

A Remote Impedance Matching Network

Reduce transmission line loss by matching your antenna at the antenna feed point.

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What could be simpler than depressing a button in the shack to match your antenna's impedance to the transceiver's desired $50\ \Omega$? The design goals of this remotely located impedance matching network are an easy to use device that would handle 500 W of power, while keeping the number of parts to a minimum.

Impedance matching networks are often called antenna tuning units (ATUs) even though they do not tune an antenna. What they do is transform impedances. This misnomer will probably live with us forever!

I have used several ATUs for many years and after seeing the changing SWR with this ATU, I believe it is an effective design.

This article is written to inspire home brewers to revisit the design concept of simultaneously rotating both the ATU's coil and capacitors. See Figures 1 and 2.

System Design

This impedance matcher is intended to be used outdoors near the antenna. If you plan to use the ATU indoors, RF safety would dictate a metal enclosure to minimize radiation. A picnic cooler provides an outdoor

moisture resistant enclosure. See Figure 3.

Another picnic cooler houses the 12 V battery for the motors. A minimum capacity of 7 Ah is required. If the ATU is used in the shack, a power supply capable of at least 5 A is required.

The differential capacitor consists of C1 and C2. Rotation of the shaft will cause C1 to increase while C2 decreases capacitance. The *differential T* ATU design is not new. There are at least two commercially available models for "in-the-shack" operation.

What is different about this design is that it can be located remotely at the antenna and has only one simple command signal. As you might know, locating the impedance matching network at or near the antenna reduces the feed line losses due to SWR. Less loss translates to stronger reception and transmission.

An external balun can be added to provide a balanced output and sometimes help

match high impedances, although a 1:1 ratio balun, or common mode choke, is the best choice for some antennas with lower impedances.

How it Works

The magic hidden in this ATU is that the variable differential capacitor shaft rotates faster than the coil shaft. A 6:1 vernier reduction drive makes the capacitor turn slower but still faster than the coil. See Figure 4. The rotating capacitor applies all values from 30 to 300 pF while the coil rotates less than 90° . The resultant effect is that a wide variety of combinations of inductance (L) and capacitance (C) are tried to match the antenna.

The coil drive shown in Figure 5 consists of Erector Set like hardware. I am always amazed at what parts are available in my junk box. Most likely your design will dictate different parts and solutions to

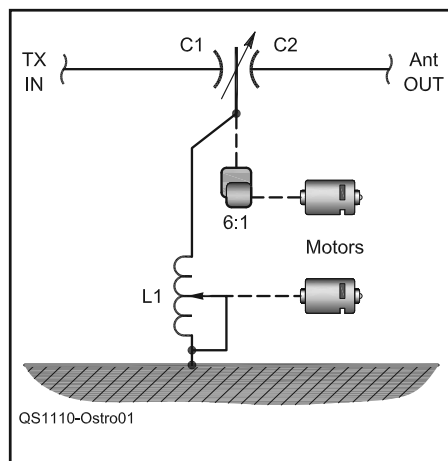


Figure 1 — Simplified schematic of the remote antenna tuner. Both motors turn together with the variable capacitor turning multiple revolutions for each turn of the rotary inductor.

