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QST Issue: Oct 1980
Title: Reflectometer For Twin-Lead, A
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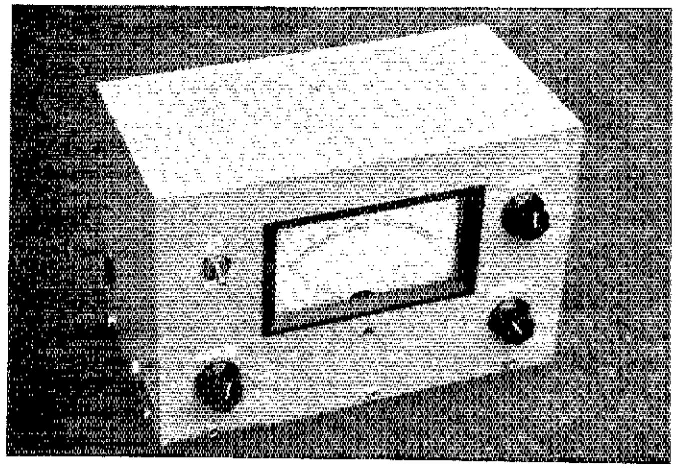
A Reflectometer for Twin-Lead

This instrument measures SWR directly on 300-ohm transmission lines from 3.5 to 450 MHz.



By Fred Brown,* W6HPH

Despite its unpopularity, twin-lead is not really bad stuff. Compared to almost any kind of flexible coaxial line, twin-lead has lower loss per unit length (when dry) and is also considerably cheaper. It is an obvious first choice for connection to a balanced antenna or for tuned-feeder antenna systems.

Amateur literature abounds with descriptions of reflectometers for 50-ohm coaxial cable, both of the bridge type and the directional-coupler version. But the user of 300-ohm twin-lead has been neglected when it comes to accurate measurement of SWR. Although measuring twin-lead SWR through a balun is possible, two problems are usually associated with such an approach. Unless the balun is perfect, it will introduce some reflection of its own, which may add to or subtract from the reflection from the load, and thereby give a misleading result. Second, most baluns have a 4:1 transformation ratio, whereas a transformation from 300 to 50 ohms requires a 6:1 ratio.

The instrument described here is a parallel-wire directional-coupler reflectometer for 300-ohm balanced line. It works on the same principle as the old twin-lamp SWR indicator (Fig. 1A). With a low standing-wave ratio, only the lamp closest to the transmitter would light. If the twin-lamp is replaced with a properly terminated directional coupler, it will be possible to determine standing-wave ratios

