

Home-Brew X-Band Wavemeter

— indispensable test gear for microwave mavens

The need to know the operating frequency of an amateur signal in the X-band assignment can be met with an adjustable cavity wavemeter and a detector. The cavity can be adjusted so that it accepts a small amount of power from the transmitter, and the detector, which is coupled loosely to the cavity, "sees" this energy and converts it to a small current that will operate a microammeter, which serves as a resonance indicator.

The wavemeter must

have some sort of dial which can be calibrated in frequency. The accuracy of this calibration will depend upon many factors, such as the temperature stability of the cavity, the resettability of the adjusting system, and the exactness of the calibration reference. There are others, but these are the three which will concern us while constructing a suitable unit. The other problems will become evident as we move along.

A cavity wavemeter is a parallel resonant circuit (see Fig. 1). You have used these devices as traps in the output of your transmitters on the lower frequencies and in many other circuits of your equipment. The operation of a microwave unit isn't different from those. The Q of the circuit in

which it is used and the Q of the wavemeter itself make the difference for a calibrated frequency reference. A microwave cavity, such as the device we are about to construct can have a working Q of nearly 3000. The working Q will depend upon the loading of the cavity and several other factors.

An important limitation to recognize is that the device we are making will put you within the band limits, but it is not an absolute frequency meter.

A cavity wavemeter circuit diagram might look like the circuit shown in Fig. 2. A difference in the circuit when using waveguide for the transmission line will be, for example, that the coupling loop in Fig. 1 is a

one-turn link to the tank coil. In the microwave configuration we will use, this is simply a small hole in the E-plane wall of the waveguide. The diameter of the hole determines how much coupling there is to the tank circuit, which, in our case, is the cavity. The diameter of the hole controls coupling and many other factors. It must be placed carefully so that the match to the transmission line will not be upset.

Now, let us examine the construction of a cavity wavemeter for X-band. (See Fig. 3.) The cavity we will construct is, in microwave parlance, a right circular cylinder cavity operating in the TE_{011} mode. It is mounted on the E-plane of an X-band waveguide, off center so that the center of the cavity will sit directly centered over a hole in the waveguide. This hole is called an iris hole. The remainder of the cavity bottom, which hangs over the waveguide, is covered with a brass half-circle soldered in place. This is shown in

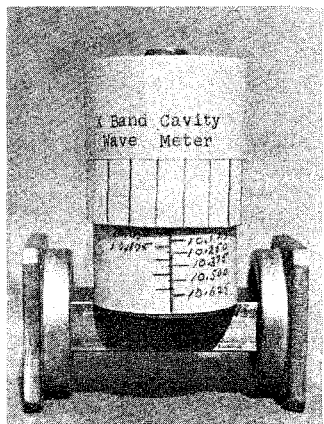


Photo A. Cavity wavemeter for X-band.

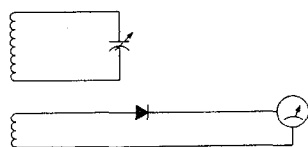


Fig. 1. Parallel resonant equivalent circuit of waveguide.

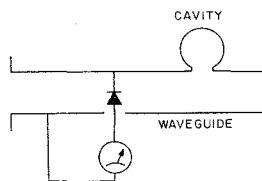


Fig. 2. Cavity wavemeter circuit diagram.

