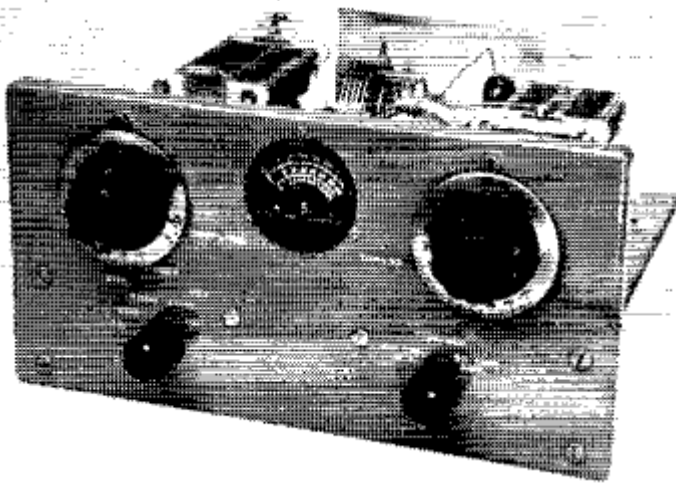
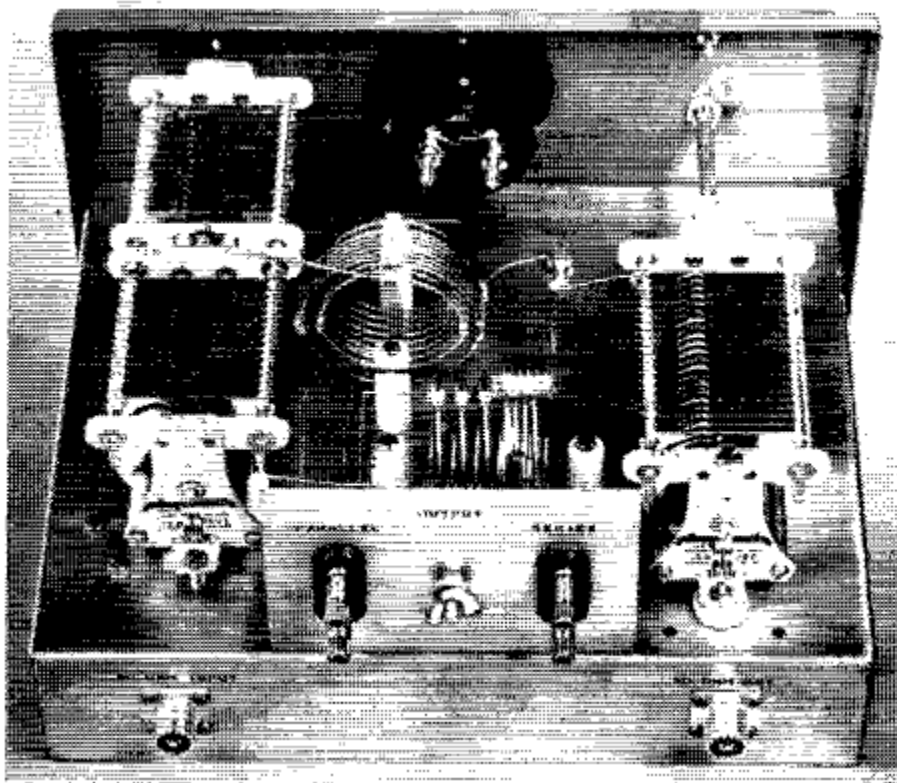


BY ALLEN W. KING,* W1CJL
QST May 1955

*Project Engineer, Harvey-Wells Electronics, Inc., Southbridge, Mass.

