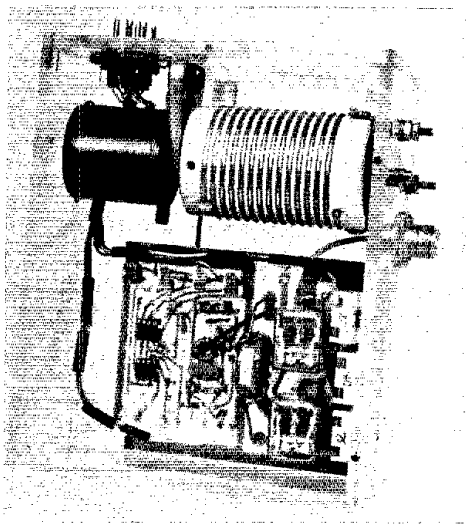
Mobile Antenna Matching — Automatically!

The ultimate in hf mobile operation is here! Band hop or operate band edge to band edge with ease. Before you can transmit your call sign, antenna matching is completed!

By Don Johnson,* W6AAQ



An automatic antenna-matching network opens up a new world of hf mobiling. By using one of the multiband mobile antennas available today,[1] it is possible to switch from band to band and operate anywhere in that band without stopping the vehicle to make adjustments. There's no need to be concerned about antenna matching — it's automatic! And, it is done so rapidly that you can beat most fixed-station operators to the new band or frequency. Numerous "mobileers" have built and enjoyed this low-cost, one-weekend construction project. The design was originated by Bruce Brown, W6TWW,[2] and a number of units were constructed by West Coast hams with his help, starting in 1976.

A glance at the bibliography will show that automatic antenna-matching networks have been on the mobileer's mind for a number of years. I remember a trunk full of dual triodes being used in the first attempt at employing an automatic antenna-matching network for 75 meters in the early '50s.

During the last couple of years I have helped a number of mobileers get their matching networks operational. With all this activity, my place became the clearing house for a few who had construction problems or suggestions. It's time this helpful information is passed to others. To ease construction and installation for the newcomer, this article provides a complete checkout procedure, from workbench to final on-the-air checks.

Twenty-meter capability has been added to the original circuit, and an improved matching section is included. The main pc board is smaller and has been rearranged. A pc board is added to accommodate the modified input circuit, and another is included for the redesigned control head. The parts used are few in number and aren't exotic. Schematic diagrams for the input, main boards and control head are shown in Figs. 1 and 2, respectively.

Packaging and Parts

Before starting a construction project, the builder usually decides on the shape and size of the final assembly. In view of the variety of variable inductors and gear-head drive motors that may be used, no firm packaging suggestions are presented.

Parts layout is not critical. The only requirement is that the roller inductor be as close as possible to the antenna base, and connected to it with a short length of *unshielded* wire.

Rotary Inductor: A minimum inductance of 10 μH is needed to cover the 75-m band. Some old a-m transmitters with rotary inductors are still around, and in many cases the price of the whole transmitter is less than the cost of a new rotary inductor! One available unit is the ARC-5 "Command Set" transmitter.[3] The rotary inductor from a 4- to 5.3-MHz transmitter is ideal.

Mounting and connecting the ARC-5 inductor to the gear-head motor may take a little work and ingenuity (see Fig. 3 and the title photo for some ideas). Over the years, good use has been made of small-diameter gas-line hose for couplings. It is an insulator, it's flexible, and, if the piece is long enough, you can even make it go around corners.

A word of caution: The ARC-5 inductor trolley wheel has a wedge shape and a nonconducting material on one side. With this configuration, an extremely small area of the wheel makes contact with the inductor wire. These 40-year-old coils may have small pits on the wire surface, which can cause an intermittent contact. Before installing the coil, move the wheel the entire length of the inductor while checking the resistance between the input and output terminals. If the resistance deviates from zero, do some investigating, because later on (during testing or after installation) you can have some very frustrating experiences caused by intermittent wheel/wire contact. To remove the oxidation and grime from the coil and mating parts, disassemble it and use household silverware tarnish remover.

