A UHF+ VSWR Bridge

Being able to measure VSWR at UHF and microwave frequencies can aid those homebrew projects

By Paul Wade, N1BWT

Hams frequently need to measure VSWR. This is paramount for antennas, as it is the only parameter conveniently measured, but it is also useful in many homebrew projects.

Most of the VSWR meters we use for antennas are based on directional couplers and require a significant amount of power for a useful reading. Many electronic devices are intolerant of that much power, and sometimes the frequency involved is outside the ham bands where it is undesirable as well as illegal to use transmitter power levels.

A simple resistive VSWR bridge can give good results over a wide frequency range with milliwatts of power. I found a nice surplus unit for the 2 to 12-GHz range which works so well that I wanted one for lower frequencies. I saw W1AIM using a bridge to trim the phasing harness for his EME array, and he reminded me that Joe Reisert, W1JR, had described one some years ago.[1] I later visited Joe at Antennaco and saw the original unit still being used to test antennas.

The W1JR unit is easily built in a small aluminum box and works up to about 450 MHz. He pointed out that the technique could be extended to several GHz—just what I was looking for. I decided to build one as small as I could using inexpensive chip resistors and capacitors that are now commonly available.

The circuit, shown schematically in Fig 1, is quite simple. How it works is more obvious if it is redrawn as a Wheatstone bridge, Fig 2, with R1 equal to R3.[2] R2 is the reference load connected to J2, and R4 is the unknown impedance connected to J3; if they are exactly the same, then the voltage at each end of R5 is the same, so there is no detected output and the VSWR is 1.0. This condition is referred to as having the bridge balanced. Any difference between R3 and R4 unbalances the bridge and causes an output from the detector. Detected output is proportional to bridge imbalance: the higher the VSWR, the greater the output.

At high frequencies, all components have inductance and capacitance. Since we would like the bridge to operate at as high a frequency as is possible, it is important to minimize the L and C by making the bridge as small as practical, and then to keep it balanced by making it symmetrical.

The smallest robust box that I could think of was a slice of X-band waveguide. I sketched out the compo-

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[1]Notes appear on page 5.

nent dimensions to see if they would fit—it was too tight for my fingers in WR-90 waveguide. K1LPS had a spare piece of WR-112, the next larger size waveguide, with inner dimensions of 0.5 inches by 1.12 inches. The parts are mounted on a small Teflon PC board with the etching pattern shown in Fig 3. Since all the lines are as short as possible, dimensions are not critical; on the original board, I cut out the pattern using a hobby knife. Note that layout and construction are symmetrical so that J2 and J3 are electrically identical and interchangeable.

Construction is straightforward. The tinned PC board is trimmed to fit snugly in the waveguide, then the SMA connectors, J1, J2 and J3, are mounted and the center pins soldered to the board to hold it in place. Then the unit is inverted to solder the ground plane side to the inside of the waveguide. After applying plenty of flux, a ring of wire solder is fitted around the perimeter of the board, ready to flow into place as soon as it reaches the melting temperature. The outside of the waveguide is heated with a propane torch applied to the side (right side in Fig 5) that has no SMA connector until the solder melts and joins the PC board to the walls of the waveguide. Don't be timid with the torch—the idea is to get everything hot quickly and remove the heat as soon as the solder flows.

If waveguide is not readily available, a suitable enclosure may be fabricated from hobby brass, as described by NJ2L.[3] The pattern in Fig 3 extends past the waveguide dimensions to allow some flexibility in packaging.

After the flux is scrubbed off, components are soldered in place. Component placement is shown in Fig 4 and the photograph, Fig 5. A small wire passes through the board to the BNC connector and R8 underneath.

Operation of the bridge is also straightforward. A modulated RF signal is applied to J1, and the detected modulation, with amplitude proportional to VSWR, appears at J4. Usually the modulation is at 1 kHz, and the detected output is connected to a surplus SWR meter, such as the HP 415. (The solid-state 415D and 415E are more stable than earlier models, but any of them work fine, as do similar instruments from several other manufacturers.) Since the SWR meter is just a tuned audio amplifier with a calibrated meter, any audio amplifier driving an output meter will do the job.

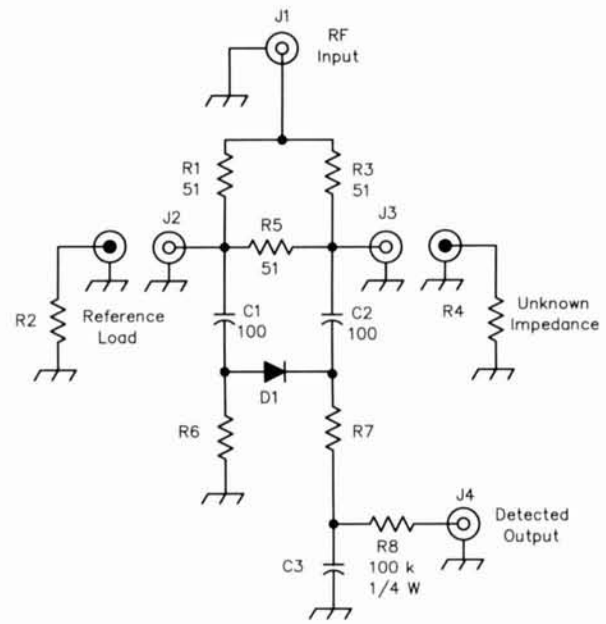

Fig 1—Schematic diagram of the VSWR bridge. All resistors and capacitors are chip devices except for R8. D1–Microwave mixer diode. R6, R7—10 to 15 kΩ.