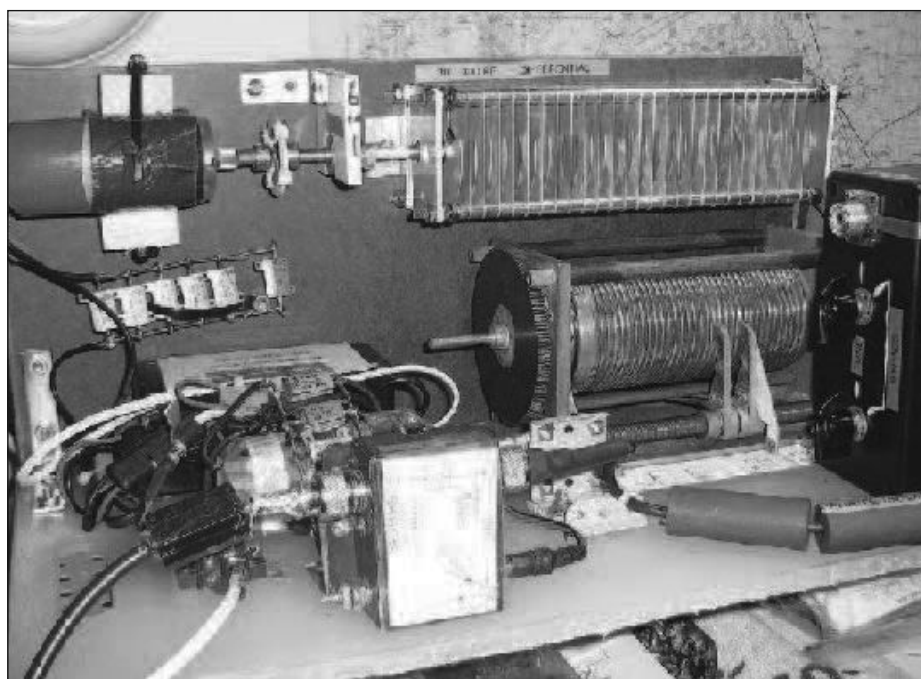


Figure 2 — View of the tuner's major components. The variable differential capacitor and its motor are at the top, the inductor below.



Figure 3 — A picnic cooler provides an outdoor moisture resistant enclosure.



Figure 4 — A 6:1 vernier reduction drive makes the capacitor turn slower but still faster than the coil. The rotating capacitor applies all values from 30 to 300 pF while the coil rotates less than 90°.

the mechanical drives.

The command signal to rotate the motors is 12 V dc. The polarity of the signal, referenced to ground, determines the direction of rotation.

Making the Match

Simply selecting either up for clockwise (CW) or down for counterclockwise (CCW) rotation direction and depressing a button makes the magic appear!

My approach to finding the correct combination of L and C is to first rotate the coil CW to the minimum value of inductance. This is close to

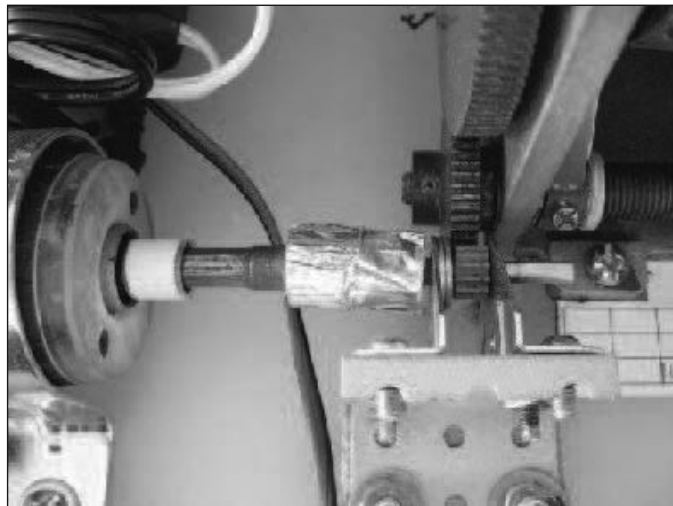


Figure 5 — Junk box gears are used to make the drive for the rotary inductor.

the desired position for the 10 meter band. Your design might include the addition of two limit switches to restrict the roller from exceeding travel at both ends of the coil.

Observe the in the shack SWR while transmitting a low power, steady carrier. Rotate CCW to increase the inductance while the capacitance changes as well. As the correct coil position is approached, the SWR will begin to swing.

At this point, jog or pulse the momentary button switch to the lowest SWR reading while watching the SWR meter for a null. Continue pulsing until

Hamspeak

Antenna tuner — Device that sits between an antenna and a transmission line, or a transmission line and a radio, and transforms the impedance to match the radio or line.

Balun — *Balanced to unbalanced* transformer or transition intended to convert signals from a balanced (with respect to ground) transmission system to an unbalanced (one side at ground potential, such as coax cable) transmission system.

Diode — Two element electronic device that passes current in one direction only. Used as a rectifier to change ac to dc, as a simple mixer, as a switch and for other functions.

Available as either a vacuum tube, or more commonly now as a semiconductor device.