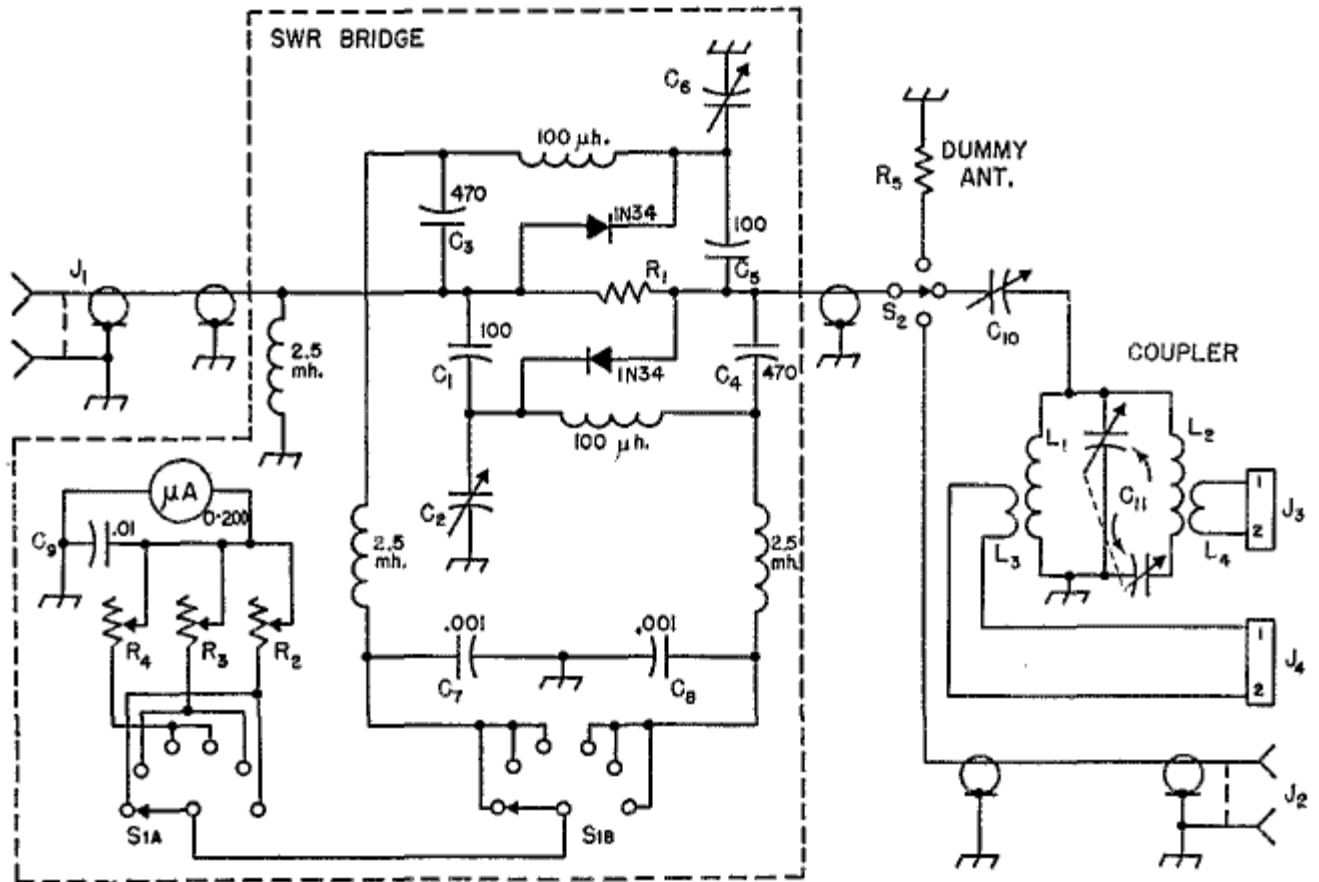


This comes close to being the ultimate in multiband antenna couplers, from the standpoint of convenience and ease of operation. Using a multiband tank in an ingenious, circuit arrangement, it offers switchless 3,5-30 Mc. operation plus quick and certain adjustment to optimum coupling by means of a built-in bridge.



When it takes more time to make frequency changes in an antenna-coupler circuit than it does in a 500 watt rig, it's high time something should be done about it. The quotation is from a 1954 QST that appeared at just about the time the "Z-match" was finished and in operation. Having been a user of allband tank circuits for the past few years, the writer had decided to attempt to use one in reverse, and some interesting results were obtained. The "Z-match" antenna coupler is designed for use with transmitters having up to 250 watts input, and will match a 50 ohm coaxial line to both reactive and nonreactive loads ranging from 10 to 2500 ohms. It covers the frequency range of 3,5 to 30 Mc. without switching coils. One of the most important features of the unit is the fact that all matching is done visually, with a Micromatch type SWR bridge. Additional features incorporated in the "Z- match" besides the allband tank circuit are a 50 ohm dummy load and a power indicating device that is left in the line at all times, reading either forward or reflected power as selected by a front-panel switch. Two output links are provided, for either low-frequency (3,5 to 7,3Mc.) output or high-frequency (14 to 30 Mc.) output. A second front-panel control is provided for the selection of various functions. The noninductive 50 ohm dummy load is connected in circuit in Position 1, while the second position switches the transmitter to the coupler proper. Position 3 switches the transmitter to a 50 ohm output connection which is independent of the coupler but allows the use of the power measuring device when feeding directly into a matched 50 ohm line. The complete schematic is shown in Fig. 1. Like most homebuilt projects, other parts can be substituted. However, care should be taken in following the layout of the unit, especially the forward and reflected power indicating device.