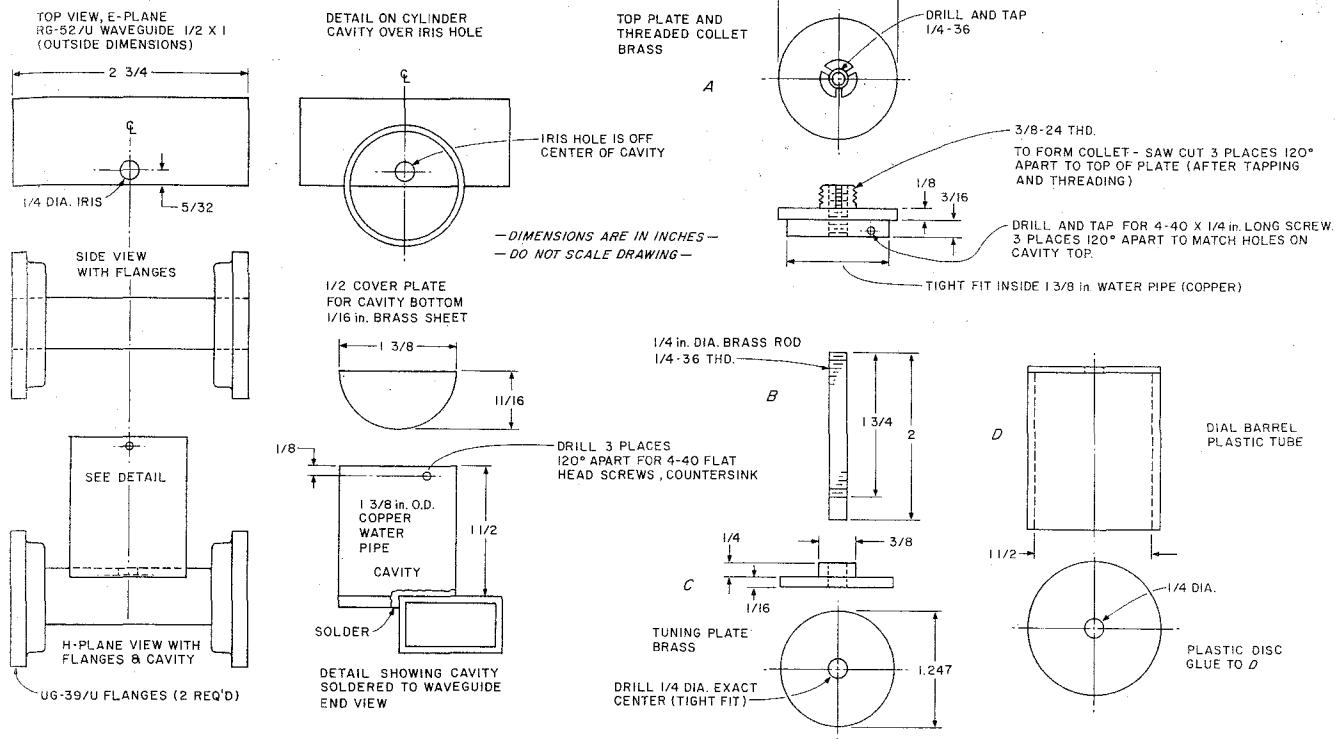


Fig. 3. Construction details for cavity wavemeter.

the photos and drawings accompanying this article.

Tuning of the cavity is accomplished by varying its length. This is done by moving a circular plate longitudinally within the cavity cylinder. A lead screw fastened to the circular plate serves as the device to move it into the cavity. The lead screw must have very fine threads, and the bushing which guides it also must have threads that fit well. A set of three cuts equally spaced around the diameter of the bushing will serve as a collet-threaded bushing when fitted with a small compression nut and lock. This particular part of the construction should be given great care since it directly affects the resettability of the wavemeter. In a commercial unit, a micrometer barrel often is used to control the circular plate motion, giving a high order of accuracy.

In the design shown, a barrel similar to a micrometer was used. It is larger, however, allowing the calibration to be inscribed

more easily—and for me to read without my glasses.

The disk is constructed from a piece of flat brass at least 1/16" thick. Dimensions of the disk shown in the drawings should be followed carefully. As you will note, the dimensions allow only .03-inch spacing between the wall and the disk edge. This means that the drive mechanism must also be placed in the center of the drive holder. In each case, it is best to have your friendly machinist fabricate these pieces on a lathe. This means that the top cover, the disk, and disk holder all must be centered exactly or the disk will rub on the cavity walls.

