A *Universal* Antenna Coupler

J. Stanley Brown, W3EHE
762 Lebanon Ave.
Pittsburgh, 28, Pa.

By ingeniously devising a method of variable link coupling to rotary inductors, W3EHE has come up with an antenna tuner capable of feeding balanced or unbalanced transmission lines from 50 ohms on up. Nothing has been spared in this installation and we offer this only as a source for further thought along these same lines.

THE greatest enjoyment that many people get out of amateur radio is in designing and building some contraption generally considered impracticable, if not even impossible, and then making it work.

My experience with antenna couplers dates back over the years to the cylindrical coil and pancake coil oscillation transformers of pre-World War I. They all worked after a fashion, on one or two frequencies, after the proper choice of words. It is almost impossible to avoid a little power flowing from antenna coupler, through the feeders, to the antenna, but a number of us have been very nearly successful in this respect.

I have always had a desire to own a coupler that will match anything from the proverbial bed spring to a pair of buried coax cables at any frequency from 29,700 *kc* to 1750 *kc*. This incidentally should all be accomplished from the front of the panel with no aid from screwdrivers, wrenches or bolt cutters.

The front-view photograph illustrates what has been accomplished for the last 4 years. It measures 19″ × 8¾″ with a 8¾″ × 13 × 17″ enclosure and, unless your time is worthless, it should not cost more than $1,000,000 to duplicate after setting up a complete machine shop.

During my years of struggle with this problem I've had but one fairly good multi-range antenna coupler, easily recognized from fig. 1, as the Collins twin-pi coupler, vintage 1933 or so[1]. Many amateurs used it on 160-80-40 and, in some cases, 20 meters. When properly adjusted, the clips to the plate tank coil could be attached or removed and the plate current dip was found at the same spot on the tuning dial. There were no roller coils around at that time so the circuit was not as finely adjustable as one would like. At the higher frequencies it was difficult to clip to the tank coil at the proper fraction of a turn. This tuner could not readily be located remotely from the transmitter, although some versions with link coupling were used.

A balanced line is generally considered the ideal means of center feeding any antenna, especially multi-frequency jobs. However, there are many forms of single wire and single coax feeds in use, and these too, must be accommodated.

Desirable Coupler Features

The old Collins twin-pi network only needed some modernizing to couple a variety of feeders and antennas to modern, single-ended, pi-network finals as well as to the center of push-pull final tanks. The following features are desirable and/or required:

1. Coax line from final amplifier to the antenna coupler.
2. Provision for r.f. bridge or Micro-match in line to the coupler, with low-pass filter in series.
3. Variable coupling from transmitter to the "cold end" of the coupler coils.
4. Reactance cancellation in the ground leg of the coax line to the coupler.
5. Ganged roller coils in the coupler.
6. R.f. ammeters in feeders.
7. Antenna selector switch.

[1]Collins, A. A., "A Universal Antenna Coupling System for Modern Transmitters", *QST*, Feb. 1934.

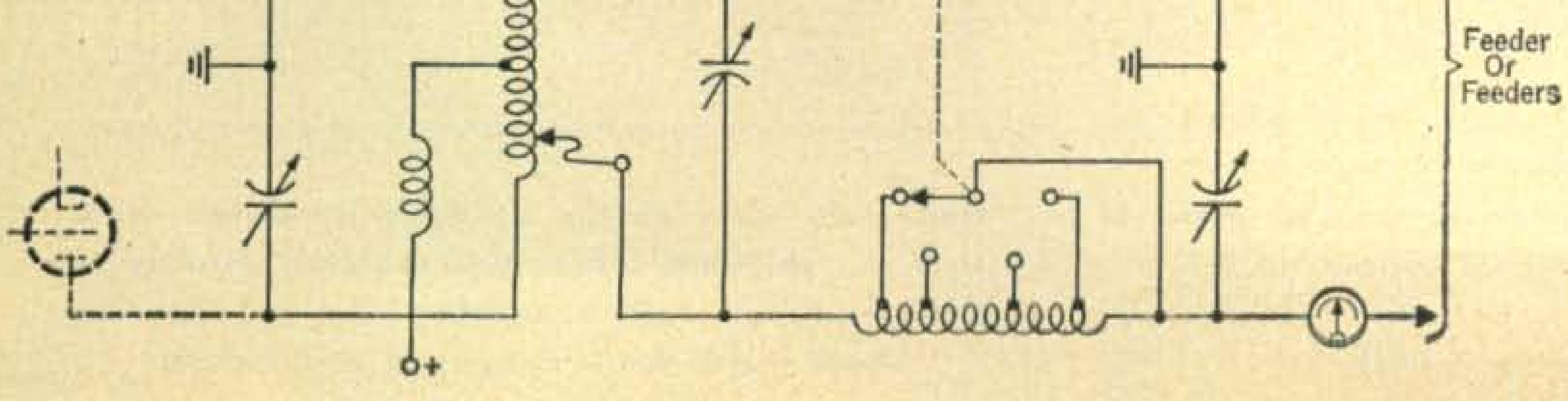


Fig. 1—Original circuit of the Collins Twin-Pi Coupler.