Construction



The "Z-match" shown in the photographs is built on an 11 3/4 x 9 1/4 x 2 1/2 inch chassis, and the panel is 12 1/4 by 6 3/4 inches. These were used because they were on hand, but any number of commercially available chassis and dust cover combinations could be used with good results. The chassis itself is used to separate the low impedance input circuits from the comparatively high Z output circuits, and no matter what size chassis is used this constructional practice should be followed. The coupling capacitor C10 is electrically above ground and is mounted on two feedthrough insulators (Johnson type 135-55), one of which is used to bring the electrical connection through the chassis to the rotor of C10. This capacitor is set back from the panel and coupled to the dial by an insulated shaft, thus eliminating body capacity. C11 is mounted at the other end of the chassis and the control is brought out through the panel with symmetry in mind. Inductors L2 and L4 are mounted near the rear output terminal panel, mainly because this is the high frequency section (14 to 30 Mc.) and over all lead length should be kept to a minimum. Coils L1 and L3 are mounted at right angles to L2 and L4 to reduce mutual coupling. The output terminal panel on the rear of the chassis has two National type FWH connectors and a wing nutted ground terminal, allowing the operator to connect either balanced or unbalanced antennas. The two output terminals (high and low frequency) could very well be one, if an antenna changeover relay was used, although separate connectors are convenient when separate antennas are used. The two rotary switches S1 and S2 are placed in a position to maintain panel symmetry, and also to keep lead lengths to a minimum for the connections to S2. As can be seen from

the photographs, the 50 ohm dummy load is mounted on standard fuse clips and the "hot" end is kept as close to the ceramic switch S2 as possible. The dummy load has been insulated from the chassis at the hot end by a 1/4 inch thick phenolic block: however, the same feedthrough that was used on C10 could be used instead. The grounded end is raised up from the chassis merely in keeping with good constructional practice. This can be done with a metal spacer having the same height as either the phenolic block or the feedthrough type insulator, whichever is used. The rear view photograph shows the output terminals marked as "parallel" and "series". These, however, could be called "low-frequency" and "high-frequency" outputs. The thought in marking them "parallel" and "series" was that the low-frequency tank coil is parallel connected, while the high-frequency tank coil is the series circuit.

SWR bridge

The SWR bridge consists of two bridges connected back to back so that incident and reflected power may be determined. The theory and operation have been ably presented elsewhere and will not be dealt with here.[1] The incident-power bridge consists of R1, C5, C6 and the transmitter output impedance: the reflected-power bridge consists of R1, C1, C2 and the load. The output of the bridge is rectified by the crystal diodes. A DC path is provided by the RF choke. The rest of the components are used for RF filtering. R1 consists of sixteen 10 ohm 1/2-watt composition resistors in parallel. Since the bridge is designed to operate from 3 to 30 Mc., it is important that noninductive resistors be used. For best results, C1 and C5 should be of the button type. They proved to be decidedly better than silver micas. Needless to say, all lead lengths should be kept as short as possible to reduce the effects of lead inductance. The layout shown in the photograph should be followed, and since this shows the placement of parts quite clearly, constructional details will be omitted. In the initial setup of the bridge, set S2 to the dummy load position, apply RF power to the input terminal, and adjust C2 for zero deflection. Next, temporarily reverse the bridge and adjust C6 for zero deflection. Then return to the original input-output connections and the bridge is ready for calibration. A good calibration will require comparison with an already calibrated power meter, or by calculation from the RF current in the dummy load as measured by an RF ammeter connected in series with the load. The fullscale power values (three ranges are provided for) may be set by adjusting R2, R3 and R4. However, an actual power calibration is not at all necessary to the operation of the "Z-match" since the bridge will serve quite well both for adjustment of coupling and for relative power indications without calibration. The meter used in the bridge has a basic movement of 0-200 microamperes, and in this case a hand-calibrated scale was made by taking the original meter plate off and reversing it. The three scales were then hand-painted on, as the photograph shows.

[1] Jones and Sonthenner, "The Micromatch" QST, April, 1947. See, also, "Recent Equipment" p. 43, QST, March, 1955

Operation

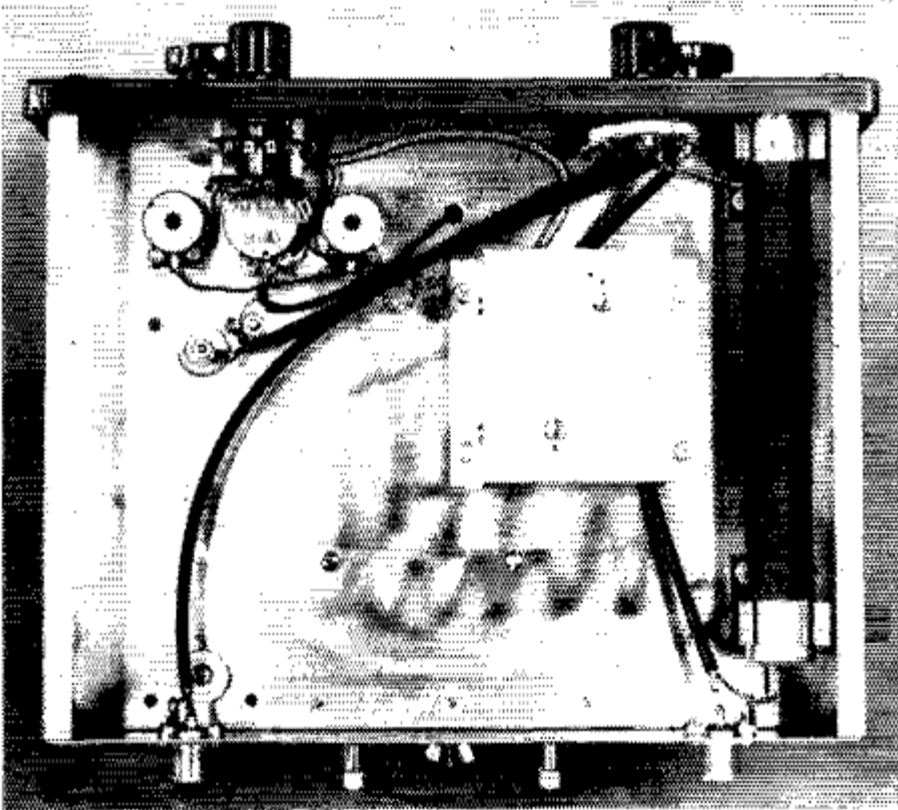
The bridge provides a visual way of adjusting the coupler, while the 50 ohm noninductive load (Global) provides a convenient load for transmitter