The disk must have some absorbing material added to the back of it. This is necessary because the back of the cavity—that is behind the disk—otherwise can support resonances which will be coupled weakly from the waveguide and will produce unwanted responses which can mislead the user. The absorbers may be constructed from a disk made

of a piece of attenuator card. If you have access to powdered iron material, paper can be shaped around the periphery of the disk to make a form. Mix the powdered iron particles with some coil dope and pour in enough to make a level surface about 1/16" thick. Be sure that the surface is held level while the mix is hardening. (Powdered iron can be obtained from cup core manufacturers or, if you are really ambitious, you can make your own simply by crushing a cup core with a steel roller. Make sure that the particles are very small.) After the mix has hardened, be sure to remove all of the paper and glue from the edge of the disk.

Next, construct the waveguide section by mounting the two flanges, one on either end of the guide. This is done by cutting the waveguide ends square and then removing all burrs from them with a smooth file. Each end will have a flange soldered in place. This is done simply by sliding the

flanges on each end of the guide, after first applying a small amount of soldering paste (flux) to each end. Now heat the entire assembly until the flux runs and turns the copper waveguide a deeper color. Apply just enough solder so that it will run around the joint. When this operation is completed, lap the ends of the flanges against a piece of very fine emery paper. Now inspect the joint to be sure that there are no gaps in the solder around the face of the joint.

Next, measure the distance between the rear butts of the flange, and in the center of this distance, using a square, draw a line across the E-plane of the waveguide.

On one side of the guide lying on this line, place a centerpunch mark at the distance from the outside wall shown in the mechanical assembly drawing, Fig. 3. Now drill the hole also described in this detail. Deburr this hole inside and out of the guide so that it is smooth. This is the iris

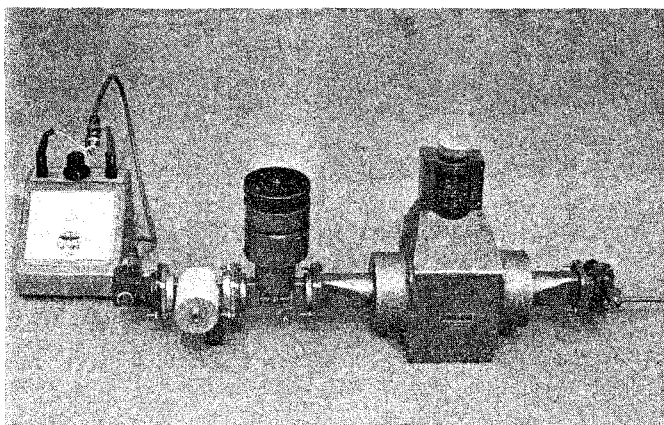


Fig. 4. Test setup for calibration, as described in the text.

coupling hole, and it should be perfectly round with no burrs or raised pieces sticking down into the waveguide. The deburring job is easy on the top of the guide and can be done with another drill bit held by hand and turned to lift off the burr. The inside of the waveguide may be done with a very small bladed knife such as an X-acto® scalpel. This can also be done from the top of the waveguide by inserting the point into the hole against the burr.

Clean a piece of copper pipe (shown in the assembly drawing) as the cavity cylinder. It should be free from all burrs on each end and

polished clean with Dutch Cleanser or a similar pot-scouring compound, particularly on the inside of the cylinder. On one end of the cylinder, using a machinist's square and try, set the center so that a pair of marks can be scribed across the open face of the cylinder and on the end of its side walls.

Using flux here, too, solder the half-circle of brass in place so that it lies on the two scribe marks just made to the bottom edges of the cylinder. Now the bottom of the cavity will be half closed. Use acid-base soldering flux for this operation.