Clutch: Using a rotary inductor that has a stop at each end of travel presents a problem when it is to be motor-driven. Limit and automatic-reversing switches are not practical with this circuit. A slipping clutch that goes into action when the

[1]Notes appear on page 20.

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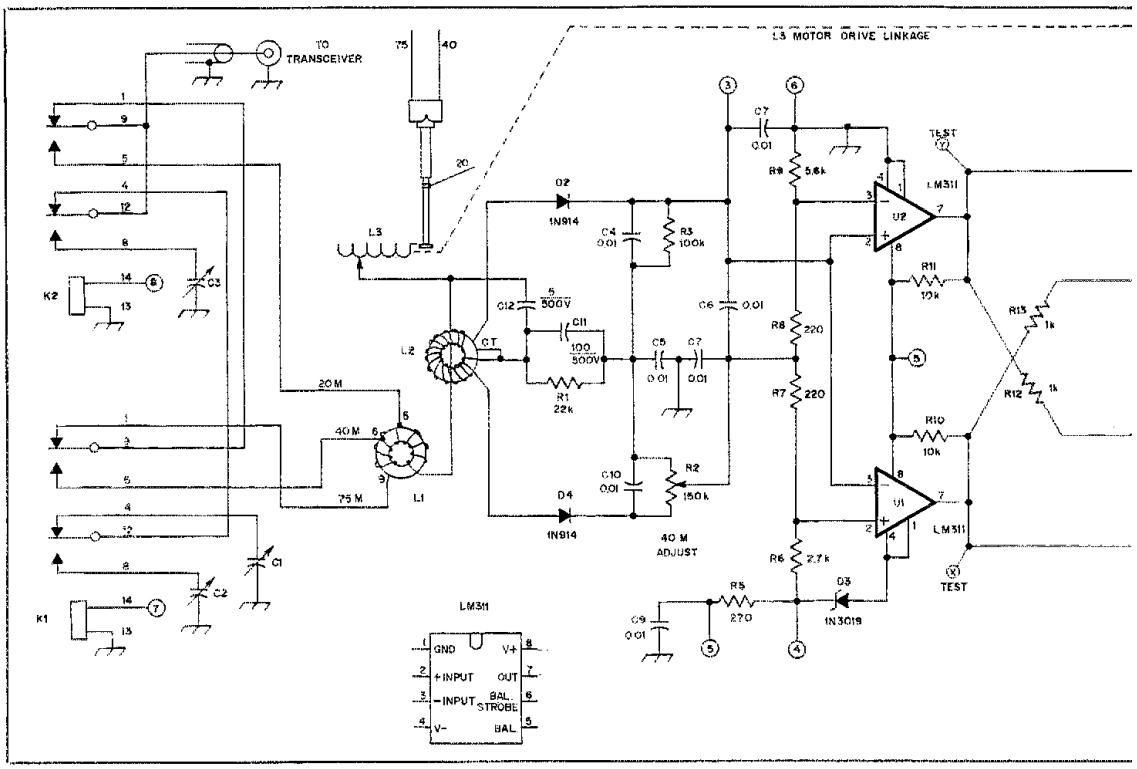


Fig. 1 — Schematic diagram of the antenna-matching unit. Fixed-value resistors are 1/4-W, 5%-tolerance, carbon-composition types.

C1 — 1000-pF, 500-V dc mica compression trimmer (Arco 310 or equiv.). See text.
C2 — 750-pF, 500-V dc mica compression trimmer (Arco 307 or equiv.)
C3 — 180-pF, 500-V dc mica compression trimmer (Arco 304 or equiv).
C4-C10, incl. — 0.01-μF, 50-V dc disc ceramic.
C11 — 100-pF, 500-V disc ceramic or silver mica.
C12 — 5-pF, 500-V disc ceramic or silver mica.
D1, D2 — Switching diode, 1N914 or equiv.
D3 — 9.1-V, 1-W Zener diode, 1N3019 or equiv. (any Zener-diode voltage from 7.5 to 11 will suffice).
K1, K2 — Dpdt, 12-V dc relay (Radio Shack 275-206B or equiv.).
L1 — 9 turns no. 18 enameled wire on Amidon T-106-2 core; tap at fifth and sixth turn (Amidon Associates, 12033 Otsego St., North Hollywood, CA 91607).
L2 — 15 turns no. 26 enameled wire, bifilar