adjustments. Our requirements were for power inputs up to 250 watts with the transmitter terminated with 50 ohms; however, work is being done on a 70 ohm version of the "Z-match" The transmitter used here has a pi-network output circuit and this is adjusted for proper plate loading with S2 in the first position, which connects the 50 ohm dummy load. Power can be read in the forward position of the bridge on the proper scale. No reflected power will be evident with the resistive load. The proper forward reading scale on M1 should be selected by means of S1, depending on the power output of the transmitter. As can be seen from the schematic and photographs, R2, R3 and R4 set the 0-10, 0-100 and 0-1000 watt full-scale levels. Reflected power calibrations are automatically taken care of by the settings of R2, R3 and R4 when adjusted in the forward position. It might be well to note here that transmitters having outputs in excess of 50 watts should be tuned up at lower power, because the dummy load in the "Z-match" is rated at 50 watts and excessive power could ruin the resistor. However, the "on-the-air" rating of the "Z-match" is much higher than 50 watts. The antenna should be connected to the output terminals J3 or J4, depending on the frequency. S2 is then switched to the second position and C10 and C11 tuned for minimum reflected power, as read on the meter. The two controls will interlock somewhat, but a few trials will readily lead to a good null. The system is then ready for use. In testing with a wide variety of both antennas and resistive loads, the reflected power was below one watt in all cases. After this minimum or zero reflected power reading has been obtained no readjustment of the transmitter is necessary if it has previously been adjusted to work into the dummy load. The tuning capacitor C11 will be near maximum capacitance for both 3,5 and 14 Mc. operation, while the setting will be near midscale at 21 Mc. On 7 and 28 Mc., the capacitance will be nearly at minimum. The setting of C10 will vary with different loads. In the third position of S2 straight-through operation can be used, enabling the amateur with a matched 50-ohm line to use the bridge. The bridge is an excellent instrument for adjusting element lengths on a beam for lowest reflected power.

Results

The "Z-match" has been in use at the writer's station for the past several months and the results have been excellent on all hands from 3,5 to 30 Mc. Two transmitters have been used. One is a Harvey-Wells T-90 Bandmaster running between 75 and 90 watts input on both CW and phone. The second, with a pair of 4-65As in the final running inputs up to 300 watts, has been used with no apparent breakdown of capacitors, coils or the Z bridge. The first transmitter utilizes a pi-network output tank, and after tuning this properly on any band into the 50 ohm load, no retuning is necessary after the "Z-match" is tuned for minimum reflected power. The second transmitter uses an allband tank with series-tuned link output and the results were the same with this output circuit. The fact that retuning the transmitter is not required after tuning the coupler for zero reflected power indicates a definite impedance match. Although the functions of the "Z-match" have been described in terms of matching the transmission line to a coax line to the transmitter, it is equally useful for coupling the line to a receiver. The same antenna is used for both transmitting and receiving at the writer's station, and received signals have been given a tremendous boost by the use of this coupler, mainly because the receiver has a nominal input impedance of 50 ohms and its antenna terminals are finally looking at the proper impedance. The send-receive switching is of course done in the coax link. After operating conventional type antenna couplers with no visual

means of obtaining a match, we wonder how many tunes a mismatch has been tolerated. Quite often, we think, at this station, because the percentage of contacts for stations called has gone up tremendously since the installation of the "Z-match" and in the recent DX contest the speed of tuning helped in running up the best score we ever had, on both phone and CW.



Switches, input circuit, bridge and dummy antenna are below chassis. The three variable resistors at the upper left in this \lew arc adjusted for proper power calibration of the bridge and thereafter left set. The Globar resistor used as a dummy antenna is along the right-hand edge.

Panel view of the "Z-match" antenna coupler. Incorporating a built-in bridge for forward and reflected power and a dummy antenna, it uses a multiband tank in a new circuit arrangement for matching the usual run of transmission-line loads to a coaxial link.

The multiband tank circuit consists of the split-stator capacitor at the left and the two inductors, with links, in the center. Coupling is controlled by the tank and the capacitor at the right. The two terminal assemblies connect to the two link coils.