The cavity may now be

mounted to the waveguide section by aligning the scribe marks on the cavity outside walls with the scribe line made on the face of the waveguide. The half circle of brass will butt against one side wall of the waveguide providing a solder surface. Using a C-clamp and a small, flat piece of wood, clamp the cavity in place, placing the wood under the clamp so that it does not mar the top of the cavity. Adjust the cavity so that it aligns with the marks on its walls and the waveguide. Make sure that the half-circle butts tightly against the side wall of the waveguide. Now apply soldering paste to the bottom of the cavity and to the waveguide surfaces that make contact with the cavity parts. Heat and solder, using just enough solder so that it will "run" when the assembly is hot enough. Let the assembly cool thoroughly before removing the clamp.

When the soldering is completed, the waveguide section should have the cavity mounted off-center on the guide with the iris hole off-center with the diameter of the cavity (see Fig. 3 details). The cavity should be in line with the scribe marks previously described as the alignment lines. If this is not the case, but the alignment marks are only a very few thousands of an inch off, do not rework to improve the alignment; this small deviation will not degrade the operation of the wavemeter too badly. Inspect the inside of the cavity where it mates with the waveguide and be sure that solder has completed the "run" around the entire cavity surface that is in contact with the waveguide.

When all soldering is complete on the waveguide and cavity body, wash off all soldering paste with very hot water. Any traces of the

paste or acid will degrade the future performance of the instrument when it causes corrosion.

The most important parts of the assembly are attempted next. These parts are shown in the mechanical drawings as parts A through D and should be assembled in this order. (Before assembly, if you desire to silver-plate all parts of the cavity and waveguide, some improvement of the cavity Q will result and the performance of the wavemeter will be better. Silver-plating can be dispensed with, however, since the unit will perform very well without it.)

Now the tuning disk and lead screw can be assembled into the bearing and collet assembly. To do this, place a lock nut of the compression type (as found on most screwdriver-adjust locking pots) on the collet—see A in Fig. 3. The locking nut is a device which has inside tapered threads, 3/8-24, and is about 1/4-inch thick. It will compress the collet against the lead screw threads causing it to move tightly in the collet bearing. Put the nut on so that it is loose.

Now, from the opposite side of the bearing plate (A), insert the threaded end of the brass 1/4-inch rod and screw it up through the collet until about an inch of it is exposed. This item is labeled B in Fig. 3. Now install piece C, the tuning disk, on the end of the brass-threaded rod. Gently heat this piece and solder it to the threaded rod, taking care not to get solder in the fine threads. When the piece is cooled, wash off all solder paste. Now, on the back of the tuning plate, add the powdered iron as described earlier.

When the three pieces have been assembled, insert the tuning plate into the cavity and align the top plate so that the three

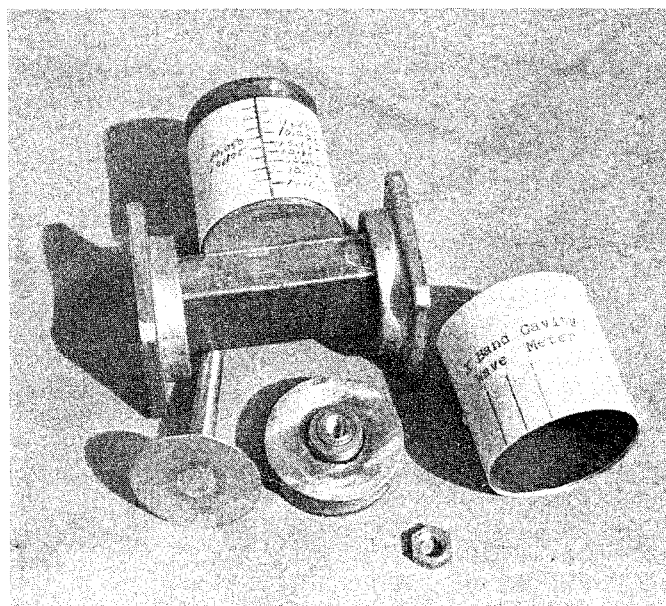


Photo B. Wavemeter parts and bottom view of the cavity, showing how it is offset from the waveguide.

screw holes in the cavity wall top mate with the three threaded holes for the three 4-40 flat-head screws, which can be found on the side of the top plate (A). Press the top plate down firmly into the cavity and install the screws to hold the plate firm.

