPA500, and KX3 kits. However, the KAT500 build is the simplest of all! The assembly process is so short that the full assembly manual is included within the user manual. I didn't bother with the first step – inventorying all parts. I decided that with so few parts, a good way to inventory them was just to build the tuner. This worked fine for me – all parts were there, and the spare-parts bag (supplied with all Elecraft kits) was not needed. Assembly consists of attaching RF connectors to the back panel, installing standoffs on the pc board and bottom cover, mounting the pc board to the bottom cover and back panel, and then attaching the front, top and side panels. Two hours will be about right for the average builder. Figure 2 shows the boxes as received (the USB cable is standard, but the 15-pin cable is optional). Figure 3 shows the KAT500 ready for the front, top and side panels.

Figure 2: KAT500 prior to unpacking. The 3-ft 15-pin cable is optional.

Figure 3: At 1.5 hours, ready for front, top and side panels.

Once the KAT500 is complete, download the KAT500 Utility from www.elecraft.com, and install the latest firmware.

The KAT500 on the bench

Bench tests were performed to assess the basic performance of the KAT500. These tests included resistive tuner matching, power loss measurements, open/short testing, and antenna port isolation.

Tuner Matching and Loss Measurements

Resistive matching range and loss testing was performed with the precision set-up described in the August QST, 2012 antenna tuner review, p. 47 (see the QST-in-depth section of that review for details). The test results are given in Table 2. Tuning power was set at 20 watts per Elecraft recommendations, though I found little difference when tuning at 10 watts. As my NIST-traceable test equipment is spec'd to +/-3% accuracy I didn't show measured losses below 3%, and measured losses above this are subject to the +/-3% accuracy.

Table 2: KAT500 Resistive load and loss testing

VSWR/Impedance		160m	80m	40m	20m	10m	6M
10:1/5Ω	Loss	7%	7%	7%	9%	11%	15%
	VSWR	2.8	1.15	1.15	1.57	1.52	1.34
8:1/6.25Ω	Loss	4%	4%	<3%	<3%	<3%	<3%
	VSWR	2.18	1.17	1.07	1.15	1.18	1.3
4:1/12.5Ω	Loss	<3%	<3%	<3%	<3%	<3%	3%
	VSWR	1.18	1.19	1.24	1.20	1.12	1.18
3:1/16.7Ω	Loss	<3%	<3%	<3%	<3%	<3%	4%
	VSWR	1.15	1.26	1.06	1.16	1.08	1.3
2:1/25Ω	Loss	<3%	<3%	<3%	<3%	4%	5%
	VSWR	1.14	1.12	1.21	1.04	1.19	1.43
1:1/50Ω Bypass	Insertion Loss	<3%	<3%	<3%	<3%	<3%	<3%
	Bypass VSWR	1.08	1.06	1.06	1.08	1.1	1.16
2:1/100Ω	Loss	4%	4%	4%	4%	4%	6%
	VSWR	1.1	1.16	1.24	1.12	1.18	1.7
3:1/150Ω	Loss	4%	4%	4%	5%	4%	<3%
	VSWR	1.16	1.06	1.16	1.11	1.51	1.31
4:1/200Ω	Loss	4%	4%	5%	5%	6%	4%
	VSWR	1.15	1.1	1.15	1.47	1.31	1.08
8:1/400Ω	Loss	6%	7%	6%	6%	8%	7%
	VSWR	1.19	1.16	1.06	1.27	1.19	1.03
10:1/500Ω	Loss	6%	6%	7%	7%	12%	19%
	VSWR	1.01	1.16	1.18	1.1	1.05	1.16

As you can see, the KAT500 achieved its 1.6:1 or better VSWR target except for low impedance 8:1 and 10:1 VSWR matching on 160 meters. And antenna tuner losses are also very reasonable, and are a bit lower than I've measured on other autotuners.

Open/Short Circuit Testing

Ideally a tuner should not be able to match an open or short. If it does, this means that it is tuning into its own internal losses. However, no antenna tuner is lossless due to finite-Q components. From past experience I've found that most wide-range antenna tuners – both manual and automatic – can find a match on one or more frequencies when connected to an open or a short. My data on the KAT500 is shown in Table 3.

Table 3: Open- and Short-Circuit testing of the KAT500

Band	Open	Short
160-17M	N	N
15M	1.25:1	N
12M	N	N
10M	N	1.45:1
6M	1.5:1	N

As Table 3 shows, the KAT500 tuner did achieve its target 1.6:1 or better VSWR match on some bands when presented with an open or short. There were some matches above a

2:1 VSWR, however a 2:1 VSWR or higher (default) opens the amp-key line. Of course, these results could change depending on the location of the open or short in your antenna system. With most antenna tuners, a successful open or short match could result in most or all of your transmit power being dissipated within the tuner - which could damage the tuner especially under high power conditions. This is NOT the case with the KAT500. As discussed earlier, the KAT500 firmware analyzes the bypassed and tuned VSWR along with transmit power and opens the amp-key line and bypasses itself under these extreme conditions.

