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Author: Frank Van Zant, K7IBA

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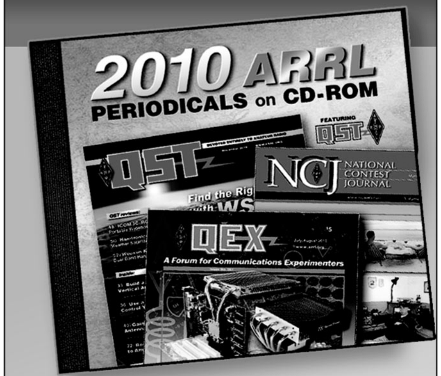

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Technical Correspondence

Conducted By Paul K. Pagel, N1FB
Associate Technical Editor

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HIGH-POWER OPERATION WITH THE TANDEM MATCH DIRECTIONAL COUPLER

☐ In January 1987 *QST*, John Grebenkemper, KI6WX, described a wattmeter that he calls the Tandem Match.[1] In April 1988 *QST*, Zack Lau, KH6CP, described a directional-coupler circuit based on the same principle as Grebenkemper's circuit—that he uses in a QRP transceiver.[2] The main advantage of Lau's circuit is a very low parts count.

This directional-coupler circuit has several advantages over the more-common Bruene directional coupler:[3] It is simpler to build, requires fewer parts and is self-balancing. Also, compensating/balancing capacitors are not needed at the input and output of the coupler. (These capacitors are required in the Bruene circuit to achieve deep nulls for accurate 50-Ω reflected-power measurement.)

In his article, Grebenkemper also described a complex log-antilog amplifier for use with the directional-coupler circuit to provide good measurement accuracy. I wanted to get away from this complex circuit, but still retain reasonable measurement accuracy over the 1- to 1500-W range. I was also willing to forfeit the SWR-computation feature.

The coupler described by Zack Lau uses ferrite toroids. Therein lies a major problem: This coupler works great at low power levels; but with high power, the ferrite toroids heat excessively, causing erratic meter readings and the potential for burned parts.