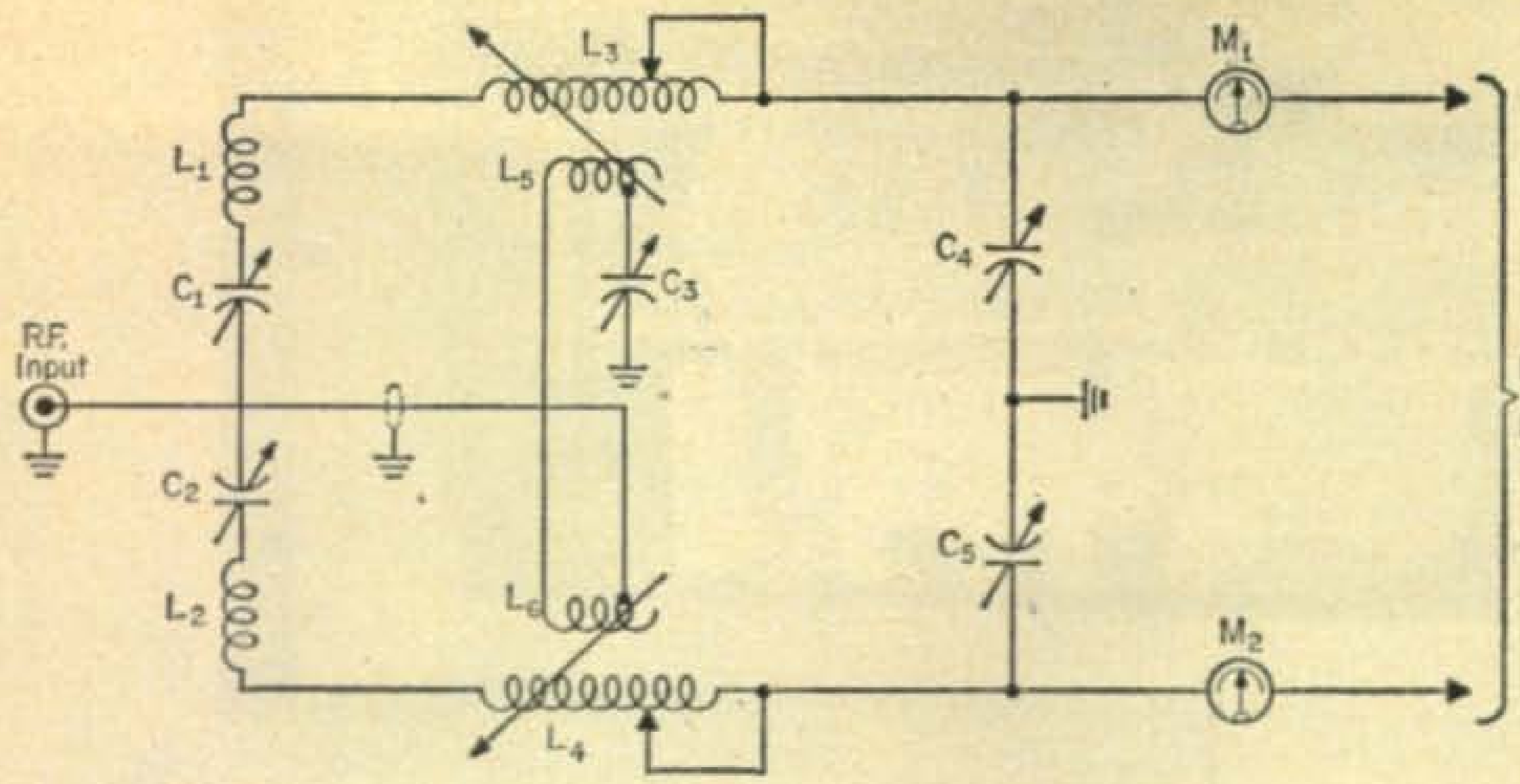


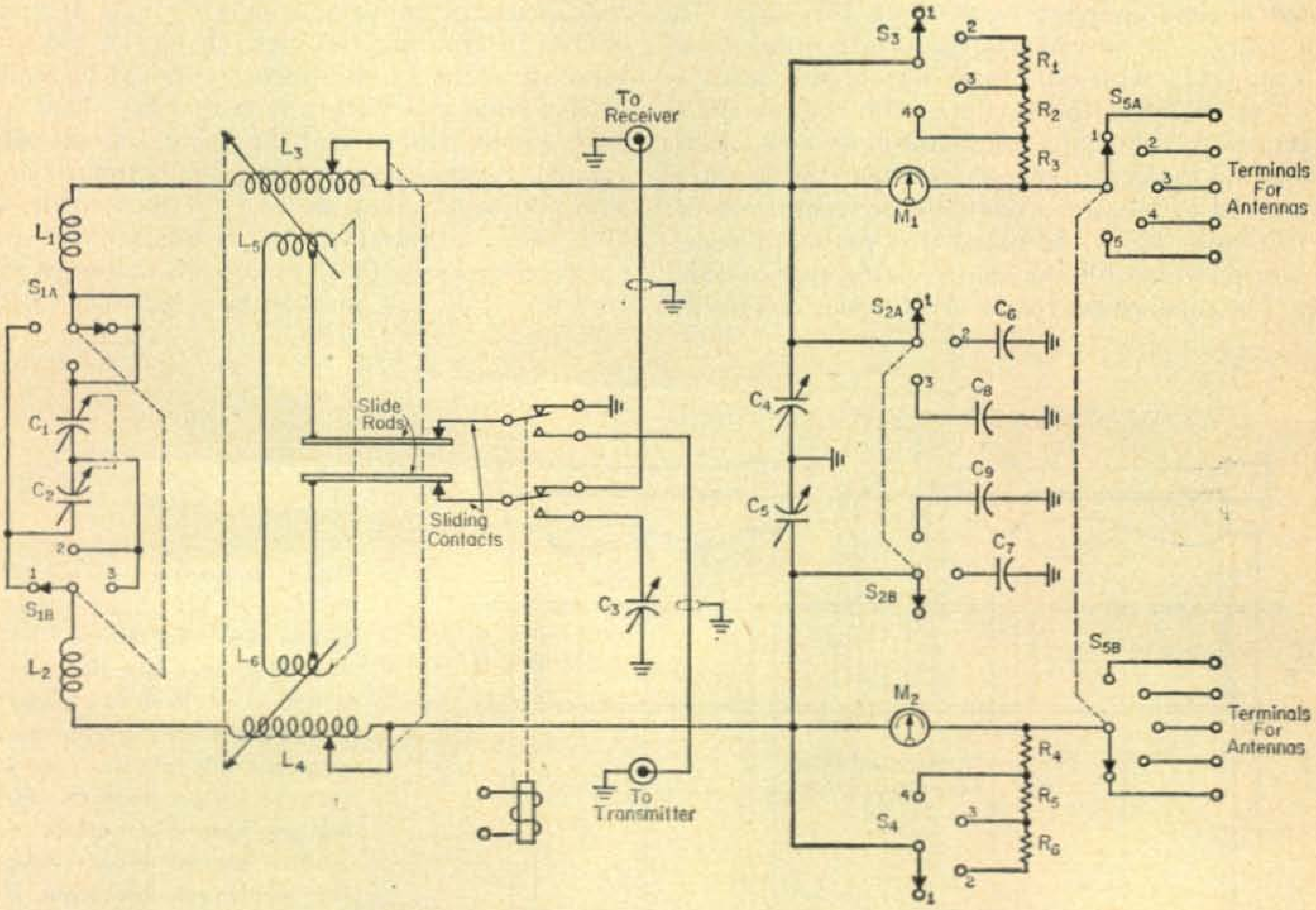
Fig. 2—Basic circuit of the Collins Twin-Pi Coupler illustrating the method used at W3EHE to link couple to the rotary inductors. Inductors L_1 and L_2 are used on ten meters.

8. R.f. probe points for 'scopes, modulation and carrier-shift indicators, etc.
9. Send-receive relay.
10. Complete front panel control.

Variable Inductors

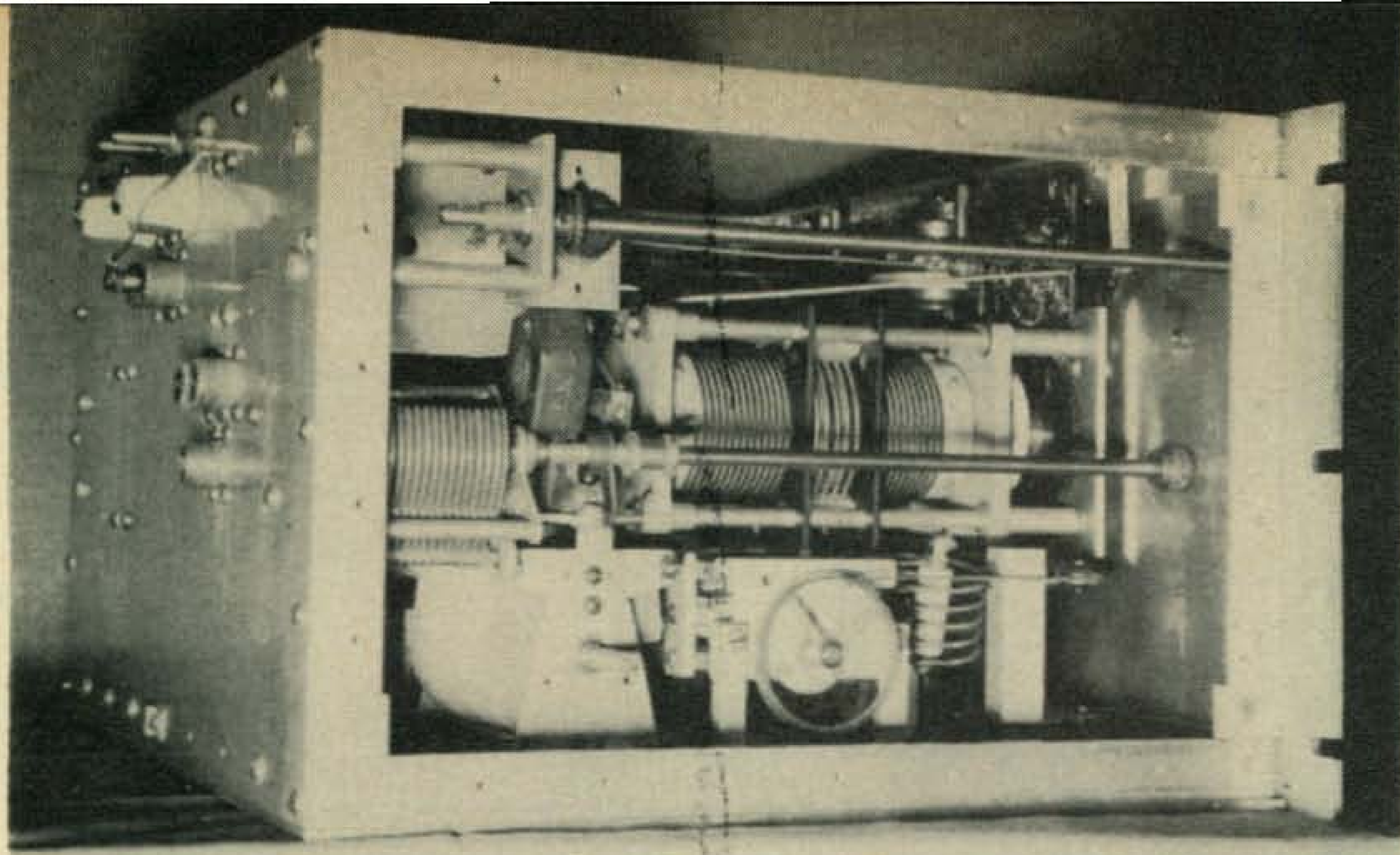
Most of these features were not too difficult to provide. One, however, was a puzzler; that was, how to gang the variable inductors and how to provide variable coupling to them. Study of the ganging problem indicated the advisability of using gears. Variable inductive coupling was a problem because of the roller and contact rod being in the way. The photograph from the top of the unit gives some clues as to the solution, and an attempt will be made to clarify the rest of the procedure.