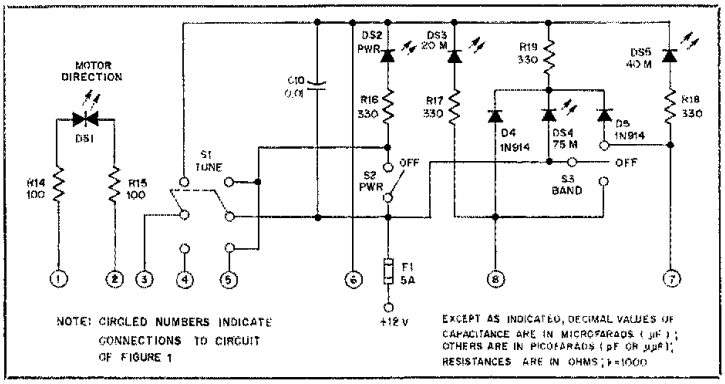


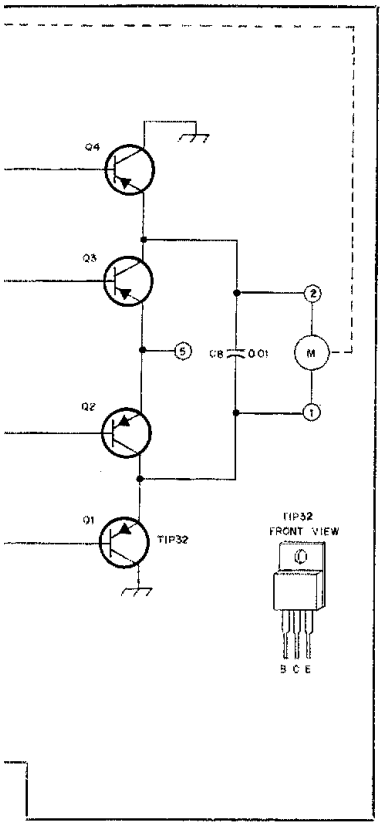
Fig. 2 — Schematic diagram of the control head. Resistors are carbon composition, 1/4-W, 5% types. [Note: Part numbers in parentheses are Radio Shack items. Equivalent units may be substituted.]

DS1 — Bipolar LED (276-035).
DS2, DS5 — Green LED (276-022).
DS3 — Red LED (276-041).
DS4 — Amber LED (276-021).
S1 — Dpdt, momentary contact, center-off toggle (275-637).
S2 — Spst toggle (275-612).
S3 — Spdt center-off toggle (275-325).
The control-head pc board may be cut to fit in a Radio Shack project case (275-220).

inductor hits the stop solves the problem and prevents motor damage.

A National Radio Velvet Vernier[4] drive works perfectly. Install the vernier between the motor drive shaft and the coil drive shaft, but *do not* secure the large outer flange that is normally bolted to the panel. There is enough drag in the vernier to rotate the inductor. When the inductor strikes the stop, the motor continues to run and the panel flange starts rotating while the coil remains stationary. In the event the vernier does not have enough drag, disassemble it, remove the grease, and bend the friction fingers to produce more friction.

Drive Motor and Gear Head: For the average constructor, a 12-V, gear-head drive motor has been the most difficult item to procure. Initially, some military surplus 1-rpm, 35-V gear-head motors were used, but that speed is much too slow; 60 rpm would be ideal. The gear-head had six planetary gears in series, but it wasn't much of a task to remove three



wound on Amidon T-44-2 core.
L3 — Variable inductor, see text.
M1 — See text.
Q1 - Q4, incl. — 1-A, 40-V power transistor, TIP-32 (Radio Shack 276-2025) or equiv.
R2 — 150-kΩ, 1/4-W (minimum) potentiometer (see text).

gears and get about 40 rpm with a 12-V supply.