Antenna Port Isolation tests

Since the KAT500 includes a 3-port antenna switch, I measured the non-selected-to-selected port isolation with an Array Solutions VNAuhf (which I had on-hand for a QST review). For this test I selected Port 1, terminated Port 1 in 50 ohms, and then measured the isolation from Port 2 and Port 3 to the transceiver port. I repeated this test for selected Ports 2 and 3 as well. Table 4 tabulates the results.

Table 4: Antenna Port to Transmitter Port Isolation (dB)

	Port 1 Selected		Port 2 Selected		Port 3 Selected	
Band	Port 2-1	Port 3-1	Port 1-2	Port 3-2	Port 1-3	Port 2-3
20M	43dB	65dB	38dB	41dB	37dB	36dB
10M	39dB	62dB	33dB	36dB	33dB	32dB
6M	35dB	58dB	29dB	30dB	28dB	26dB

So what does this data show? Assume you have a 20 meter antenna selected on Port 3. Any 20 meter signals on antenna 1 will show up 37dB down from your port 3 signal, and 20 meter signals on antenna 2 will show up 36dB down (about six S-units in both cases). Of course, if the unselected antenna is not optimized for the same band as the selected antenna, the isolation from common signals will be greater. So the KAT500 antenna switch will be adequate for many installations. The interesting measurement was the Port 3-1 isolation, as it was very different from the Port 1-3 isolation. I would expect these measurements to be closer together, as we see in the other ports.

KAT500 On The Air

Because I have an Elecraft K-line station I used properly-built interface cables between the K3, KAT500 and KPA500. The use of these cables permits automatic band changing and antenna selection within the KAT500 and KPA500 when changing bands with the K3. Elecraft sells an optional three-foot cable for K-line interfacing. For different cable length requirements or non-Elecraft interfacing you can buy or build your own cables. The KAT500 manual gives the necessary cable details. It is important to note that regular SVGA cables CANNOT be used, as many have some of the conductors shorted to each other, shorted to ground, or missing – and some connections must be interrupted for proper operation. I purchased and modified 1- and 6-foot DB15HD M/F extension cables from www.cablewholesale.com (10H1-20201NF and 10H1-01106 respectively) as my K3 is placed directly on top of the KAT500, and my KPA500 amplifier is located off to the side (see Figure 4).


Figure 4: AD5X Station Set-up

My antenna system consists of three antennas: A 43-foot vertical, a 20/15/10/6 meter rotatable dipole, and a 4-element 6-meter beam – perfect for the KAT500 three antenna ports. I put the 43-foot vertical on Port 1, and the rotatable dipole on Port 3 so I could take advantage of the greater isolation between the two ports when Port 1 is selected. The rotary dipole and 6-meter beam didn't need tuning, as they are both resonant in the CW portions of the bands where I normally use them. Table 5 shows the 43-foot vertical in-shack un-tuned and tuned VSWR as measured by my Array Solutions PowerMaster.

Table 5: 43-foot vertical testing

Band	Shack VSWR no tuning	KAT500 Tuned Shack VSWR
160M	*1.4:1	1.1:1
80M	*1.8:1	1.1:1
60M	3.7:1	1.1:1
40M	2.1:1	1:1
30M	2.7:1	1.15:1
20M	3.6:1	1:18
17M	2.3:1	1.2:1
15M	1.6:1	1.1:1
12M	2.2:1	1.3:1
10M	1.9:1	1:1

*The 43-foot vertical has the remote 160/80 meter matching as described in my January 2010 QST article, page 34.

First I set-up the desired antenna ports for each band. The KAT500 defaults to "all antennas enabled" with the "last used" antenna preferred. However, I wanted to refine this further – which is an easy task with the KAT500 Utility. I wanted the 43-foot vertical available for 160-10 meters, the rotatable dipole for 20/15/10/6 meters, and the 6-meter beam for 6 meters only. Figure 5 shows the KAT500 Utility "Antennas"

configuration page. On that screen, I selected Ports 1 and 3 for 20 meters – the 43-foot vertical and rotary dipole. And I specified that the last antenna used would be the preferred antenna whenever I returned to that band. By checking the different bands, you can make the appropriate antenna selection for that band.

