

AT-897

Automatic Antenna Tuner

Manual

Version 1.0G



LDG Electronics

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LDG AT-897 Automatic Antenna Tuner for the FT-897

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Introduction

Congratulations on selecting the LDG AT-897 tuner. The AT-897 is designed to work as an integrated component of your Yaesu FT-897 transceiver. It will tune dipoles, verticals, Yagis or virtually any coax-fed (unbalanced) antenna. It will match an amazing range of antennas and impedances, far greater than some other tuners you may have considered. Also, it consumes very little power while tuning and zero power otherwise, which makes it ideal for battery-powered operations.

LDG pioneered the automatic, wide-range switched-L tuner in 1995. From its laboratories in St. Leonard, Maryland, LDG continues to define the state-of-the-art in this field with innovative automatic tuners for every amateur need.

Jumpstart, or “Real hams don’t read manuals!”

Ok, but at least read this one section before you transmit:

- 1. Connect the CAT/Linear jack on your FT-897 transceiver to the CAT In jack on your AT-897 tuner using the provided cable.**
- 2. Connect the HF/50 MHz jack on your FT-897 transceiver to the Radio jack on your AT-897 tuner using an RG-8X coaxial cable jumper (not included).**
- 3. Connect your antenna coax lead to the Antenna jack on the back of your AT-897.**
- 4. Power up your FT-897 and select the desired operating frequency.**
- 5. Select AM, FM, CW or PKT mode, then key down to transmit a carrier**
- 6. Press the Tune button on the front panel of your AT-897 tuner until the red LED comes on, then immediately release.**
- 7. Wait for the tuning cycle to end (red LED goes off), then unkey.**
- 8. Reset your FT-897 transceiver to your desired operating mode.**
- 9. You’re ready to transmit**

Features

- ?? Automatically matches antennas from 6 – 800 ohms impedance, or a 10:1 SWR
- ?? Very low current consumption: 300 mA during turning, less than one microamp in standby, or can be turned off completely. No cooling fan needed! Your AT-897 is ideal for battery powered operations.
- ?? Uses latching relays, to retain tuned setting indefinitely even when power is completely removed
- ?? Powered by the FT-897 through the CAT cable (provided); no external power source required
- ?? CAT port access provided
- ?? Tunes in less than 8 seconds, usually around 4 seconds

Specifications

- ?? Microprocessor controlled, switched L tuning network
- ?? Antenna impedance: 6 to 800 Ohms (Approximately up to 10:1 SWR)
- ?? Continuous coverage 1.8 to 54 MHz
- ?? Latching Relays hold tuned setting indefinitely, even when power is removed
- ?? Tunes nearly any coax fed or unbalanced input antenna. Use optional Balun for long wires or balanced input antennas
- ?? Mounts directly on the side of the Yaesu FT-897, provides side feet attachment
- ?? Dual function tune control button – Tune or Bypass
- ?? Power rating HF: 0.1 to 100 Watts
- ?? Provides CAT port access
- ?? Tuning time: 1 to 8 seconds, 4 average
- ?? Compatible with the W4RT Electronics One-Touch-Tune Interface (see <http://www.w4rt.com>)
- ?? Power requirements: 10 to 15 volts DC @ 300 mA during tune
- ?? Operating voltage supplied via the FT-897 CAT/Linear Port (cable supplied with tuner)
- ?? Enclosure sizes: 11.5” x 3.25” x 1.5”
- ?? Weight: 2 pounds

Getting to know your AT-897

Your AT-897 is a quality, precision instrument that will give you many years of outstanding service; take a few minutes to get to know it.

The four side feet from your AT-897 fit on the tuner so you can set it down on its side without danger of scratching the finish. While your AT-897 is intended to be integrated with your FT-897 transceiver, you can use the tuner simply sitting on a table, not mounted on the FT-897 transceiver.

Your AT-897 is designed specifically for use with the FT-897 transceiver, and is customized to its power levels. However, your AT-897 can be used with a wide variety of transmitters and transceivers. If you use it with a different radio, be sure to observe the power limits listed in the specifications. Power levels significantly above specifications will definitely damage or destroy your AT-897 tuner.