Now screw in the tuning plate by adjusting the threaded rod; see that it moves in and out of the cavity easily, and adjust the collet lock nut so that the rod moves firmly but not hard. Now put a dab of Super Glue® on the lock nut, taking care not to get it in the cracks of the collet and on the lead screw threads. This will lock the collet lock nut in place.

Now the last piece, D, can be assembled. Simply glue the plastic disk to the top of the 1-1/2-inch diameter tube. This tube can be made from any available plastic or metal material. It fastens to the extended end of the threaded brass rod with two 1/2-36 nuts. Place one nut on the end of the rod and engage enough threads to allow about 1/4" to protrude through the assembled dial barrel (D). Then place another nut with the same threads on the rod and tighten until it is firm and the tube will not rotate. Now you have a micrometer barrel dial and a completed assembly. When rotated, it actuates the threaded lead screw and serves as a dial. It should move freely without touching the outside walls of the cavity. Cover the outside of this tube with a piece of paper. Also cover the cavity outside wall with white paper so that calibration marks can be added.

To calibrate the wavemeter you will need a signal source which can be tuned over at least the amateur assignment. Calibration points beyond the band on either end are a valuable asset and should be in-

cluded. The source can be your uncalibrated X-band transmitter, a signal generator, or simply a klystron and power supply. A calibrated wavemeter and an attenuator ending in a crystal detector mounted in a waveguide adapter make up the waveguide components required for calibration. A meter to register the crystal current will serve as the reaction indicator. Fig. 4 shows how to connect these devices for calibration.

Let's assume you are using a klystron and power supply to do the job. Be sure that the klystron is oscillating in a mode that will not stop or "squeg" during the operation. Once it is oscillating, adjust the attenuator to provide a three-quarter scale reading on the current meter. Set the klystron so that it is in the range of 9.8 GHz to 12 GHz by adjusting its frequency control. Now adjust the calibrated wavemeter (which we will call the reference wavemeter from now on) until you see a pronounced dip in the output-current indicating meter. By adjusting the frequency control on the klystron and the reference wavemeter, you should be able to set up the starting calibration frequency of 9.8 GHz. When you have this frequency and you are sure of it, detune the reference wavemeter. Now tune the device you have just constructed until you get a similar reaction on the output-current meter. The dial barrel will be quite near the top of the wavemeter cavity. Now simply make a pencil or pen mark on the calibration dial paper, using the moving barrel edge as a guide for your pencil.

Continue the calibration process, setting the frequency changes in 50-MHz steps, for a start. Put the coarse calibrations on one side of the calibration line and fine steps on the other

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side. If you decide to make the calibration steps at a finer set of divisions after you have done a coarse calibration, do not remove the coarse steps; they can be your check points to check out how well the device resets.

The drawings showing the mechanical construction of the wavemeter are supplemented by photographs so that you can verify how the assembly goes together. It is not difficult, and most amateurs who have had experience with hand tools should be able to complete the unit satisfactorily. It is hoped that the meter will be helpful to those amateurs who want to know that they are within the X-band confines.

To use the wavemeter in your rig, simply place it in the waveguide circuit, which is the output toward the antenna, then tune it until you get a reaction in

your power-output indicator, read off your frequency, and then detune the wavemeter. You may leave it in the line since it will cause very little loss to your output.

Materials for this device were obtained from Lectronic Research Labs, Inc., Atlantic and Ferry Ave., Camden, New Jersey. All of the materials for waveguide components are listed in their catalog. There are numerous other sources of material for this band and others, but this catalog should be in the hands of all microwave enthusiasts.

All letters with questions regarding this and other articles I have written will be answered if the writer includes an SASE. All telephone calls also will be answered, but please remember what your time zone is so that I don't get your call in the early hours of the morning. ■