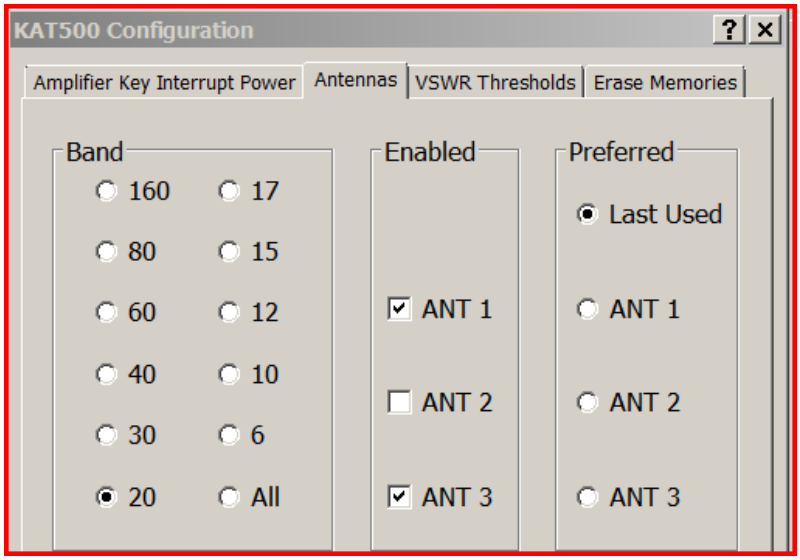

Figure 5: Antennas selected for 20 meters

Next I memorized tuning for the appropriate antennas on all bands. You can see your tuning solutions on the KAT500 operation page. Figure 6 is an example of my 43-foot vertical 20 meter solution.

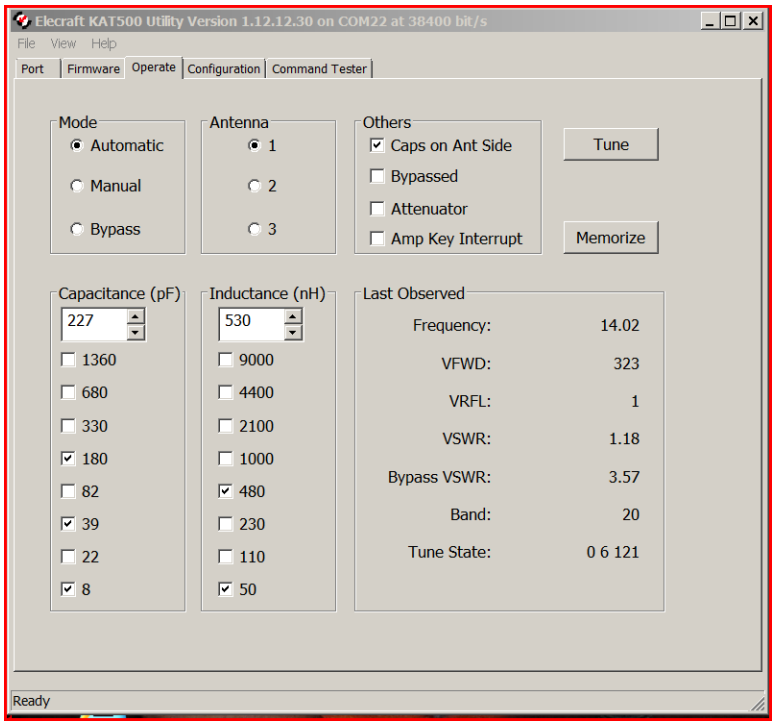

Figure 6: KAT500 tuning solution, 43-foot vertical on 20 meters

Once everything is set-up, operation is a breeze. I literally don't have to think when changing bands between 60- and 6-meters, as the KAT500 picks the right antenna and tuning solution as it follows my K3. I do have to manually enable the 160- or 80-meter remote match for my 43-foot vertical – but then the KAT500 selects the final match based on the band data input. A very pleasant experience indeed! So now I leave my KPA500 amplifier set to stay in OPERATE when I change bands for 40-6 meters. I do have the amplifier drop to STANDBY on 160- and 80-meters in case I forget to set my 43-foot vertical remote matching switch.

Operation will be just as seamless with Yaesu transceivers as they have the same band data interface. There is an ICOM interface whereby KAT500 tuning and low-power transceiver output occurs automatically when you push the ICOM TUNE button (I'm looking forward to when this is implemented in the K-Line). With other transceivers, a short RF signal results in the appropriate band, antenna and tuning memory selection.

Summary

There are definite benefits in using an auto-tuner, primarily because it extends your no-tune operating range on many, if not most, bands. The KAT500 provides this capability for any transceiver and/or medium-to-high power HF amplifiers feeding less than perfect antenna systems.

Manufacturer: Elecraft, PO Box 69, Aptos, CA 95001-0069; tel 831-763-4211; fax 831-763-4218; www.elecraft.com.
List Prices: KAT500-F $699.95. KAT500-K $649.95. E850463 Optional 3-foot KAT500-to-KPA500 or K3 Cable $24.95.