A survey of antenna tuners — how QST and Lew McCoy, W1ICP, pioneered the "Transmatch"

ham radio TECHNIQUES

Bill Orr, W6SAI

Society seems to go through a progression of fads. Senior citizens well remember when miniature golf courses, "Amos 'n' Andy," and the snood were all the rage in the thirties and forties. Most of us can name some post-war fads: the hula hoop, tail fins on autos, and hot tubs.

Amateur Radio, being in some ways a mirror of society, also has its fads. Old timers remember from pre-war times the Astatic D-104 microphone, the RME-69 receiver, preselectors, and the Johnson-Q antenna. In vogue today are keyboards and RTTY,quad antennas, speech processors, SWR meters, baluns, and antenna tuners. Time will tell which of these technological developments will be of the greatest benefit to Radio Amateurs.

This brings me in a roundabout way to the subject of this column: antenna tuners. If you look in the various ham magazines, you'll see a bunch of advertisements featuring antenna tuners. Everybody has gotten in on the act! You can even buy an antenna tuner to match the decor of your equipment. Obviously, you've got to have an antenna tuner to be a part of the action.

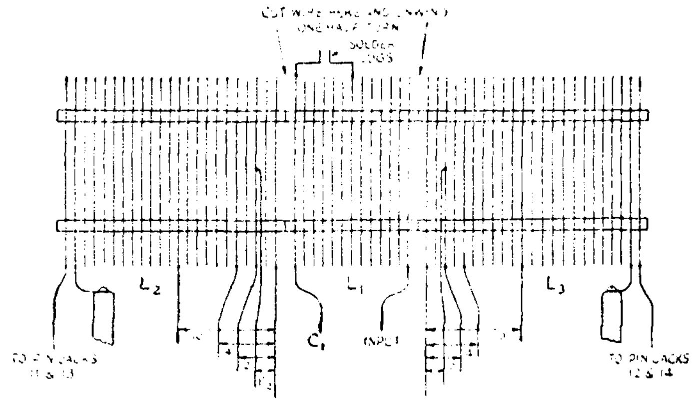
antenna tuner? what's that?

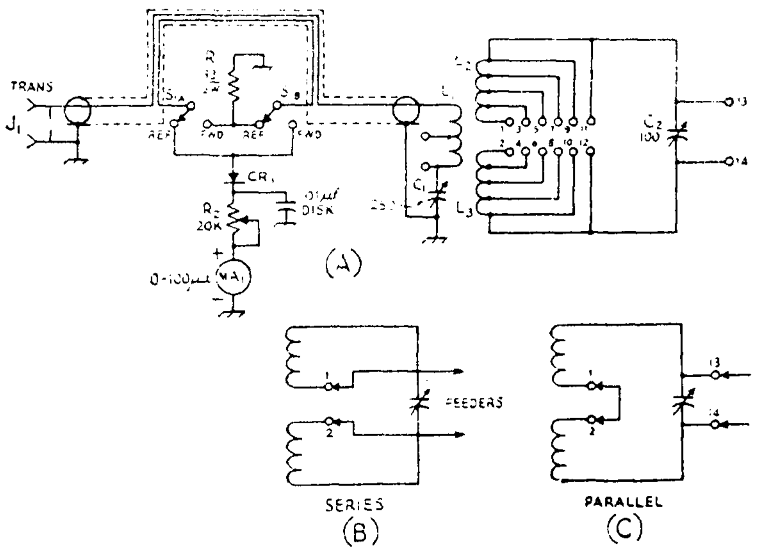
The term *antenna tuner*, as By Goodman, W1DX, once pointed out, is a misnomer. *It doesn't tune the antenna*. Rather, it's a matching device that translates the electrical characteristics of the antenna system into values more compatible with the communications equipment attached to the antenna.

Back in the days of open-wire feedlines and simple antennas, the antenna tuner was a resonant circuit coupled to the transmitter. A few copper alligator clips on the tuner coils permitted the operator to make loading adjustments to his taste. He didn't worry about the standing wave ratio (SWR) on the feedline — these magic initials were unknown to most Amateurs.