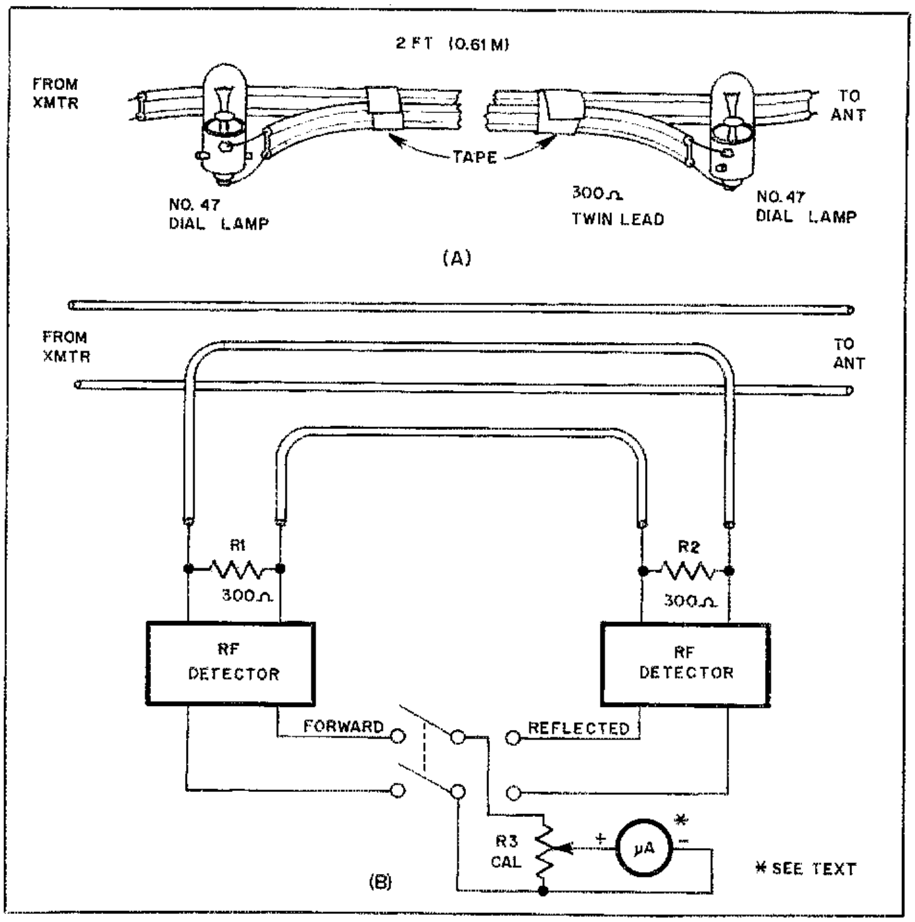


Fig. 1 — The twin-lamp SWR indicator, shown at A, is a crude form of reflectometer. With a high SWR, both lamps will light with equal brightness. With low SWR, only the lamp on the left side will be illuminated. A laboratory-type reflectometer, such as illustrated at B, is similar in principle to the twin-lamp arrangement, but yields accurate, quantitative results. The twin-lead ribbon and dial lamps have been replaced with a properly terminated directional coupler. The meter can be calibrated to read SWR directly.

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accurately by measuring the rf voltage across the 300-ohm termination (Fig. 1B). If properly constructed, the rf detector on the left will respond only to energy on the transmission line flowing from left to right. The detector on the right will give a dc output proportional to the energy propagating in the opposite direction. If the sensitivity control is adjusted for full scale reading with the switch in the *forward* position, the meter scale can be calibrated to read SWR directly with the switch in the *reverse* position, as with any reflectometer.

The Circuit

The complete schematic diagram is shown in Fig. 2. Originally it was hoped that a completely passive instrument could be built, but the 0 to 100 microammeter did not provide sufficient sensitivity for low-power measurements. Accordingly, a dc amplifier (Q1 and Q2) was incorporated. If a 0 to 10 microammeter is available (they *do* make them), the dc amplifier can be omitted. Fig. 2 shows connections for such an alternative.

In Fig. 2 the forward and reflected signals are detected by D1 and D2, respectively. The resulting dc voltage is transferred through S1 to the 500-kΩ sensitivity control. These two dc voltages are also made available to an external voltmeter by means of test-prod jacks (J1, J2 and J3) located on the side of the cabinet. A digital millivoltmeter will permit measurements with a very small amount of rf power in the transmission line, as little as 50 mW at 10 meters. Furthermore, two external meters, or one external meter in conjunction with the internal meter, will permit simultaneous observation of both forward and reflected power.

C1 and C2 in Fig. 2 are dc blocking capacitors to prevent the dc voltage from D1 reverse biasing D2. Only one of these capacitors is really needed, but two are used to maintain symmetry and balance. The two 150-ohm, quarter-watt resistors (5% tolerance) terminate the coupled line section and transfer the detected dc voltage to the isolating resistors, R1 and R2.

The dc voltage from the sensitivity control is applied to the gate of JFET Q1, a source follower, which drives the base of the common-emitter stage, Q2. This transistor is one arm of a bridge; the other arms are R3, R4 and R5 in conjunction with the three diodes, D6, D7 and D8. The diode strings, D3 through D5 and D6 through D8, are each made up of three germanium diodes in series and are used for temperature compensation. Although the resulting compensation seems nearly perfect, it was deemed prudent to locate the zero-adjustment potentiometer, R5, on the front panel for easy access.