- C1, C5 — Erie button type or equivalent.
- C2, C6 — Tubular-type variable, 0,5-5 pf, (Erie type 532-08).
- C3, C4 — Mica or ceramic.
- C7, C8, C9 — Disk ceramic.

C10 — 340 pf. variable (Bud 1529).
C11 — 250 pf. per section variable (Bud 1556)
R1 — 0,625 ohm, 8 watts (sixteen 10 ohm, 1/2 watt composition resistors in parallel).
R2 — 2,5 kOm carbon potentiometer.
R3 — 25 kOm carbon potentiometer.
R4 — 50 kOm carbon potentiometer.
R5 — 50 ohms, 50 watts (GE Global type CX).
L1 — 3,4 uH.; 7 3/4 turns No. 14, 2 1/16-inch diam. 1 1/4 inches long.
L2 — 1,7 uH.; 5 1/2 turns No.14, 2 1/16-inch diam., 1 5/8 inches long.
L3 — 2,35 uH; 6 1/2 turns, No.14, 2 5/8 -inch diam., 5/8 inch long.
L4 — 1,8 uH.; 4 3/4 turns, No.14, 2 5/8-inch diam., 1/2 inch long.
J1, J2 — Coaxial connectors.
J4, J4 — Binding-post assemblies (National type FWH).
S1 — Rotary switch, 2 poles, 6 positions (bakelite wafer).
S2 — Rotary switch, 1 pole, 3 positions, shorting (ceramic wafer).

The bridge assembly. The circuit arrangement is made symmetrical for the purpose of reducing the effects of stray capacitance and inductance. The resistors in the center (R1) are assembled in the form of a cylinder supported by soldering their leads to circular pieces of wire. This reduces inductance and tends to assure uniform current distribution throughout the assembly.

***The "Z-Match" Antenna Coupler
Impedance Matching the Easy Way***

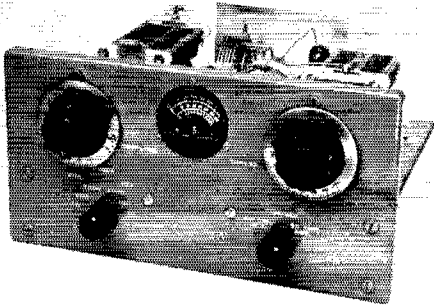
***BY ALLEN W. KING,* W1CJL
QST May 1955***

The "Z-Match" Antenna Coupler

Impedance Matching the Easy Way

BY ALLEN W. KING,* WICJL

"WHEN it takes more time to make frequency changes in an antenna-coupler circuit than it does in a 500-watt rig, it's high time something should be done about it." The quotation is from a 1954 *QST* that appeared at just about the time the "Z-match" was finished and in operation. Having been a user



Panel view of the "Z-match" antenna coupler. Incorporating a built-in bridge for forward and reflected power and a dummy antenna, it uses a multiband tank in a new circuit arrangement for matching the usual run of transmission-line loads to a coaxial link.

of all-band tank circuits for the past few years, the writer had decided to attempt to use one in reverse, and some interesting results were obtained.

The "Z-match" antenna coupler is designed for use with transmitters having up to 250 watts input, and will match a 50-ohm coaxial line to both reactive and nonreactive loads ranging from

* Project Engineer, Harvey-Wells Electronics, Inc., Southbridge, Mass.

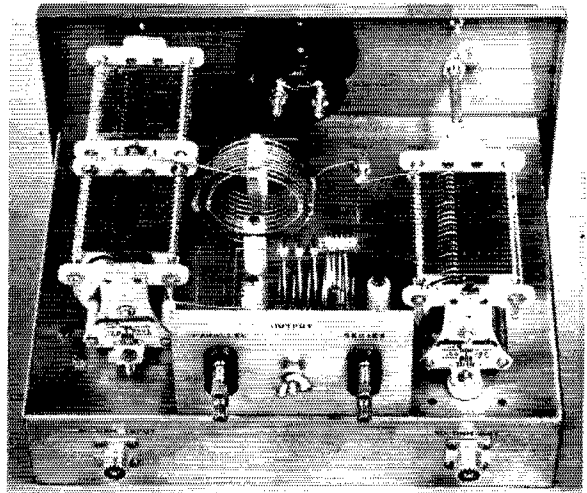
The multiband tank circuit consists of the split-stator capacitor at the left and the two inductors, with links, in the center. Coupling is controlled by the tank and the capacitor at the right. The two-terminal assemblies connect to the two link coils.

• This comes close to being the ultimate in multiband antenna couplers, from the standpoint of convenience and ease of operation. Using a multiband tank in an ingenious circuit arrangement, it offers switchless 3.5-30-Mc. operation plus quick and certain adjustment to optimum coupling by means of a built-in bridge.

10 to 2500 ohms. It covers the frequency range of 3.5 to 30 Mc. without switching coils. One of the most important features of the unit is the fact that all matching is done visually, with a Micromatch type s.w.r. bridge.