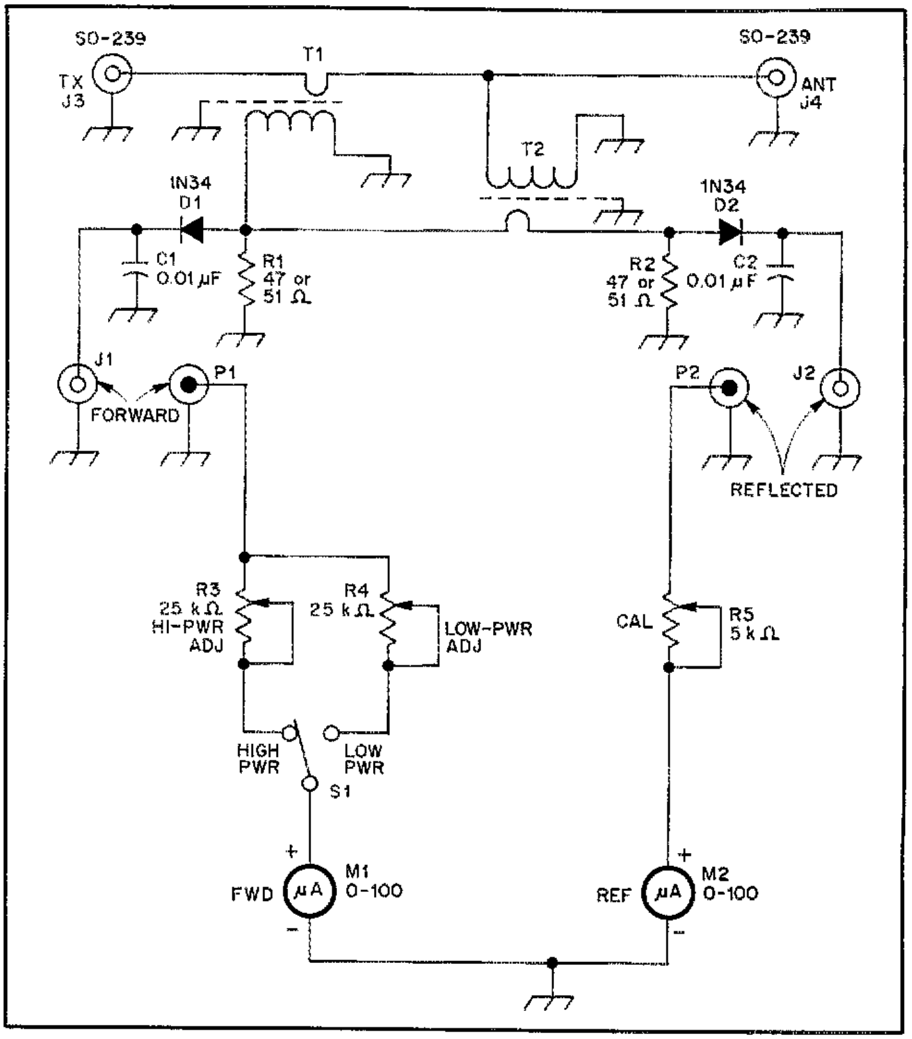

Fig 1—Schematic diagram of the high-power directional coupler. D1 and D2 are germanium diodes (1N34 or equiv). R1 and R2 are 47- or 51-Ω, ½-W resistors. C1 and C2 have 500-V ratings. The secondary windings of T1 and T2 each consist of 40 turns of no. 26 to 30 enameled wire on T-68-2 powdered-iron toroid cores. If the coupler is built into an existing antenna tuner, T1's primary can be part of the tuner's coaxial output line. The remotely located meters (M1 and M2) are connected to the coupler box at J1 and J2 via P1 and P2.

The Revised Design

To solve the problems caused by using ferrite toroids at high power levels, I used powdered-iron toroids for the pickup transformers in my version of Zack Lau's basic circuit. The number of turns of wire on the powdered-iron toroid is increased to compensate for the lower permeability of the powdered iron. Increasing the number of secondary turns on these transformers ensures that the windings have a high enough impedance to operate properly on 160 and 80 meters, and do not short circuit the high-power signal path.

I decided to use two meters, one for forward power and one for reflected power, each using the same scales. For this purpose, I bought two 100-µA meters[4] with scales that were already calibrated for 0 to 150 W and 0 to 1500 W. See Fig 1. The outputs from germanium (1N34) detector diodes D1 and D2 provide fairly accurate meter readings, particularly if the meter is calibrated to coincide with the transmitter power output (using R3, R4 and R5) at midscale meter readings. If the winding sense of the turns of the toroidal transformers is reversed, the meter readings are also reversed (the forward-power meter becomes the reflected-power meter, and vice versa).

Construction

Fig 2 shows the physical layout of the coupler. The pickup unit is mounted in a 3.5 × 3.5 × 4-inch box, and the meters, PC-mount potentiometers and HIGH/LOW power switch are mounted in a separate box or a compartment in an antenna tuner. Parts for this project are available from the suppliers listed in Table 1.

The pickup transformers are wound on T-68-2 powdered-iron toroid cores. The secondary windings consist of 40 turns (per core) of no. 26 to 30 enameled wire. Spread the turns evenly around each core. The transformers are each mounted on short sections of RG-8 coaxial cable, which act as the primary windings of the transformers. The RG-8 leads use electrostatic Faraday shields that are grounded at one end only. (The shield is simply the copper braid of the coax, appropriately trimmed to suit this need). The shield is wrapped with fiberglass tape.[5] An excellent alternative to fiberglass tape—with even higher

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Table 1

Parts Suppliers

Amidon Associates, 12033 Otsego St, North Hollywood, CA 91607 (toroid cores, fiberglass tape).

Fair Radio Sales, PO Box 1105, Lima, OH 45802 (meters).

Palomar Engineers, PO Box 455, Escondido, CA 92025 (toroid cores).

Radio Shack® stores (misc parts).

RADIOKIT, PO Box 973, Pelham, NH 03076 (misc parts, toroid cores).

Surplus Sales of Nebraska, 1315 Jones St, Omaha, NE 68102 (0-150/1500-W-scale meters, A&M model no. 255-138, approx $10 each).

