The Elecraft KAT500 and KXAT100 Tuners

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Excerpted from

The Elecraft KPA500 Amplifier and KAT500 Tuner

and

The Elecraft KX3-Line: KX3, KXPA100, PX3 and KX3-2M

The KXAT100 and KAT500 autotuners are L-networks, where the C can be on the transmitter side (C – L) or on the antenna side (L – C).

1. Tuning Strategies

The tuners can achieve a very low VSWR over a wide range of tuning requirements by using two types of tuning strategies – *Memory Recall Tuning* and *Full Search Tuning*. The tuners' operating modes, auto and manual, use these strategies in different ways to provide tuning.

Memory Recall Tuning

When you have trained the tuner to achieve an acceptable match at an operating frequency, it stores the L and C values and the antenna being used in a memory segment to be recalled the next time that frequency is encountered. This allows the tuner to very quickly retune itself when you change bands or change frequencies within a band without going through a lengthy tuning cycle. Section 4 describes a process you can use to "train" your tuner for all your favorite operating frequencies. Subsequently, when a transmit frequency is known, it is converted to a segment number in the present band that is used to look up L–C settings stored for that segment. A *Memory Recall Tune* is very fast.

Here is a summary of the *Memory Recall Tuning* process:

- When a band change (QSY to a new band) is detected based on band data sent by the K3 or KX3 or by a frequency measurement:
  - The amplifier keying line is always interrupted. If for some reason it cannot be interrupted, a band change is not made.
  - The tuner restores the L and C values and the antenna last used on this band.
  - The keying line is restored.
- When a frequency change (QSY in band) is detected based on data from the K3, KX3 or a frequency measurement, the tuner recovers the L and C values and the antenna last used on this frequency.
  - If the L and C values and antenna are different than the current values, the amplifier keying line is interrupted and the new L-C values and antenna are switched in.
  - The keying line is restored.

Full Search Tuning

When RF is present, the frequency and VSWR are measured at intervals using RF sensing (this takes a few milliseconds). A *Full Search Tuning* cycle can be started by the tuner when it is operating in AUTO mode, RF is present, and the VSWR exceeds a dangerous threshold. It can be instigated also by tapping the tuner's TUNE switch and applying RF. The *Full Search Tuning* procedure can be summarized by the following:

- The amplifier keying line is always interrupted.
- The tuner bypasses the L–C network and measures the bypass VSWR.
  - If the VSWR is below an acceptable low level so that the tuner doesn't need to be in the circuit, the L–C network is bypassed and keying is re-enabled.
- If the VSWR is above a dangerous threshold, a *Memory Recall Tune* is done and VSWR is checked again.
- If the VSWR is still above the threshold, the *Full Search Tuning* proceeds:
  - The tuner steps through L–C values to reduce VSWR to the best value it can find below the dangerous threshold.
  - If successful,
    - The L–C values and antenna are stored in the memory segment associated with this frequency.
    - The keying line is closed and full-power operation continues.
  - If not successful,
    - The keying line remains open and a SWR fault LED is turned on.

The total time taken for a *Full Search Tune* is variable and depends on the VSWR the tuner is trying to correct.

Signal Requirements for *Full Search Tuning*: The VSWR measurement algorithm used in the KAT500 tuner calculates the forward and reverse voltages at slightly separated times. In the KXPA100, while forward and reverse voltages are captured simultaneously, VSWR measurements made at low power are apt to be different than those made at high power due to circuit non-linearities. To be able to calculate VSWR accurately, a steady RF signal is required. An ATU tune signal is ideal. It is a particularly difficult challenge to calculate VSWR with a SSB waveform. SSB operators should use a constant signal when tuning rather than the HHHEELLLLOOO we often hear on the bands.

2. Manually Activating the Tuner

You can instigate a *Full Search Tune* to find the L–C combination needed for your present frequency and antenna by tapping the tuner's TUNE switch and applying RF from your transceiver. For the case of the KAT500, 20 watts is preferred and for the KXAT100, 5 watts.

When RF is applied you will hear relays clicking. If an acceptable VSWR is found, the final value is displayed briefly the tuner's SWR LEDs.

3. Auto Tuner Operation Modes

The tuners have three operating modes – bypass, automatic tuning, and manual tuning. You choose either of these modes by tapping the MODE switch on the tuner's front panel. Although the AUTO mode seems like it would be the best mode to use, the MAN mode is better, as we shall describe below.

In each of the tuner operating modes there are two tuning strategies as described in Section 1. These are (1) *Memory Recall Tuning*, where the tuner briefly opens the keying line and retrieves from memory previously stored L—C values appropriate for the current antenna and frequency, and (2) *Full Search Tuning* where the tuner opens the keying line for a time long enough to try different L—C combinations to correct the VSWR.

Automatic Tuning Mode

In the automatic tuning mode the tuner continuously monitors the transmitted frequency, calculates the VSWR, and then performs the following:

- If the antenna has been changed by tapping the ANT switch,
    - The tuner does a *Memory Recall Tune*.
- If the frequency has changed to a new band (QSY to a new band),
    - The tuner does a *Memory Recall Tune* for the last used frequency in that band.
- If the frequency has changed in the same band (QSY in-band),
    - The tuner does a *Memory Recall Tune*.
- If the *Memory Recall Tunes* do not reduce the VSWR to less than a threshold level above which may be harmful,
    - The tuner does a *Full Search Tune*.

The tuner can perform *Memory Recall Tunes* followed by a *Full Search Tune* when the band, frequency, and/or antenna changes in AUTO mode.

If it detects a high VSWR after a *Full Search Tune*, the keying line is opened and an SWR Fault is displayed until the VSWR is corrected. The keying line will not be closed until the fault is corrected and RF transmissions stop.