There is only one front panel control: the Tune button. This button begins a tuning cycle, and also can place the tuner in “bypass” mode; see operating instructions. A front panel LED indicates tuner activity.



On the back panel, there are five connectors:

- ?? RF in (marked “Radio”, standard SO-239 socket)
- ?? RF out (marked “Antenna”, standard SO-239 socket)
- ?? CAT In: accepts cable from FT-897 CAT socket (cable provided)
- ?? CAT Out: provides CAT connection for external functions
- ?? OTT: connection for W4RT Electronics “One-Touch Tune” module



Installation

Installation will vary with and without the W4RT Electronics “One-Touch Tuning” module. Your AT-897 tuner is intended for indoor use; it is not water resistant. If you use it outdoors (Field Day, for example) you must protect it from rain and excessive moisture.

Mounting your AT-897 tuner

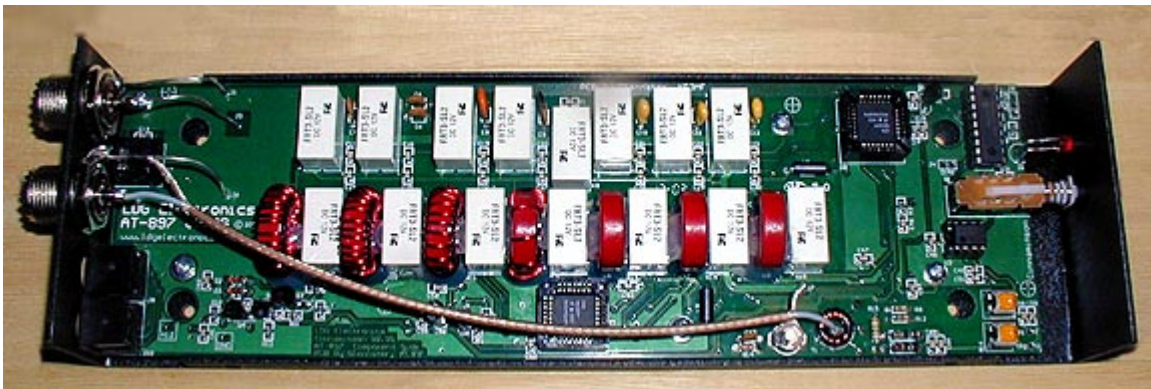
Your AT-897 tuner is designed to be integrated with your FT-897 transceiver by mounting it on the left side of the transceiver. You don't have to mount it; it will work fine just sitting on the table next to the radio. However, you'll be missing out on one of the key features of your AT-897. No modifications to your FT-897 transceiver are required; you don't even have to open the transceiver's case.

To mount your AT-897 you will need a small Phillips (cross point) screwdriver. Mounting will go much smoother if the screwdriver is magnetized. If your screwdriver is not magnetized, you will need tweezers. Be sure to control static discharge. A grounded static mat is best, but at least touch a ground point like a light switch before beginning and periodically during installation to control static buildup.

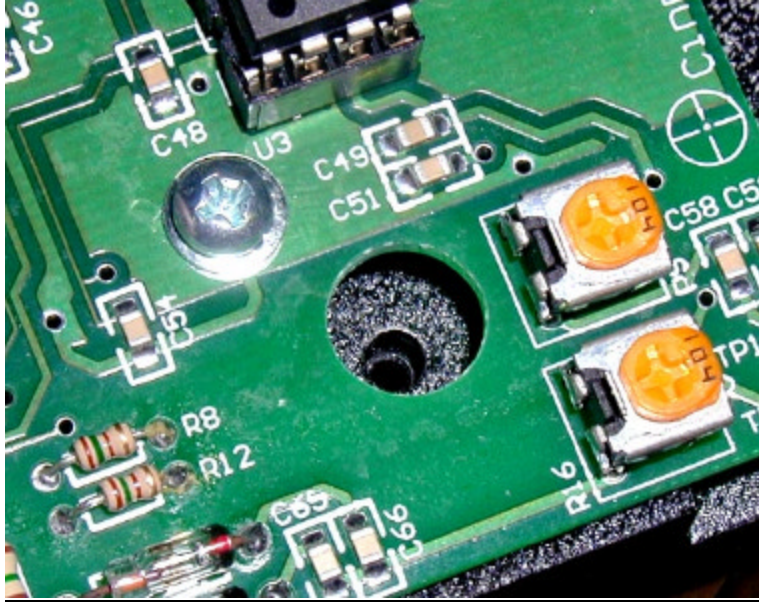
Follow these simple steps to mount your AT-897 tuner:

1. Disconnect all cables from the tuner, and disconnect your FT-897 transceiver from its external power supply, including the internal batteries if installed.
2. Remove the four plastic feet on the left side of your FT-897 transceiver (as you look at it from the front). Carefully set them aside; you'll reinstall them in a few minutes.
3. Remove the cover of your AT-897 tuner by removing the four flat-head screws on the top and bottom right of the tuner (as you look at it from the front). Again, set these aside for later re-installation. Carefully lift the cover clear. The AT-897 circuitry will be fully exposed throughout the mounting procedure; take care not to damage it.
4. Position the tuner over the holes you opened in the side of the transceiver when you removed the side feet. The end of the tuner with coax connectors goes toward the back of the transceiver. Line up these holes with the four mounting holes in the tuner. Locate the four mounting screws provided with the AT-897. The tuner mounting holes are recessed beneath the PC board under four round holes; this is why you need a magnetized screwdriver or tweezers. Using your magnetized screwdriver or tweezers, place the four provided mounting screws into the mounting holes and gently tighten them; do not overtighten.
5. Place the tuner cover back in position and secure by replacing the four flat-head screws you removed earlier.
6. Screw the four plastic feet you removed from the radio into the four holes on the left side of the tuner (as viewed from the front).

That's it! You're ready to install the connection cables between the tuner and the transceiver, and the power supply (or batteries).



Interior of AT-897 tuner



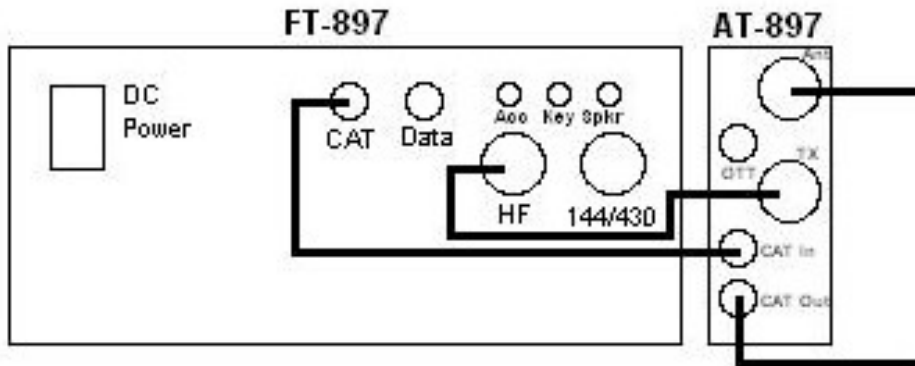
Recessed mounting hole

Standard Connections

Connect the CAT port on your FT-897 transceiver to the CAT In port on the back of your AT-897 tuner with the cable provided. The CAT Out port on the back of your AT-897 provides pass-through of all CAT functions for connection to external systems. Connect any external CAT systems to the CAT Out jack on the back of the tuner. If you don't use external CAT systems, just leave this jack empty.

Connect the HF/50 MHz antenna jack on your FT-897 transceiver to the Radio jack on the back of our AT-897 tuner using an RG-8X jumper (user supplied) with standard PL-259 plugs. Properly soldered connectors will be far more satisfactory and reliable than crimp-on or "solderless" connectors. Attach your antenna lead-in coax to the Antenna jack on the back of your AT-897 tuner.

Your AT-897 tuner is now ready to use!