Construction

The directional coupler should be less

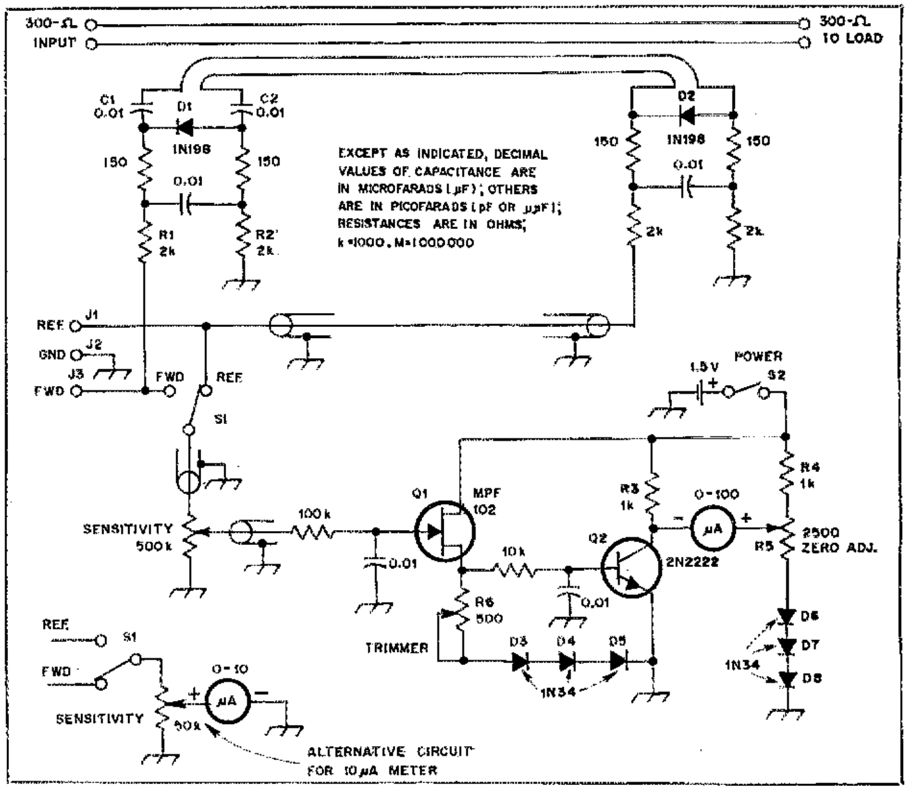


Fig. 2 — Complete circuit of the reflectometer. The dc amplifier (Q1 and Q2) is powered by a single 1.5-V cell. Current drain is about 1 mA. If a 0- to 10-μA meter is available, the dc amplifier can be omitted, as shown at the lower left.