The SWR meter. With the availability of good, inexpensive coaxial cable after World War II, the switch-over from open-wire lines was inevitable. At about that time, Amateur Radio was introduced to the SWR meter. And the Federal Communications Commission introduced the Novice license, which brought a large number of new Amateurs on the air.

The influx of new, inexperienced hams on 80 and 40 meters brought a blizzard of problems for the FCC and Amateur Radio. The beginner's transmitter was unsophisticated and, more often that not, a prolific generator of strong harmonic signals. Moreover Amateur Radio as a whole was plagued with serious television interference (TVI) problems. Many





(A) Circuit diagram of the antenna coupler and s.w.r. bridge. (B) Series tuning. (C) Parallel tuning.

C_1—250-μμf. variable capacitor (Hammarlund MC-250-M).
C_2—100-μμf. variable capacitor (Hammarlund MC-100-SX).
CR_1—1N34A germanium diode.
J_1—Coaxial chassis receptacle, SO-239.
L_1, L_2, L_3—See Fig. 2 and text.
MA_1—0-100 microammeter, or other range, depending on sensitivity required.
R_1—33 ohms, ½-watt carbon resistor.
R_2—20,000-ohm potentiometer.
S_1—D.p.d.t. "tone control" switch (Centralab 1462).

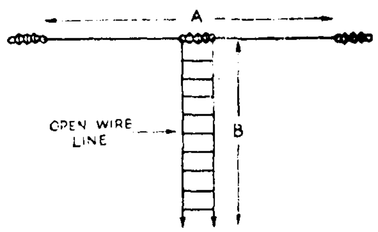
fig. 1. The antenna-tuner design that started it all. Shown in the March, 1959, issue of *QST*, this design brought the antenna tuner out of the dark ages. It incorporated a simple SWR bridge made from a length of coaxial line and a link-coupled circuit that could be adjusted for either series or parallel tuning of an open-wire transmission line. The air-wound coil is about 2 inches in diameter, 10 turns per inch. (Drawings from *QST*, March, 1959.)

Tuning Information

Parallel	*Series*
Connect feeders to 13 and 14, jumper 1 and 2	Connect feeders to 1 and 2

Short following terminals with jumpers

3.5 Mc.	——	——
7.0 Mc.	11 and 9 —	12 and 10
14.0 Mc.	11 and 7 —	12 and 8
21.0 Mc.	11 and 5 —	12 and 6
28.0 Mc.	11 and 3 —	12 and 4



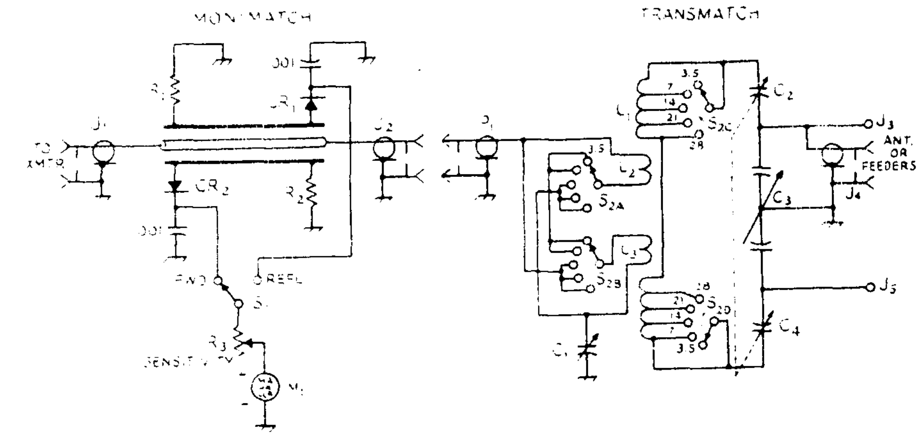
The length *A* should be more than a quarter wavelength at the lowest operating frequency. When you determine the length of A to half the distance, add a sufficient length of feed line (B) to equal a quarter wavelength or multiple thereof. For example, let's assume you can put up an antenna 80 feet long and you plan to operate on the 3.7-Mc. Novice band as the lowest frequency. From the formula

$$\frac{246}{3.7} = 66.5 \text{ feet}$$
$$66.5 - 40 = 26.5 \text{ feet}$$

the feeder length, or

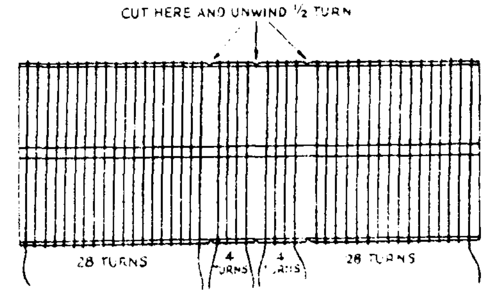
$$2 \times 66.5 = 133$$
$$133 - 40 = 93 \text{ feet.}$$