A telephone rotary dial mechanism can provide the gear reduction. It may be driven with an automobile windshield-washer pump motor. Couple the rotary inductor shaft to the shaft that ordinarily connects to the dial.

The 12-V reversible motors used for raising and lowering automobile door windows are another source of gear-head motors. They rotate at the proper speed, and are easy to couple to. However, they demand heavy current, and an auxiliary relay circuit must be used. A suitable circuit is shown in Fig. 4.

Other parts: L2 is usually mounted on the pc board.[5] An insulated, unshielded lead from one of the two output terminal pads on the input pc board is passed through the center of L2 and on to the input end of the rotary inductor. Use as short a lead length as possible.

Type 30 mica compression padder capacitors are used for C1, C2 and C3. These units measure 7/8 × 15/16 inch (22.23 × 23.8 mm), and are rated for 500 dc working volts. While these capacitors are found frequently in junk boxes and at flea markets, they are often difficult to locate as new items. Even when a source is located, the particular unit desired may not be stocked.[6] The only difference between units in the type-30 series is the number of plates in each padder. If a quantity of *any* value can be obtained, they may be modified so that C1 has a total of 10 plates; C2, 7 plates and C3, 4 plates. Before installation, each capacitor should be adjusted to the value shown in the parts list. If this is not done, the tune-up will be complicated.

Almost any pnp power transistor with ratings equivalent to or greater than those

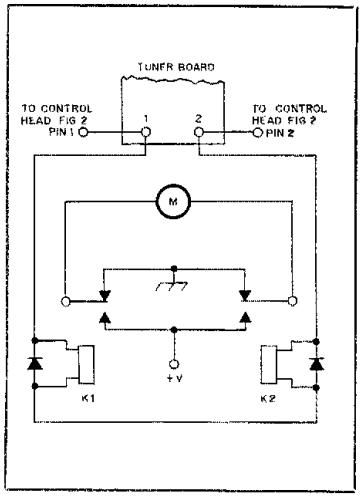
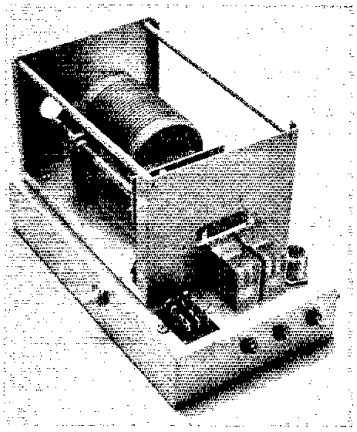
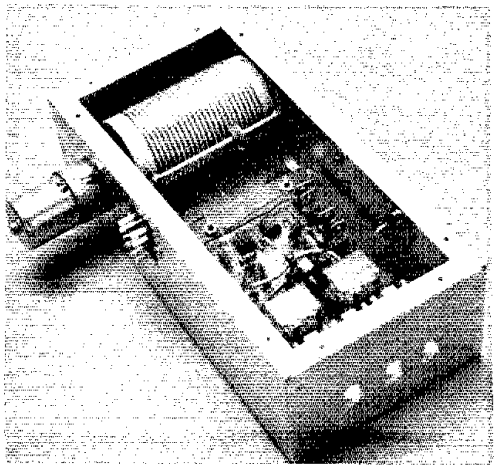


Fig. 4 — An alternative circuit using relays to control a heavy current motor.





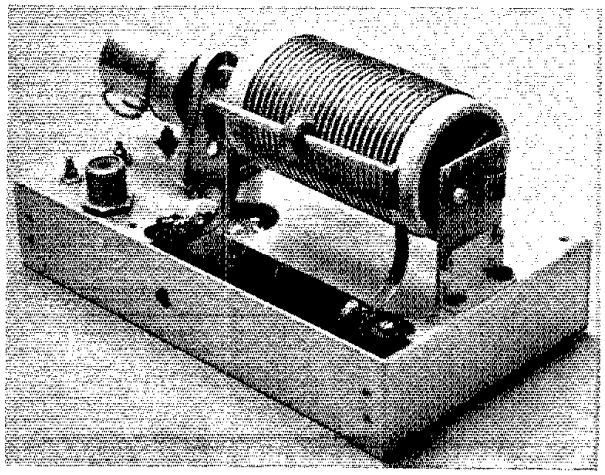


Fig. 3 — Some of many ways in which the automatic antenna-matching network may be constructed. The unit shown in the title-page photograph is used for demonstration purposes only.

of the TIP-32 can be used for Q1 through Q4. These transistors are normally in an off state, and are fully on only when the motor is running. No heat sinking is required.