LED, light emitting diode — Semiconductor device from which light is emitted when current flows. These were originally used in place of incandescent bulbs as indicator lights. They now can be used in place of larger light bulbs and form the basis of some display screens. See hyperphysics.phy-astr.gsu.edu/hbase/electronic/leds.html.

RF safety assessment — Evaluation of intensity of radio energy emanating from a radio transmitter and comparison to allowed

levels based on FCC requirements. Every Amateur Radio station is required to perform such an assessment. The process is described in the ARRL book *RF Exposure and You*, and on the FCC website at www.fcc.gov/oet/info/documents/bulletins/#65.

SWR — Standing wave ratio. Measure of how well a load, such as an antenna, is matched to the design impedance of a transmission line. An SWR of 1:1 indicates a perfect match. Coaxial cables, depending on length, type and frequency can often work efficiently with an SWR of 3:1, sometimes higher. Solid state transmitters frequently require an SWR of 2:1 or less for proper operation.

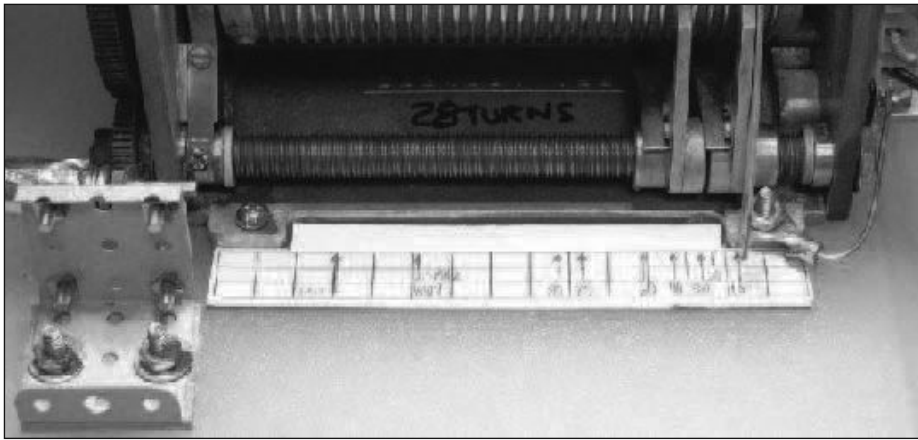


Figure 6 — The coil positions for the various bands are shown next to the inductor's roller drive.

another null is achieved. The new null should be at a lower SWR. Repeat the CCW search for the minimum null — close to a 1:1 SWR.

I find a perfect null (1:1 SWR) on all ham bands from 80 through 10 meters while

tuning my 80 meter loop. The coil positions for the various bands are shown in Figure 6.

Assembly Details

The in-shack control box is shown in Figure 7. The wiring diagram is Figure 8.



Figure 7 — The simple in-shack motor control box.

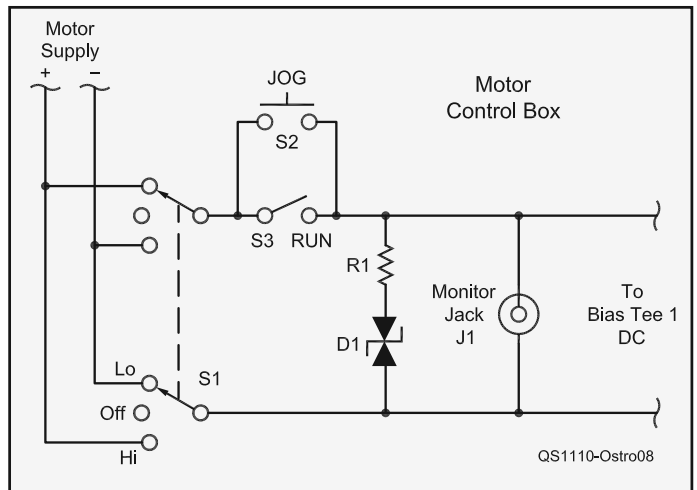


Figure 8 — Schematic of the motor control box.