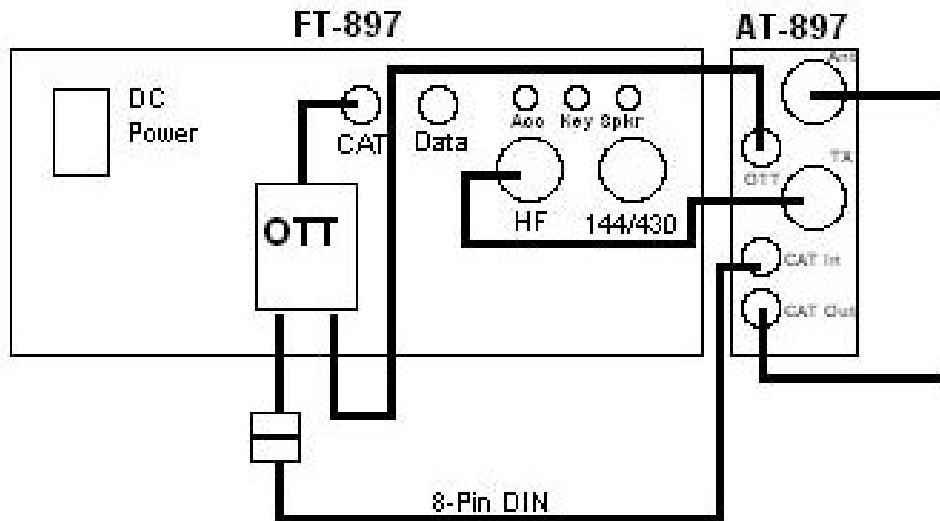
Connections with W4RT Electronics OTT-897 module

Connect the OTT module CAT input to the CAT/Linear jack on the back of your FT-897 transceiver as usual. Connect the OTT-897 line to the OTT jack on the back of your AT-897 tuner using the provided cable with the OTT-897. Using the provided DIN cable, connect the CAT output line of the OTT module to the CAT In jack on the back of your AT-897 tuner. Connect any external CAT systems to the CAT Out jack on the back of the tuner. If you don't use external CAT systems, just leave this jack empty.

Connect the HF/50 antenna jack on your FT-897 transceiver to the Radio jack on the back of our AT-897 tuner using an RG-8X jumper with standard PL-259 plugs (not provided). Properly soldered connectors will be far more satisfactory and reliable than crimp-on or "solderless" connectors. Attach your antenna lead-in coax to the Ant jack on the back of your AT-897 tuner.

You may want to use cable ties to neaten up the installation.

Your AT-897 tuner is now ready to use!



Operating Instructions

Operation couldn't be simpler:

Normal operation

Set your FT-897 transceiver to AM, FM, CW or Packet mode. Press and hold the PTT switch on the microphone (close key on CW) to transmit a carrier. While transmitting a carrier, press the Tune button on the front of your AT-897 tuner until the red LED on the tuner front panel lights (usually about a half second), then immediately release. An automatic tuning cycle will begin. You will hear the relays in your AT-897 as they switch in and out seeking a match; they make a buzzing noise. The tuning cycle will end in a few seconds (LED goes off); unkey your FT-897 transceiver ? you're ready to operate.

Operation with W4RT Electronics OTT-897 module

Simply press the tune button on your AT-897 tuner until the red LED lights, then immediately release. The radio will automatically switch to Packet mode, transmit a carrier and start an automatic tuning cycle. When the cycle ends, the radio will automatically unkey and revert to its previous mode.

Sleep mode

When the tuning cycle ends, the tuner automatically enters a "sleep" state in which it draws less than one microamp of current. The latching relays will hold the tuned configuration indefinitely, even if you remove power by unplugging the CAT cable. The tuner will automatically "wake up" the next time you start a tuning cycle.

Bypass mode

To place your AT-897 in bypass mode, press the Tune button on the front of the AT-897 tuner and quickly release before the red LED comes on (less than a half-second). The tuner will switch to bypass; RF from your FT-897 transceiver will go directly to the antenna with no matching.

A word about tuning etiquette

Be sure to pick a vacant frequency to tune. With today's crowded ham bands, this is often difficult. However, do your best to avoid interfering with other hams as you tune. Your AT-897's very short tuning cycle, usually only a few seconds or so, minimizes the impact of your tuning transmissions.

Theory of Operation

Some basic ideas about impedance

The theory underlying antennas and transmission lines is fairly complex, and in fact employs a mathematical notation called “complex numbers” that have “real” and “imaginary” parts¹. It is beyond the scope of this manual to present a tutorial on this subject, but a little background will help you understand what your AT-897 is doing, and how it does it.