Figure 2 is the basic schematic diagram of the coupler and fig. 3 is the circuit as constructed.



C_1, C_2—100 mmf variable, transmitting type spaced .093".
C_3—350 to 500 mmf variable, see text.
C_4, C_5—500 mmf variable transmitting type spaced .045".
C_6, C_7—400 mmf surplus transmitting mica 3000 w.v. matched, see text.
C_8, C_9—900 mmf surplus transmitting mica 3000 w.v. matched, see text.
L_1, L_2—5 Turns #12, 1½" dia. × 1½" long.
L_3, L_4—24 μh—rotary inductor from BC-375 or equivalent (E. F. Johnson 229-203).
L_5, L_6—5 Turns each of #12 soft drawn copper, wire spaced, 2⁷⁄₁₆" diameter, see text and fig. 4.
M_1 M_2—R.f. ammeter 0—0.5 amperes.
R_1, R_2, R_3, R_4, R_5, R_6—Meter Shunts, see text.

Fig. 3—Actual wiring diagram of the Universal antenna tuner showing input and output capacitor switching. Care should be taken to insure that the meter shunts are carefully matched.



Side view illustrating the method of mounting the rotary inductors and the associated gearing arrangement. The link can be seen mounted on the rotary inductor spacing bars. The ten meter inductor and input tank capacitor C_1 are mounted below the rotary inductor. The long shaft coupled to the right angle gearing arrangement at the upper left is the antenna selector switch. Mounted below the right angle drive is the link loading capacitor C_3 and below is C_4, one of the output tank capacitors. Balanced and unbalanced output connectors are mounted on the rear panel.

The roller coils used were from the BC-375 transmitter and are about 24 microhenries each. They were geared together on the ground side of the insulated flexible coupling, with three 2½" p.d., 32 pitch gears. The two outside gears are brass, Boston Cat. G111 with 1/16" face. The middle gear is steel, Cat. 53280 with 3/16" face. The counter dials are removed from both roller-coil units and one is installed on the center-gear shaft. Figure 4 indicates the method of making a common drive unit out of the two coils. It will be noted that outboard bearings are provided for the shafts of the two outside gears. The inboard bearing is at the roller coil itself. The center-gear shaft is fastened to the turns-counter dial mechanism which has a good bearing of adequate cantilever strength. Any other good roller coils of similar inductance may be used. If it is not desired to tune the 160 meter band, an inductance value of about 15 microhenries should be suitable. At this point it is well to note that no "dead spots" were found with a grid dip meter in any of the amateur bands covered. Using the output of an 813 with 500 watts input, no parts of these roller coils have shown any warmth to the touch. Prior to this final arrangement, these same coils had been in use on a full 1 kw unit and had been satisfactory.