This can be carried out for greater feeder lengths, depending on the requirements of the installation.



Circuit diagram of the transmatch and Monimatch.

C —250-μμf. variable, 0.045-inch spacing for high power (Johnson 250E20); 0.025-inch spacing for low power (Hammarlund MC-250-M).
C_2, C_4—100-μμf. variable, 0.125-inch spacing for high power (Johnson 100E45); 0.025-inch spacing for low power (Hammarlund MC-100-M).
C_3—100-μμf.-per-section, dual variable, 0.125-inch spacing for high power (Johnson 100ED45); 0.025-inch spacing for low power (Hammarlund MCD-100-M).
CR_1, CR_2—1N34A germanium diodes.
J_1, J_2, J_3—Chassis-type coax receptacles, type SO-239
J_4, J_5—Feed-through insulators.
L_1, L_2, L_3—See Fig. 2 and text.
M_1—0–1 ma. or less; see text.
P_1—Coax plug, type PL-259.
R_1, R_2—For 50-ohm bridge, 150 ohms, ½-watt composition; for 70-ohm bridge, 100 ohms, ½-watt composition.
R_3—20,000-ohm control, linear taper.
S_1—Rotary, 1 pole, 2 positions (Centralab type 1460).
S_2—Ceramic rotary, 4 poles, 5 positions, 1 pole per section, 4 sections (Centralab index type P-122 with type "T" or "X" sections).



This drawing shows how to make the coil assembly. Not shown are the taps needed for changing bands. The tap points listed below all are counted from the outside ends of the coil.

7 Mc.—12 turns.
14 Mc.—23 turns.
21 Mc.—25 turns.
28 Mc.—26 turns.
The coil stock in 3 inches in diam., No. 14, 8 turns per inch

fig. 2. The 1961 version of the Transmatch. The SWR bridge is shown at left. The coils are tapped, and a rotary switch is used to select the proper inductance. Note that a coaxial plug (J4) has been added to the output terminations of the tuned circuit. Only one-half of the tuner circuit is used for the coaxial connection. (Drawings from *QST*, November, 1961.)

Amateurs thought that perhaps the old-fashioned antenna tuner might solve these problems. How could the old-design tuner be adapted from open-wire line to coaxial line?

The antenna tuner and SWR bridge circuit. Several solutions to this problem were introduced during the 1950s, but the most popular and effective tuner was that developed by Lew McCoy, W1ICP, the Novice Editor and Technical Assistant for *QST* magazine. An early version of Lew's device is shown in **fig. 1**. This tuner adapts a medium-power transmitter having a 50-ohm coaxial antenna output to a center-fed, all-band antenna. A simple SWR meter is incorporated into the tuner. Small copper clips make connections to the tuner coil as the band is changed. This is a practical all-band (80- through-10-meter) antenna and tuner, and I recommend it to any Amateur looking for a versatile, simple, and inexpensive antenna system. For more details, refer to the March, 1959, issue of *QST*, pages 11-15.

Later, in the November, 1961 *QST* Lew showed a high-power (500-watt) version of his tuner — a deluxe model having a wider adjustment range — and he called it a Transmatch. Again, it was designed to match a 50-ohm coaxial antenna output to an antenna having a balanced feed system. But he also added a coaxial output plug to the Transmatch to match to a 50-ohm transmission system. In this manner, the Transmatch could be used as a highly selective circuit in a 50-ohm coaxial system that would greatly attenuate the harmonics of the transmitter. The circuit is shown in **fig. 2**.

By 1966 the impetus had switched to harmonic suppression on 50-ohm transmission lines; so the October, 1966, issue of *QST* featured a simplified McCoy Transmatch that eliminated the SWR meter and emphasized single-ended output (**fig. 3**).