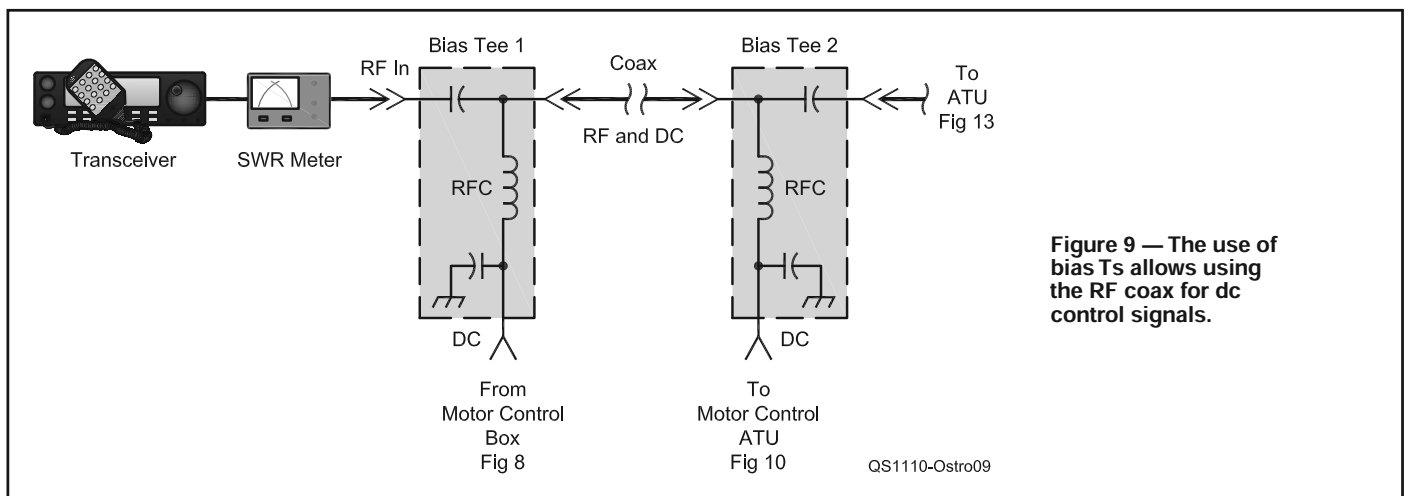


Figure 9 — The use of bias Ts allows using the RF coax for dc control signals.

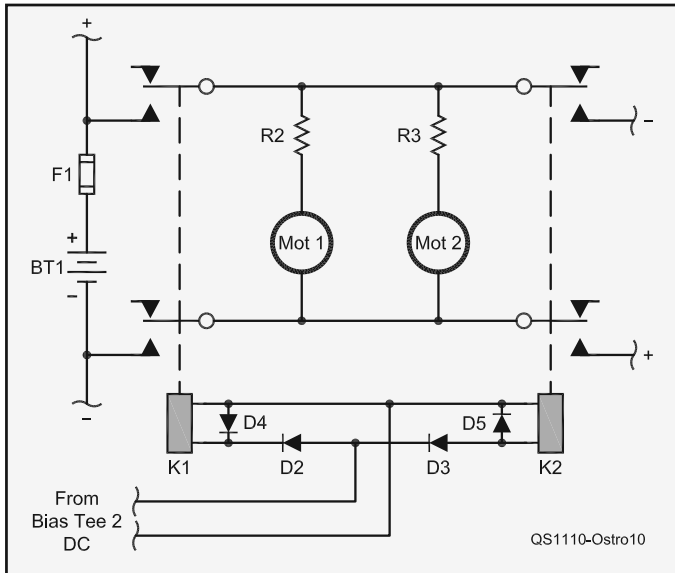


Figure 10 — The motor control wiring in the ATU.