If surplus LM311s are purchased, they should be checked before use (testing is covered later). R2 may be mounted on or off the pc board. Once it is adjusted, R2 need not be touched again, so it is okay to "bury" it. When R2 is installed on the pc board, set the wiper arm so a resistance reading of 1 kΩ is obtained between the potentiometer arm and the cathode of D1. Final adjustment (if required) will be made later.

Fixed-resistor values are not critical. However, the resistances of resistor pairs R7/R8, R10/R11 and R12/R13 should be kept within 5% of one another.

An eight-conductor rotator cable (such as Belden 8448) may be used to connect the control head to the matching-network chassis. Note that no ground connection is made directly to the vehicle at the control-head end of the cable. A ground strap is connected to the vehicle frame at the network chassis location. That is the *only* ground connection in the system.

Control Head

The operator's position control panel is the only part of the system that is continually on display. You can customize it to fit the dashboard or just twist a couple of wires together and let them hang around your knees. One flashy Mercedes has a control head built into an unused ashtray. When the ashtray is opened the control head is turned on automatically and is indirectly illuminated! Others have been incorporated into the face of an analog clock and an on-board computer.

S1 permits operator control of the rotary inductor. It is a spring-return, center-off dpdt switch. While the transceiver accessory socket usually supplies the 12 volts required for the control head, it may be desirable at times to turn the unit off independently of the transceiver on/off switch. S2 performs this function. Note that S2 does not have to be activated for S1 or S3 to function. S3, an spdt center-off switch, selects the proper input matching network for the band in use.

You may want to control the network band switching from the transceiver band switch (see Fig. 5). If control voltages from the band switch are not brought out to an auxiliary socket, you might be able to make connections without even putting a soldering iron to your cherished rig; diodes can be used to achieve this. Locate a connector in the rig with pins that have the band-change voltages on them. This should be a positive 8- to 12-V potential. Push the anode lead of a diode (one for each band desired) in alongside the proper pin, and bring out an insulated lead from the diode cathode. This lead should not be connected directly to the relay coil.

Indicators: A bipolar LED (DS1) is in parallel with the motor winding. It indicates the direction of motor travel and extinguishes when tuning is completed. DS2 shows when power is applied and the system is ready to function automatically. DS3 through DS5 are band indicators. Color coding is used, so the selected band can be determined by noting the LED color: red, 20 meters; yellow 40 meters; green, 75 meters.

DS4 can be turned off only when power is removed from the control-head supply lead. If the supply voltage is derived from the transceiver accessory socket, DS4 should extinguish when the transceiver is turned off.

Workbench Checkout

Before heading out to the car with the finished unit, make the following checks (it is a lot easier to do this on the workbench than standing on your head in the trunk!):

1) Locate pads X, Y, C and B on the main pc board. Solder short pieces of bus wire to these pads and let the wires protrude through the board about 1/4 inch (6 mm) on the component side. Do *not* install U1 and U2. (The control head is not needed for the following steps.)

2) Apply 12-volts dc to the main board (positive to terminal 5, ground at terminal 6).

3) Connect a jumper wire between test point X and ground. The drive motor should run. Note the direction of travel. Remove the jumper.

4) Connect a jumper wire between test point Y and ground. The drive motor should run in the opposite direction. Remove the jumper. (So far, the motor circuit and four power transistors have been checked.)

5) Remove the power connection to the board and insert U1 and U2 into their sockets. Note that the ICs face in opposite directions.

6) Reconnect the supply voltage. The motor may start to turn, but *should not* continue to run. If the motor stops turning, proceed to step 9.