In simple DC circuits, the wire resists the current flow, converting some of it into heat. The relationship between voltage, current and resistance is described by the elegant and well-known “Ohm’s Law”, named for Sir George Simon Ohm of England, who first described it in 1826. In RF circuits, an analogous but far more complicated relationship exists.

RF circuits also resist the flow of electricity. However, the presence of capacitive and inductive elements cause the voltage in the circuit to lead or lag the current, respectively. In RF circuits this resistance to the flow of electricity is called “impedance”, and can include all three elements: resistive, capacitive, and inductive.



The output circuit of your transmitter consists of inductors and capacitors, usually in a series/parallel configuration called a “pi network”. The transmission line can be thought of as a long string of capacitors and inductors in series/parallel, and the antenna is a kind of resonant circuit. At any given RF frequency, each of these can exhibit resistance, and impedance in the form of capacitive or inductive “reactance”.

Transmitters, transmission lines, antennas and impedance

The output circuit of your transmitter, the transmission line, and the antenna all have a characteristic impedance. For reasons too complicated to go into here, the standard impedance is about 50 ohms resistive, with zero capacitive and inductive components. When all three parts of the system have the same impedance, the system is said to be “matched”, and maximum transfer of power from the transmitter to the antenna occurs. While the transmitter output circuit and transmission line are of fixed, carefully designed impedance, the antenna presents a 50 ohm, non-reactive load only at its natural resonant frequencies. At other frequencies, it will exhibit capacitive or inductive reactance, causing it to have impedance different from 50 ohms.

When the impedance of the antenna is different from that of the transmitter and transmission line, a “mismatch” is said to exist. In this case, some of the RF energy from the transmitter is reflected from the antenna back down the transmission line, and into the transmitter. If this reflected energy is strong enough it can damage the transmitter’s output circuits.

The ratio of transmitted to reflected energy is called the “standing wave ratio”, or SWR. An SWR of 1 (sometimes written 1:1) indicates a perfect match. As more energy is reflected, the SWR rises to 2, 3 or higher. As a general rule, modern solid state transmitters must operate with an SWR of 3 or less. Tube exciters are more tolerant of high SWR. If your 50 ohm antenna is resonant at your operating frequency, it will show an SWR of 1. However, this is usually not the case; operators often need to transmit at frequencies other than resonance, resulting in a reactive antenna and a higher SWR.

¹ For a very complete treatment of this subject, see any edition of the ARRL Radio Amateur’s Handbook

$$SWR = \frac{1 + \sqrt{R/F}}{1 - \sqrt{R/F}} \quad \text{where } F = \text{Forward power (watts)}, R = \text{Reflected power (watts)}$$

SWR is measured using a device called an “SWR bridge”, inserted in the transmission line between the transmitter and antenna. This circuit measures forward and reverse power from which SWR may be calculated (some meters calculate SWR for you). More advanced units can measure forward and reverse power simultaneously, and show these values and SWR at the same time.

An antenna tuner is a device used to cancel out the effects of antenna reactance. Tuners add capacitance to cancel out inductive reactance in the antenna, and vice versa. Simple tuners use variable capacitors and inductors. The operator adjusts them by hand while observing reflected power on the SWR meter until a minimum SWR is reached. Your LDG AT-897 automates this process.

No tuner will fix a bad antenna. If your antenna is far from resonance, the inefficiencies inherent in such operation are inescapable; it's simple physics. Much of your transmitted power may be dissipated as heat in the tuner, never reaching the antenna at all. A tuner simply “fools” your transmitter into behaving as though the antenna were resonant, avoiding any damage that might otherwise be caused by high reflected power. Your antenna should always be as close to resonance as practical; this is especially important for low-power operation.