Additional features incorporated in the "Z-match" besides the all-band tank circuit are a 50-ohm dummy load and a power-indicating device that is left in the line at all times, reading either forward or reflected power as selected by a front-panel switch. Two output links are provided, for either low-frequency (3.5 to 7.3 Mc.) output or high-frequency (14 to 30 Mc.) output. A second front-panel control is provided for the selection of various functions. The noninductive 50-ohm dummy load is connected in circuit in Position 1, while the second position switches the transmitter to the coupler proper. Position 3 switches the transmitter to a 50-ohm output connection which is independent of the coupler but allows the use of the power-measuring device when feeding directly into a matched 50-ohm line.

The complete schematic is shown in Fig. 1. Like most homebuilt projects, other parts can be substituted. However, care should be taken in



following the layout of the unit, especially the forward- and reflected-power indicating device.

Construction

The "Z-match" shown in the photographs is built on an $11\frac{3}{4} \times 9\frac{1}{4} \times 2\frac{1}{2}$ -inch chassis, and the panel is $12\frac{1}{4}$ by $6\frac{3}{4}$ inches. These were used because they were on hand, but any number of commercially-available chassis and dust-cover combinations could be used with good results.

The chassis itself is used to separate the low-impedance input circuits from the comparatively high-Z output circuits, and no matter what size chassis is used this constructional practice should be followed. The coupling capacitor C_{10} is electrically above ground and is mounted on two feed-through insulators (Johnson type 135-55), one of which is used to bring the electrical connection through the chassis to the rotor of C_{10} . This capacitor is set back from the panel and coupled to the dial by an insulated shaft, thus eliminating body capacity. C_{11} is mounted at the other end of the chassis and the control is brought out through the panel with symmetry in mind. Inductors L_2 and L_4 are mounted near the rear output terminal panel, mainly because this is the high-frequency section (14 to 30 Mc.) and over-all lead length should be kept to a minimum. Coils L_1 and L_3 are mounted at right

angles to L_2 and L_4 to reduce mutual coupling.

The output terminal panel on the rear of the chassis has two National type FWH connectors and a wing-nutted ground terminal, allowing the operator to connect either balanced or unbalanced antennas. The two output terminals (high and low frequency) could very well be one, if an antenna changeover relay was used, although separate connectors are convenient when separate antennas are used.

The two rotary switches S_1 and S_2 are placed in a position to maintain panel symmetry, and also to keep lead lengths to a minimum for the connections to S_2 . As can be seen from the photographs, the 50-ohm dummy load is mounted on standard fuse clips and the "hot" end is kept as close to the ceramic switch S_2 as possible. The dummy load has been insulated from the chassis at the hot end by a $\frac{1}{4}$ -inch-thick phenolic block; however, the same feed-through that was used on C_{10} could be used instead. The grounded end is raised up from the chassis merely in keeping with good constructional practice. This can be done with a metal spacer having the same height as either the phenolic block or the feed-through type insulator, whichever is used.

The rear-view photograph shows the output terminals marked as "parallel" and "series." These, however, could be called "low-frequency"

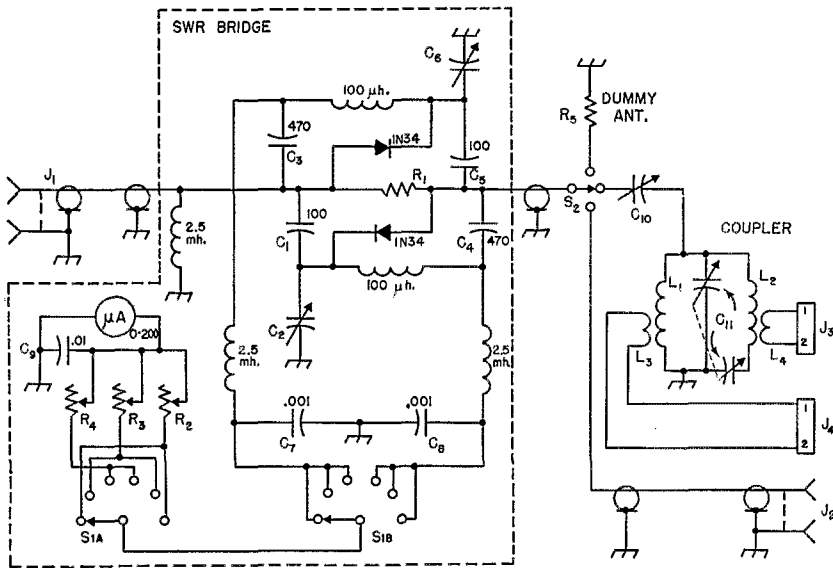
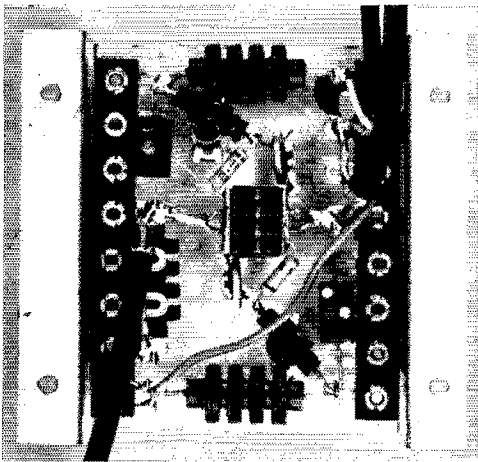


Fig. 1 — Circuit diagram of the "Z-match."