7) If, in step 6, the motor continues to run, swap the ICs in the sockets. If the motor now runs continuously in the other direction, you probably have a bad IC.

8) In the event the motor continued to run in the *same* direction as it did in step 6 after swapping the ICs, remove the ICs. With power applied to the main board, measure the voltage distribution across voltage divider (R5, R6, R7, R8 and R9). The voltage at the junction of D3, R5 and R6 should be equal to the Zener-diode voltage of D3. If a 9-V Zener diode is used, the voltage at pin 2 of U1 should be about 6.5 and about 6 at pin 3; the voltage at pin 3 of U2 will be slightly less.

9) With the ICs installed and power applied, connect 1.5 V across test points B and C (a battery will do). The motor should run. Reverse the battery polarity, and the motor should run in the opposite direction.

10) Temporarily connect a jumper from terminal 3 to terminal 4 on the main board. The motor should run. Remove the jumper and connect it from terminal 3 to terminal 6. The motor should run in the opposite direction. Remove the jumper. This completes the workbench checkout.

Preliminary Checks in the Vehicle

The final resting place of the matching-network chassis must be as close as practical to the base of the antenna. An insulated, *unshielded* lead, as short and direct as possible, is connected from the output of the rotary inductor to the antenna base. This wire actually becomes part of the antenna and a long lead here would

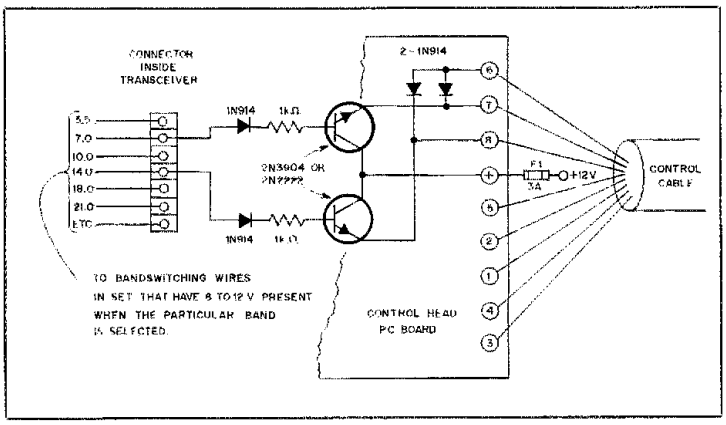
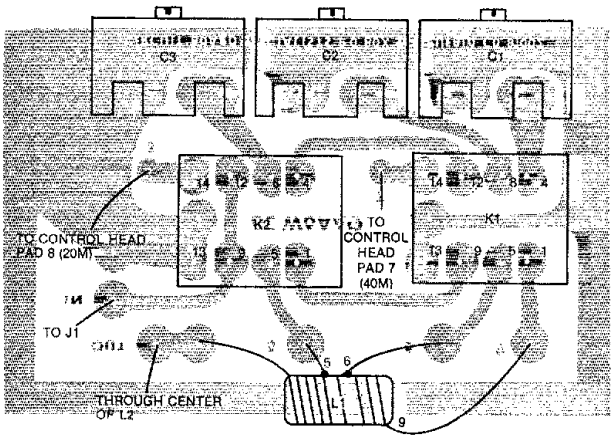
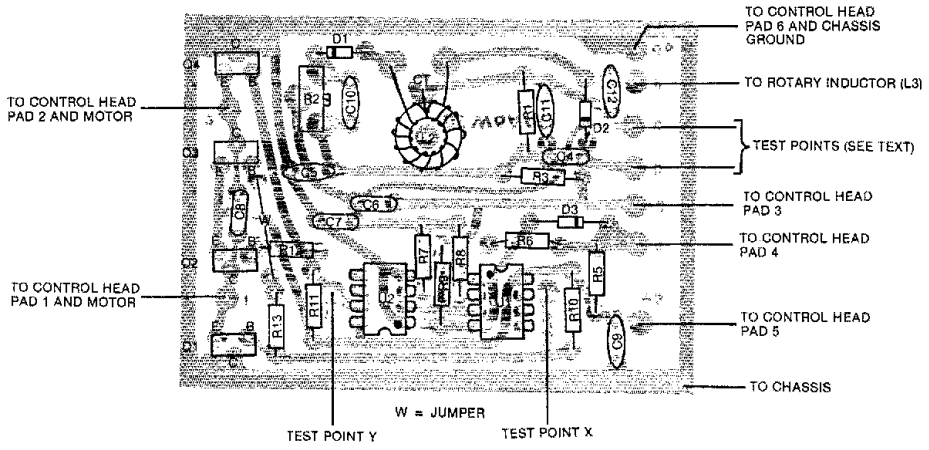