		Forward Power (Watts)								
		20	30	40	50	60	70	80	90	100
Reflected Power (Watts)	2	1.92	1.70	1.58	1.50	1.45	1.41	1.38	1.35	1.33
	4	2.62	2.15	1.92	1.79	1.70	1.63	1.58	1.53	1.50
	6	3.42	2.62	2.26	2.06	1.92	1.83	1.75	1.70	1.65
	8	4.44	3.14	2.62	2.33	2.15	2.02	1.92	1.85	1.79
	10	5.83	3.73	3.00	2.62	2.38	2.22	2.09	2.00	1.92
	12	7.87	4.44	3.42	2.92	2.62	2.41	2.26	2.15	2.06
	14	11.24	5.31	3.90	3.25	2.87	2.62	2.44	2.30	2.20
	16	17.94	6.42	4.44	3.60	3.14	2.83	2.62	2.46	2.33
	18	37.97	7.87	5.08	4.00	3.42	3.06	2.80	2.62	2.47
	20	-	9.90	5.83	4.44	3.73	3.30	3.00	2.78	2.62
	22	-	12.92	6.74	4.94	4.07	3.55	3.21	2.96	2.77
	24	-	17.94	7.87	5.51	4.44	3.83	3.42	3.14	2.92
	26	-	27.96	9.32	6.17	4.85	4.12	3.65	3.32	3.08
	28	-	57.98	11.24	6.95	5.31	4.44	3.90	3.52	3.25
	30	-	-	13.93	7.87	5.83	4.79	4.16	3.73	3.42
	32	-	-	17.94	9.00	6.42	5.18	4.44	3.95	3.60
	34	-	-	24.63	10.40	7.09	5.60	4.75	4.19	3.80
	36	-	-	37.97	12.20	7.87	6.07	5.08	4.44	4.00
	38	-	-	77.99	14.60	8.80	6.60	5.44	4.71	4.21
	40	-	-	-	17.94	9.90	7.19	5.83	5.00	4.44
42	-	-	-	22.96	11.24	7.87	6.26	5.31	4.68	
44	-	-	-	31.30	12.92	8.65	6.74	5.65	4.94	
46	-	-	-	47.98	15.08	9.56	7.27	6.02	5.22	
48	-	-	-	97.99	17.94	10.63	7.87	6.42	5.51	
50	-	-	-	-	21.95	11.92	8.55	6.85	5.83	

SWR Lookup Table

Find SWR at intersection of forward power column and reflected power row.

The LDG AT-897

In 1995 LDG pioneered a new type of automatic antenna tuner. The LDG design uses banks of fixed capacitors and inductors, switched in and out of the circuit by relays under microprocessor control. A built-in SWR sensor provides feedback; the microprocessor searches the capacitor and inductor banks, seeking the lowest possible SWR. The tuner is a “Switched L” network consisting of series inductors and parallel capacitors. LDG chose the L network for its minimum number of parts and its ability to tune unbalanced loads, such as coax-fed dipoles, verticals, Yagis; in fact, virtually any coax-fed antenna. The inductors are switched in and out of the circuit by relays controlled by the microprocessor. An additional relay switches between high and low impedance ranges.

The capacitors are connected to ground with the seven inductor relays. Another relay switches the entire capacitor bank to the input or output side of the inductor. This switching allows the AT-897 to automatically handle loads that are greater than 50 ohms (high setting) and less than 50 (low setting). All of the relays are DPDT types sized to handle up to 100 watts continuously.

The SWR sensor is a variation of the Bruene circuit. This SWR measuring technique is used in most dual-meter and direct-reading SWR meters. Slight modifications were made to the circuit to provide voltages (instead of currents) for the analog-to-digital converters (ADCs) that provide signals proportional to the forward and reverse power levels. The single-lead primary through the center of the sensor transformer provides RF current sampling. Diodes rectify the sample and provide a dc voltage proportional to RF power. Variable resistors calibrate the FORWARD and REVERSE power levels. Once adjusted, the forward and reverse power sensors produce a calibrated DC voltage proportional to the forward and reverse RF power levels. These two voltages are read by the ADCs in the microprocessor. Once in a digital format, they are used to calculate SWR in real time.

The relays operate from 12 volts DC supplied by your FT-897 transceiver via the CAT cable. The total current drawn by the AT-897 depends primarily on the number of energized relays, with the maximum current drain being approximately 300 mA, but only during the few seconds a tuning cycle is running. At all other times, the tuner is in a “sleep” mode drawing less than one microamp. The latching relays retain the tuned setting indefinitely, even when power is removed. The last tuned setting will still be set on the next power-up.