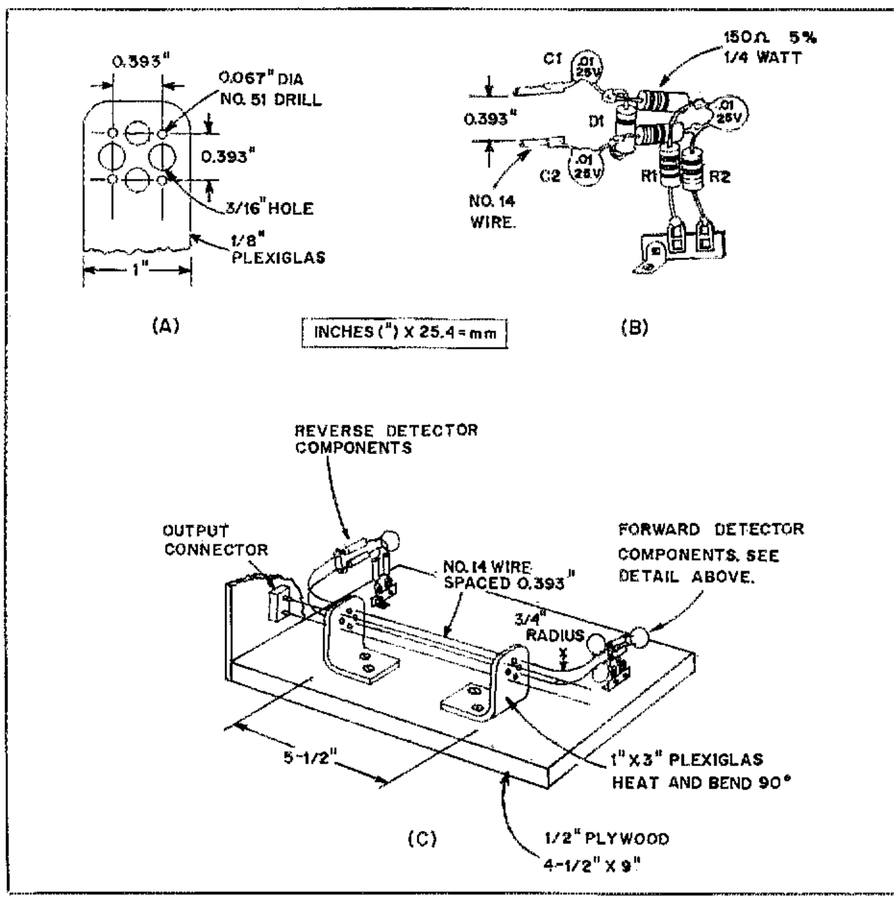


Fig. 3 — Construction details of the parallel-wire directional coupler. Drilling dimensions for the directional coupler wire-holder bracket are at A. Detail of the directional coupler at the "forward" termination end is presented at B. The "reverse" termination is identical, except for the omission of C1 and C2. With the exception of R1 and R2, all components have the shortest possible leads. The drawing at C shows the parts layout.

than a quarter-wavelength long at the highest desired operating frequency. A length of 6 inches permits operation up to 450 MHz, although a longer length would give greater sensitivity at the lower frequencies. Construction details of the directional coupler are given in Fig. 3. A wire spacing of 6.13 times the wire diameter will give the desired 300-ohm impedance. The dimensions shown are correct for no. 14 bare wire (0.064 inch or 1.63 mm dia). The four wires are held in place with brackets formed from 1/8-inch (3.18-mm) Plexiglas. The amount of dielectric material between the wires is reduced by drilling 3/16-inch (4.76-mm) holes midway between the wire holes.

Minimizing stray coupling is important. Therefore, all wiring and components should be kept at least 1 inch (25 mm) away from the directional coupler lines.

For proper termination, the detector components must have the shortest possible leads, as shown in Fig. 3. No tie points are used to mount these components. They are supported in air by the ends of the coupled line section and by resistors R1 and R2. Germanium diodes are said to be subject to damage by soldering temperatures, but the 1N198s suffered no apparent ill effects even though the 1/8-inch leads were soldered without heat sinks.

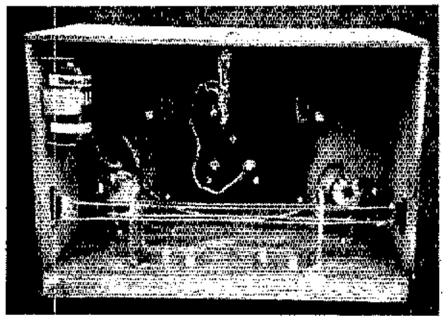
The base of the instrument is a 4-1/2- × 9-inch (115- × 230-mm) piece of 1/2-inch (13-mm) plywood. The sides and top are cut from 1/8-inch (3-mm) Plexiglas and stuck together with Super Glue. Overall height is 6 inches (152 mm). The dc amplifier components are all mounted on a 2-inch (50-mm) square piece of perfboard.

Input and output connectors are Radio Shack no. 274-342. They are not 300-ohm connectors, with the result that there is a slight impedance bump on the line. Reflection is negligible at hf, but not at 450 MHz. Uhf performance can be improved by drilling holes through the plastic between the conductors of these connectors to remove as much dielectric material as possible. A better connector combination would be the James Millen no. 37412 plug and no. 33102 socket, which are compatible with Mosley 300-ohm connectors.

Checkout and Operation

To prevent possible meter damage, a wise precaution is to disconnect the meter when the dc amplifier is first tried. Trimmer potentiometer R6 should be adjusted for a potential (with respect to ground) of about 0.8 volt on the collector of Q2. R5 should then be adjusted to give the same voltage at the wiper that existed before the meter was connected.