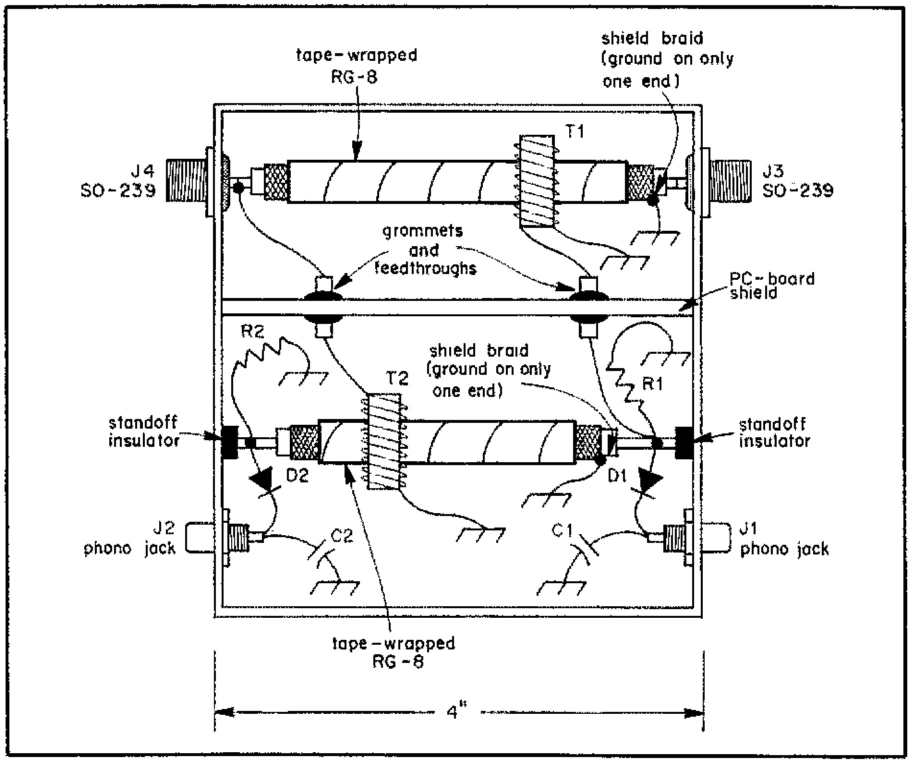

Fig 2—Directional-coupler construction details. Grommets or standoff insulators can be used to route the secondary windings of T1 and T2 through the PC-board shield. A 3.5 × 3.5 × 4-inch box serves as the enclosure.

RF voltage-breakdown characteristics—is ordinary plumber's Teflon® pipe tape, available at most hardware stores.

By using no. 26 to 30 wire on the cores, the cores slip over the tape-wrapped RG-8 lines. With no. 26 wire on the toroids, a single layer of tape (slightly more with Teflon tape) over the Faraday shield provides an extremely snug fit for the core. Use care in fitting the cores onto the RG-8 assemblies. See Fig 2 for guidance.

The primary winding for T1 is a 3½-inch length of RG-8. This lead carries the high-power RF from the input to the output of the pickup box. The RG-8 is stripped of its outer insulation and part of its shield braid. A section is cut out of the cable dielectric to expose the inner conductor where one end of T2's multiturn winding is connected. This connection can be made at J4, if it is convenient to do so.

A length of the shield braid is left on the coax. Solder a ground lug to one end of a short piece of tinned no. 22 copper wire. Then, wrap the other end of this wire around the braid of the coax, and solder the connection. The Faraday shield formed by the remaining braid is then wrapped with a layer of fiberglass or Teflon tape, and the toroid core, T1, is slipped over it. The ends are then soldered to coaxial jacks J3 and J4. If the coupler is mounted in an existing antenna tuner, T1's primary can be the output coaxial cable in the tuner, and you don't need to add jacks at J3 and J4.

Mount a PC-board shield in the center of the box between T1 and T2 to minimize coupling between the transformers. T2 is mounted similarly to T1. T2's primary is made of a piece of RG-8 suspended at each end by standoff insulators. T2's core is mounted over a tape-wrapped electrostatic shield that is grounded at one end. After the toroids are mounted on the RG-8 sections, they can be coated with polystyrene Q-dope, or a spot or two of RTV sealant to hold the windings in place on the core and to hold the cores to the RG-8 primary windings.

Tune Up and Operation

The coupler has excellent directionality. The meters can be calibrated for various power levels by using an RF ammeter in series with a 50-Ω dummy load. Calculate I^2R for each power level, and mark the meter faces accordingly. R3, R4 and R5 can be used to adjust the meter readings within the ranges. Nonlinearities in the diodes are thus taken into account, and the signal-processing amplifier circuit of the January 1987 article is not needed for relatively accurate power readings.

The coupler circuit and physical configuration are reliable. Start the tune-up process using about 10 W, adjust the antenna tuner for a 1:1 SWR (no reflected power), and increase power while adjusting the tuner to maintain minimum reflected power. I made up a tune-up chart for each of my antennas to make initial tune up easy, quick and safe.

I built the circuit described here into several antenna tuners with good success. I tested the bridge on 160 meters at 1.5-kW output, and it worked well. On the 80-through 10-meter bands, I used between 1.2- and 1.5-kW output, and the circuit worked fine. I could easily tune the antenna for a 1:1 SWR using the null indication provided.

The wattmeter's null readings that corresponded to amplifier-tuning settings for a 50-Ω output, as confirmed by a 50-Ω dummy load, were in close agreement. Checks with a Palomar noise bridge and a Heath® Antenna Scope also verified these findings. This circuit should handle more than 1.5 kW, *as long as the SWR on the feed line through the wattmeter is kept at or near 1:1.*

The only problem I encountered occurred on one occasion when the antenna tuner was not coupled to a load. Naturally, the SWR was extremely high, and the output transformer's secondary winding opened like a fuse when transmitter power was applied. This happened because of the excessively high voltage coupled into T2's secondary winding from the primary line. This damage was easily and quickly repaired.—*Frank Van Zant, KL7IBA, 2424 Virgo Dr, Colorado Springs, CO 80906*

Notes

[1] J. Grebenkemper, "The Tandem Match: An Accurate Directional Wattmeter," *QST*, Jan 1987, pp 18-26.

[2] C. Hutchinson and Z. Lau, "Improving the HW-9 Transceiver," *QST*, Apr 1988, pp 27-29.

[3] W. Bruene, "An Inside Picture of Directional Wattmeters," *QST*, Apr 1959.

[4] I purchased them from Surplus Sales of Nebraska; see Table 1.

[5] Available from Amidon Associates; see Table 1.

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