The microprocessor’s internal oscillator runs at 4 MHz. This means that one instruction cycle executes in 0.9 ms. The main tuning routine takes about 75 cycles to make a tuner adjustment and take a new SWR measurement, or 67.5 ms per tuner adjustment. If running at maximum speed, the microprocessor can try all inductor-capacitor combinations in just 8.8 seconds. Unfortunately, the mechanical relays can’t react as quickly as the microprocessor, and the tuning speed must be slowed down to compensate for relay settling time.

The tuning routine, written in a computer language, uses an algorithm to minimize the number of tuner adjustments. The routine first de-energizes the high/low impedance relay if necessary, and then individually steps through the inductors to find a coarse match. With the best inductor selected, the tuner then steps through the individual capacitors to find the best coarse match. If no match is found, the routine repeats the coarse tuning with the high/low impedance relay energized. The routine then fine tunes the capacitors and inductors. The program checks LC combination to see if a 1.5 or lower SWR can be obtained, and stops when it finds a good match.

The microprocessor runs a fine tune routine just after the tuner finds a match at an SWR of 1.5 or less. This routine tries to get the SWR as low as possible (not just 1.5); it takes about a half second to run. There is also a quick tune mode. If the SWR is below 2.0 when you press the tune button to start a tuning cycle, the tuner will first run the fine tune routine to see if it can achieve a low SWR without a complete re-tune. This also takes about a half second to run. If it does not find a good match, then it runs the main tuning routine.

Care and Maintenance

Your AT-897 tuner is essentially maintenance-free; just be sure to observe the power limits discussed in this manual. The outer case may be cleaned as needed with a soft cloth slightly dampened in household cleaning solution. As with any modern electronic device, your AT-897 can be damaged by temperature extremes, water, impact or static discharge. LDG strongly recommends that you use a good quality, properly installed lightning arrestor in the antenna lead.

Technical Support

We are happy to help you with your AT-897. Telephone technical support is available at 410-586-2177 weekdays from 9 am to 5pm Eastern Time. Inquiries by Fax at 410-586-8475 are welcome, and prompt e-mail support is available at ldg@ldgelectronics.com.

Warranty and Service

Your AT-897 is warranted against defects in parts or workmanship for one year from purchase. The warranty does not cover damage due to abuse or exceeding specifications. This warranty applies to the original purchaser only; it is not transferable. A copy of the receipt showing the purchaser's name and the date of purchase must accompany units returned for warranty service. All returns must be shipped to us pre-paid; we will not accept units with postage due. A return form is provided on our web site for your convenience.

If you need to return your AT-897 to us for service, package it carefully, keeping in mind that we will re-use your packaging to return the unit to you. A self-addressed return-shipping label, while not required, will help insure speedy and accurate delivery of your repaired unit. Include a full description of the problem, along with your name, address and a phone number or e-mail address where we can reach you with any questions. Repairs average about 3 to 6 weeks.

We will be glad to service your AT-897 after the warranty period has ended. We will notify you of repair charges by phone or e-mail, and bill you after repairs are completed.

Firmware upgrades

From time to time LDG may release upgraded firmware for the AT-897, refining operation and adding features. Your AT-897 is not field programmable; you will have to remove the present processor chip (U1) and replace it with the upgrade chip.

To replace the processor, unplug the tuner, touch a ground point to avoid static discharge damage, and remove the cabinet cover. Use an IC extraction tool and pull gently and evenly on both sides to extract the chip. Press the upgrade chip into the socket, observing the key. Replace the cabinet cover; your upgraded AT-897 is ready to use.

You will return the old processor chip to LDG; upgrades will be sold by exchange only. The processor chips are recycled and reprogrammed to minimize future upgrade costs. Upgrades are expected to cost about \$10-\$20 with chip exchange, and will be announced on our web site when available.

Feedback

If you have an idea to improve our software or hardware, please send us a description. If we incorporate your idea in the AT-897, we'll send you a free upgrade as a "thank you".

We encourage everyone who uses the AT-897 to contact us (card, letter or e-mail preferred) telling us how well it works for you. We are also always looking for photographs of our products in use; we frequently place such pictures on our Web site (www.ldgelectronics.com).