Fig. 5 — If the transceiver used provides band-switching voltages at a connector, this method may be used to control band switching of the antenna matching network automatically.



(A)



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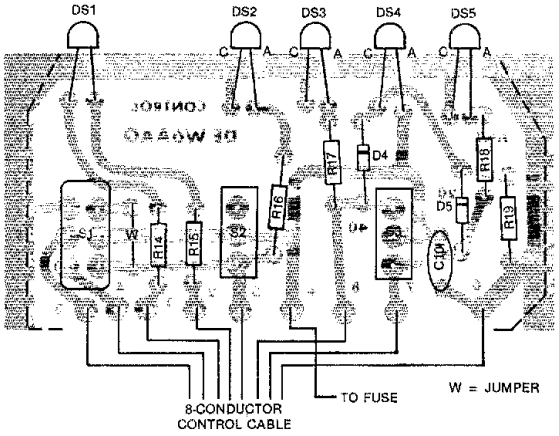
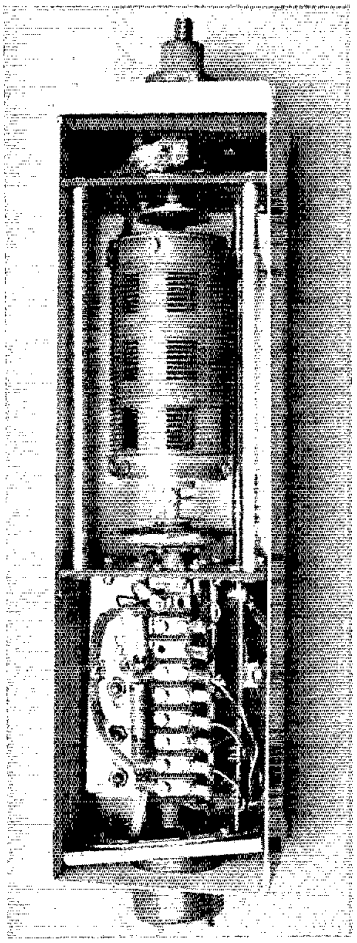
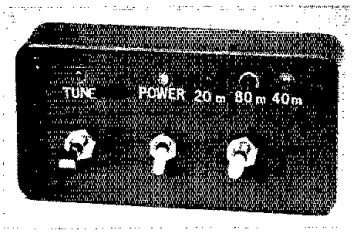


(C)

Parts-placement guides for the mobile antenna-matching network. Components are mounted on the nonfoil side of the boards. Shaded areas represent copper on the foil sides of the boards. At A is the input-network board; at B, the main board; at C, the control-head board. The circuit-board etching patterns appear on page 44. Designations C and A near the LEDs indicate the cathode and anode leads.



In this version of the matching network, a vernier drive mechanism is employed as a slipping clutch.



This control head is built into a small, plastic enclosure.

be undesirable. Do not use coaxial cable between the inductor and the antenna base! This error has been one of the most common ones made.

1) With the matching network at the chosen location, place it in a position where you can observe the operation of the relays and reach the padder capacitor adjustment screws.

2) Connect a heavy, short ground lead from the matching-network chassis to a clean electrical ground spot on the vehicle chassis. Connect the control head to the network assembly.

3) With S2 OFF, actuate S3 (the BAND switch) to determine if the proper relay closes, as indicated by the control-head LEDs. K1 closes in the 40-m position, K2 closes in the 20-m position, and no relays should be energized in the 75-m position of S3.