In 1967 an entirely different approach to an "antenna tuner" was described by Lance Johnson, K1MET. He built a simplified, single-ended tuner based upon a T-section network that provided an unbalanced-to-balanced match for a 50-ohm transmission system (**fig. 4**). This compact and simple Transmatch is an excellent solution to some of today's problems with solid-state rigs: it will reduce the SWR on an antenna system to near unity, so that the transmitter does not suffer reduced power output caused by operation into a mismatched load.

the "Line Flattener"

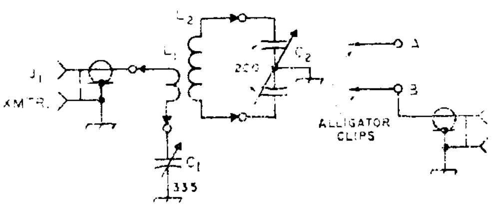
This circuit has shown up in Radio Amateur literature numerous times since its first introduction by K1MET (then an ARRL Lab Assistant). Previously, it had been in wide commercial use but somehow had never filtered into ham literature. In addition to providing a good match, the T section (**fig. 4**) provided up to 20 dB attenuation for transmitter harmonics falling into the TV channels. An extremely practical circuit, this low-cost device is recommended to today's Amateurs who have solid-state transmitters and who wish to achieve easy and efficient antenna matching with a minimum of fuss.

By now the name Transmatch was slipping into the public domain, and almost every "antenna tuner" was called a Transmatch. (Too bad, Lew. You've suffered the fate and fame of Kodak™ and Xerox™!)

A simplified Line Flattener for a tri-band beam (10-15-20 meters) can be built. Capacitor C1 is reduced to 250 pF, capacitor C2 is removed, and the end of coil L2 is connected directly to receptacle J2 (**fig. 4**). Then, coils L1 and L2 are reduced to nine turns each. Readers with a good memory will recall that I described a compact, 100-watt version of the Line Flattener in my antenna column in *CQ*, April, 1979. A somewhat similar device was also described by W6EBY in the September, 1978, issue of *ham radio* (page 22).

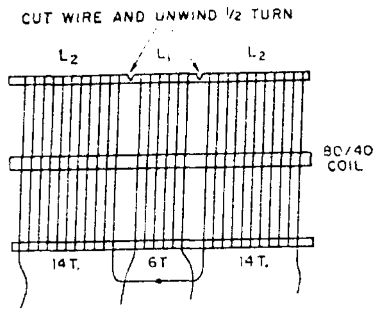
back to the Transmatch

By 1961 the antenna tuner had taken an interesting turn, and an article describing the "50-Ohmer" by Lew McCoy appeared in the July, 1961, issue of *QST* (**fig. 5**). This device was a form of Line Flattener designed to be used with a coaxial system to reduce the SWR on the



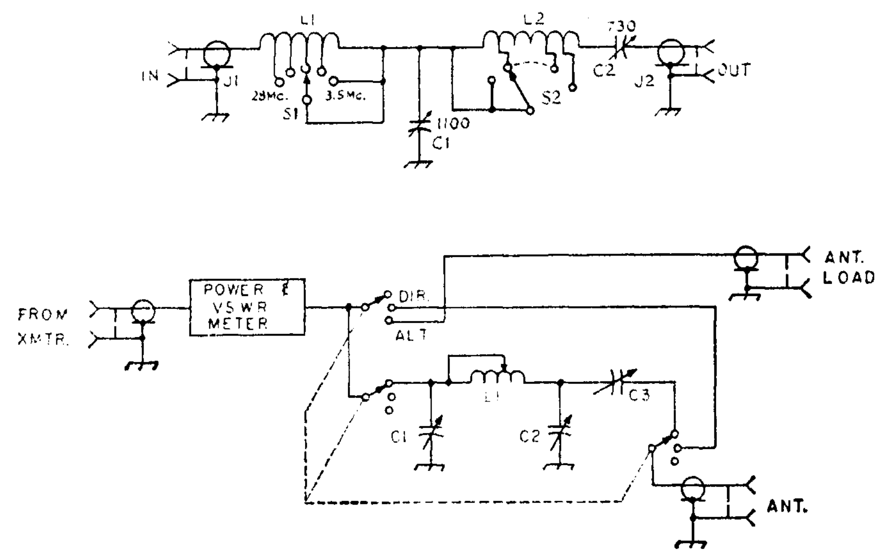
Circuit diagram of the transmatch. Balanced feeders should be attached to A and B.