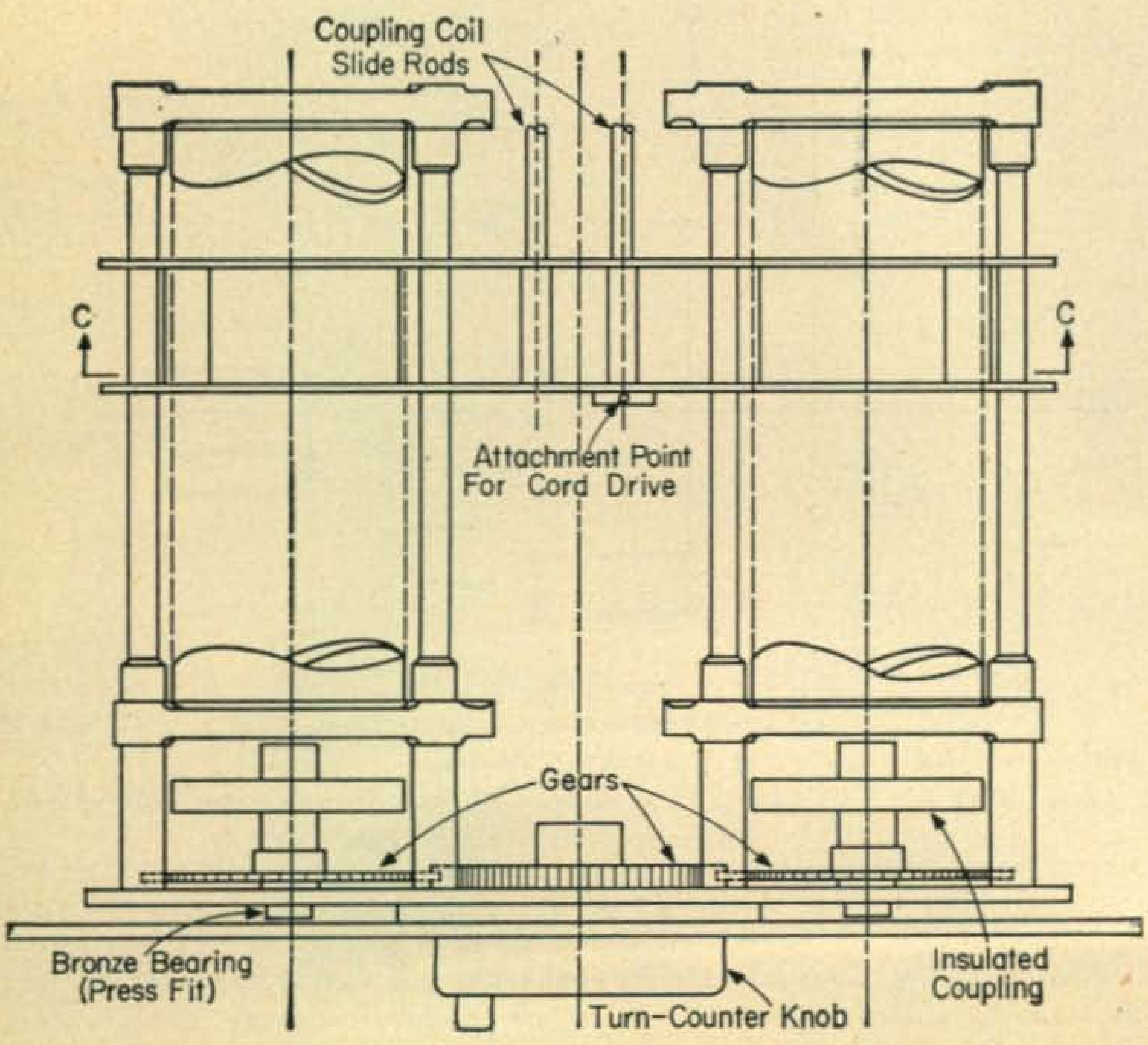


Fig. 4—Diagrammatic view of the two BC-375 rotary inductors as seen from the top. This view illustrates how the links L_5 and L_6 are fixed to a moveable train which rides on the original rails of the rotary inductor. Wiper contacts riding on slide bars insure a positive contact at all times. The whole variable train is pulled back and forth over the rotary inductors by means of a pully arrangement. The front panel control is located between the r.f. ammeters.