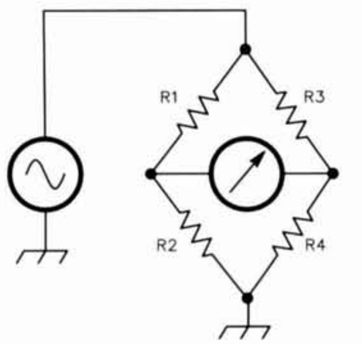

Fig 2—The Wheatstone bridge is the fundamental circuit within the instrument.

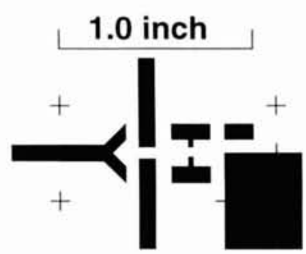

Fig 3—Etching pattern for the printed-circuit board. Use Teflon board and trim to fit the enclosure (1/32 inch recommended thickness).

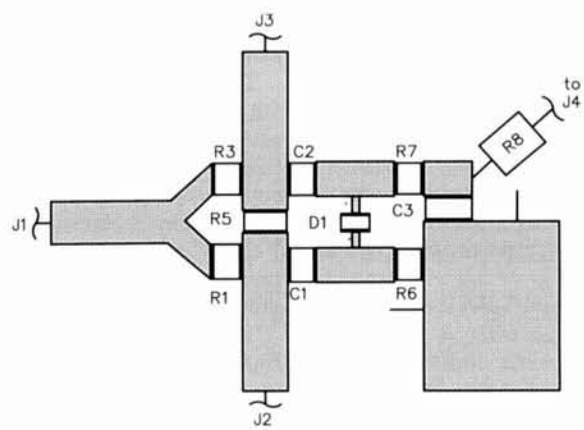

Fig 4—Component placement diagram for the VSWR bridge.

A good 50-Ω termination is connected at J2 as the reference load: the quality of the reference load is important since all other impedances are compared to it. In fact, we could measure VSWR on a 75-Ω cable by using a 75-Ω termination at J2.

To calibrate a measurement, connect a coaxial short circuit at J3 and adjust the SWR meter scale for infinite VSWR, or 100% power reflected. The unknown impedance is then connected at J3 to measure its VSWR. However, what a typical SWR meter such as the HP415 displays is return loss, the percentage of reflected power in dB. Most microwave engineers use return loss directly, but if you are more comfortable with VSWR, this is the equation for conversion (remember that *RL* is a negative number):

$$SWR = \frac{1 + 10^{\frac{RL}{20}}}{1 - 10^{\frac{RL}{20}}}$$

Since we have tried to keep the bridge balanced and symmetrical, a good test is to put good loads on both J2 and J3, then swap them. The measured VSWR should be low (high return loss) and identical in both cases.

Now that we've gone to the effort of using chip components and making the VSWR bridge as small as possible, how much have we gained? With good 50-Ω SMA terminations at J2 and J3, return loss was greater than 30 dB (VSWR < 1.2) from 10 MHz through 2304 MHz, while at 3456 MHz, the return loss was 22 dB (VSWR = 1.9), so performance is degraded but still usable. However, at 5760 MHz it was worthless. So we have increased the upper frequency limit to at least five times as high as the original version.

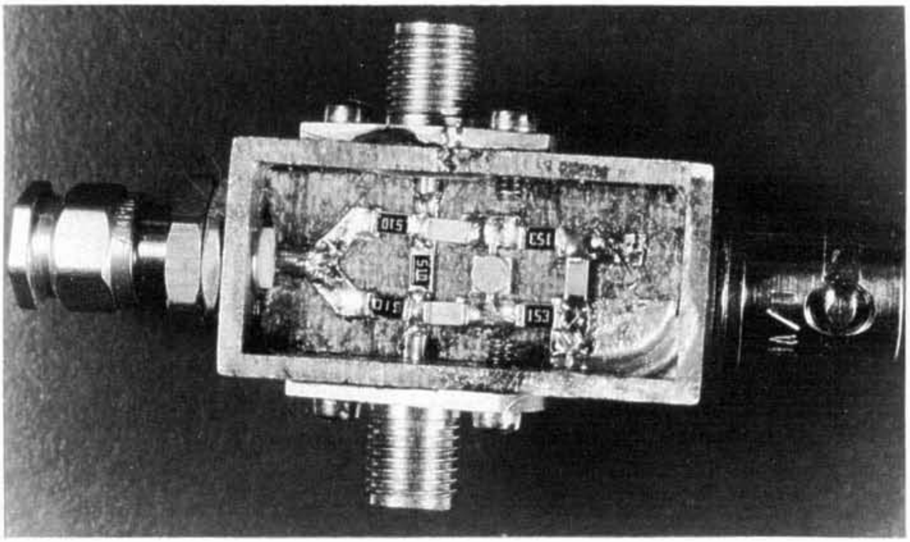

Fig 5—The completed bridge assembly.

It is possible that this style of VSWR bridge could be pushed even higher in frequency by making it even smaller, using tiny (and more expensive) microwave chip capacitors and resistors.

Notes

Parts and boards are available from:
DownEast Microwave
954 Rt 519
Frenchtown, NJ 08825
Tel: 908-996-3584

[1]Reisert, Joe, W1JR, "Matching Techniques for VHF/UHF Antennas," *ham radio*, July 1976, pp 50-56.

[2]Ryder, John D., *Networks, Lines and Fields*, Prentice-Hall, 1955, pp 32-37.

[3]Healy, Rus, NJ2L, "Building Enclosures for Microwave Circuits," *QEX*, June 1994, pp 15-17.