C_1—335 pf. variable (Millen 19335 or equivalent).
C_2—200 pf. dual variable, 0.077-inch air gap for 1 k.w. (Millen 16200), 0.022-inch air gap for 150 watts and less (Millen 28200).
J_1, J_2—Coax chassis fitting, SO-239.
L_1, L_2—See Fig. 3 and text.



Details for making the 80/40-meter coil. The 20-meter coil consists of 2 turns for L_1 and 6 turns for L_2 (3 turns on either side of L_1). Details for the 15/10-meter coil are given in the text. The coils are mounted on Millen type 40305 plugs and the socket is Millen type 41305. Coil stock is Polyphase PIC type 1778, 3-inch diameter, 6 turns per inch, No. 12 solid wire.

fig. 3. The tuned-circuit antenna-matching device reduced to the simplest form. The SWR meter is eliminated, but provision for 50-ohm coaxial output is included. (Drawings from October, 1966, *QST*.)



Circuit of the 300-watt transmatch. Capacitances are in pf.
For simplicity, only a few of the taps on L_2 are shown.

C_1—365-pf. variable, 3-section, receiving t.r.f. type (Miller 2113 or equivalent).
C_2—365-pf. variable, 2-section, receiving t.r.f. type (Miller 2112 or equivalent).
J_1, J_2—Coax chassis fitting, SO-239.
L_1—13 turns No. 14, 1¾-inch diam., 8 turns per inch, tapped at 3, 5, 9, 11 and 12 turns from J_1 end (Polycoil 1764 or equivalent).
L_2—21 turns same coil stock as L_1, tapped every other turn.
S_1—Ceramic rotary, 1 section, 1 pole, 2-6 positions (Centralab PA 2003 or equivalent).
S_2—Ceramic rotary, 1 section, 1 pole, 2-11 positions (Centralab P-270 index & YD section or equivalent).

fig. 4. The 1966 Transmatch (top). This is a T-section network that provides a match within a 50-ohm transmission line system. The configuration is well suited to today's solid-state equipment. Tuner is designed to cover 160 through 10 meters. A pi-network circuit, below, is used in the Drake MN-4 matching network. (*Drawings from QST, October, 1967.*)

transmission line. It used a "bandswitching adjustable transformer" capable of handling SWR values as high as 5 to 1. Of interest to the circuit connoisseur is the use of a split-stator tuning capacitor with network input attached to the floating rotor.

This shunt provided a capacitive short circuit to ground for the transmitter harmonics and gave protection up to 20 dB for harmonics falling into the TV channels — a slightly different version of the K1MET design.

the Ultimate Transmatch

In July, 1970, W1ICP came up with the Ultimate Transmatch in his "Beginner and Novice" column of *QST*. This circuit was a sophisticated version of the 50-Ohmer, adapted for either coaxial lines or balanced lines. A 1-to-4 ferrite balun was used to achieve balanced output (**fig. 6**). This Transmatch combined simplicity and flexibility, requiring only one split-stator capacitor, one single-section capacitor, and one variable inductor. Many of the antenna couplers sold today employ this circuit or variations of it. The output termination for the balanced configuration is 200 ohms when the input to the Transmatch is 50 ohms.