4) S2 is still in the OFF position. Move S1 (TUNE) from the center-off position to one side and then the other. The motor should first turn in one direction and then the other as the switch is operated. During this test, the motor should not run with the switch in the center-off position.

5) With S2 in the OFF position, connect a 50-ohm coaxial-cable lead from the transceiver to the input of the matching-network chassis. Manually, position the pickup on the rotary inductor for minimum inductance.

6) S2 is still OFF. Turn on the transceiver and set it for operation on 75 meters. Set the control head BAND switch to 75 meters. (It is assumed that your antenna is already resonant on this band at the highest intended operating frequency.) Switch to transmit, and tune the transceiver to the frequency of lowest indicated VSWR. (This will not necessarily be 1:1.) Return the transceiver to the RECEIVE mode.

7) Now place S2 in the ON position. Switch to TRANSMIT and move the transceiver down the band about 15 kHz from the point of lowest VSWR. The motor should turn the inductor to increase the inductance until the system is in resonance and it is back at the point of lowest VSWR.

If the motor turned in the wrong direction (decreasing the inductance), reverse the leads that interconnect terminals 1 and 2 of the main board to the motor. Don't move the leads to the control head. There's no way to predict the direction of motor travel initially because the number of reversals in the gear head, the direction in which L2 was wound and the direction the wire was passed through L2 from L1 all affect motor direction. If it ran correctly the first time, consider yourself lucky! Don't install the unit permanently yet.

Tune-Up and Adjustment in the Vehicle

Do not park the vehicle under or near other antennas, telephone- and power-line drops. Get out from under that shade tree too!

With S2 OFF, set the transmitter to the center of the band being used. Key the transmitter, and operate S1 to move the rotary inductor to produce resonance as indicated by the lowest VSWR. Now adjust the appropriate padder capacitor for lowest VSWR indication. If the padders were set accurately to the values indicated, they will have to be moved very little. If the VSWR did not come down to 1:1, move the inductor (using S1) as before, and readjust the padder capacitor. Repeat this procedure for the other bands.

Adjustment of R2

Once the padder-capacitor adjustments have been completed, return the transceiver and matching network to the 40-m frequency at which you adjusted C2. Place S2 in the ON position. Switch the transceiver to transmit, and adjust R2 for the lowest VSWR reading as you rock the transceiver VFO back and forth 10 or 20 kHz. This can all be done while using low power.

Install the unit permanently, and don't forget to use a heavy ground lead to the chassis. Unless you've wired the band-changing relays to be operated by the transceiver, remember to set the control-head BAND switch to the band of operation. If you don't, the first thing you will notice is that the receiver sounds dead. Then all you have to do is key the transmitter and the matching network will adjust itself automatically!

With the antenna mentioned earlier,[7] and a 20-m adapter, you will be pleased to see the VSWR will be at "rock bottom" from end to end on each band. Using the information presented here, you should experience success from the first time the switch is turned on.

I'd like to thank all the mobileers who brought their problems, solutions and suggestions to my attention. Maybe a number of readers have the "upstairs gears" grinding with ideas and other applications for this or a similar circuit. I'd be interested in hearing of them. QST

Notes

[1]D. Johnson, "Build a Weird 2-Band Mobile Antenna," *73*, Oct. 1976, p. 20.

[2]B. Brown, "Tennamatic: An Auto-Tuning Mobile Antenna Tuner," *73*, July 1979, p. 132.

[3][Editor's Note: Fair Radio Sales, P.O. Box 1105, 1016 E. Eureka St., Lima, OH 45802.]

[4][Editor's Note: Available from Strux Corp., 100 E. Montauk Hwy., Lindenhurst, NY 11757.]

[5]A complete set of drilled pc boards is available from Circuit Board Specialists, P.O. Box 969, Pueblo, CO 81002. A set of wound and dipped toroids (L1, L2) is available from the same source.

[6][Editor's Note: Types 302 through 306, inclusive, are available from Allied Electronics, 401 E. 8 St., Fort Worth, TX 76102. They are listed in catalog 810 on p. 80.]

[7]See Note 1.

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