- C_1, C_5 — Erie button type or equivalent.
- C_2, C_6 — Tubular-type variable, 0.5-5 μf . (Erie type 532-08).
- C_3, C_4 — Mica or ceramic.
- C_7, C_8, C_9 — Disk ceramic.
- C_{10} — 340- μf . variable (Bud 1529).
- C_{11} — 250- μf .-per-section variable (Bud 1556).
- R_1 — 0.625 ohm, 8 watts (sixteen 10-ohm $\frac{1}{2}$ -watt composition resistors in parallel).
- R_2 — 2500-ohm carbon potentiometer.
- R_3 — 25,000-ohm carbon potentiometer.
- R_4 — 50,000-ohm carbon potentiometer.
- R_5 — 50 ohms, 50 watts (GE Global type CX).
- L_1 — 3.4 μh .; 7 $\frac{3}{4}$ turns No. 14, 2 1/16-inch diam.,

- 1 $\frac{1}{4}$ inches long.
- L_2 — 1.7 μh .; 5 $\frac{1}{2}$ turns No. 11, 2 1/16-inch diam., 1 $\frac{5}{8}$ inches long.
- L_3 — 2.35 μh .; 6 $\frac{1}{2}$ turns No. 11, 2 $\frac{5}{8}$ -inch diam., 5 $\frac{1}{4}$ inch long.
- L_4 — 1.8 μh .; 13 $\frac{1}{4}$ turns No. 11, 2 $\frac{5}{8}$ -inch diam., 1 $\frac{1}{2}$ inch long.
- J_1, J_2 — Coaxial connectors.
- J_3, J_4 — Binding-post assemblies (National type FWH).
- S_1 — Rotary switch, 2 poles, 6 positions (bakelite wafer).
- S_2 — Rotary switch, 1 pole, 3 positions, shorting (ceramic wafer).



The bridge assembly. The circuit arrangement is made symmetrical for the purpose of reducing the effects of stray capacitance and inductance. The resistors in the center (R_1) are assembled in the form of a cylinder supported by soldering their leads to circular pieces of wire. This reduces inductance and tends to assure uniform current distribution throughout the assembly.

and "high-frequency" outputs. The thought in marking them "parallel" and "series" was that the low-frequency tank coil is parallel connected, while the high-frequency tank coil is the series circuit.

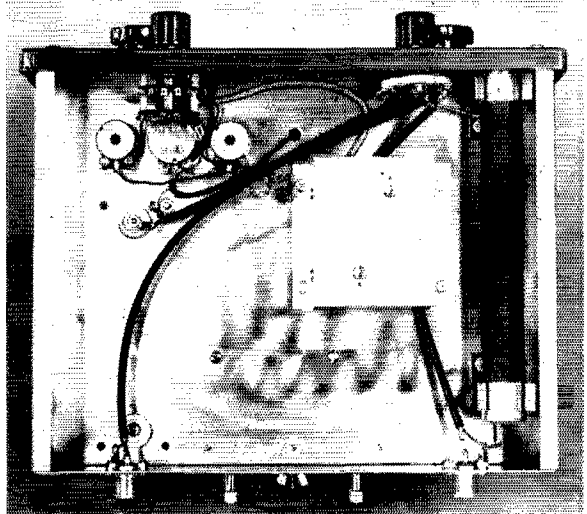
S. W. R. Bridge

The s.w.r. bridge consists of two bridges connected back to back so that incident and reflected power may be determined. The theory and operation have been ably presented elsewhere and will not be dealt with here.¹

The incident-power bridge consists of R_1 , C_5 , C_6 and the transmitter output impedance; the reflected-power bridge consists of R_1 , C_1 , C_2 and the load. The output of the bridge is rectified by

¹Jones and Sontheimer, "The Micromatch," *QST*, April, 1947. See, also, "Recent Equipment," p. 43, *QST*, March, 1955.

Switches, input circuit, bridge and dummy antenna are below chassis. The three variable resistors at the upper left in this view are adjusted for proper power calibration of the bridge and thereafter left set. The Globar resistor used as a dummy antenna is along the right-hand edge.



the crystal diodes. A d.c. path is provided by the r.f. choke. The rest of the components are used for r.f. filtering.