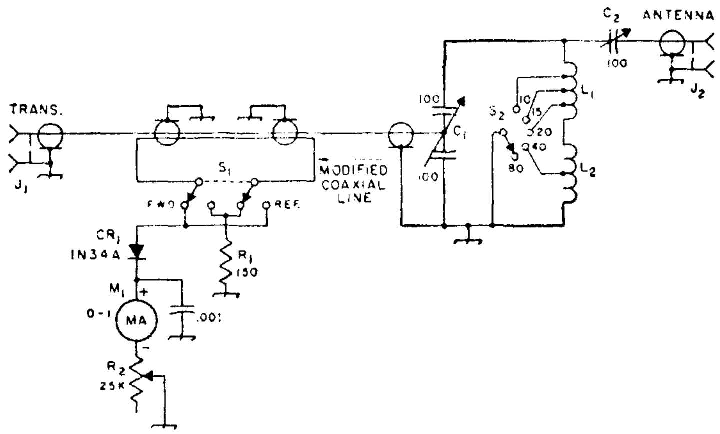
The use of a ferrite balun, however, should be approached with caution. Most balanced lines are other than 200 ohms (300 ohms for TV ribbon line, and 450-600 ohms for open-wire transmission line). Ferrite baluns don't like to work into a mismatch because of core saturation. The result of this misuse is increased harmonic radiation and the chance of balun flashover at medium power levels. An air-core balun at this point is recommended.

the SPC Transmatch

Shown in the 1981 *ARRL Handbook* is the SPC Transmatch (SPC standing for series-parallel-capacitance) — another offspring of the long series of antenna matching units pioneered by W1ICP and others. A simplified schematic of the *ARRL Handbook* version is shown in **fig. 7**. This unit was developed by Doug DeMaw, W1FB. It provides a wide range of matching and gets around the ferrite-core balun problem by substituting an air-core device.

which antenna tuner to build or buy?

So much for the background of the Transmatch, now firmly established as part of the history of Amateur Radio. Much information is available for the interested Amateur who



Circuit diagram of the 50-Ohmer. Decimal values of capacitances are in uf., others are in $\mu\mu$f.

C_1—100-$\mu\mu$f.-per-section, split stator (Hammarlund HFBD-100-C).

C_2—100-$\mu\mu$f. variable (Hammarlund MC-100-SX or Johnson 100 FD 20H).

CR_1—1N34A germanium diode.

J_1, J_2—Coax chassis terminal, SO-239.

L_1—9¾ turns No. 14, 1¾-inch diam., 4 turns per inch (B & W Miniductor 3021, Illumitronic Air Dux 1404T). 14-Mc. tap 2½ turns from junction of L_1L_2; 21-Mc. tap 7½ turns from junction of L_1L_2; 28-Mc. tap 7½ turns from junction of L_1L_2.

L_2—28 turns No. 14, 1¾-inch diam., 8 turns per inch (B & W Miniductor 3022, Illumitronic Air Dux 1408T). 7-Mc. tap 5 turns from the junction of L_1L_2.

M_1—0–1 milliammeter.

R_1—150 ohms, ½ watt.

R_2—25,000-ohm control, linear taper.

S_1—2-pole, 2-position switch (Centralab 1462).

S_2—Ceramic rotary, one section, one pole, 5 positions (Centralab type 2501).

fig. 5. The 50-Ohmer circuit of 1961 is the forerunner of today's Transmatch. The split-stator capacitor C1 provides good rejection of the transmitter harmonics and provides TVI protection when it is properly adjusted. Note that high-impedance output for two-wire transmission line has been dropped. (*Drawing from July, 1961 QST.*)

wants to buy or build a Transmatch. As to the question, "Which antenna tuner should I build or buy?," the first answer is, Don't use an antenna tuner unless you really need it. Too many Amateurs are swept away by antenna tuner fever when they could just as well get along without one.*

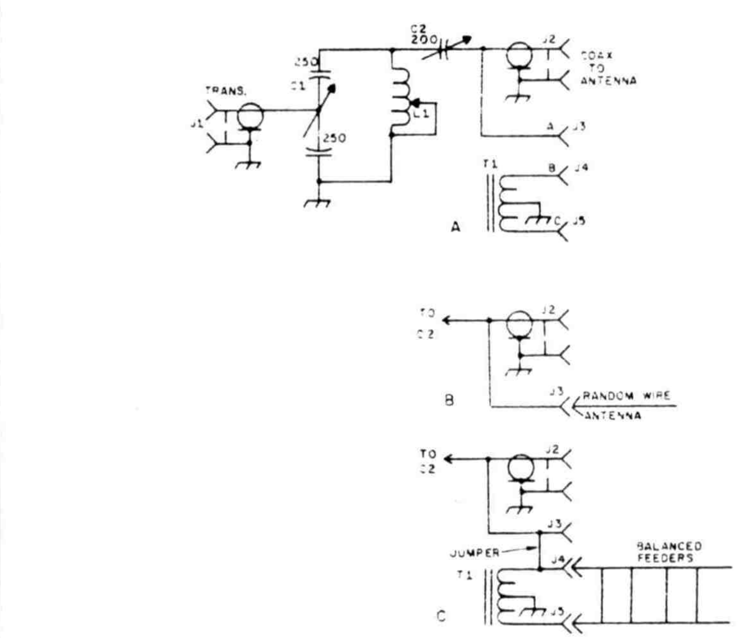
Where the Transmatch really shines is in conjunction with a solid-state transmitter and, say, a triband antenna. The tribander provides various terminating impedances as operation is conducted across the bands, and sometimes the solid-state transmitters encounter loading problems, especially at the band edges. The Transmatch will transform the odd-ball impedance at the station end of the transmission line into 50 ohms, which is what you would want for a good match to the transmitter.