If the dc amplifier is working properly, a low-power source of rf can be applied to the 300-ohm input through a suitable balun. The rf coupling to the detectors is



This inside view shows the parallel-wire directional coupler built on the plywood base. The dc amplifier circuit board is located at the top center for easy access. Power for the dc amplifier is provided by the 1.5-V "C" cell held in the clip on the left sidewall. A penlight cell would be entirely adequate.

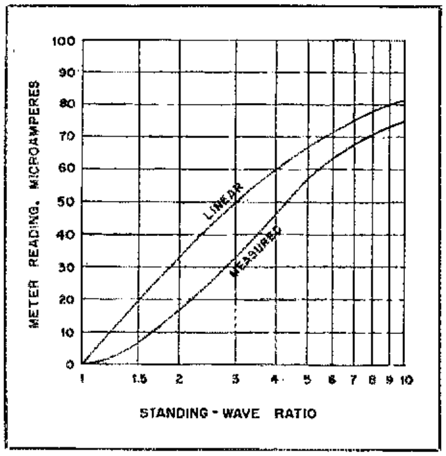


Fig. 4 — Standing-wave ratio vs. meter reading, assuming the sensitivity control is first adjusted for full-scale reading with S1 in the *forward* position. The "measured" curve was determined for the maximum sensitivity setting of the author's unit, which resulted in full-scale deflection with 115 mV dc at J3. The "linear" curve will apply if this dc potential is greater than about 0.5 V.

directly proportional to frequency, which means that every time the frequency is halved, *four* times as much rf power is required for full-scale deflection. The minimum power requirement per band is as follows: 80 meters, 12 watts; 40 meters, 3 watts; 20 meters, 0.75 watt; 10 meters, 200 milliwatts; and 2 meters, about 10 milliwatts.

With the reflectometer terminated in either an open or short circuit (infinite SWR), practically the same meter reading should be obtained with S1 in either the FORWARD or REVERSE position. A pair of 150-ohm, 2-watt resistors connected in series with short leads will make a fairly good matched load, usable from 40 through 6 meters. With such a load, the reflected meter reading should be less than one tenth the forward reading.

Linearity

The detector response to rf input voltage will be almost perfectly "square law" for detector outputs below 50 mV dc. This means the dc output will be proportional to the *square* of the rf input voltage. For dc output voltages greater than 0.5 V, the relationship between rf input and dc output will be nearly linear.

Accordingly, to measure SWR accurately, it will be necessary to know whether the detectors are operating in accordance with the square law, linearly or something in between. Usually it will be in between.

In the author's unit, full-scale deflection occurs with a dc input to Q1 of 115 mV (measured at J3). At this level, the detectors are operating near their square-law region.

The graph of Fig. 4 shows the measured value of SWR vs. meter reading for a detected output voltage from the *forward* detector of 115 mV dc. For comparison, a curve of SWR is shown, assuming the detectors are perfectly linear. Where the instrument is operating at less than full gain, the actual SWR will lie somewhere between these two curves. At detector output levels greater than 0.5 V, the linear curve should be quite accurate. The experimental curve should be accurate for a level near 100 to 120 mV, measured at J3. At lower detector output voltages, the actual SWR will be slightly higher than that shown by the experimental curve. QST

RALPH M. HEINTZ, W6RH

QST sadly announces the passing of Ralph M. Heintz, W6RH, who was 88 years old when he died in May. The firm of Heintz and (Jack) Kaufman was famous for transmitter design and transmitting vacuum tubes. In its lobby W1AW proudly displays an "H & K" TPTG transmitter, featuring a pair of 204As, that was used at W1MK until a flood messed it up and prompted the building of W1AW in Newington. Heintz and Kaufman were also the founders of the commercial wireless company Globe Wireless.

A leader in the scientific world, Ralph was the genius behind many of the electronic developments we now take for granted. His expert talents, however, were not limited to just radio and electronics — he patented a stratified-charge automobile engine that featured greater gas economy and cleaner combustion. Honda presently uses an engine based on these principles. A keen insight and understanding of the needs of surgeons led him to the development of specialized instruments for use in eye surgery. This outstanding man, with over 200 patents to his credit, was honored in 1976 when the San Francisco Patent Law association named Ralph Heintz "The Inventor of the Year."