VSWR-initiated tuning *Full Search Tuning* occurs **only** in the AUTO mode.

If you have trained your tuner as shown in Section 4, you should NOT leave the tuner in AUTO mode unless it is remotely located where you cannot easily tap the TUNE button.

Manual Tuning Mode

If you select the manual tuning mode the tuner will NOT enter a *Full Search Tuning* cycle if it detects a high VSWR, which it does in AUTO mode. Naming this the "manual" tuning mode is somewhat misleading. The tuner in fact does automatically do a tune by recovering pre-determined L—C values when needed. It does not automatically do the *Full Search Tune* described above.

In manual mode the tuner continuously performs the following actions:

- If the antenna has been changed by tapping the ANT switch,
    - The tuner does a *Memory Recall Tune*.
- If the frequency has changed to a new band (QSY to a new band),
    - The tuner does a *Memory Recall Tune*.
- If the frequency has changed in the same band (QSY in-band),
    - The tuner does a *Memory Recall Tune*.
- When RF is present the tuner continuously monitors the transmitted RF and calculates the VSWR. If the *Memory Recall Tunes* do not reduce the VSWR to less than the damaging threshold,
    - The tuner does NOT do a *Full Search Tune* like it does in AUTO mode.
    - The keying line remains open and an SWR fault is indicated.

The tuner can perform *Memory Recall Tunes* when the band, frequency and/or antenna changes in MAN mode.

In MAN mode the ATU does not change tuner settings based on VSWR, and the ATU does not perform *Full Search* tunes unless you press the TUNE button.

Bypass Mode

Switching to bypass mode allows RF to bypass, or go around, the tuner's L–C network. The VSWR metering circuits are still active, which allows you to display the antenna feedline's VSWR. The antenna switch is changed to the last-used antenna upon band changes.

Table 3-1. Tuning modes.

Mode	Tuning Strategy
Bypass	None; if high VSWR found, the keying line is NOT interrupted.
Manual	Memory Recall Tune; if high VSWR found, the keying line is interrupted until the VSWR is corrected.
Automatic	Memory Recall Tune; if high VSWR found, the keying line is interrupted and a Full Search Tune is activated; if VSWR can be corrected, the keying line is restored.

Which Mode Should I Choose?

Even though the *Full Search Tuning* feature of the automatic mode sounds ideal, for normal operation you should chose the manual mode. Here is the reason for this choice.

The tuner continuously measures the RF and calculates the VSWR. Because of hardware limitations, instantaneous VSWR calculations may not be correct, either because there is a slight delay between the measurement of the forward and reverse voltages used to calculate VSWR, or, in a rapidly changing waveform such as SSB, measurements taken at low power and high power points in the waveform may be different. In automatic mode, the tuner could proceed to an unnecessary *Full Search Tune*, which is disturbing to the operator, to say the least.

In manual mode, if the incorrect VSWR is calculated, the tuner does not proceed to the *Full Search Tune*. To effectively use the manual mode, do the following:

- Initialize your tuner's memory segments for all frequencies in all bands (see Section 4).
- Choose the manual mode for normal operation.

This strategy is a good idea. If a momentary "bad" VSWR is calculated, the tuner takes no action because tuner settings are changed only if the frequency changes, not if there is high VSWR. If a serious antenna problem occurs with sustained high VSWR, such as the wrong antenna selected on a remote switch or your antenna falls down, the tuner holds the keying line open and illuminates the SWR fault LED. You can then take correction action manually, determining first if the wrong antenna is selected or if there has been an antenna failure.

How Does the Tuner Know What Frequency I am On?

When you change bands the K3 sends that information to the KAT500 (K3 *CONFIG:KAT3* tap $\boxed{1}$ for *KAT500Y*). The KX3 also sends that information to the KXPA100. The tuner then retrieves the last used L--C tuner values from the tuner memory. As you change frequency on this new band, the VFO frequency is sent to the tuners. This is done even when receiving so that the tuner can do a *Memory Recall Tune* to be ready when you transmit. Additionally, the tuners continually measure the frequency when RF is present as a safety measure.

4. Initializing Tuner Memories

The KXAT100 and KAT500 tuners have memories that store L–C tuner values for each antenna and each memory segment in the frequency bands shown in Table 4-1. When the tuner has detected the operating frequency and achieved an appropriate VSWR through tuning, it stores the L and C values and the antenna being used to be recalled the next time that frequency and that antenna is encountered. This allows the tuner to very quickly retune itself – without going through a lengthy retuning cycle – when you change bands or change frequencies within a band. When you are next on that frequency the stored L–C settings are looked up and compared with the currently used values. If L–C settings need to be changed, they will be, typically in less than 50 ms.

Table 4-1 shows the memory segments used for each of the frequency bands from 1.8 to 60 MHz. The memory segments are smaller for the lower frequency bands because antennas for these bands are more sharply resonant and need to have the tuning changed in narrower segments.

Table 4-1. KXAT100 frequency memory segments.

Frequency Band	Memory Segment Width
Below 3 MHz	10 kHz
3 MHz – 26 MHz	20 kHz
26 MHz – 38 MHz	100 kHz
38 MHz – 60 MHz	200 kHz

Use the manual tuning procedure described in Section 2 to program the L–C memories.

> Hint: When training your tuner for various operating frequencies, it is useful and instructive to monitor the tuner's operation with the KXPA100 or KAT500 Utility *Operate* screen.

Tuner operation is automatic after you have initially set it up this way. The tuner determines what L–C values and antenna are needed for your operating frequency. If they are different than what is currently selected, the tuner opens (interrupts) the key line and then chooses the antenna and changes the L and C values to the values stored in the frequency segment. It then allows the tuner to be keyed. This is a Memory Recall Tune described in Section 4.

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