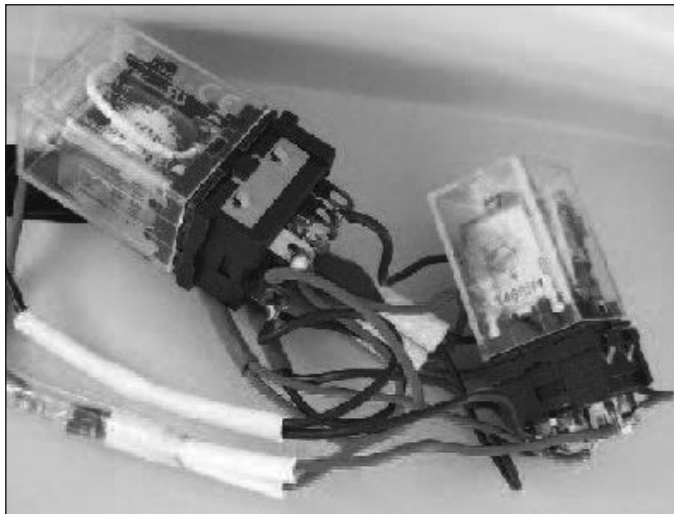


Figure 11 — View of the relays wired and ready to install

done by two tensioned bars, a very high current design. This treasure was mistakenly stored in the junk box. Your coil can be any roller inductor of about 30 turns. See the component list.

No attempt has been made to provide coil position information. In practice, it is simple to find the band you last matched and then rotate CW for up or CCW for down to another band. The most challenging aspect of this project was to find a suitable motor and couple it to the capacitor and coil.

The bottom line is this ATU design is a relatively simple approach to impedance matching. It uses no microprocessors or relays to switch RF components.

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Figure 12 — Detailed view of the interconnection of the tuning elements.

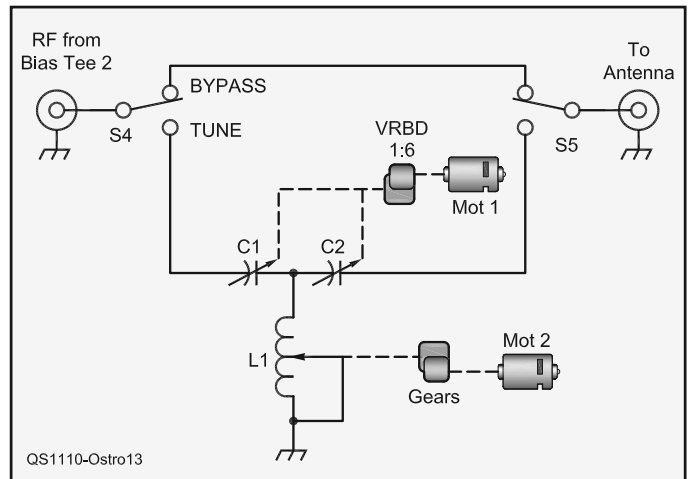


Figure 13 — Schematic diagram of the ATU portion of the remote unit and parts list of total project.

- B1** — Battery, vehicle jump start type, 12 V, minimum of 7 Ah capacity (Harbor Freight 38391).
- BT1, BT2** — Bias T dc power injector (MFJ-4116).
- C1, C2** — Capacitor, differential type, 30-300 pF (MFJ-282-2015).
- D1** — Diode, LED, bi-color (red-green) (Mouser 606-7011X1/5).
- D2-D5** — Diode, 1N4005 (Mouser 821-1N4005).
- F1** — Fuse, 10 A, fast blow (RadioShack 270-1015).
- FB** — Ferrite beads (Palomar FB-56).
- J1** — Jack, RCA chassis mount (RadioShack 274-852).
- K1, K2** — 12 V, 10 A DPDT plug-in relay with socket (Radio Shack 275-0218).
- L1** — Roller inductor, approximately 29 μ H (MFJ 404-1052).
- Mot1, Mot2** — Motor from discarded Skil 2.4 V electric screwdriver.
- PS1** — 120 V ac adapter with 12 V dc output to 500 mA (RadioShack 273-357).
- R1** — 2.2 k Ω , 1/8 W resistor (RadioShack 271-007).
- R2, R3** — 6 Ω resistor, five 30 Ω , 10 W resistors in parallel (Mouser 284-HS10-30).
- S1** — DPDT switch, center-off (RadioShack 275-664).
- S2** — SPST switch, momentary contact (RadioShack 275-1547).
- S3** — SPST switch (RadioShack 275-645).
- S4, S5** — SPST switch, ceramic (Surplus Sales of Nebraska SWR-B-52108).
- Vernier reduction ball drive, 6:1** (MFJ-729-0142-1).