The transmitter employing vacuum tubes and a pi-network output circuit is considerably more tolerant of a high SWR antenna load, and in most cases a Transmatch is not required to match a 50-ohm line to the transmitter, with one exception: 80 meters. The great majority of 80-meter ham antennas cannot work across the whole band without exhibiting a high value of SWR at one end of the band or the other. And here is where a Transmatch is worthwhile. Even though the antenna may be operated "off tune" and may exhibit a high SWR on the feedline, the Transmatch can provide a satisfactory load for the transmitter.

Which model Transmatch to build or buy? I'm not going to get into a dispute over that. My Transmatch needs are modest, so I have a haywire version of the T-section device shown in **fig. 4**. In fact, I have two of them. One is built up very pretty in a low-profile case, complete with SWR meter and all bells and whistles. The other one is built upon a small sheet of plywood, and the components are interconnected with flexible leads and copper-plated battery clips. It is very flexible and I can rearrange the circuit at a moment's notice to fit the need at hand.

If I were buying a Transmatch I would want to look inside the pretty case and examine the innards. Is a good quality ceramic switch used? Do the capacitors have sufficient plate spacing for the power level indicated? Are all rf connections well made — solid and firm? Is there sufficient air space around the inductor so that the metal cabinet is not inductively coupled to the coil, producing an unwanted shorted turn in the metal of the box? Sometimes a

*However the antenna matching unit does attenuate harmonics. **Editor**



Circuit diagram of the Ultimate Transmatch.

C1 – Split-stator variable, 250 pF per section; see text. For low-power version, E.F. Johnson type 16250; or similar, for high-power version, Millen type 16250, or similar.

C2 – 200-pF variable, for low power, E.F. Johnson type 167-12 or similar, for high power, Millen type 16520, .171-inch spacing, 16520A, .077-inch spacing, or similar.

J1, J2 – Coax chassis fitting, type SO-239.

J3,J4,J5 – Feed through insulators.

L1 – Roller inductor, see text. If 160-meter operation is desired, total inductance should be 28 uH, E.F. Johnson type 229-203; otherwise, 18 uH is adequate, E.F. Johnson type 229-202.

T1 – 1-to-4 balun; see text for details, cores are Amidon type T-200-2.

fig. 6. The Ultimate Transmatch of 1970. The split-stator circuit is used, and a ferrite-core balun has been added for balanced feeders. (*Drawing from QST, July, 1970, page 24.*)

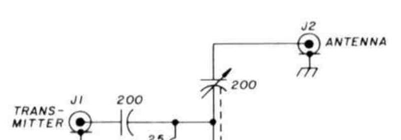


fig. 7. The SPC Transmatch shown in the 1981 *ARRL Handbook* is merely the Transmatch of W1ICP hooked up backwards! For balanced lines, an air-core balun is attached to antenna receptacle J2.

photograph of the interior of the tuner will give you these answers.

Note: A few months ago I offered readers of this magazine a reprint of my series of articles entitled "Design Considerations for Linear Amplifiers." This brochure has been reprinted and is again available. If you wish a copy, I'll be happy to send one to you for two 18-cent stamps (overseas readers send four IRCs). Write to me at EIMAC, 301 Industrial Way, San Carlos, California 94070 U.S.A.

ham radio