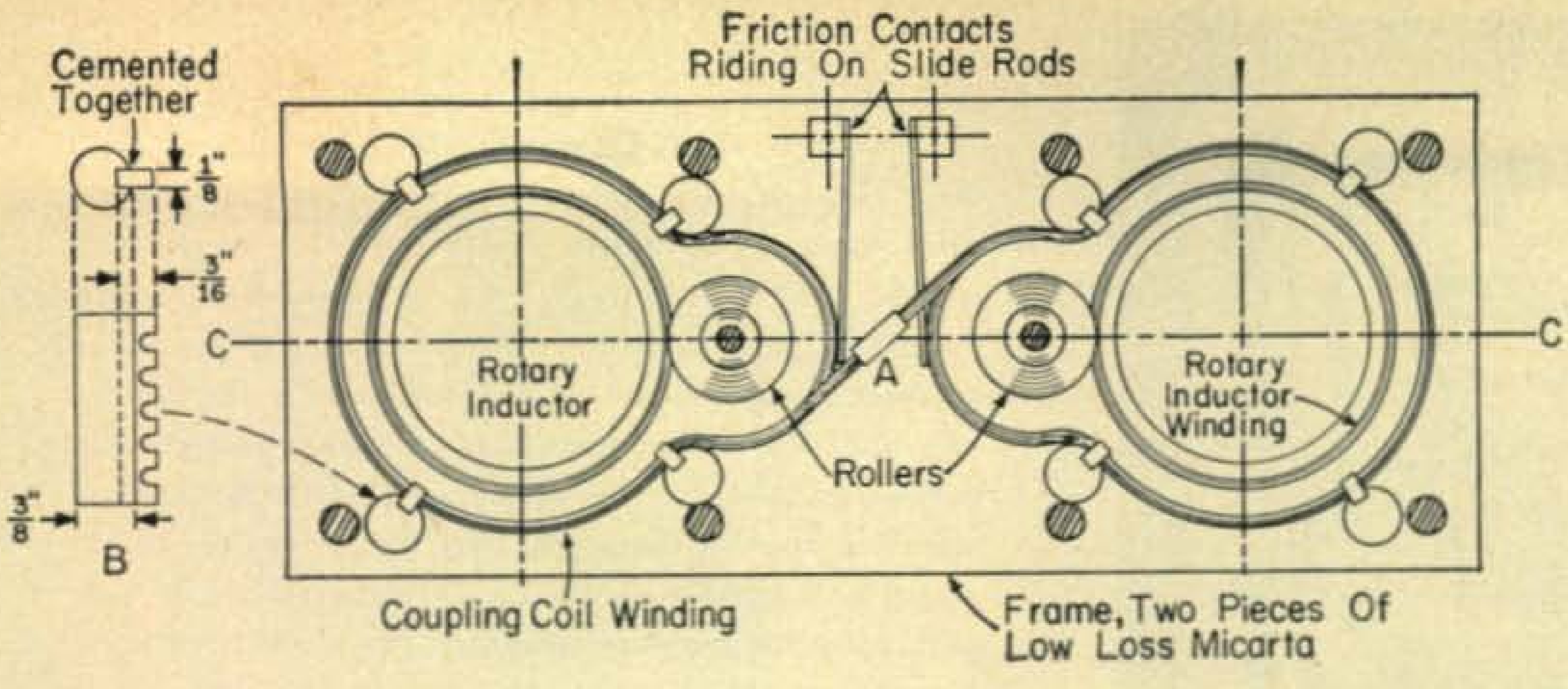


Fig. 5—This view illustrates how L_5 and L_6 are wound to allow passage over the roller contact of the rotary inductor. Both coils are joined at point A and the other ends of the inductors are fixed to the wiper contacts which ride on the slide rods. Detail B illustrates the method of mounting the five turn links on the polystyrene spacers.

Variable Coupling

Now comes "the part that can't be done;" how to get sliding coupling coils to work with roller coils. There's nothing to it! The end of the two roller coils with the coupling coils attached looks like fig. 5. The coupling coils are simply deformed to clear the roller and are perfectly normal in other respects.

The coupling coils were made on a winding form, of the same shape that they are, out of #12 bright, tinned, soft copper wire. They should be wound so that they are same relative polarity as the coils they couple to. To help in getting this correct, visualize them as though they were wound as a continuous length in the same direction, and over the two roller coils placed end to end. Then move the two roller coils to a parallel position with half of the coupling coil winding surrounding each. The two halves of the coupling coil are still connected by the "bent turn" (detail A, fig. 5) and are phased correctly.

In obtaining variable coupling to the roller coils, the roller coil tie rods are used as mechanical slides for the insulated supporting frame of the coupling coils. Metal slide rods are used to connect to the coupling coils. The top view photograph shows the cord drive method of moving the coupling coils. The control wheel is calibrated to indicate degree of coupling. The number of turns of the coupling coil can be adjusted only by getting inside the box, but it has never been necessary to change the number in use (2 per coil) for operation from 10 through 160 meters. External means of making such a change would be next to impossible. Fortunately, the degree of coupling variation available is more than adequate to make up for fixed coupling coil turns.

The roller coils are 2" in diameter and are on 5" centers, thus providing a separation of 1½ coil diameters. Mutual coupling between them has not been a source of trouble.

Input and Output Tuning

The input and output variable capacitors are controlled from concentric dials with common knob (in and out) control. Actually, this refinement is not as convenient as the independent dials used on the bread board model.

The output padding capacitors are employed in 400 and 500 mmf steps and are 3000 w.v. (surplus) transmitting micas. They are switched in pairs, and the pairs were selected by a capacitance bridge to be within ±1 mmf of each other. Total output capacitance is about 1400/1400 mmf.

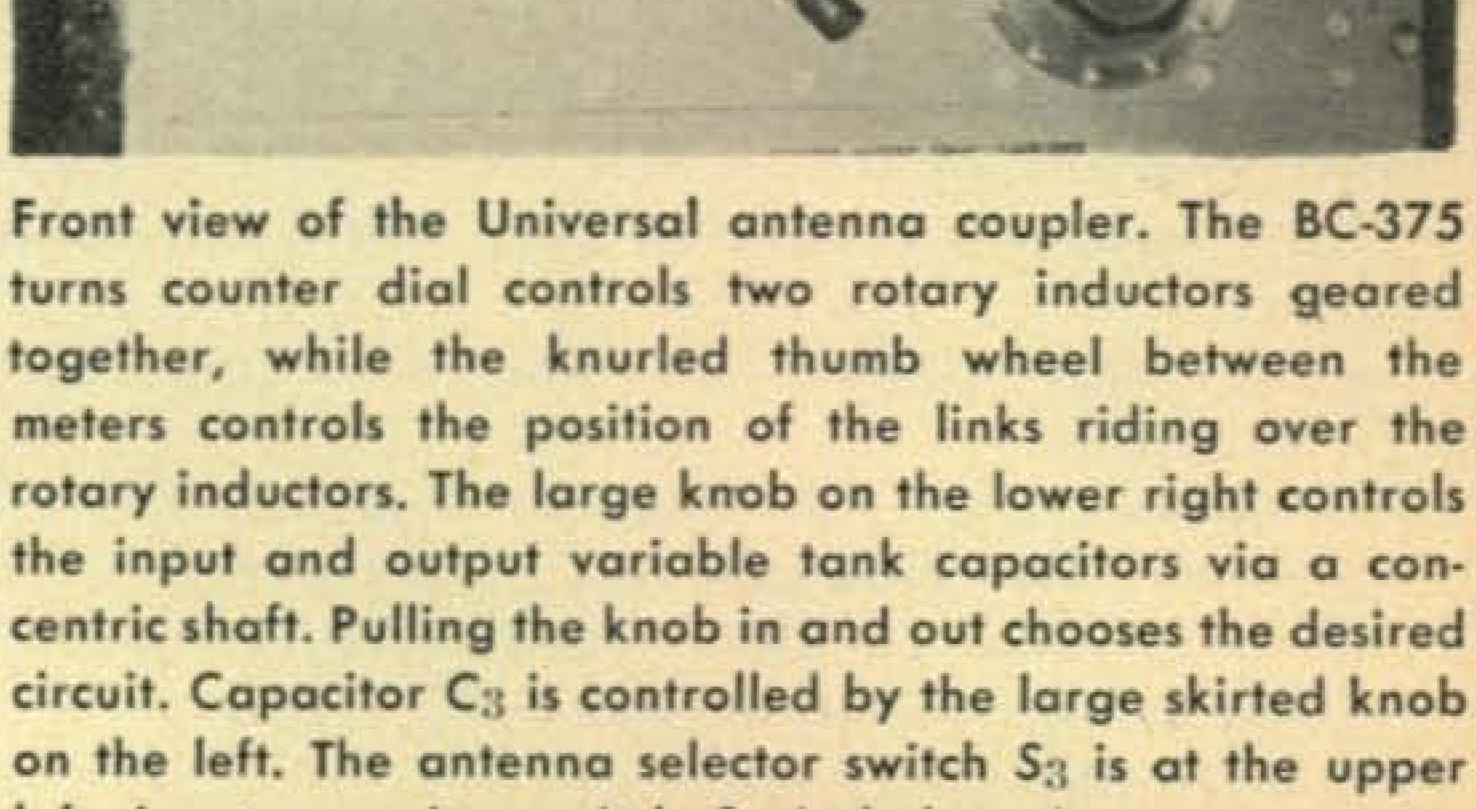
The input variable capacitor (C_1C_2) consists of two 100 mmf units, ganged. It is switched to use 2 sections in series (50 mmf), 1 section (100 mmf) or 2 sections in parallel (200 mmf). These capacitors are well clear of, and insulated from, the chassis and controls. Plate spacing is .093".