R_1 consists of sixteen 10-ohm $\frac{1}{2}$ -watt composition resistors in parallel. Since the bridge is designed to operate from 3 to 30 Mc., it is important that noninductive resistors be used. For best results, C_1 and C_5 should be of the button type. They proved to be decidedly better than silver micas. Needless to say, all lead lengths should be kept as short as possible to reduce the effects of lead inductance. The layout shown in the photograph should be followed, and since this shows the placement of parts quite clearly, constructional details will be omitted.

In the initial set-up of the bridge, set S_2 to the dummy load position, apply r.f. power to the input terminal, and adjust C_2 for zero deflection. Next, temporarily reverse the bridge and adjust C_6 for zero deflection. Then return to the original input-output connections and the bridge is ready for calibration. A good calibration will require comparison with an already-calibrated power meter, or by calculation from the r.f. current in the dummy load as measured by an r.f. ammeter connected in series with the load. The full-scale power values (three ranges are provided for) may be set by adjusting R_2 , R_3 and R_4 . However, an actual power calibration is not at all necessary to the operation of the "Z-match," since the bridge will serve quite well both for adjustment of coupling and for relative power indications without calibration.

The meter used in the bridge has a basic movement of 0-200 microamperes, and in this case a hand-calibrated scale was made by taking the original meter plate off and reversing it. The three scales were then hand-painted on, as the photograph shows.

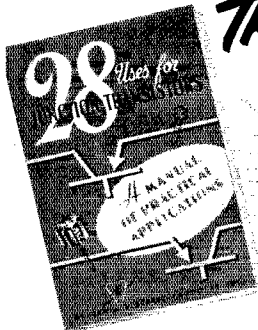
Operation

The bridge provides a visual way of adjusting the coupler, while the 50-ohm noninductive load

(Continued on page 116)

NEW!

"28 Uses for JUNCTION TRANSISTORS"



Only 25¢

Build your own TRANSISTOR DEVICES

- dynamic microphone • audio preamplifier
- five-watt audio amplifier • multivibrator
- 100 KC oscillator • DC voltmeter
- field strength meter

You'll find complete instructions for these and many other equally useful transistorized devices in Sylvania's new booklet.

This new booklet is a must for anyone interested in getting a firsthand practical understanding of the transistor. Each of the circuits has been designed by Sylvania engineers, built around Sylvania transistors and tested in Sylvania Laboratories to give you a compilation of practical transistor data. Circuit descriptions are preceded by a full, referenced chapter on Transistor Theory.

Pick up your copy at your Sylvania Distributor—or send 25¢ in coin with this coupon.



SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC.
1100 Main Street, Buffalo 9, N. Y.

SYLVANIA ELECTRIC PRODUCTS INC.
1100 Main Street, Buffalo 9, N. Y.

Enclosed is 25¢ in coin for my copy of *28 Uses of Junction Transistors*.

Name _____

Address _____

City _____ Zone _____ State _____

Results

The "Z-match" has been in use at the writer's station for the past several months and the results have been excellent on all bands from 3.5 to 30 Mc. Two transmitters have been used. One is a Harvey-Wells T-90 Bandmaster running between 75 and 90 watts input on both c.w. and 'phone. The second, with a pair of 4-65As in the final running inputs up to 300 watts, has been used with no apparent breakdown of capacitors, coils or the Z bridge. The first transmitter utilizes a pi-network output tank, and after tuning this properly on any band into the 50-ohm load, no retuning is necessary after the "Z-match" is tuned for minimum reflected power. The second transmitter uses an all-band tank with series-tuned link output and the results were the same with this output circuit. The fact that retuning the transmitter is not required after tuning the coupler for zero reflected power indicates a definite impedance match.

Although the functions of the "Z-match" have been described in terms of matching the transmission line to a coax line to the transmitter, it is equally useful for coupling the line to a receiver. The same antenna is used for both transmitting and receiving at the writer's station, and received signals have been given a tremendous boost by the use of this coupler, mainly because the receiver has a nominal input impedance of 50 ohms and its antenna terminals are finally looking at the proper impedance. The send-receive switching is of course done in the coax link.

After operating conventional-type antenna couplers with no visual means of obtaining a match, we wonder how many times a mismatch has been tolerated. Quite often, we think, at this station, because the percentage of contacts for stations called has gone up tremendously since the installation of the "Z-match," and in the recent DX contest the speed of tuning helped in running up the best score we ever had, on both 'phone and c.w.

Mobile Antenna Tuning

(Continued from page 18)

completed unit is ready for testing and adjustment. With all turns of the variable series antenna inductor removed (tap at top of L_1 in Fig. 4), the externally-mounted loading coil (center or base) should be adjusted for resonance at the extreme high end of the band in use. This adjustment will place the transmitter and the antenna system on precisely the same frequency. Temporarily disconnect the tuning motor from the control unit. Adjust balance control R_1 to its electrical center position, and adjust the sensitivity control to the point where both relays K_1 and K_2 (Fig. 3) are operated, as evidenced by illumination of both indicator lamps, I_1 and I_2 . Then slowly back off the sensitivity control until either one or both relays deenergize. If both relays

(Continued on page 120)