The output variable capacitors, (C_4C_5) are 500 mmf each, .045" plate spacing and coupled together mechanically.

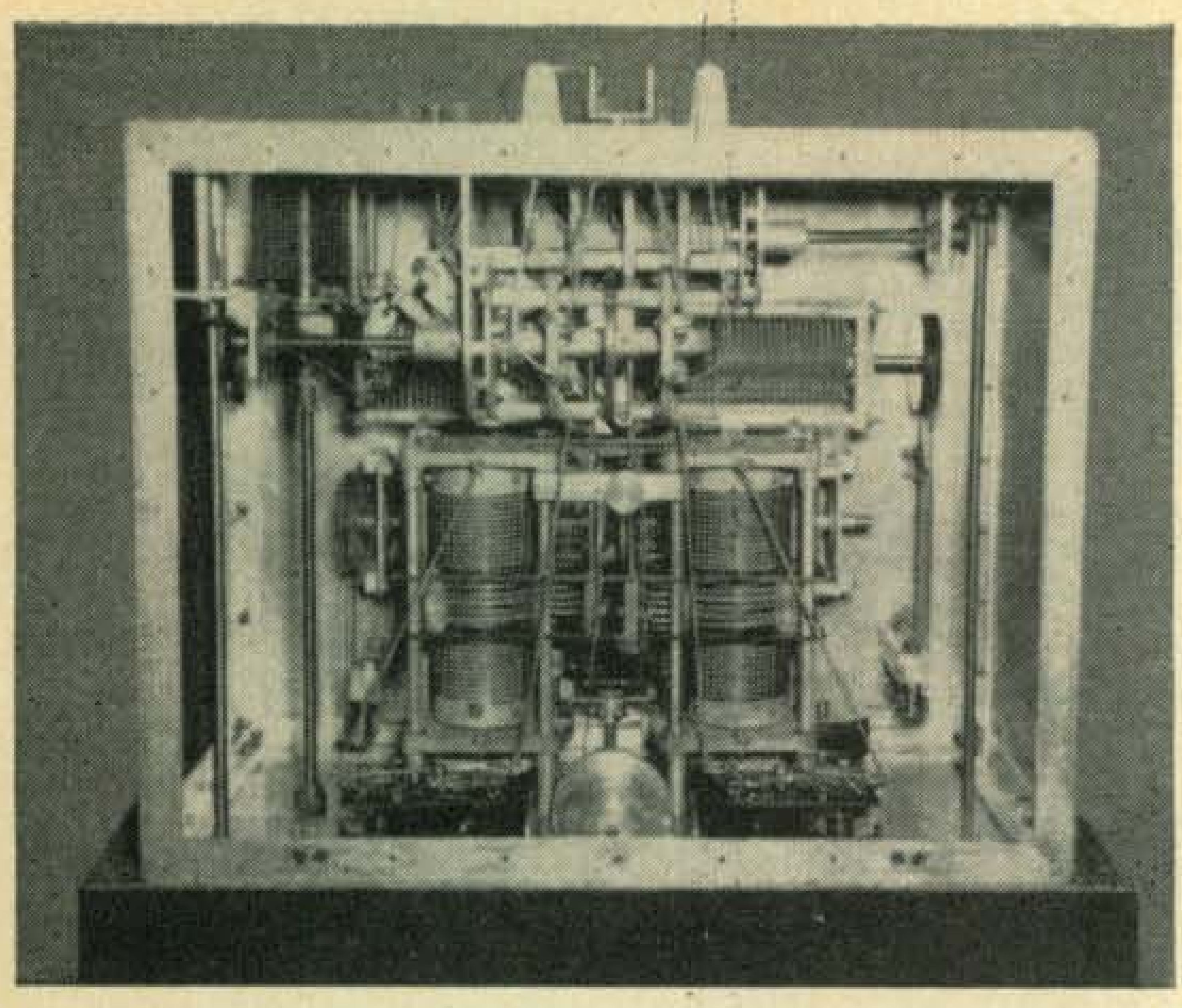
The 10 meter coils may be seen in the end-view photograph. A fortunate choice of diameter, turns and spacing permits the use of 1 turn or so of roller coil in the circuit on the 10 meter band. This is adequate to couple to the transmitter at this frequency.

R.F. Ammeters

The r.f. ammeters are 0 to 0.5 amps and have 3 steps of shunt switching from the front panel. This is a tricky thing to do. Shunts, switches and meters must be absolutely symmetrical for the meters to read the same with equal amounts of r.f. In adjusting a pi-network a very low-reading rf ammeter is



Front view of the Universal antenna coupler. The BC-375 turns counter dial controls two rotary inductors geared together, while the knurled thumb wheel between the meters controls the position of the links riding over the rotary inductors. The large knob on the lower right controls the input and output variable tank capacitors via a concentric shaft. Pulling the knob in and out chooses the desired circuit. Capacitor C_3 is controlled by the large skirted knob on the left. The antenna selector switch S_3 is at the upper left, input capacitor switch S_1 is below the turns counter dial and output capacitor switch S_2 is at the far right.



Cover Photo

Top view of the antenna tuner showing component layout and shaft placement. The large hub at the bottom, controls the sliding rack which couples L_5 and L_6 to the rotary inductors. The large ceramic rotary switch at the top selects the antenans and the wafer switch at the rear selects the output capacitors. The pulley and cords mechanism attaches to the large skirted knob on the front panel and by a push or a pull, either input or output capacitor may be selected. The relay and mica capacitors can be seen nestled under the large switch at the rear.

a help when starting to match. When the first output indication is reached, further adjustment requires a higher-range ammeter. By means of the shunts, these meters cover 0 to about 5 amps, in overlapping ranges. Silicon or germanium rectifier-type output indicators might be used instead of r.f. ammeters, and being basically linear in scale, instead of current-squared, might require less range-adjustment. This can be a troublesome output device when coupling to feeders in the presence of standing waves. It should be remembered that whenever a 500 to 1000 watt transmitter is matched to a variety of loads from 50 ohms to several thousand ohms a very wide-range output-indicating device is required.

Adjustment

Initial adjustments of such a device should be made at the lowest power input possible. A grid-dipper is helpful in the first rough settings. Calibration cards should be made of final settings at several places in each band. To return to the best match of transmitter-to coupler-to feeders is then a very simple matter.

The 350 mmf variable capacitor in the coax lead from the final amplifier is very useful in arriving at a low standing wave ratio at this point. A v.s.w.r. device, such as a Jones Micro-match, left continuously in the circuit, is strongly recommended. Life is probably much simpler without it, but its use encourages the efficient use of tubes and components in the final amplifier and it gives the low pass filter a better chance to perform its function. If a low pass filter is used (and it should be) it should be connected in the coax line from the transmitter after the v.s.w.r. device.

This tuner has been used very satisfactorily to feed:

a. 52 ohm dummy antenna, with one end grounded.
b. 52, 104, 200, 300, and 600 ohm dummy antennas with balanced feed to both ends.
c. A full sized 20 Meter beam with Tee-match, fed by buried, parallel RG-8/U, 52 ohm cables. (104 ohm feed).
d. A full size Hy-Gain 10-15-20 Meter beam with buried RG-8/U cable to the Gamma match.
e. A 120 ft. flat-top, single wire, center fed with 2" spaced feeders about 75 feet long. All bands 10 to 160 meters.
f. The same antenna, with the feeders tied together and used on 160 meters.

When used with a single wire line, the other feeder position can be grounded or not, as the operator sees fit. My experience is that it works best without the ground. When the unused position is grounded, there is current in the unused r.f. ammeter. This is annoying, and probably isn't doing any good.

There are a few miscellaneous points that are worth mentioning. This matching device is just as good for receiving as it is for transmitting, so a d.p.d.t. relay is mounted in the cabinet to transfer the coupling coil leads. The 350 mmf variable capacitor, in series with the coax from the transmitter, is used only when transmitting. About 500 mmf would probably be a better value, if there is room for it.

The antenna selector switch selects any of several coax fittings and one pair of porcelain feed-through insulators.

The coupling coils are adjusted to be close to the "cold-end" of the roller coils as indicated by the location of the roller contact. This is not difficult as calibration of the turn counter and coupling control were made so that they coincide. If coupling coils are moved beyond the roller contact, towards the "cold end," most of the coupling is then to the shorted turns on the roller coils.

There are several places where an r.f. probe may be inserted. One is to the "hot side" of the coupling coils. Others are at the r.f. ammeters ahead of the antenna selector switch.

The components and their arrangement provides the antenna tuner I have always thought of as ideal. I realize that no true amateur ever copies anything and it is therefore strongly suggested that any attempt to re-produce one of these units be nursed carefully through the breadboard stage. When possible, try mounting grounded, non-magnetic, metal sheets in similar positions to the components that the parts of the cabinet will be. In this way it will be possible to eliminate any undesirable effects before final assembly. ■